UNIVERSITY OF CAPE COAST

COMMODITIES PRICES, BANKING SECTOR'S FINANCIAL SOUNDNESS, AND THE MACRO-ECONOMY OF GHANA

COLLINS BAFFOUR KYEI

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BY

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Thesis submitted to the Department of Economic Studies of the School of Economics, College of Humanities and Legal Studies, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Economics.

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DECLARATION

Candidate's Declaration

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

Candidate's Signature…….. Date: ……

Name: Collins Baffour Kyei

Supervisors' Declaration

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

Principal Supervisor's Signature: …….. Date: …….

Name: Dr. William Godfred Cantah

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Name: Dr. Peterson Owusu Junior

ABSTRACT

The recent high volatility of prices in international commodity markets has increased concerns for countries that rely heavily on commodity exports. When commodity prices decrease, it can lead to lower economic growth and increased demand for credit, which can negatively impact financial soundness. Therefore, the study assesses the effect of commodity prices on banking sector's financial soundness indicators (BsFSI) as objective one, the influence of macroeconomic variables in the relationship between commodity prices and BsFSI as objective two, and the interconnectedness among commodity prices, BsFSI and the macro-economy of Ghana as objective three. The study followed positivist quantitative and explanatory research. Seventeen variables measured on a monthly basis over a period spanning from January 2007 to March 2022 were employed. The inferential techniques employed in the order of the objectives are (a) Quantile Regression and non-parametric causality test, (b) Bi-wavelet and Partial wavelet, and (c) Time-varying parameter Vector Autoregression (TVP-VAR) connectedness and Wavelet multiple. Objective one found significant effects of commodity prices on Ghana's BsFSI at diverse market conditions. The second objective revealed that macroeconomic variables influence the nexus between commodity prices and BsFSI in Ghana across time and frequency. The final objective found that Ghana has a significantly high degree of connectedness among commodity prices, BsFSI, and macroeconomic variables. The study recommends that policy measures on cocoa export should be tailored to bolster the sector's resilience, given its influence on foreign exchange earnings. Also, there should be a prudent approach in managing non-performing loans as it is imperative to prevent overborrowing and potential insolvency risks, especially among banks with higher capital adequacy ratios.

KEY WORDS

Commodity Prices

Commodity-dependent

Financial soundness

Macroeconomic variables

Quantile Regression

TVP VAR Connectedness

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DEDICATION

To Mrs Adwoa Mansa

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AfCFTA	African Continental Free Trade Area
AMH	Adaptive Market Hypothesis
BsFSI	Banking sector's Financial Soundness Indicators
M2	Broad Money Supply
CAMELS	Capital Adequacy, Asset Quality, Management Soundness, Earnings, Liquidity, and Sensitivity to Market Risk
CAR	Capital Adequacy Ratio
CIEAR	Composite Index of Economic Activity (Real)
CLASL	Core Liquid Assets to Short-Term Liabilities
CLATA	Core Liquid Assets to Total Asset
CD	Credit to Deposit
GFC	Global Financial Crises
HMH	Heterogeneous Market Hypothesis
INF	Inflation
IMF	International Monetary Fund
MPR	Monetary Policy Rate
NPL	Non-Performing Loans
PWc	Partial wavelet coherence
QR	Quantile Regression
ROA	Return on Asset
ROE	Return on Equity
TB	Trade Balance
TVP-VAR	Time-varying parameter Vector Autoregression
UNCTAD	United Nations Conference on Trade and Development

CHAPTER ONE

INTRODUCTION

Commodity prices are subject to significant price swings due to various factors, including changes in supply and demand, geopolitical tensions, weather patterns, and investor speculation (Agarwal et al., 2016). Commodity price fluctuation has been common in international markets for many years (Abaidoo et al., 2021; Cantah, 2018). Recently, high volatility in prices of international commodity markets has aroused concerns among export-dependent countries because volatility in prices can momentarily impact their economies. A decrease in commodity prices may result in reduced revenue and economic growth for countries whose economies rely heavily on exporting those commodities.

Reduced revenue would result in a surge in demand for credit, as households and firms may need to borrow more to maintain their standard of living and to fund their operations, which can put pressure on the financial system and negatively impact financial soundness (Kinda et al., 2018; Mupunga & Ngundu, 2020). Therefore, countries that rely heavily on exporting commodities may need to take action to alleviate the impacts of price volatility. However, there is dearth empirical support in addressing this issue. The study focuses on interconnectedness among commodities, the banking sector's financial soundness, and the macro-economy of Ghana. This chapter looks at the background and the research problem of this study. Also, research objectives and hypotheses are stated. Furthermore, the significance, limitations and delimitation of the study are discussed. This chapter ends with the organisation of the study.

Background to the Study

The trend in commodity prices has been a concern to economists, investment analysts, experts in industries, and policymakers because of price volatility in the international commodity markets. The worth of exports globally in commodities in nominal terms increased by $700 billion (+19%) from 2008–2009 to 2018–2019, reaching $4.38 trillion (United Nations Conference on Trade and Development (UNCTAD), 2021). Major commodity price fluctuations have been associated with global financial crises (GFC), geopolitics, or pandemic (Naser, 2019; Yang et al., 2022). To mention a few; oil price shocks in the 1970s linked to the Kumar war, the 1990 Iraq invasion of Kuwait, the US invasion of Iraq in 2003, the 2008 financial crises, the Ebola pandemic in Africa in 2014, and the COVID-19 in 2020, among others, are all periods in which the world saw high commodity price volatility which affected the financial sector through a decrease in economic growth, an increase in unemployment, and a rise in the overall prices of products (Abaidoo et al., 2021; Kinda et al., 2018).

The indication of these crises has also facilitated the undeniable importance of a sound financial sector, which helped some economies sail through the crises while others experienced financial instability (Mupunga & Ngundu, 2020; Vo et al., 2019). Furthermore, the influence of these crises on the financial sector is heavily dependent on the nature of the macro-economy; a weak(strong) economy increases(reduces) the impact of a decrease in commodity prices on the financial sector (Abaidoo et al., 2021; Boateng et al., 2022).

The effectiveness of the financial sector is mostly established following the guidance from capital adequacy, asset quality, management soundness, earnings, liquidity, and sensitivity to market risk (CAMELS) framework (Abusharbeh, 2020; Sundararajan et al., 2002). Bank of Ghana, among many other central banks and financial administrative agencies, provide routine information on the banking sector's financial soundness indicators (BsFSI) to assess the strength of the financial sector (Abaidoo et al., 2021; Sundararajan et al., 2002). It is knowingly established that the behavioural patterns of financial sector players are not symmetrical across time and frequency; investors respond to shocks in the economy differently, corroborating the adaptive market hypothesis (AMH) (Lo, 2004) and heterogeneous market hypothesis (HMH) (Müller et al., 1993, 1997). In light of the AMH and HMH, the study posits that BsFSI exhibits varying degrees of effectiveness because of events and structural changes over different periods in the economy (Boateng et al., 2021; Frimpong et al., 2021; Niepmann, 2013).

The BsFSI comprises specific indicators that capture factors that threaten the financial system of the whole economy (Alodayni, 2016). The BsFSI includes but not limited to Credit to Deposits (CD), Return on Assets (ROA), Capital Adequacy Ratio (CAR), Core Liquid Assets to Total Assets (CLATA), Non-Performing Loans (NPL), Core Liquid Assets to Short-term Liabilities (CLASL), and Return on Equity (ROE) (Sundararajan et al., 2002). FSI provide up-to-date, first-hand information on the health of the banking sector, the non-bank financial sector, the position of the real estate and financial markets, as well as businesses and households (Sundararajan et al., 2002). BsFSI is key for financial stability, critical for maintaining financial stability

and monitoring financial institutions' performance to identify any potential systemic risks that could result in a crisis (Pietrzak, 2021; Uysal & Ucler, 2017).

Therefore, BsFSI is considered necessary, as the role of Banks is to facilitate the distribution of funds from the depositor to the productive sectors of various economies (Almahadin et al., 2020; Ramlall, 2018). Hence, enormous determinants of BsFSI have been the quest for policymakers and academicians (Alodayni, 2016; Diaconu & Oanea, 2014; Vo et al., 2019). A mammoth of studies has also argued that the BsFSI responds differently to non-symmetrical behaviours of market participants (Garcia & Panetti, 2017; Hau et al., 2020; Huang et al., 2012; Martínez et al., 2020).

UNCTAD (2021) postulated that commodity-dependent countries' financial stability depends primarily on export earnings. In sub-Saharan Africa, most nations are commodity-dependent countries exporting sole or multiple natural resources (agricultural produce, energy, and mining). Based on the level of dependency, a slump in prices, such as in 2014-2016, especially for crude oil, of more than 40%, resulted in reduced export earnings of such countries (Agarwal et al., 2016; Kinda et al., 2018). In 2014, the average commodity prices of cocoa, gold and crude oil were USD 3003.38, USD 1266.76, and USD 99.43, respectively. However, in 2016 these commodity prices saw tremendous reduction; cocoa was USD 2848.95, gold was USD 1248.11, and crude oil was USD 45.04 (*Commodity Prices – Bank of Ghana*).

Similar can be said of crude oil between 2019 and 2020, when the average yearly price reduced from USD 64.1875 to USD 43.18. Significant drops in commodity prices have made academicians and policymakers question whether the world is entering a low prices era for commodity-exporting

countries and the implications (Carpantier, 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020; Okyere & Mensah, 2021). Myriad studies corroborate this and have established the significant impact of commodity exportation on BsFSI (Abaidoo et al., 2021; Mupunga & Ngundu, 2020).

More explicitly, the influence of commodity prices on BsFSI is established by directly and indirectly through macroeconomic variables (Kinda et al., 2018; Mupunga & Ngundu, 2020). The direct channel holds that in the recession era, when commodity prices experience volatility, industries linked to commodities, such as energy, agriculture, and mining, often confront financial challenges. (Tahar et al., 2021). As businesses struggle, loan repayment capacities diminish, leading to a surge in non-performing loans (NPLs) and weakening the asset quality of banks. Moreover, collateral values decline during periods of low commodity prices, potentially hampering banks' ability to recover outstanding loans in cases of default. Households and firms' ability to pay up debt as it falls due are also unfavourably affected due to the economic downturn (Naraidoo & Paez-Farrell, 2022).

The situation negatively weakens the BsFSI through increased non-performing loans (Abaidoo et al., 2021; Agarwal et al., 2016). As such, a slump(boom) in commodity prices is expected to decrease(increase) economic activities through government, households, and firms' gains and losses (Abaidoo et al., 2021). In a circular flow of an economy, households are expected to deposit their excess income with banks; likewise, banks also make available funds to borrowers (Firms and Governments) who invest in productive areas in the economy, which enhance the financial stability of the economy (Borio & Drehmann, 2011; Obuobi et al., 2020; Vo et al., 2019).

Also, waning export revenues could cause a surge in withdrawals of deposits by households to smoothen their consumption, causing liquidity challenges (Labys & Maizels, 1993; Sanya, 2020). Furthermore, a persistent slump in commodity prices can deleteriously affect the banking sector's soundness by plummeting international reserves and amplifying the risk of currency disparities (Ben Haddad et al., 2021; Fry-McKibbin & Souza, 2018; Tran, 2021). The irrational behaviour of market participants toward the financial system makes it difficult for the government to decide which bank to bail out in situations of unsoundness (Garcia & Panetti, 2017).

Similarly, a tumble in commodity prices diminishes government revenues which reverberate through an economy, casting a shadow on the soundness of its banks, a cascade of effects can ensue (Kinda et al., 2018; Naser, 2019; Siaw et al., 2018). The diminished capacity of borrowers to repay loans, coupled with the depreciation of assets used as collateral due to economic uncertainty, heightens the risk of non-performing loans within banks. The economic slowdown that often accompanies this scenario further erodes credit quality, as businesses face challenges in generating revenue and individuals contend with reduced income (Abaidoo et al., 2021; Baloch & Danish, 2022; Obuobi et al., 2020). The monetarists believe that the central bank’s effort through expansionary monetary policy may cause inflation. Also, an increase in the money supply or a decrease in interest rates can lead to excessive borrowing and speculation, resulting in financial instability.

Also, the financial fragility’s view of instability holds that booms and recessions in the business cycle disrupt the banking sector's soundness due to excessive debt, weak regulation, and interconnectedness of financial institutions

(Abaidoo et al., 2021; Babihuga, 2007; Borio & Drehmann, 2009, 2011). As such, a weakness(strength) in macroeconomic variables causes unrest(stability) in the financial sectors of commodity-dependent countries (Fisher, 1933). In detail, an increase in the commodity price will cause debtors and creditors to have irrational expectations that investment gains will linger to rise to pass their actual values. Therefore, when gains cease to rise, borrowers abruptly realise that their cash inflows are impossible to meet their debt repayment plan, leading to distress selling, which consistently reduces price (Abaidoo et al., 2021). Hence, borrowers attempt to liquidate their investments to meet their debt servicing obligations, resulting in a loss of confidence and credit collapses, which causes financial institutions to become illiquid and unable to meet the financial quest of the households (Guzman, Medina & Soto, 2014; Kannapiran, 2000).

Indirectly, macroeconomic variables like inflation, monetary policy rate, composite index of economic activity (real), broad money supply, exchange rate and trade balance, are how commodity prices impact the financial sector's stability (Chuku & Simpasa, 2018; Nya & Onyimadu, 2019; Siklos, 2021; Smales, 2017). The selection of these specific macroeconomic variables for analysis is underpinned by the interplay of diverse economic theories and hypotheses. First, the inclusion of inflation, monetary policy rate, and composite index of economic activity (real) aligns with the theory of instability proposed by monetarists. These variables are crucial in gauging the stability of the economy, as fluctuations in inflation and the effectiveness of monetary policy can impact overall economic activity.

Second, the incorporation of broad money supply and exchange rate resonates with the Financial Fragility approach, which emphasizes the fragility of financial systems and the potential for imbalances to disrupt economic stability. Furthermore, Schwartz's hypothesis underscores the importance of economic stability, making CIEAR an apt choice as it provides insights into overall economic health. Lastly, the HMH and Adaptive Market Hypothesis AMH elucidate the complexities of market behaviour. Trade Balance augments this understanding by capturing the dynamics of international trade and its impact on Ghana's economy. Thus, the chosen macroeconomic variables collectively enable a comprehensive examination of the relationships between market commodity prices and BsFSI in Ghana.

Countries engaged in commodity exportation have their real exchange rate tied to trade balance (Archer et al., 2022). Hence, the exchange rate is a foundation of severe financial uncertainty in a period of tumbling commodity prices (Uysal & Adalı, 2022). However, the central banks use reserves to curb commodity prices' negative impact on currency depreciation (Salisu et al., 2018). As international reserves decrease, government and domestic banks borrow from the international market, thus growing foreign currency-denominated debt (Jena, 2017). A substantial depreciation from an enormous waning commodity price causes a reduction in the net worth of the banking sector, primarily banks with substantial foreign currency debts are affected negatively, increasing bank instability (Kinda et al., 2018; Mupunga & Ngundu, 2020).

The negative connectedness between exchange rate and slump commodity price has its root in the balance of payment theory (Kung'u, 2017).

According to the balance of payments theory, a deficit (surplus) in the balance of payments causes the domestic currency's value to decline (increase) compared to the value of diverse currencies (Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022; Labys & Maizels, 1993; Vo et al., 2019). A positive (negative) balance of payment occurs when a reduction (surge) in exported commodity prices like gold, cocoa, and crude lure additional importers to request extra (fewer) of the specific commodity on the global market. Intuitively, commodity price fluctuations tend to raise or decline the value of a country's currency compared to the US Dollar.

Nevertheless, the Schwartz hypothesis (Schwartz, 1995) also holds that commodity price fluctuations may lead to financial sector distress and instability (Ghosh & Parab, 2019). Put another way, the Schwartz hypothesis suggests that continuous price increment promotes speculative borrowing and investment because there is a belief that prices will continue to rise and increase gains from investments (Minsky, 1977; Mishkin, 1999). As such, a significant drop in commodity prices has an equivalent rise in borrower defaults which negatively affects lenders' equity, increasing the likelihood of financial sector failures (Abaidoo et al., 2021). The effect of commodity price shock on the macroeconomic environment of commodity-dependent countries is far worse (Agarwal et al., 2016; Chuku & Simpasa, 2018; Mupunga & Ngundu, 2020; Swaray, 2008; Tahar et al., 2021).

The study assessed the effect of gold, cocoa and crude oil prices on the BsFSI while considering the influence of some selected macroeconomic variables in the Ghanaian economy. Ghana is used in the study because it is a commodity-dependent country with a price stabilisation policy to limit

commodity "side selling" (Okyere & Mensah, 2021). Cocoa, gold and crude oil contribute over 80% of merchandise exports in Ghana (UNCTAD, 2021). The UNCTAD (2021) report has established that gold, cocoa and oil exportation accounted for 70.6% in 2008-09 and 81.4% in 2018-19 of Ghana's merchandise exports. Hence, UNCTAD (2021) corroborated these assertions that these commodities are the most significant export in Ghana. As of 2021, cocoa, gold and oil contributed 19%, 45% and 21% shares in the national exports of Ghana corroborating these assertions that these commodities are the most significant export in Ghana.

The markets for gold, cocoa, and crude oil in Ghana exhibit varying levels of diversity (Boateng et al., 2022; Kyei et al., 2023). The gold market is relatively diverse, involving large-scale and small-scale mining companies, as well as activities such as refining and trading. The cocoa market is characterized by significant diversity, with cocoa farmers, cooperatives, traders, and chocolate manufacturers playing key roles (Okyere & Mensah, 2021). The crude oil market, while less diverse, has been undergoing efforts to increase local participation (Asafo-Adjei, Adam, et al., 2021). The macro economy of Ghana is taking shape with major policies geared towards strengthening the financial sector (Asafo-Adjei, Boateng, et al., 2021; Boateng et al., 2022; Obuobi et al., 2020; Okyere & Mensah, 2021). However, there is scanty literature on the interconnectedness between commodity prices, banking sector financial soundness and macroeconomic variables.

Following the theories from the monetarist's view and financial fragility, commodity prices are expected to impact the financial sector soundness while the macroeconomic environment influences these co-

movements (Abaidoo et al., 2021; Vo et al., 2019). However, paucity is seen in the Ghanaian setting based on the findings from (Abaidoo et al., 2021; Archer et al., 2022; Barson et al., 2022; Boateng et al., 2022; Kinda et al., 2018; Okyere & Mensah, 2021). Also, from the asymmetric and time-based behaviour of households and firms, HMH holds that decisions from these market participants would affect the financial sector on diverse time horizons having in mind the risk and returns of their decisions, and AMH says market participants adapt to the market dynamics which happens through time.

The behaviours of market participants toward the financial sector produce a different degree of impact in diverse economies leading to a plethora of literature to assess the determinants of the financial sector soundness (Benvenuto et al., 2021; Bernini & Brighi, 2011; Garcia & Panetti, 2017; Hau et al., 2020; Huang et al., 2012; Martínez et al., 2020; Niepmann, 2013; Xing et al., 2020). These studies concluded that the banking sector received different impacts from determinants due to the non-symmetrical patterns of investors' behaviour across time; however, they focused on corporate governance, credit creation, systemic risk and macroprudential policy. Hence, the current study adds to the findings to assess commodity prices' impact on the BsFSI. This would reveal AMH because of the irrational behaviour of households and firms.

Furthermore, the role of macroeconomic variables in the nexus between commodity prices on the BsFSI has been established in the nascent and fledgling body of literature (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020). Monetarists posit that unplanned monetary policy expansion in commodity price crises causes financial instability. In contrast, financial fragility holds that the financial system's stability is inherently fragile and that

small shocks can have significant and far-reaching consequences, leading to a financial crisis (Bordo & Wheelock, 1998). Balance of payment theory and Schwartz hypothesis posit that exchange rate and inflation intensify the influence of commodity prices on financial soundness (Kung'u, 2017; Schwartz, 1995). As such, the study investigated the influence of macroeconomic variables on the connexion between commodity prices and the BsFSI in Ghana.

Also, the degree of connectedness among commodity prices, BsFSI and macroeconomic variables over time has received less blatant exposure from empirical studies. Under interconnectedness, one can assess how the variables influence themselves in a single system across time. Interconnectedness allows policymakers to identify the behaviour (produce or receive a shock) of specific variables in a model over time. In a pairwise manner, most studies assess the nexus between commodity prices and macroeconomic variables (Barson et al., 2022; Cantah, 2018; Céspedes & Velasco, 2012; Guzman, Medina & Soto, 2014; Jena, 2017; Sanya, 2020; Smales, 2017; Tahar et al., 2021; Uysal & Adalı, 2022), BsFSI and macroeconomic variables (Anshu & Gakhar, 2019; Babihuga, 2007; Borio & Drehmann, 2011; Ghauri et al., 2019; Lindgren et al., 1996; Siklos, 2021). However, only (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020) assessed macroeconomic variables as the conduit through which commodity price shocks cause financial instability but not their interconnectedness across time. Assessing the variables in pairs hinders policy assessment as policymakers are not able to diagnose the specific impact of each variable in the model with respect to time. Therefore, the current study assessed

the interconnectedness among commodity prices, BsFSI and macroeconomic variables.

Statement of the Problem

The discourse surrounding the nexus among commodity prices, the BsFSI, and macroeconomic variables in Ghana indicates policymakers in Ghana face a significant challenge in understanding and navigating the intricate relationships among the variables. This knowledge gap impedes their ability to devise targeted policies and strategies, resulting in potential vulnerabilities within the financial sector and the broader economy. There is an evident need to bridge this gap, enabling effective decision-making and promoting resilience in the face of changing commodity dynamics and economic conditions. There is urgency to grasp the intricate connections between these variables which is evident in a multitude of studies that have evaluated the impact of commodity prices on BsFSI (Abaidoo et al., 2021; Agarwal et al., 2016; Kim, 2018; Kinda et al., 2018; Mupunga & Ngundu, 2020). However, prevailing results often confine themselves to conventional econometric techniques, thereby neglecting the asymmetrical behavioural patterns exhibited by investors across different time frames and frequencies (Garcia & Panetti, 2017; Lo, 2004; Müller et al., 1993, 1997; Niepmann, 2013).

Moreover, the existing body of literature predominantly consists of cross-country panel studies that only offer a partial view of the intricate nexus, with their focus restricted to aggregated regional dynamics rather than tailored insights relevant to country-specific context, such as Ghana (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020). The literature also lacks a comprehensive understanding of the impact of commodity prices on BsFSI,

particularly considering the complexities of asymmetric, non-linear, and non-stationary dynamics proposed by approaches like AMH and HMH.

Simultaneously, little is known regarding the role of the macroeconomic environment within the nexus, a role that is well-established in the Financial Fragility hypothesis (Abaidoo et al., 2021). Furthermore, the dynamics of the problem vary across different time horizons (HMH's concept) and frequency domains (as proposed by AMH) (Müller et al., 1993, 1997; Paulson & Leuty, 2016) . Traditional econometric tools and Fourier analysis fall short in capturing the nuanced dynamics within a time-frequency domain, impeding empirical understanding and potentially hindering effective policy implementation.

Amid this backdrop, the study aligns with Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth) and SDG 17 (Partnerships for the Goals), in its pursuit of fostering economic stability, informed decision-making, and collaborative development initiatives. Current literature largely examines relationships in pairs, providing incomplete insights into the behaviour of individual variables within an integrated model. As such, assessing the interconnectedness of commodity prices, financial sector soundness, and macroeconomic variables holistically offers policymakers valuable insights into potential spillover effects, positive or negative feedback loops, and resilient responses to shocks.

Considering the gaps, this study endeavours to comprehensively assess the nexus among commodity prices, BsFSI, and macroeconomic variables in Ghana. Drawing on insights from existing studies (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020), the current research expands on these gaps by incorporating asymmetric behaviours, time and frequency dimensions,

and interconnectedness. Through the application of novel techniques like Quantile Regression (QR), wavelet approaches, and Time-Varying Parameter Vector Autoregression (TVP-VAR) connectedness, the study aims to offer a more holistic understanding of the complex relationships involved. This also contributes to informing more effective economic policies within the context of Ghana's commodity-driven economy. Hence, the study examines the effect of commodity prices on Ghana's BsFSI. It further assesses the impact of macroeconomic variables on the nexus between commodity prices and BsFSI in a time and frequency domain. Furthermore, the degree of connectedness amid commodity prices, BsFSI and macroeconomic variables are also examined in this study.

Purpose of the Study

The study examines the interconnectedness among commodity prices, banking sector's financial soundness and macroeconomic variables in Ghana.

Research Objectives

The purpose of the study can be achieved through the specific objectives are to:

1. examine the effects of commodity prices on the banking sector's financial soundness in Ghana;
2. estimate the influence of macroeconomic variables on the relationship between commodity prices and banking sector's financial soundness in Ghana;
3. assess the degree of connectedness among commodity prices, banking sector's financial soundness and macroeconomic variables in Ghana.

Research Hypotheses

The research objectives led to the formulation of the following research hypotheses:

1. H_0: There are no effects of commodity prices on the banking sector's financial soundness in Ghana

   H_1: There are effects of commodity prices on the banking sector's financial soundness in Ghana
2. H_0: Macroeconomic variables do not influence the relationship between commodity prices and banking sector's financial soundness in Ghana.

   H_1: Macroeconomic variables influence the relationship between commodity prices and banking sector's financial soundness in Ghana
3. H_0: Ghana has no degree of connectedness among commodity prices, banking sector's financial soundness, and macroeconomic variables.

   H_1: Ghana has a degree of connectedness among commodity prices, banking sector's financial soundness, and macroeconomic variables

Significance of the Study

The findings derived from this study could benefit several diverse stakeholders. The study provides policymakers options to regulate the nature of the BsFSI to match the fluctuations in the commodity market (cocoa, gold and crude oil) while considering the behavioural patterns of investors. The government may find this study extremely useful, as sound BsFSI may encourage investor propensity to direct their investment to the Ghanaian

economy, enabling the African Continental Free Trade Area (AfCFTA). Also, households and firms would benefit from this study, as sound BsFSI would encourage savings and increase funds available for firms to take as loans and increase investment, holding other things constant.

Furthermore, policy maker, households, and firms can rely on partial wavelet coherence (PWc) to understand the pure coherence between commodity prices and BsFSI. With that, the known influence of macroeconomic variables on the co-movements of the variables is taken out of the equation, which enhances the decision-making process while providing an understanding of the lead-lag relationship amid commodity prices and BsFSI. The results of this study inform and guide the formulation of macroeconomic policies in Ghana and developing commodity-dependent countries, which would help the economy adopt fluctuations in commodity prices.

The interconnectedness among the individual variables also provides information on which receives or provides more shock in the model. This may guide how the Ghanaian government, in conjunction with diverse stakeholders, such as the Ministry of Trade and Industries, Ministry of Finance and the Bank of Ghana, to provide detailed policies that factor in the individual variables in the study. The findings from the study bridge gaps in theories and hypotheses regarding financial sector stability.

Delimitation of the study

The scope of the study is to examine the interconnectedness among commodity prices, banking sector's financial soundness and macroeconomic variables in Ghana using monthly data spanning from 2007 to March 2022. A total of 183 observations were used in the study. First, the study employs QR,

while using a non-parametric causality test to test for causality (Jeong et al., 2012). The wavelet techniques, specifically bi and partial wavelet, were employed to assess the influence of macroeconomic variables on the coherence between commodity prices and the BsFSI in Ghana. Finally, the TVP-VAR connectedness approach was used to assess the interconnectedness among the variables under study (Antonakakis et al., 2019, 2020). The commodity prices included in the study are monthly averages of international brent crude oil, cocoa, and gold prices. These were selected because they are the dominant commodities in the Ghanaian economy and provide more than 60% of export revenues (Ministry of Finance, 2022; UNCTAD, 2021).

The study also employed CD, CLATA, ROA, CLASA, ROE, CAR and NPL. The study included all these variables to deliver a holistic assessment of the financial sector indicators. The macroeconomic variables selected for the study were based on empirical and theoretical reviews. The variables identified and included are Inflation, Broad Money Supply, Monetary Policy Rate, Composite Index of Economic Activity (Real), Exchange Rate and Trade Balance. The study also controlled for the effect of GEPU to help provide a clear picture of the variables in the study. The study exempts variables such as savings and deposits, public debt, etc., stated in literature to serve as a channel of commodity price influencing BsFSI. Nonetheless, the variables included in the study can provide a general solution to the problem under study.

Limitations of the Study

The study is robust but restricted in some forms. Quantile on Quantile estimations could also provide detailed findings due to the heterogeneous nature of the commodity prices. Also, the study could have decomposed the series to

provide frequency-dependent asymmetric results for the quantile estimations. Nonetheless, the inference techniques employed in the study provide time and frequency results and minimise the data's noise, which is detailed based on the discussions. The study is also quantitative, ignoring the qualitative aspect of the variable that could have provided additional information to the results and discussions. However, the quantitative results are reliable and objective.

Organisation of the study

The thesis is structured into five chapters. Chapter one focused on the study's introduction, which includes the background, statement of the problem, objectives and research questions, significance of the study, and how the study will be organised. Chapter two provides comprehensive reviews of relevant literature to the study. It provides a theoretical and empirical study perspective based on the research objectives. Chapter three explains the research methods that were used in the study. It explains the model specification processes and how the study employed the model. Also, the data sources and measurements were described. Chapter four reports the results of the study. It analyses and interprets the results, and Chapter five offers the summary, conclusions, recommendations, and suggestions for future studies.

CHAPTER TWO

LITERATURE REVIEW

Introduction

The study examines the interconnectedness of commodity prices, the banking sector's financial soundness, and Ghana's macro-economy. This chapter has four broad sections: theoretical, conceptual, and empirical review, as well as the transmission mechanism. The theoretical review stimulates the study in a theoretical context. On the other hand, the empirical review addresses what other studies closely related to this study have done about this subject matter. The transmission mechanism shows how the variables are related to each other. Lastly, the overview of key variables provides a detailed explanation of the variables and a graphical representation of their current trends. The chapter ends with a summary of all that has been discussed.

Theoretical Review

There have been theoretical developments in the interest of the banking sector's financial stability/instability. Therefore, this study adopts the following theories to elaborate on the purpose of the study: (1) the theory of instability proposed by monetarists and (2) the Financial Fragility approach. The study also elaborates on (1) Schwartz's hypothesis, (2) heterogeneous market hypothesis (HMH), and (3) adaptive market hypothesis (AMH).

Monetarists' view on financial instability

The monetarists' view on financial instability is a perspective that suggests that financial instability is caused by monetary policy that is too slack or too tight (Friedman & Schwartz, 1963). According to monetarist theory, commodity prices are affected by changes in the money supply and interest rates

(Abaidoo et al., 2021). This view argues that a rise in the money supply or a decrease in interest rates can lead to excessive borrowing and speculation, resulting in financial instability. Similarly, a drop in the money supply or a surge in interest rates can result in a tightening of credit, leading to financial instability. According to this view, a wobbly monetary policy can result in an increase in commodity prices, which can result in excessive borrowing and speculation. This can create a situation where prices become disconnected from underlying economic fundamentals and a bubble form. When the bubble bursts, it can result in a financial crisis.

Vo et al. (2019) probed into financial instability; their conclusion on monetarists' view is that sudden upsurge and slump of liquidity in the market ascribed to asymmetrical and unpredictable monetary policy that is announced by policy makers without a corresponding consideration to the probable trade-offs amid economic growth and rate of inflation causes instability in the financial sector. The monetarists' view is employed in this study to explain how monetary policy and inflation could affect Ghana's banking sector's financial soundness. According to the monetarists' view, financial instability is caused by changes in the money supply and the cost of borrowing, which is influenced by government monetary policy (Bordo & Wheelock, 1998). According to this view, changes in the money supply can lead to changes in interest rates, which can influence commodity prices (Bordo & Wheelock, 1998). That is, if the money supply increases (decreases) and interest rates fall (rises), this could increase (reduce) demand for commodities, resulting in higher (lower) commodity prices (Abaidoo et al., 2021; Vo et al., 2019).

Financial fragility's approach

The financial fragility approach links financial instability unswervingly to the business cycle's peak and trough (Bordo & Wheelock, 1998). The financial fragility approach is rooted in Fisher's (1933) debt-deflation theory, which was extended in a number of studies (Borio & Drehmann, 2009, 2011; Friedman, 1986; Kaufman, 1986; Kindleberger, 1979; King, 1994; Minsky, 1972, 1977). The financial fragility view argues that a financial system is vulnerable to instability and crisis due to excessive debt, weak regulation, and interconnectedness of financial institutions. This view suggests that the financial system's stability is inherently fragile and that small shocks can have significant and far-reaching consequences, leading to a financial crisis.

The financial fragility view applies to the interconnectedness among commodity prices, financial sector soundness and macroeconomic stability by recognizing that fluxes in commodity prices can significantly impact the financial sector and the overall economy (Bordo & Wheelock, 1998). The financial Fragility argument is that debtors and creditors have an irrational expectation that investment gains will linger to rise past their real values. Therefore, when gains cease to rise, borrowers abruptly realise that their cash inflows are impossible to meet their debt repayment plan, leading to distress selling, which consistently reduces price (Abaidoo et al., 2021). Hence, borrowers attempt to liquidate their investments to meet their debt servicing obligations, resulting in a loss of confidence and credit collapse, which in turn causes financial institutions to become illiquid, leading to their inability to meet the demand for cash.

In conclusion, financial fragility holds that if a large portion of the financial sector is invested in commodities and the prices of these commodities drop, it can cause a decline in the value of assets, leading to a decrease in the capital of financial institutions. This can result in decreased lending and investment, which can ripple effect on the overall economy. Also, a drop in commodity prices can lead to a decrease in the value of the currency, making it more problematic for the financial sector to repay its foreign debt. This can result in financial instability and potentially a financial crisis. In summary, the financial fragility view recognizes the interdependence between commodity prices, financial sector soundness and macroeconomic stability. A change in one of these components can momentarily impact the others and create a fragile financial system and economy. The incorporation of M2 and EXR resonates with the Financial Fragility approach, which emphasizes the fragility of financial systems and the potential for imbalances to disrupt economic stability.

Schwartz Hypothesis

Schwartz Hypothesis, as proposed by Schwartz (1995), probes into how price-level fluctuations may lead to financial sector distress and instability (Bordo & Wheelock, 1998). The hypothesis suggests that the speed and magnitude of the transmission of changes in international prices to domestic prices are not symmetric, meaning that different products may respond differently to market conditions and events (Bordo & Wheelock, 1998). This can result in financial instability as different products may have varying impacts on the overall economy (Abaidoo et al., 2021). The Schwartz Hypothesis posits that when inflation persists, it fosters a culture of speculative investment and borrowing, as people anticipate that prices will continue to climb (Minsky,

1977; Mishkin, 1999). Consequently, default rates among borrowers increase, eroding lenders' equity and potentially leading to a surge in financial institution failures. However, even in the absence of inflation or disinflation, real shocks - such as those witnessed in commodity markets during the 1970s, early 1980s, and 2014-2016 - can still trigger severe financial distress.

Although Schwartz (1995) does not provide a direct framework for how fluctuations in the inflation rate can cause financial (in)stability, her account is consistent with Lucas's (1973) model of monetary misperceptions. Schwartz's (1995) model presumes that individuals cannot accurately distinguish shifts in relative prices from changes in the overall price level, leading to a misallocation of resources that is eventually corrected once the true nature of a price shift becomes apparent. Thus, in a commodity-dependent country, a firm may increase its output in response to a perceived surge in commodity demand reflected in rising market prices. However, if the producer understood that the price hike merely reflected a general increase in prices across goods and services rather than a shift in relative prices favouring the firm's output, the producer would likely not find it lucrative to boost production. Therefore, the Schwartz hypothesis is incorporated into the study to explain the effect of changes in commodity prices on Ghana's banking sector's financial soundness.

Heterogeneous Market Hypothesis (HMH)

The heterogeneous market hypothesis suggests that markets may have unique characteristics and market dynamics over time that cause markets participant to change their decisions (Müller et al., 1993). The HMH posited by Müller et al. (1993), volatility exemplifies market participants' behaviour rather than just a sign to price changes. Volatility is an indicator of the persistence of

trends, positively correlated with market activity, volume and presence, as well as an understanding of the market structure (Müller et al., 1993, 1997). The HMH asserts that market participants are not homogeneous because of their respective endowments, interest, degree of risk and available news and how they interpret and react to this news (Müller et al., 1993; Owusu Junior, Frimpong, et al., 2021). This heterogeneity can result in varying market responses to the same information, leading to non-linear and non-symmetric price movements. HMH proposed that the market is composed of different participants, each with its time horizon, which can be modelled as an intrinsic time. The intrinsic time is constructed by the time series, not an external clock.

The HMH is adopted in this study because the commodity market has different market participants dealing at diverse frequencies which is shown in the wavelet analysis. That is, those trading at a high frequency and those of low frequency. The various trading frequencies show different reactions to the same news in the commodity market (Bossman et al., 2022). The commodity market is heterogeneous, with market participants' time horizons represented as intrinsic time; short-term, medium-term and long-term (Asafo-Adjei, Boateng, et al., 2021; Hau et al., 2020). Each market participant's response time to news, such as covid-19 commodity price shock, etc., is linked to its time horizon and distinguishing trading frequency (Boateng et al., 2021). In a heterogeneous market like the commodity market, different participants can probably arrive at different commodity prices and decide to perform their transactions in diverse market conditions (Müller et al., 1997).

Adaptive Market Hypothesis (AMH)

The Adaptive Market Hypothesis (AMH) proposes market efficiency can vary over time and across market conditions, with different degrees of efficiency in different market environments based on economic, social and political events (Lo, 2004). The theory asserts that market participants react to new information and adjust their expectations, accordingly, leading to changes in asset prices. The AMH posits that markets are not guided by rationality but rather by emotions such as fear and greed (Lo, 2004). Lo (2004) postulated AMH is based on evolutionary principles with the notion of bounded rationality. The AMH is built on the idea that prices in the market depend on the prevailing environmental circumstances and the quantity and characteristics of diverse market participants (Owusu Junior, Frimpong, et al., 2021). The economic profit in a market is contingent on the number of market participants and market conditions.

The AMH suggests that the behaviour of market participants evolves over time as they adapt to changing market conditions. This adaptation is driven by learning, experience, and feedback mechanisms. AMH acknowledges the presence of both rational and irrational behaviours in financial markets, and it explains market dynamics as a combination of periods of efficiency and inefficiency. Therefore, AMH opined that trading in markets experiences gains and losses due to changing market conditions, the barrier to entry or exit from the industry, and the nature and degree of profit opportunities obtainable. As such, the number of participants in the market changes to correspond with the economic opportunities. The AMH is adopted to explain that different conditions in the market produce diverse market efficiencies. AMH would be

used to understand the behaviour of market participants towards BsFSI under different market conditions.

Overview of Key Variables

This section explains in detail the critical concepts used in the study. Generally, the study discusses commodity prices, BsFSI and some selected macroeconomic variables in Ghana as well as a graphical representation of the trend of each concept.

Commodity Prices

Commodities are considered natural resources that serve as intermediate goods in manufacturing (Chuku & Simpasa, 2018). Generally, there are different categories of commodities, namely, crude oil, metals (which comprises of but are not limited to tin, iron, aluminium, nickel-copper, ore, lead uranium and zinc), agricultural materials such as timber, wool, cotton rubber and hides, food items like oils, seafood meat, sugar, oranges and bananas, and beverages such as coffee, tea and cocoa (UNCTD, 2021). Commodity exportation generates revenues stabilising many economies, with commodity-dependent economies having over 60% of their merchandise export from commodity exportation (Laksaci, 2016).

As a commodity-dependent company, Ghana is blessed with most commodities in commercial quantities. However, the dominant ones in their export activity are cocoa, gold and crude oil (Bank of Ghana, 2021a). Commodity provides the Ghanaian economy with income and employment for individuals and industrial raw materials and resources for use and exportation (Okyere & Mensah, 2021). The work of Okyere and Mensah (2021) posited that cocoa exportation contributes to a large amount of revenue in Ghana. Similarly,

studies postulated that revenue from cocoa, gold and crude oil exportation account for large amounts of exportation in Ghana (Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022; Boateng et al., 2022). The trend of major international commodity prices from January 2007 to March 2022 exported in Ghana is presented in Figure 1.

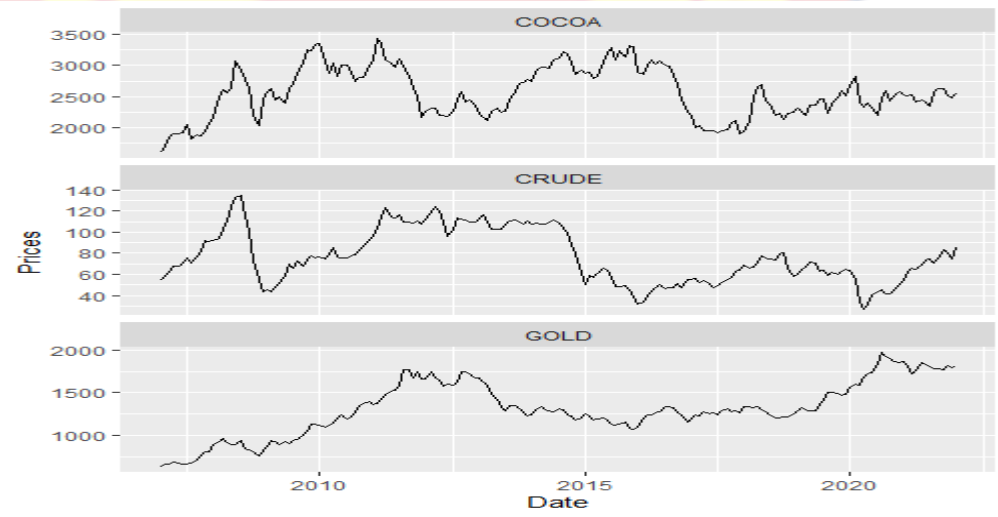

Figure 1: Trend of major international commodity prices exported in Ghana. Source: Author's Construct (2023)

Figure 1 depicts that cocoa price has been volatile over the past 15 years, fluctuating on supply and demand dynamics, weather conditions, and economic developments. From 2007 to 2022, the international cocoa price has generally trended upward, reaching peaks in 2010, 2016 and 2020. However, there have also been price drops in specific years, such as in 2008 due to the GFC and in 2015 due to increased supply and lower demand (Asafo-Adjei, Adam, et al., 2021). Overall, the international cocoa price has remained relatively high, reflecting the ongoing demand for cocoa products and the limited global supply of cocoa beans.

The crude oil price has been volatile from 2007 to March 2022. The price experienced a significant increase in the mid-to-late 2000s, peaking at over $140

per barrel in 2008 before plummeting during the GFC. The price then gradually recovered and reached another peak in the mid-2010s, hovering around $100 per barrel before declining again in 2014. Since then, the price has remained relatively low and stable, fluctuating between $40 and $60 per barrel until the end of 2020. In 2021, the price rose due to increased demand and supply disruptions instigated by the COVID-19 pandemic. As of March 2022, the Brent crude oil price is around $70 per barrel.

The gold price increased from around $700-$800 per fine ounce in 2007 to a peak of over $1,900 in 2011 and then fluctuated over the following years, with a general upward trend. From late 2020 to March 2022, gold prices reached new all-time highs above $2,000 per fine ounce due to global economic uncertainty, low-interest rates, and increased demand for safe-haven assets (Boateng et al., 2022). In a more contemporary context, the COVID-19 pandemic and the accompanying uncertainty and economic disruption have contributed to increased demand for gold and a rise in its price. Overall, the trend in international gold prices has been upward over the past 15 years, reflecting both the general upward trend in commodity prices as well as specific factors that have driven demand for gold.

Exportation of cocoa was 2,661.36m in 2017, 2,180.00m in 2018, 2,288.41m in 2019, 2,328.16m in 2020 and 2,851.12m in 2021. Within the same periods in millions, gold exportation was 5,786.16, 5,435.70, 6,229.69, 6,799.09, and 5,083.14. Similarly, Crude oil export revenues were 3,114.93m in 2017, 4,573.43m in 2018, 4,493.07m in 2019, 2,910.62m in 2020 and 3,947.72m in 2021. Fluctuations in commodity prices shown in Figure 1 are known to worsen the BsFSI of Ghana (Bank of Ghana, 2021a). Notably, the

negative impact of a slump in commodity price is felt more in an export-dependent economy like Ghana; it reduces household and government revenue which increases the chance to default on loan payments, thereby disturbing the financial soundness of Banks (Mupunga & Ngundu, 2020).

Banking sector's financial soundness

The banking sector plays an essential function in the contemporary economy by facilitating financial intermediation, which refers to the process of directing money from those who save to those who invest while making a profit from the risk they expose themselves to (Abaidoo et al., 2021). An unsound banking sector would hinder economic growth and household investments (Agarwal et al., 2016). The financial sector crises in 1990 ignited the search for financial soundness indicators (FSI) (Babihuga, 2007). The search gave birth to macroprudential indicators, and later, the IMF discovered some core FSI (Sundararajan et al., 2002). Since then, IMF and the World Bank have spearheaded the dimension and practice of FSI (Babihuga, 2007).

The BsFSI has gone through vigoro to arrive at this point, following some guidance from the CAMELS framework (Abusharbeh, 2020; Sundararajan et al., 2002). FSIs are comprehensive indicators that assess the overall financial well-being and stability of financial institutions, as well as their corporate and household clients within a given country (Chauhan & Ramesha, 2016; Mupunga & Ngundu, 2020; Ramlall, 2018; Sundararajan et al., 2002). FSI comprises aggregated individual institution data and market-based indicators that represent the environments in which financial institutions operate.

Thus, FSI comprises specific indicators that capture factors that threaten the financial system of the whole economy (Alodayni, 2016). FSI offers insights into the stability and effectiveness of the banking sector, as well as the state of financial and real estate markets, non-bank financial institutions, and the financial standing of corporations and households (Sundararajan et al., 2002). Monitoring the soundness of these institutions is vital for detecting any potential accumulation of systemic risk that could precipitate a crisis (Diaconu & Oanea, 2014; Pietrzak, 2021; Uysal & Ucler, 2017). The range of FSIs speckled somewhat conditional on the specific country case, but the idea of the CAMELS framework always holds. CAMELS framework analyses six bank soundness indicators: capital adequacy, asset quality, management soundness, earnings, liquidity, and sensitivity to market risk (Sundararajan et al., 2002).

The capital adequacy ratio (CAR) shows the solvency of banks (Mupunga & Ngundu, 2020; Obuobi et al., 2020). The resilience of financial institutions to disruptions in their balance sheets depends on their capital adequacy and availability (Abusharbeh, 2020). CAR is a metric for gauging a bank's ability to withstand losses, with a higher ratio indicating a greater capacity to absorb losses without jeopardizing solvency (Kinda et al., 2018). A decline in this ratio may indicate elevated risk exposure and potential issues with maintaining adequate capital levels (Anshu & Gakhar, 2019).

A common indicator of the asset quality of a bank or financial system is the non-performing loans (NPLs) to total loans ratio (Sundararajan et al., 2002). Asset quality ratios provide insight into the composition of a deposit taker's assets and reveal potential vulnerabilities stemming from non-performing loans and insufficient diversification. They offer a glimpse into the likelihood of

losses and risks that a deposit taker might face (Obuobi et al., 2020). It is important to consider recovery rates alongside NPL trends, as they provide insights into the capacity of financial institutions to manage large portfolios of non-performing loans. Recovery rates reflect the extent of effort or capability of financial institutions in handling high levels of NPLs (Sundararajan et al., 2002). Thus, loan concentration increases banks' exposure to sector-specific shocks or crises (Kinda et al., 2018).

Bank margins, income, and expenses broadly proxies bank earnings and profitability (Sundararajan et al., 2002). According to Vittas (1991), three operating ratios are commonly employed to evaluate the performance of banks: operating asset ratios, operating income ratios, and operating equity ratios. However, because there are variations in capital structure, business mix, and accounting practices among banks across countries and over time, it is necessary to examine several operating ratios concurrently to obtain a more comprehensive understanding of bank performance (Abaidoo et al., 2021). Capital structure differences pertain to variations in bank leverage, while business mix differences arise from dissimilar combinations of high- and low-profit activities. Accounting practices that affect operating ratios include the assessment (and reassessment, in the context of inflation) of assets, the management of depreciation reserves, employee pension schemes, loan-loss provisions, and the application of undisclosed reserves (Sundararajan et al., 2002).

The resilience of a banking system in the face of shocks is influenced by the level of liquidity (Abusharbeh, 2020; Ramlall, 2018). Liquidity measures, such as the liquid asset ratio (i.e., liquid assets to total assets), the ratio of liquid

assets to short-term liabilities, or loans to assets, serve as standard liquidity indicators. Liquidity pertains to cash and any asset that can be quickly converted to cash without significant losses (Obuobi et al., 2020). Liquidity measures reveal the maturity structure of an asset portfolio and can reveal excessive maturity mismatches that signal a need for more prudent liquidity management (Naser, 2019).

The Bank of Ghana presents data on BsFSI, such as CAR, NPL, ROE, ROA, CLATA, CLASL, and CD (*Financial Soundness – Bank of Ghana*, n.d.). These indicators' trends from January 2007 to March 2022 are presented in Figure 2. Figure 2 depicts that the CD ratio was very high at the beginning of 2007, with a corresponding decrease in CAR and NPL up to 2010 when there was a sharp decrease in CD and a beginning rise in CAR and NPL. The higher CD environment means strong demand for credit due to relatively slow deposit growth. A low CD ratio has been the trend since 2015; CD keeps reducing, suggesting poor credit growth compared with deposit growth. The slip to a historic low CD could be linked to the high NPL in the same season, which keeps banks relaxed about giving out loans. Low values of CAR before 2010 show the banks did not have enough capital on reserves to handle the inevitable shock. The trend of CAR saw flexible fluctuations with significant falls in 2016 and 2020, which can be linked to the international commodity price fall in 2015 and the Covid-19 pandemic peak in 2020. NPL was at its highest between 2015 to 2020, as shown in Figure 2.

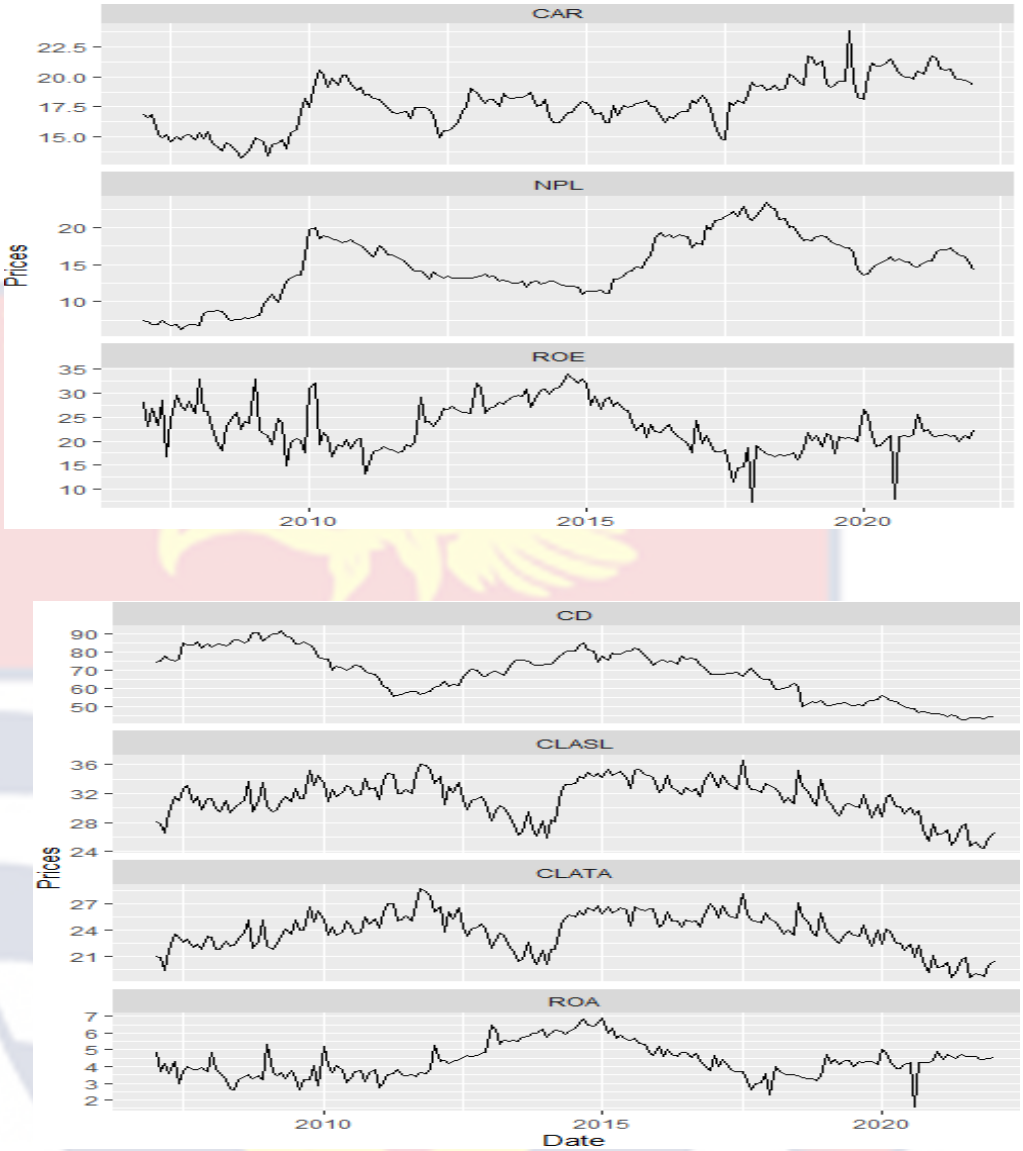

Figure 2: Trend of BsFSI of Ghana
Source: Author's Construct (2023)

Figure 2 shows that in the last decade, Ghana's 2015 to 2020 period was its darkest moment. Almost all the indicators were decreasing or opposite the preferred direction. The profitability indicators ROE and ROA were reducing, and the same observations were seen with CLATA and CLASL, which are the Liquidity indicators. The spike before the 2020 year in the CAR trend can be allied to the clean-up in the banking sector in 2019.

Trends of Ghana's Macroeconomic variables

Macroeconomic variables are key economic indicators that provide a broad understanding of an economy's overall health and performance (Babihuga, 2007). Macroeconomic variables' trends also signal when there is a recession and economic growth and provide a platform to anticipate some major occurrences in the economy. Some of the selected macroeconomic indicators for Ghana include Inflation (INF), Monetary Policy Rate (MPR), Composite Index of Economic Activity (Real) (CIEAR), Broad Money Supply (M2), Exchange Rate (EXR) and Trade Balance (TB) which align with the theories adopted in the study. These indicators are relevant due to their ability to provide insights into inflationary pressures, monetary policy effects, economic fluctuations, financial sector stability, currency risk, trade imbalances, and the varying strategies and behaviours of market participants. The first three selected macroeconomics are presented in Figure 3, and the last three are presented in Figure 4. The study shows the trends from January 2007 to March 2022.

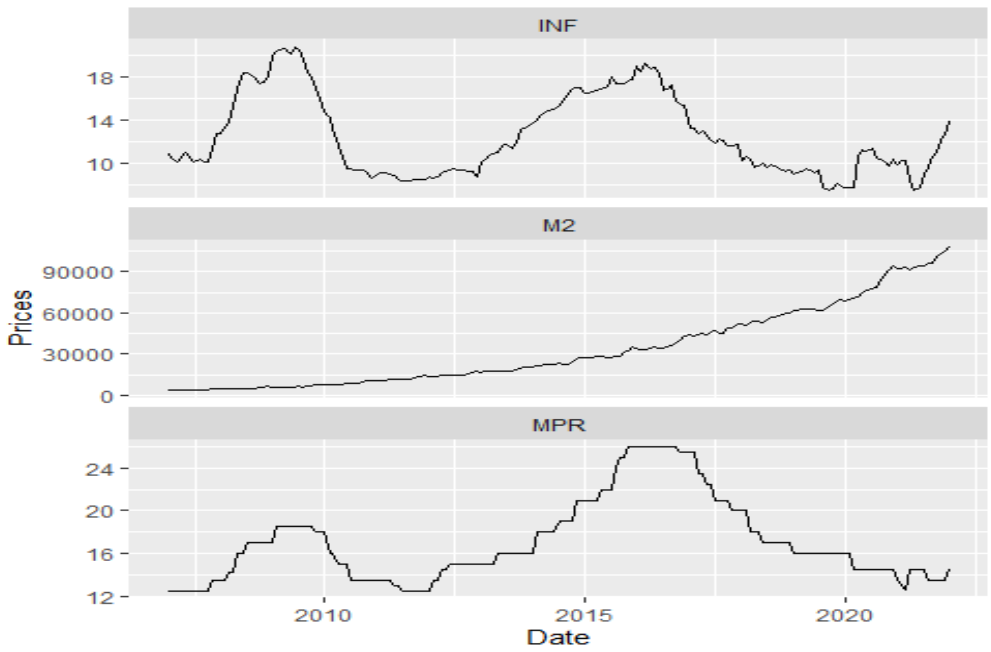

Figure 3: Trend of broad money supply, inflation and monetary policy rate
Source: Author's Construct (2023)

Inflation (INF)

Inflation is a crucial macroeconomic indicator that holds a substantial impact on macroeconomic stability and serves as a primary focus of macroeconomic policy aimed at attaining sustainable rates of economic growth and development in numerous countries (Boateng et al., 2022; Guzman, Medina & Soto, 2014; Naser, 2019; Vo et al., 2019). In an economy experiencing inflation, the effectiveness of money as a medium of exchange and store of value is compromised, leading to negative consequences for output, employment, and real income (Rover et al., 2013). As the overall price level rises, borrowing costs, represented by interest rates, also increase, decreasing investment levels across the economy (Schwartz, 1995).

With the reduced investment, the level of loan repayment is also reduced, causing distress in the financial sector (Bordo & Wheelock, 1998). The trend of INF in Figure 3 is due to the inflation-targeting regime that started in 2007. At that time, BoG set its target of a 5% inflation rate. Inflation rates fell significantly below ten (10) from 2010 through 2012. The average inflation rate in Ghana from 2007 to 2021 was 15.6%. The highest inflation rate was recorded in 2008, at 22.9%, while the lowest was in 2015, at 9.0%. However, the consumer price inflation rate rose to 12.6% in December 2021, the highest annual inflation rate since the basing of the Consumer Price Index (CPI) basket in 2019. This increase is attributed to several factors, including the rise in crude oil prices, exchange rate depreciation, and upward adjustments in ex-pump prices.

Broad money supply (M2)

Broad money is the sum of the Ghana cedi notes and coins and the Bank of Ghana and building society deposits held by the Ghana non-bank private sector (Antwi et al., 2020). Apart from the currency in circulation and sight deposits held by domestic non-banks, the broad money supply measure also encompasses time deposits and short-notice savings deposits held by domestic non-banks. The shape of M2 is either constant or rising, as shown in Figure 3. In general, the M2 is rising, but the trend depicts a sharp rise in 2021 and a slight drop in 2022 before another rise.

Between December 2020 and December 2021, the annual growth rate of M2 decelerated from 27.6% to 12.3%, indicating a slower expansion of the money supply during the year. From January 2021 to September 2021, the monthly growth rate of M2 fluctuated, ranging from a low of 0.6% in May 2021 to a high of 6.9% in March 2021. The total value of M2 in Ghana increased from GHS 139.3 billion in December 2020 to GHS 155.2 billion in December 2021, reflecting an overall growth in the money supply. Over the past five years (2017-2021), the average annual growth rate of M2 in Ghana was about 20.4%, indicating a relatively rapid expansion of the money supply. Overall, the trend of broad money supply in Ghana has been positive, indicating growth in the economy and the financial sector.

Monetary policy rate (MPR)

The primary objective of price stability is achieved by anchoring short-term market interest rates through the Monetary Policy Rate (MPR), which also signals the stance of monetary policy (Mohammed, 2021). In an inflation-targeting system, the primary tool for regulating the economy is the monetary

policy rate, which affects aggregate demand and inflation patterns through the interest rate channel. Moreover, the monetary policy rate impacts the economy through credit availability, exchange rates, and market expectations (Siklos, 2021). Taylor (1993) suggests that when inflation exceeds its target or when output is above its full-employment level, a relatively high-interest rate, commonly referred to as MPR, should be employed to decrease inflationary pressure. As a result, MPR and real interest rates are frequently used interchangeably. In 2021, there was a reduction of 100 basis points in the MPR from 14.5% to 13.5% in May, and then further lowered to 13.0% in September as part of the Bank of Ghana's efforts to support economic recovery from the COVID-19 pandemic in Figure 3. In 2020, the MPR was reduced from 16.0% to 14.5% in March and then to 14.5% in September in response to the pandemic-induced economic slowdown and inflationary pressures. In 2019, the MPR was raised from 17.0% to 20.0% in January to curb inflation and stabilize the currency, then gradually reduced to 16.0% by the end of the year. In 2018, the MPR was reduced from 20.0% to 18.0% in March and then to 17.0% in November as inflation moderated and economic growth improved.

Composite index of economic activity (Real)

The Composite Index of Economic Activity (Real) measures the short-term dynamic is aggregated economic activities of a country (Boateng et al., 2022). CIEAR brings out short-term economic analysis. CIEAR is a Bank of Ghana product that helps the bi-monthly report and policy interest rate setting of the Monetary Policy Committee. The BoG uses CIEAR to track business confidence as its measure closely tracks GDP (Boateng et al., 2022). Figure 4 shows that CIEAR showed a sharp reduction in 2020 owing to the COVID-19

pandemic, with a year-on-year waning of 3.2% in June 2020. CIEAR rebounded in the second half of 2020 and showed a positive year-on-year growth rate of 3.3% in December 2020. CIEAR continued to expand in the first half of 2021, with a year-on-year growth rate of 8.7% in June 2021. However, the CIEAR growth rate slowed in the second half of 2021, with a year-on-year growth rate of 4.3% in November 2021.

Exchange rate

Since ancient times, economics and finance literature have emphasised the importance of exchange rates, specifically in international trade (Ca' Zorzi et al., 2017; Zankawah & Stewart, 2019). The exchange rate is a key macroeconomic variable of a country's economic standing globally and is a measure for assessing its level of international competitiveness on the global stage (Dornbusch, 1985). The exchange rate is the value at which a currency of one nation can be traded or converted for another nation's currency (Jääskelä & Smith, 2013). This suggests that the value of the exchange rate is a solid economic basis that influences other economic factors. The two main exchange rate regimes are fixed/ pegged and floating/flexible (Carrière-Swallow et al., 2021).

With the fixed exchange rate, currency devaluations and revaluations were only allowed within the predetermined range (Eguren-Martin, 2016). A country's monetary authorities' flexible exchange rate system allows the exchange rate to alter freely in line with the foreign exchange market forces of buying and selling (Carrière-Swallow et al., 2021). Although a highly fluctuating currency poses a considerable risk to trading partners, the floating exchange rate is widely acknowledged as efficient in modern market economies

(Eguren-Martin, 2016; Towbin & Weber, 2013). The trend of EXR in Figure 4 is not surprising because the Ghanaian currency has seen drastic depreciation against the US dollar. In 2017, the cedi was trading at around 4.5 to 1 US dollar, but by 2021, it had weakened to around 6.0 to 1 US dollar. The exchange rate has been characterized by significant volatility, with sudden and sharp fluctuations that can make it difficult for businesses to plan and invest (Carrière-Swallow et al., 2021).

Trade balance

A country's trade balance is an important macroeconomic indicator that reflects the difference between the value of goods and services that a country exports and imports (Rees, 2013). Between 2007 and 2022, the trade balance of many countries fluctuated, with some countries experiencing a trade surplus and others a trade deficit. Ghana has experienced a fluctuating trade balance over the past decade, with the values ranging from a low of USD -1,781.8 million in 2015 to a high of USD 1,107.6 million in 2020. According to the BoG report, the country's trade balance reduced from USD 2,256.8 million in 2018 to USD 2,043.0 million in 2019 and stood at USD 1,107.6 million in 2020 (Bank of Ghana, 2021a). This suggests that the country is still heavily reliant on imports and has been unable to boost its export competitiveness. Several factors have contributed to Ghana's trade imbalance, including the country's overreliance on a few export commodities, such as gold and oil, which are vulnerable to price volatility (Cantah, 2018). The Ghanaian government has implemented several policy measures to address the trade imbalance, including export promotion schemes, import substitution policies, and measures to boost domestic manufacturing. The trend of the trade balance is shown in Figure 4.

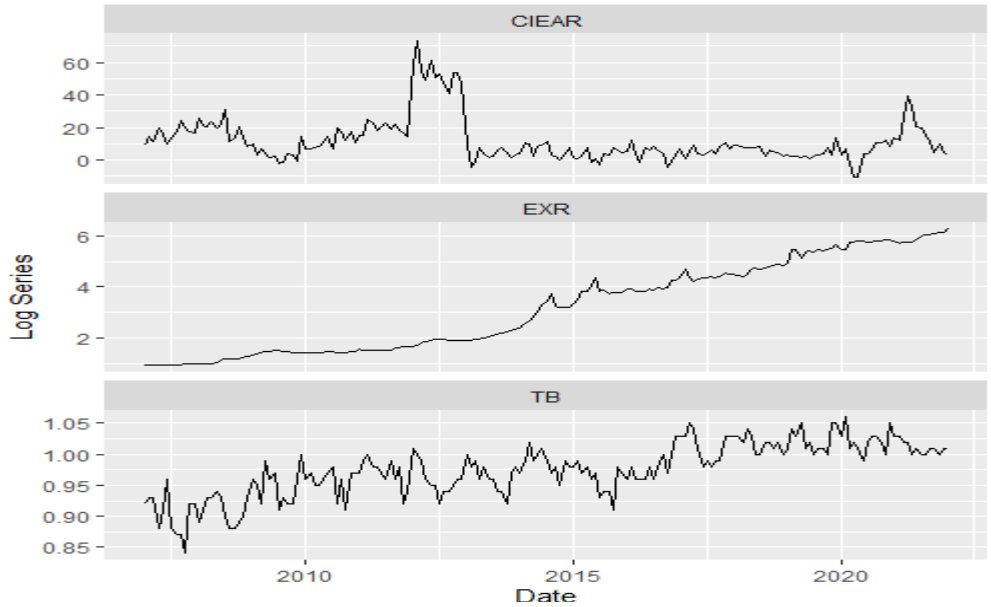

Figure 4: Trend of composite index of economic activity (real), exchange rate and trade balance
Source: Author's Construct (2023)

Transmission Mechanism

A rise (decline) in commodity prices can increase (reduce) the profitability of firms in the commodity sector which increase (reduce) the export earnings of a commodity-dependent country, increasing (decreasing) economic growth as a result of increasing (decreasing) trade balance, leading to higher (lower) levels of borrowing and lending activities (Enwereuzoh et al., 2021; Kinda et al., 2018). Also, it increases (decreases) the risk of financial instability if borrowers are unable(able) to repay their debts. But events similar to the crude oil price slump in 1984-1986, the commodity price drop in 2014-2016, and the COVID-19 pandemic caused households and firms' behaviour patterns to differ across time (Owusu Junior, Frimpong, et al., 2021). This asymmetric and time-based behaviour of households and firms causes the relationship between commodity prices and commodity-dependent countries' financial soundness to be supported by AMH (Lo, 2004) and HMH (Müller et al., 1993, 1997).

Also, a decrease in export earnings can lead to a decline in the value of a country's currency, eroding people's purchasing power and confidence in the economy. Furthermore, the government may have to resort to measures such as printing more money, which can lead to inflation. Similarly, fewer export earnings make it more difficult for the government to meet its obligations (Abaidoo et al., 2021). These can reduce confidence in the banking system, causing people to withdraw their savings from banks and convert them into assets they believe will hold their value better. Finally, causing difficulties with liquid assets because banks may not have enough cash to meet the demand for withdrawals. As such, illiquid banks may have to borrow from other banks, which can increase the cost of borrowing and lead to a shortage of credit.

Furthermore, suppose commodity prices increase (decrease), it may lead to higher (low) economic growth and an increase in credit demand, which in turn can drive up (bring down) credit-to-deposit ratios, return on assets, capital adequacy ratios and a decrease (increase) in non-performing loans. Improved (reduced) performance of financial institutions can result in lower (higher) financial instability (Abaidoo et al., 2021; Enwereuzoh et al., 2021). If commodity prices increase (decrease), it can lead to an improvement (reduction) in the balance of payments and an increase (decrease) in liquid core assets, which can help to ensure (endanger) the stability of the financial sector (Kinda et al., 2018).

Empirical Review

This section presents empirical works on the connectedness of commodity prices, banking sector financial soundness and macroeconomic variables that emerged over the years.

Relationship between commodity prices and the Banking sector's financial soundness

Prior studies on commodity prices and Banking sector financial soundness have focused on either sole commodity price, commodity prices shock or a specific banking sector financial soundness. Some specific empirical studies are;

Alodayni (2016) probed into the effect of oil prices on bank stability across Gulf Cooperation Council (GCC) Oil exporting countries. The author used 38 GCC banks which data period of 2000 to 2014. The methodologies employed by the paper are GMM, fixed effect model and PVAR. GMM and fixed effect models determined non-performing loans (NPLs) response to macroeconomic variables. The Panel VAR model examined the macro-financial linkages between GCC banking systems and the real economy. The results showed that oil price determines financial stability, specifically NPL.

Miyajima et al. (2017) assessed the impact of oil prices on the banking system in the GCC countries. The time span of the data used was 1999 to 2014. The study employed multivariate econometric and Panel VAR. The multivariate results show that oil prices and economic activity significantly affect bank asset quality. The study suggests that if oil prices continue to decline and GDP growth slows, there could be an increase in the ratio of non-performing loans (NPLs) to gross loans. The second analysis, which used a panel VAR approach, found feedback loops between oil price movements, bank balance sheets, and asset prices in the Gulf Cooperation Council (GCC). A decrease in oil prices would lead to a rise in the NPL ratio and a reduction in the real growth rates of bank credit and deposits. There was also a feedback effect within bank balance sheets,

where a higher NPL ratio would result in lower real bank credit and deposit growth. Equity price performance amplifies the bank liquidity feedback loop from an adverse oil price shock.

The empirical study of Miyajima (2017) probed into the Oil-Macro-financial linkage in Saudi Arabia using data from 1999-2014 and employed a multivariate panel model and a panel VAR model. First, a panel multivariate model results opined that lower growth rates of oil prices and non-oil private sector GDP increase NPL ratios, representing higher bank solvency risk.

Kinda et al. (2018) researched whether commodity price shocks weaken countries' financial sectors. The authors used 71 countries with data spanning from 1997 to 2013. They employed seven financial sector indicators (NPL, ROE, provision to NPL, ROA, liquid assets to deposits and short-term funding, the cost-to-income ratio, and regulatory capital to risk-weighted assets). The authors finally adopted the panel fixed effect method to help assess the effect of commodity price shock on BsFSI. The results showed that commodity shocks are highly correlated to financial sector fragility. That is, negative shocks affect high financial sector fragility. More specifically, countries with no sovereign wealth fund, poor governance and not under IMF programs are more affected by NPL bank costs. They concluded that positive commodity shocks could cost systematic banking crises as they reduce bank profitability.

Following the methodology of Kinda et al. (2018), Mupunga and Ngundu (2020) investigated the influence of commodity price shocks on financial stability in some selected commodity-dependent countries in the southern part of Africa from the period of 2000 to 2015. Their results were similar to that of Kinda et al. (2018). As such, they discovered that negative

price commodity shock increases NPL and reduces banks' profitability, as shown in ROE and ROA. The study also concluded that the main transmission channel of commodity shock to financial stability is GDP growth, fiscal revenue, savings and fiscal deficit.

Okyere and Mensah (2021) examined the impact of cocoa price shock on banks' profitability in Ghana. The study period was from 2010 to 2020, employing vector error correction model, cointegration, and impulse response functions. The findings showed a negative relationship between cocoa prices and banks' profitability in the short term. The causality test results confirmed the significant effect, emphasising cocoa prices' unidirectional impact on bank profitability.

The following hypothesis is formulated from the empirical review:

H_1: There are significant effects of commodity prices on the banking sector's financial soundness in Ghana.

Influence of macroeconomic variables on the relationship between commodity prices and Banking sector financial soundness

Commodity prices have been established in literature to influence the banking sector's soundness directly. However, based on prior studies, it can be established that commodities prices can indirectly, through macroeconomic variables, affect the banking sector's financial soundness. Some empirical studies are as follows

Babihuga (2007) did study the relationship between macroeconomic and financial soundness indicators. The study included many macroeconomic indicators which are considered vital to economic development. The study used panel data from 96 countries from 1998 to 2005 and employed pool OLS, fixed

effect and GMM. The results showed that inflation and real exchange rate negatively influence ROE. In contrast, NPL is influenced positively by inflation, interest rate, and trade term and negatively by the real exchange rate. CAR fluctuates negatively with real exchange and interest rates and positively with inflation.

Sheefeni (2015) assessed the macroeconomic determinants of non-performing loans in Namibia from 2001 to 2014. The econometric techniques employed are cointegration, granger causality, impulse response functions, and forecast error variance decomposition. The results established a long-run relationship between non-performing loans and macroeconomic variables such as GDP, interest rate and inflation rate. The interest rate was found to granger cause non-performing loans in the long run. The impulse results showed that in the short run, only GDP determines NPL, but in the long run, all the GDP, interest rate, and inflation rate determine NPL.

The empirical study of Miyajima (2017) probed into the Oil-Macro-financial linkage in Saudi Arabia using data from 1999-2014 and employed a multivariate panel model and a panel vector autoregression model. The panel VAR model results suggested that lower macroeconomic conditions (lower growth of oil prices and nonoil private sector GDP) lead to weaker bank balance sheet conditions (higher NPL ratios, lower deposit and credit growth), which spill back to weak macroeconomic conditions further.

Mohammed (2021) researched the effects of oil price shocks on the exchange rate, monetary policy rate and inflation in Ghana. The study sample period was monthly data from 1973 to 2018. The author used SVAR and OLS techniques while splitting the dataset into two-period net export and net

importer. The study found no significant impact of oil price shock on the exchange rate, monetary policy rate and inflation in all datasets. The findings are also supported by a robustness check.

Abaidoo et al. (2021) assessed the stability in the banking industry and commodity price volatility of 30 developing economies through the generalised two-step methods of the moments technique. The annual data from 2002 to 2018 was used. The results presented that the impact of commodity price shocks on bank stability depends on the kind of commodity exportation by the country. Also, they indicated the macroeconomic variables (government effectiveness and corruption control) moderate the impact of commodity prices on financial sector stability.

The following hypothesis is formulated from the empirical review:

H_2: Macroeconomic variables influence the relationship between commodity prices and banking sector financial soundness in Ghana.

Connectedness among Commodity Prices, Banking sector financial Soundness and Macroeconomic Variables

The relationship between commodity prices, BsFSI, and macroeconomic variables has been examined mainly in economics and financial literature pairs. Prior studies on this interconnectedness include Commodity-Macroeconomic nexus (Basarir & Bayramoglu, 2018; Céspedes & Velasco, 2012; Chuku & Simpasa, 2018; Kannapiran, 2000; Naraidoo & Paez-Farrell, 2022; Nya & Onyimadu, 2019; Swaray, 2008), Macroeconomic-Banking sector financial soundness (Anshu & Gakhar, 2019; Babihuga, 2007; Ghauri et al., 2019; Naser, 2019), Commodity-Macroeconomic-financial soundness nexus

(Abaidoo et al., 2021; S. Ghosh, 2010; Kinda et al., 2018; Mupunga & Ngundu, 2020; Siklos, 2021; etc.).

Interdependencies among commodity prices, banking sector financial soundness and macroeconomic variables are probed from different perspectives as provided by prior literature. While some studies consider interdependencies by observing the relationship dynamics from a univariate perspective (Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022), others consider the bivariate case (Salisu et al., 2018). Moreover, multivariate analysis has increased growing attention among researchers and policy-makers since the financial sector does not operate in a vacuum (Abaidoo et al., 2021; Boateng et al., 2022; Miyajima, 2017), as well as studies that combine both bivariate and multivariate analyses (Kinda et al., 2018; Mupunga & Ngundu, 2020). However, a multivariate analysis is preferred to provide a full glimpse of the interconnectedness among the various variables in the study simultaneously.

The following hypothesis is formulated from the empirical review:

H_3: Ghana has a significant degree of connectedness among commodity prices, banking sector financial soundness, and macroeconomic variables.

Gaps Identified

Prior literature reviews on the nexus between commodity prices, banking sector financial soundness and macroeconomic variables have mostly focused on developed countries with little emphasis on researchers on developing countries, specifically Ghana (except Abaidoo et al., 2021; Archer et al., 2022; Barson et al., 2022; Boateng et al., 2022). From the reviews presented, there is a clear path that commodity price fluctuations directly affect financial sector soundness, especially in commodity-dependent countries

(exports have 60% or more merchandise). However, the nature of the macro-economy increases or decreases the effect of commodity price fluctuations on the financial sector (Kinda et al., 2018; Mupunga & Ngundu, 2020). The reviews also provided an understanding that macroeconomic variables can partial out the impact of shocks in a slump in commodity price on financial sector soundness (Abaidoo et al., 2021).

However, not enough studies have assessed the relationships between these three variables. Under interconnectedness, one can assess how the variables influence themselves in a single system across time. Interconnectedness allows policymakers to identify specific variables' behaviour (produce or receive a shock) in a model over time. In a pairwise manner, most studies assess the nexus between commodity prices and macroeconomic variables (Barson, Owusu Junior & Adam, 2022; Cantah, 2018; Jena, 2017; Sanya, 2020; Smales, 2017; Tahar et al., 2021; Uysal & Adalı, 2022), banking sector financial soundness and macroeconomic variables (Anshu & Gakhar, 2019; Babihuga, 2007; Borio & Drehmann, 2011; Ghauri et al., 2019; Lindgren et al., 1996; Siklos, 2021). However, only (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020) assessed macroeconomic variables as the conduit through which commodity price shocks cause financial instability but not their interconnectedness across time. Assessing the variables in pairs hinders policy assessment as policymakers cannot diagnose the specific impact of each variable in the model concerning time; therefore, requires an empirical study of the situation.

The Ghanaian economy is well-documented commodity-dependent (UNCTAD, 2021). However, most research has focused on a specific

commodity from the country's major exports (Abaidoo et al., 2021; Okyere & Mensah, 2021). This further heightens the myopic view on the policy rolled out by policymakers based on the recommendations from those studies. Therefore, a study that would include the major exports in Ghana (Gold, Cocoa and Crude Oil) and all the BsFSI data provided by the BoG is needed (Abusharbeh, 2020; Boateng et al., 2022). This is necessary because the impact of commodity price would differ among the various types of BsFSI (Benvenuto et al., 2021; Martínez et al., 2020; Sundararajan et al., 2002).

Also, little has been done by prior studies on the nexus between commodity prices, banking sector financial soundness and macroeconomic variables in the application of techniques such as (a) Quantile Regression with robustness causality test from (Jeong et al., 2012), which is nonparametric causality test is employed to achieve the causality in the quantile regression estimation, (b) Bi-wavelet and Partial wavelet (c) TVP-VAR connectedness and Wavelet multiple. These techniques are specifically relevant for assessing time-varying and frequency-dependent techniques to capture the interdependencies issue adequately. They can also overcome the problem of non-stationarity, non-linearity, and asymmetry in variables while providing lead-lag relationships between the variables under study in the time and frequency domains.

Chapter Summary

The chapter was divided into three sections; theoretical review, review of concepts and empirical review, with the study's objectives duly explained under each section. The theories adopted in the study are theories of instability proposed by monetarists such as (Friedman & Schwartz, 1963), the Financial

Fragility approach (Borio & Drehmann, 2009, 2011; Fisher, 1933; Friedman, 1986; King, 1994; Minsky, 1972, 1977). The study also elaborates on Schwartz's hypothesis as explained by (Bordo & Wheelock, 1998).

The conceptual review was covered under thematic headings; commodity prices, banking sector financial soundness and macroeconomic variables. The theoretical and empirical review indicated a relationship between commodity prices, BsFSI and macroeconomic variables. However, little is known about their quantile relationship, the influence of macroeconomic variables on the relationship between commodity price and BsFSI and the interconnectedness among them. It was further noted that GEPU is included in the study for a commodity-dependent country like Ghana to control global economic policy uncertainty.

CHAPTER THREE

RESEARCH METHODS

Introduction

The current study examines the interconnectedness of commodity prices, BsFSI and the macro-economy of Ghana. This chapter offers an in-depth elaboration of the sound and transparent method employed to achieve the purpose of the study, holding firm to the empirical and theoretical context of the study. This chapter explains the research paradigm, design, approach, transmission mechanism, theoretical and empirical model specification, justification and measurement of variables, data sources and description, estimation procedure and techniques, model specification, data processing and analysis. The chapter ends with a chapter summary.

Research Philosophy, Approach and Design

This study adopted the positivist research philosophy because it aims to examine the interconnectedness among commodity prices, BsFSI and macroeconomic variables in Ghana. The positivist research philosophy emphasizes the scientific method, empirical observation, and objective analysis in studying social phenomena (Hughes & Hoffmann, 2018). The study is guided by three hypotheses that can be tested using quantitative techniques based on the positivist philosophy. The study aims to generate empirical evidence to support or reject the hypotheses related to the interconnectedness of commodities market, financial sector, and key macroeconomic variables in Ghana.

Positivism also emphasises objectivity and impartiality in research, which is particularly important in analysing economic data where personal

biases can significantly impact results (Tamminen & Poucher, 2020). The positivist approach allows for employing and analysing large amounts of empirical data, which is crucial for understanding complex economic relationships among the variables used (Thorpe & Holt, 2015). The positivist philosophy is reflected in using rigorous quantitative methods to draw causal inferences about the relationships (Creswell & Creswell, 2018).

The study adopted the quantitative approach in the positivist philosophy to enable the researcher to draw generalizable conclusions about the relationships between the commodity markets, financial sector, and macro-economy in Ghana based on the research objectives (Jackson & Dolan, 2021). The focus on statistical analysis and causal inference in a positivist approach provides researchers with the tools to predict future economic outcomes and develop policy recommendations (Jackson & Dolan, 2021). Replicability, objectivity, and generalization of findings are advantages of quantitative research over qualitative design (Rahi, 2017). However, quantitative research also has flaws because it neglects crucial human components like respondents' emotions, behaviour, and feelings.

The explanatory nature of the research objectives motivated the researcher to employ an explanatory research design under the quantitative research approach. The explanatory research design would focus on using statistical analysis to determine the cause-and-effect relationship between the commodities market, the BsFSI, and the macro-economy in Ghana over time, using monthly time series data (Creswell & Creswell, 2018). In line with the research objectives, positivism philosophy, quantitative approach, and explanatory design are suitable for the study.

Theoretical Model Specification

The financial fragility model (Borio & Drehmann, 2009, 2011; Fisher, 1933; Friedman, 1986; Kaufman, 1986; Kindleberger, 1979; King, 1994; Minsky, 1972, 1977) was the main theoretical model on which this study's empirical model was developed. According to the financial fragility model, financial instability arises when the financial system is fragile, making it vulnerable to small shocks that can cause large, cascading losses (Borio & Drehmann, 2009). The model posits that financial (in)stability arises from interactions of a set of variables in an economy, policy instruments employed by the economy and some exogenous shocks. The model assumes retrospective identification of financial instability by breaking down historical events into "shocks" and the system's inherent response. According to Borio and Drehmann (2009), financial fragility can be modelled as

$$M = f(X, I, \mu) \quad (1)$$

Where M represents financial stability or instability is a measure of output of the structural model of the economy, which is a function connecting a set of variables X to policy instruments I and exogenous shocks μ. The model is not limited to variables and instruments, as numerous economic policy instruments affect the financial sector (Borio & Drehmann, 2009, 2011). As such, the researcher can include variables and instruments deemed fit.

Borio and Drehmann (2011) posited that equation (1) provides a basis for formulating effective policies by examining how the system would react under various instrument configurations. Since there are diverse economic conditions, several studies have proposed that the financial fragility model

should be specified to comprehend the characteristics of the particular economy under study (Borio & Drehmann, 2009, 2011; Goodhart et al., 2004).

Empirical Model Specification

The financial fragility model proposed by Borio and Drehmann (2011), as elaborated in the theoretical model specifications, needs to be expanded to factor in some specific features that can affect the financial soundness of Ghana. As a result, this research expands the variables and policy instruments that would significantly influence Ghana's BsFSI. Quite several papers have posited how variables such as commodity prices, a composite index of economic activity, inflation, broad money supply, exchange rate and trade balance, as well as policy instruments like monetary policy rate and Global Economic Policy Uncertainty, affect the financial soundness of Ghana (Abaidoo et al., 2021; Kinda et al., 2018; Okyere & Mensah, 2021). As such, equation (1) can be expanded as

$$FSI_{jt} = f(Cocoa_t, Gold_t, Crude_t, INF_t, MPR_t, M2_t, CIEAR_t, TB_t, EXC_t, \mu) \quad (2)$$

Where cocoa, gold and crude are the major commodities exported in Ghana. Also, Inflation Rate (INF), Monetary Policy Rate (MPR), Broad Money (M2) Composite Index of Economic Activity (Real) (CIEAR), Exchange Rate (EXR) Trade Balance (TB). Finally, FSI_{jt} represents BsFSI, j denotes specific BsFSI such as CAR, NPL, ROE, ROA, CLASL, CLATA and CD. t represents time.

Equation (2) is modified to include Global Economic Policy Uncertainty (GEPU) which is noted to affect international commodity prices and the macro-economy of Ghana (Asafo-Adjei, Boateng, et al., 2021; Boateng et al., 2022; Frimpong et al., 2021; Shen et al., 2018). Equation (3) can be stated as

$$FSI_{jt} = f(Cocoa_t, Gold_t, Crude_t, INF_t, MPR_t, M2_t, CIEAR_t, TB_t, EXC_t, GEPU_t, \mu) \quad (3)$$

Natural logarithm was used to transform equation (3) to take care of outliers noted in the datasets and to make the relationships between variables easier to interpret and estimate. Also, it can help to reduce heteroscedasticity, which occurs when the variance of the error term is not constant across the range of the dependent variable (Cantah, 2018). The final function employed in the study is presented in equation (4).

$$LFSI_{jt} = f(LCocoa_t, LGold_t, LCrude_t, LINF_t, LMPR_t, LM2_t, LCIEAR_t, LTB_t, LEXC_t, LGEPU_t, \mu) \quad (4)$$

Justification and Measurement of Variables

This study employs monthly data on commodity prices, BsFSI and some selected macroeconomic variables of Ghana. The commodity prices are monthly averages of the International Brent Crude Oil Price (US$/Barrel), International Cocoa Price (US$/Tonne), and International Gold Price (US$/fine ounce). These are the dominant commodities in the Ghanaian economy and provide more than 60% of export revenues (Ministry of Finance, 2022; UNCTAD, 2021). Some previous studies have employed these same set of commodities to assess how they affect the Ghanaian economy (Abaidoo et al., 2021; Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022; Kinda et al., 2018; Okyere & Mensah, 2021).

Cocoa prices are measured using futures contracts traded on commodity exchanges such as the New York Mercantile Exchange (NYMEX) and the Intercontinental Exchange (ICE) in US dollars per metric tonne. Brent crude oil prices are based on benchmark spot prices published daily by pricing agencies like Platts and Argus, which reflect the cost of a barrel of oil in US dollars and are based on physical trading in the North Sea. Gold prices are measured using

the London Bullion Market Association (LBMA) Gold Price, which is a benchmark spot price for gold set twice daily by London-based gold dealers, quoted in US dollars per troy ounce and used as a reference price for gold trading and investment worldwide.

The study employed BsFSI such as Credit to Deposits (%), Core Liquid Assets to Short-term Liabilities (%), Return on Assets (ROA)-Before Tax (%), Core Liquid Assets to Total Assets (%), Return on Equity (ROE)-After Tax (%), Capital Adequacy Ratio (%), and Non-Performing Loans (%). The BoG obtains financial and operational data from Deposit Money Banks (DMBs) in Ghana to measure the various BsFSI. These variables provide a holistic assessment of the financial sector indicators to solve a more diverse perspective than an index. The different parameters in CAMELS Framework provide economists and policymakers with different views about the banking sector. Using all of them simultaneously will give a full picture of BsFSI (Bank of Ghana, 2021a; Sundararajan et al., 2002).

The macroeconomic variables selected for the study were based on empirical and theoretical reviews (Abaidoo et al., 2021; Borio & Drehmann, 2009, 2011; Kinda et al., 2018). Hence, the variables identified and included are Inflation, Broad Money Supply, Monetary Policy Rate, Composite Index of Economic Activity (Real), Exchange Rate and Trade Balance. The study included the inflation variable to test the Schwartz hypothesis (Schwartz, 1995). When commodity prices increase, it can lead to inflationary pressure in the economy, which can increase the cost of borrowing for banks, reducing their profitability and potentially leading to an increase in non-performing loans. Also, if inflation is already high, an increase in commodity prices can

exacerbate inflation and lead to further economic instability, which can also negatively impact BsFSI (Mahama, 2019). Inflation was measured by headline inflation (%) Year-on-Year. Headline inflation as a proxy for overall inflation in Ghana is based on its comprehensiveness, data availability, transparency, policy implications, and impact on inflation expectations.

When commodity prices increase, it can increase the money supply as more money flows into the economy, which can result in inflation and a reduction in the purchasing power of money (Kinda et al., 2018). This can have negative effects on BsFSI, as inflation can increase the risk of non-performing loans and reduce the value of assets held by banks. The broad money supply (M2) was used to measure the broad money supply by the BoG in the economy. M2 is an appropriate proxy for the broad money supply in Ghana due to its comprehensive coverage of all types of money in circulation, its stability, its link to monetary policy, and its availability.

Also, a high (lower) monetary policy rate may make it more difficult (easy) for banks to obtain credit and finance, which can reduce (increase) their ability to absorb losses from changes in commodity prices. This can lead to higher (low) non-performing loans and lower (increase) capital adequacy ratios, potentially weakening (strengthening) the soundness of the banking sector. The BoG monetary policy rate (MPR) measures the monetary policy rate. The MPR allows the central bank to implement monetary policy effectively and transparently. By setting the MPR, the central bank can influence the cost of credit in the economy and steer macroeconomic outcomes towards desired objectives.

The short-term economic performance was measured with the Composite Index of Economic Activity (Real) CIEAR posited by the BoG. Ghana's economy heavily relies on gold, crude oil and cocoa exports. Any negative shocks to their prices can have a ripple effect on the banking sector, leading to increased non-performing loans, lower capital adequacy ratios, and reduced profitability. Employing the CIEAR of Ghana would help to measure how economic performance influences the effect of commodity prices (cocoa, crude oil and gold) on Ghana's banking sector soundness as used by other studies (Boateng et al., 2022).

The exchange rate was proxy by the rate of Ghana cedis to USD. An appreciation of the cedi resulting from increased commodity prices can have positive and negative effects on the banking sector. While it can reduce the cost of credit and increase banks' capital adequacy ratios, it can also lead to a shortage of foreign exchange, reduce export revenue, and negatively impact banks' balance sheets. In essence, an increase in commodity prices, especially if a country is heavily dependent on imports of these commodities, can disrupt the balance of foreign exchange inflows and outflows. This disruption can trigger a sequence of events that ultimately leads to a shortage of foreign exchange. In summary, the exchange rate of Ghana plays a crucial role in determining the effect of commodity price fluctuations on the soundness of the country's banking sector. The exchange rate between the Ghana cedis and the US dollar is an important proxy for the exchange rate in Ghana because it reflects the relative strength or weakness of the Ghanaian economy. It has a significant impact on Ghana's international trade and balance of payments as

well as US dollar is a stable and widely traded currency (Owusu Junior et al., 2018).

Finally, suppose Ghana's trade balance is positive (negative). In that case, it indicates that the country is exporting (importing) more goods than it is importing (exporting), which can increase (decrease) foreign exchange earnings. This can lead to an/a increase (decrease) in foreign reserves for the country, which can positively (negatively) impact the soundness of the banking sector. The trade balance is included as a proxy for the external balance. Trade Balance was measured as the difference between the log of merchandised export and the log of merchandised import which is a commonly used method that has several advantages, including reducing the impact of outliers, focusing on merchandise trade, capturing changes in trade volume, and allowing for more accurate comparisons and analyses (Rose & Yellen, 1989; Wilson, 2001). As already discussed in the empirical section, the macroeconomic variables are seen to be indirect channels for commodity price fluctuations to affect the financial soundness of an economy (Chuku & Simpasa, 2018; Kinda et al., 2018; Mupunga & Ngundu, 2020; Siklos, 2021; Uysal & Adalı, 2022).

The study also included Global Economic Policy Uncertainty (GEPU) as a control variable. GEPU is included in the study because external uncertainty shocks can distort the relationship between commodity prices and BsFSI. GEPU is used to take care of external uncertainty shocks. GEPU refers to the degree of unpredictability or ambiguity surrounding government policies and regulations that impact the economy (Frimpong et al., 2021). GEPU can affect commodity prices by impacting the demand for commodities and the level of investment in the sector (Boateng et al., 2022). For example, uncertainty

surrounding trade policies could lead to reduced demand for commodities such as cocoa or crude oil, resulting in a decline in prices. GEPU can also impact the financial soundness of the banking sector by affecting the availability of credit, loan defaults, and capital adequacy (Asafo-Adjei et al., 2020).

Model Specification

This section discusses four models: Quantile regression, Bi-wavelet, Partial wavelet, and TVP-VAR connectedness which were used to achieve the study hypothesis. A detailed explanation of the models is provided subsequently.

Quantile regression (QR)

The study employed QR, as postulated by Koenker and Bassett (1978), to test the study's first hypothesis. Thus, the quantile regression is used to assess the effect of commodity prices on BsFSI. Also, a causality in quantile test, a non-parametric causality test (Jeong et al., 2012), would also help quantify the relationship under study across the entire distribution. QR provides detailed results across diverse distributions compared to mean-based techniques and can also handle most dataset's non-linearity, non-normality and non-stationarity characteristics (Koenker & Bassett, 1978). QR is useful for capturing the adaptive nature of financial sector soundness and providing insights into the behaviour of different financial sector conditions. The QR would provide policymakers options to regulate the adaptive behaviour of market participants towards BsFSI to match the distinct characteristics of fluctuations in the commodity market (cocoa, gold and crude oil). The study presents the cumulative distribution of condition-dependent variables $Y, where\ Y$ is the set

of BsFSI employed in the study given the explanatory variable $X_i, where\ i$ is cocoa, gold, crude and dummy variable.

The study controlled for the effect of commercial crude oil exportation using a dummy variable. This allows to isolate the impact of oil prices without the confounding effect of revenue from crude oil exports, and gain insights into the underlying factors that contribute to financial stability. The dummy variable (DMV) has 1 as when commercial export of crude started and 0 as before crude oil export period in Ghana. The model employed in this study is

$$BsFSI_{jt} = \beta_0^\tau + \beta_1^\tau(Cocoa_t) + \beta_2^\tau(Gold_t) + \beta_3^\tau(Crude_t) + \beta_4^\tau(DMV_t) + \varepsilon_t^\tau \quad (5)$$

that is $BsFSI_{jt}$ represents Y, j denotes specific BsFSI such as CAR, NPL, ROE, ROA, CLASL, CLATA and CD at monthly time t, β_1^τ, β_2^τ, $and\ \beta_3^\tau$ are coefficients of cocoa, gold, and crude, ε_t^τ is the error term at time t, and τ is the τ^{th} quantile ranging $0 < \tau < 1$. DMV represents dummy variable.

The plethora of works on QR confirms that quantile regression allows one to model the conditional quantiles of the dependent variable given the independent variables as opposed to OLS (Altunbaş & Thornton, 2019; Archer et al., 2022; Barson, Owusu Junior, Adam, et al., 2022; Boateng et al., 2021; Demir et al., 2022; Koenker & Bassett, 1978). Koenker and Bassett (1978) posited that regressing the conditional quantile $0 < \tau < 1$ of dependent variables is a non-linear function by independent variable the instead of following OLS conditional mean approach of the regressand and, as such, QR probes into a more detailed proportion of the dependent variable by the independent variable. In matrix notation, the quantile regression from equation 5 can be specified as

$$Q[y|x,\tau] = x'\beta_\tau \; such \; that \; prob[y \leq x'\beta_\tau|x] = \tau, 0 < \tau \; < 1. \qquad (6)$$

where y is the dependent variable and x is a vector of independent variables.

A QR utilizes the asymmetric absolute loss function, which provides a viable alternative to ordinary least squares (OLS) that relies on the squared error loss function. (Koenker, 2008). The main objective of quantile regression is to estimate the conditional quantiles of the response variable given a set of predictor variables. This estimation technique is helpful in quantile regression as it allows for estimating different quantiles of the response variable, providing a more comprehensive understanding of the relationship between the independent and dependent variables. As such, the quantile coefficient is calculated by minimising the problem stated as

$$F_t[\beta_\tau|y,X] = \sum_{t:\{y_t \geq x_t'\beta_\tau\}}^{n} \tau|\, y_t \; - \; x_t'\beta_\tau| + \sum_{t:\{y_t < x_t'\beta_\tau\}}^{n} (1-\tau)|\, y_t \; - \; x_t'\beta_\tau| \qquad (7)$$

$$= \sum_{t=1}^{n} \rho(\, y_t \; - \; x_t'\beta_\tau|\tau) \qquad (8)$$

where

$$\rho(e_{t,\tau}|\tau) = \begin{Bmatrix} \tau e_{t,\tau} & if \; e_{t,\tau} \geq 0 \\ (\tau-1)e_{t,\tau} & if \; e_{t,\tau} < 0 \end{Bmatrix}, e_{t,\tau} = \; y_t \; - \; x_t'\beta_\tau \qquad (9)$$

The relationships between BsFSI and commodity prices were examined across 19 proportional quantiles, $[0.05 \leq \tau \leq 0.95]$, *where* τ *increases by* 0.05.

Table 1: Quantile levels and market conditions

Quantile	τ Level	Market Condition
Lower	$0.05 \leq \tau \leq 0.35$	Slump
Intermediate	$0.40 \leq \tau \leq 0.65$	Normal
Higher	$0.70 \leq \tau \leq 0.95$	Boom

Note: τ is the probability level which increases by 0.05

Source: Author's Construct (2023)

Slump conditions indicate weak financial soundness, suggesting that Banks are vulnerable to financial stress and may be unable to withstand external shocks or economic downturns. Normal conditions are those that indicate a reasonable level of financial soundness. These conditions suggest that Banks are operating stably and sustainably and can withstand some financial stress or economic shocks. Boom conditions are those that indicate strong financial soundness. These conditions indicate that Ghana Banks are operating very efficiently and effectively and can withstand significant financial stress or economic shocks (Bank of Ghana, 2021b).

Bi-wavelet and partial wavelet (PWc)

Bi-wavelet and Partial wavelet were employed to examine the second hypothesis. The study employed the Bi-wavelet to understand the time and frequency comovements between commodity returns and BsFSI and PWc to assess the role of macroeconomic variables on the nexus between commodity returns and BsFSI across time and frequency (Barson, Owusu Junior, & Adam, 2022; Boateng et al., 2022; Grinsted et al., 2004; Torrence & Compo, 1998; Veleda et al., 2012). These techniques involve decomposing the data signal into localised time and different frequency components using wavelets and then estimating the coefficients of each wavelet component in order to capture the underlying patterns in the data even if there is non-stationary data (Gouhier et

al., 2013). The estimation technique used in Bi-wavelet and Partial wavelet analysis is a wavelet-based estimation with Monte Carlo. The wavelet coherent approaches, specifically bi and partial wavelet, employed in the study can capture the non-symmetrical behavioural patterns toward the financial sector. It also captures the variables' time and frequency relationships, which were ignored in most studies when they employ standard econometric tools or Fourier analysis (Anshu & Gakhar, 2019; Chuku & Simpasa, 2018; Ghauri et al., 2019; Sanya, 2020; Swaray, 2008).

Bi-wavelet

Bi-wavelet provides time-frequency setting estimation for two variables; in this study, the variables are specific commodity price and specific BsFSI (Asafo-Adjei et al., 2020). The study can also infer whether the two variables are interdependent or contagious from the wavelet results. How the bi-wavelet and PWc results are estimated are as follows.

Continuous wavelet transform (CWT)

Discrete wavelet transforms (DWTs) and continuous wavelet transforms (CWTs) are two wavelet transformations (Owusu Junior et al., 2018). The study relied on CWT as it has a better job in decomposing time series data into elementary functions, is easy to interpret, detects peaks and fluctuations and reflects the changing characteristics of non-stationary signals (Asafo-Adjei, Adam, et al., 2021; Owusu Junior, Adam, et al., 2021; Pal & Mitra, 2019). The mother wavelet has (a) location or time denoted as $(\imath)$ showing the specific place or time of the wavelet and (b) frequency represented as $(\jmath)$ tells the stretched nature of the wavelet (Gouhier et al., 2013). This is in equation 10

$$\mathcal{MW}_{i,\mathcal{s}}(t) = \sqrt{\mathcal{s}}^{-1}\,\mathcal{MW}\left(\frac{t-i}{\mathcal{s}}\right),\ \mathcal{MW}(\bullet) \in \mathcal{L}^2(\mathcal{R}) \qquad (10)$$

i.e. $\sqrt{\mathcal{s}}^{-1}$ is the normalization factor, guaranteeing the mother wavelet has a variance equal to one (Owusu Junior, Adam, et al., 2021). Mathematically it can be represented by $\left[\mathcal{MW}_{i,\mathcal{s}}(t)\right]^2 = 1$. The equation 11 which is Morlet wavelet equation is

$$\mathcal{W}^M(t) = \pi^{-1/4} e^{i\delta_o t} e^{-t^2/2} \qquad (11)$$

$\delta_o = 6$ is the focal frequency of the wavelet; hence it provides tolerability of the Morlet function (Owusu Junior et al., 2018). The decomposition feature of the mother wavelet for a time series; $x(t)$ is presented in equation 12 as

$$\mathcal{W}_x(i,\mathcal{s}) = \int_{-\infty}^{\infty} x(t)\,\sqrt{\mathcal{s}}^{-1}\mathcal{MW}\left(\frac{t-i}{\mathcal{s}}\right)dt \qquad (12)$$

$\mathcal{MW}$ is a multifaceted conjugate solution in the mother wavelet function. With the selected time-series variables and the specific features of $\mathcal{MW}(\bullet)$ the function becomes $w_x(i,\mathcal{s})$ (Cai & Sakemoto, 2022). CWT is used to decompose and reconstruct the function $x(t)\ \mathcal{L}^2(\mathcal{R})$.

$$x(t) = \frac{1}{C_{\mathcal{W}^M}}\int_0^{\infty}\left[\int_0^{\infty}\mathcal{W}_x(i,\mathcal{s})\,\mathcal{MW}_{i,\mathcal{s}}(t)di\right]\frac{d\mathcal{s}}{\mathcal{s}^2}, \mathcal{s} > 0 \qquad (13)$$

Wavelet transform coherence (WTC)

Torrence and Compo (1998) posited that WTC is a squared absolute cross-spectrum value normalization to a solitary wavelet power spectrum. Equation 14 estimates the squared wavelet coefficient

$$\mathcal{R}^2(x,y) = \frac{\left|\Phi\left[\frac{1}{\mathcal{s}}\mathcal{W}_{xy}(i,\mathcal{s})\right]\right|^2}{\Phi\left(\frac{1}{\mathcal{s}}|\mathcal{W}_x(i,\mathcal{s})|^2\right)\Phi\left(\frac{1}{\mathcal{s}}\left|\mathcal{W}_y(i,\mathcal{s})\right|^2\right)} \qquad (14)$$

i.e. Φ is a smoothing factor that stabilities resolution as well as significance, and $\mathcal{R}^2(x, y)$ is between 0 and 1; $0 \leq \mathcal{R}^2_{xy}(i, \mathcal{s}) \leq 1$. $\mathcal{R}^2_{xy}$ near 0 illustrates a weak coherence, whereas a value near 1 denotes strong co-movements (Boateng et al., 2022; Gouhier et al., 2013; Owusu Junior, Adam, et al., 2021). WTC exemplifies a wide-ranging nexus among the time series data in the time-frequency domain. The brighter colour connotes stronger nexus. The Monte Carlo procedure tests the statistical significance of these relationships because WTC coefficients are unidentified theoretical distributions (Gouhier et al., 2013; Torrence & Compo, 1998).

WTC phase difference

The WTC Phase difference displays the oscillation interruptions in a particular time series. Bloomfield et al. (2004) posit the difference in phase between two variables $x(t)$ and $y(t)$, is considered in equation 15. However, an interval is $-\pi \leq \emptyset_{xy}(i, \mathcal{s}) \leq \pi$.

$$\emptyset_{xy}(i, \mathcal{s}) = \tan^{-1}\left(\frac{\Im\left\{\mathcal{s}(\frac{1}{\mathcal{s}}\mathcal{W}_{xy}(i, \mathcal{s}))\right\}}{\Re\left\{\mathcal{s}(\frac{1}{\mathcal{s}}\mathcal{W}_{xy}(i, \mathcal{s}))\right\}}\right) \quad (15)$$

$\Im$ and $\Re$ in equation 15 represent imaginary operators and real operators. The phase pattern dimension on the wavelet coherence map offers importance to the wavelet coherence difference as a source of inspiration (Pal & Mitra, 2019). Dimensional arrows offer distinguished phase patterns. In this study, the bi-wavelet estimation is between commodity prices and BsFSI. Bi-wavelet uses wavelet-based estimation, a statistical technique that uses wavelet transforms to analyse and estimate complex time-varying signals and processes. This approach involves decomposing a signal into different frequency components using wavelets and estimating each wavelet component's coefficients to capture

the underlying patterns in the data. Unlike traditional time-series analysis, wavelet-based estimation provides a time-frequency representation of the data that can help identify the signal's most important components and reveal underlying structures that may be obscured in time-series data.

Partial wavelet coherence (PWc)

PWc like partial correlation minimizes "pure" correlation between commodity prices and BsFSI when controlling the impact of macroeconomic variables $z(t)$ on the wavelet coherence between commodity prices $x(t)$ and BsFSI $y(t)$ (Boateng et al., 2022; Cai & Sakemoto, 2022; Frimpong et al., 2021). PWc would provide a more accurate correlation between commodity prices and BsFSI. The coherence among the three variables can be paired as;

$$\mathcal{R}(x,y) = \frac{\Phi[\mathcal{W}(x,y)]}{\sqrt{\Phi[\mathcal{W}(x)] \times \Phi[\mathcal{W}(y)]}} \tag{16}$$

$$\mathcal{R}^2(x,y) = \mathcal{R}(x,y) \times \mathcal{R}(x,y) \tag{17}$$

$$\mathcal{R}(x,z) = \frac{\Phi[\mathcal{W}(x,z)]}{\sqrt{\Phi[\mathcal{W}(x)] \times \Phi[\mathcal{W}(z)]}} \tag{18}$$

$$\mathcal{R}^2(x,z) = \mathcal{R}(x,z) \times \mathcal{R}(x,z) \tag{19}$$

$$\mathcal{R}(z,y) = \frac{\Phi[\mathcal{W}(z,y)]}{\sqrt{\Phi[\mathcal{W}(z)] \times \Phi[\mathcal{W}(y)]}} \tag{20}$$

$$\mathcal{R}^2(z,y) = \mathcal{R}(z,y) \times \mathcal{R}(z,y) \tag{21}$$

PWc in equation 22

$$\mathcal{R}_p^2(x,y,z) = \frac{|\mathcal{R}(x,y) - \mathcal{R}(x,z)\bullet\mathcal{R}(x,y)^*|^2}{[1-\mathcal{R}(x,z)]^2[1-\mathcal{R}(y,z)]^2} \tag{22}$$

i.e. $0 \leq \mathcal{R}_p^2(x,y,z) \leq 1$ where x and y represent the commodity price and BsFSI while z represents the selected macroeconomic variables of Ghana. PWc follows Monte Carlo methods estimation to estimate the level of

significance (Cazelles et al., 2008; Gouhier et al., 2013). A low $\mathcal{R}_p^2$ region is where a high $\mathcal{R}^2$ region point to that time series y don't have a substantial impact on x however, the time series z controls the variance of x (Owusu Junior et al., 2018). However, in the case of no changes between $\mathcal{R}_p^2$ and $\mathcal{R}^2$, both y and z have a significant impact on x. The estimation technique used in partial wavelet coherence is wavelet-based estimation. Wavelet-based estimation uses Monte Carlo simulation to analyse signals and extract information about the underlying signals and how they change over time.

TVP-VAR connectedness

Finally, the study used TVP-VAR connectedness with wavelet multiple as a robustness check to test the last hypothesis. Both estimation techniques would provide the detailed interconnectedness of the variables in time (TVP-VAR) and Frequency (Wavelet multiple) (Antonakakis et al., 2020; Boateng et al., 2022; Diebold & Yilmaz, 2012). In time past, most studies employed the traditional VAR model, which uses stationarity variables (Antwi et al., 2020). However, most researchers confirm that stationarity is a restrictive assumption (Alodayni, 2016). Also, VAR models estimate many parameters, some of which are insignificant with longer lags than necessary (Punzi, 2019). This necessitated the development of the Bayesian VAR, which corrects this problem by restricting these coefficients and assuming that their likelihood of being close to zero is higher than that of the coefficients for shorter lags (Ca' Zorzi et al., 2017). Yet, these models could not capture the time-varying nature underlying the variables in the analysis.

Therefore, to apprehend the time-varying nature of the variables in the study, the TVP-VAR propound by Antonakakis et al. (2020), together with

ideas from Diebold and Yilmaz (2012) and Koop and Korobilis (2014), is employed. TVP VAR debilitates the burden of (a) losing information, (b) arbitrarily rolling window size selection (the study sets at 200), and (c) sensitivity to outliers (Antonakakis et al., 2020). The TVP-VAR connectedness model uses lag one, posited by the Bayesian information criterion (BIC).

$$y_t = B_t y_{t-1} + \varepsilon_t \qquad \varepsilon_t | F_{t-1} \sim N(0, \Theta_t) \qquad (23)$$

$$vec(B_t) = vec(B_{t-1}) + v_t \qquad v_t | F_{t-1} \sim N(0, \Psi_t) \qquad (24)$$

The model consists of several variables, including the current dependent variable y_t, lagged dependent variable y_{t-1}, and an error term ε_t, all of which are $K \times 1$-dimensional vectors. In addition, the model includes the following variables with matrix dimensions: $\beta_t \; and \; \Theta_t$, both of which are $K \times K$ matrices $vec(B_t) \; and \; v_t$ both of which are $K^2 \times 1$ vector and Ψ_t is a $K^2 \times K^2$ matrix, F_{t-1} retains information with it until $t-1$ (Antonakakis et al., 2019). Notably, all parameters B_t makes it possible for the connectedness to vary over time with other variables. Furthermore, the variance-covariance matrices, $\Theta_t \; and \; \Psi_t$ are also varying over time. his is important because previous research has shown that variances and covariances for heterogeneous variables are typically time-varying (Balcilar et al., 2021; Ben Haddad et al., 2021; J. Huang et al., 2022; Jebabli et al., 2014; Yang et al., 2022).

Koop and Korobilis (2014) proposed a TVP-VAR model that accounts for multivariate stochastic volatility, which can help overcome the problem of overparameterization. This approach applies to datasets containing three, seven, or 25 variables representing small, medium and large. It selects the appropriate model size based on the historical predictive likelihoods of the variables of interest (Amoako et al., 2022). This method's ability to change the model size

is an important advantage. In addition, it is essential to allow for stochastic volatility in the error terms and for the TVP-VAR coefficients to vary over time, as suggested (Antonakakis et al., 2019).

Hence with generalized impulse response functions (GIRF) and generalized forecast error variance decomposition (GFEVD) (Koop et al., 1996; Pesaran & Shin, 1998), TVP-VAR is translated into vector moving average (VMA) representation (Yang et al., 2022). The estimation follows the Wold representation theorem

$$y_t = \sum_{j=0}^{\infty} L' W_t^j L \varepsilon_{t-j}, where\ A_{j,t} = L' W_t^j L \tag{25}$$

$$y_t = \sum_{j=0}^{\infty} A_{j,t} \varepsilon_{t-j} \tag{26}$$

where $L = [I_N, \ldots, 0_p]'$ $is\ an\ N_p \times N$ dimensional matrix, $W = [\beta_t\ ;\ I_{N(p-1)}, 0_{N(p-1)\times N}]$ is an $N_p \times N_p$ dimensional matrix, and A_{it} is an $N \times N$ dimensional matrix. The GIRFs $\Psi_{j,t}^{g}(J)$ represent the impulse response functions of all variables g to a shock in variable i at time t. This expression allows us to estimate the impact of a shock in variable i on all other variables without a structural model (Gabauer & Gupta, 2018). The difference is accounted to the shock in variable i, which can be calculated by

$$GIRF_t(J, \delta_{j,t} F_{t-1} = E\left(Y_{t+J} \middle| \varepsilon_{j,t} = \delta_{j,t} F_{t-1}\right) - E(Y_{t+J} | F_{t-1}) \tag{27}$$

$$\Psi_{j,t}^{g}(J) = \frac{A_{J,t} S_t \varepsilon_{j,t}}{\sqrt{S_{jj,t}}} \frac{\delta_{j,t}}{\sqrt{S_{jj,t}}} \qquad \delta_{j,t} = \sqrt{S_{jj,t}} \tag{28}$$

$$\Psi_{j,t}^{g}(J) = S_{jj,t}^{-\frac{1}{2}} A_{J,t} S_t \varepsilon_{j,t} \tag{29}$$

where $\Psi_{j,t}^{g}(J)$ is the GIRFs of variable $j\ and\ J$ is the forecast horizon which is 5, $\delta_{j,t}$ the selection vector with a value of one in the j^{th} position and zero otherwise, and F_{t-1} represents the information set until $t-1$ (Ben Haddad et al., 2021). Subsequently, the study computes the GFEVD, which can measure one variable's forecast error variance on others (Balcilar et al., 2021). This is calculated as follows

$$\tilde{\Phi}_{ij,t}^{g}(J) = \sum_{t=1}^{J-1} \frac{\Psi_{ij,t}^{2,g}}{\sum_{j=1}^{N}\sum_{t=1}^{J-1}\Psi_{ij,t}^{2,g}} \tag{30}$$

Where $\sum_{j=1}^{N}\tilde{\Phi}_{ij,t}^{g}(J) = 1$, and $\sum_{j=1}^{N}\tilde{\Phi}_{ij,t}^{N}(J) = N$

Using the GFEVD, the study constructs the total connectedness index (TCI) by

$$C_{t}^{g}(J) = \frac{\sum_{i,J=1,i\neq j}^{N}\tilde{\Phi}_{ij,t}^{g}(J)}{\sum_{j=1}^{N}\tilde{\Phi}_{ij,t}^{g}(J)} \tag{31}$$

$$C_{t}^{g}(J) = \frac{\sum_{i,J=1,i\neq j}^{N}\tilde{\Phi}_{ij,t}^{g}(J)}{N} \tag{32}$$

The connectedness approach is used to quantify how a shock in one time series variable affects other variables in the system. The total directional connectedness from variable i TO variable j refers to the extent to which the shock in variable i is transmitted to variable j stated as

$$C_{i\rightarrow j,t}^{g}(J) = \sum_{i,J=1}^{N}\tilde{\Phi}_{ji,t}^{g}(J) \tag{33}$$

Further, the study quantifies the directional connectedness variable i receives it from variables j, known as total directional connectedness FROM others and posited as

$$C_{i\leftarrow j,t}^{g}(J) = \sum_{i,J=1,i\neq j}^{N} \tilde{\Phi}_{ij,t}^{g}(J) \tag{34}$$

$$C_{i,t}^{g} = C_{i\rightarrow j,t}^{g}(J) - C_{i\leftarrow j,t}^{g}(J) \tag{35}$$

$$\Pi_{i,t} = \frac{C_{i\rightarrow j,t}^{g}(J) - C_{i\leftarrow j,t}^{g}(J)}{C_{i\rightarrow j,t}^{g}(J) + C_{i\leftarrow j,t}^{g}(J)} \tag{36}$$

$$\Lambda\Pi_{i,t} = \left|\Pi_{i,t}\right| \tag{37}$$

The symbol of the net total directional connectedness determines whether a variable i is driving the network $C_{i,t}^{g} > 0$ or driven by the network $C_{i,t}^{g} < 0$ (Balcilar et al., 2021; Ben Haddad et al., 2021). To normalize the calculation between 1 and +1 $\Pi_{i,t}$ is introduces. Furthermore, the study examines bidirectional relationships by breaking down the net total directional connectedness and calculating the net pairwise directional connectedness (NPDC).

$$NPDC_{ij}(J) = \tilde{\Phi}_{ji,t}^{g}(J) - \tilde{\Phi}_{ij,t}^{g}(J) \tag{38}$$

$$P\Pi_{i,t}(J) = \frac{NPDC_{ij}(J)}{\tilde{\Phi}_{ji,t}^{g}(J) + \tilde{\Phi}_{ij,t}^{g}(J)} \tag{39}$$

$$\Lambda P\Pi_{i,t} = \left|P\Pi_{i,t}(J)\right| \tag{40}$$

$NPDC$ depicts if the model is driving variable i or the opposite holds while $P\Pi_{i,t}(J)$ holds $NPDC_{ij}(J)$ between -1 and +1. TCI used to calculate market interconnectivity is represented

$$C_{t}^{g}(J) = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\Phi}_{ji,t}^{g}(J)}{\sum_{i,j=1}^{N} \tilde{\Phi}_{ji,t}^{g}(J)} = \frac{\sum_{i,j=1,i\neq j}^{N} \tilde{\Phi}_{ji,t}^{g}(J)}{N} \tag{41}$$

Pinpointing what can be classified as a high level of interconnection is TCI. Monte Carlo simulations indicate the own variance share is always more significant or equal to the cross variance share (Antonakakis et al., 2019;

Gabauer, 2021). TCI ranges from $0,\frac{N-1}{N}$ and not [0,1], making analyses more challenging. As such TCI is modify as

$$C_t^g(J) = \left(\frac{N}{N-1}\right)\frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\Phi}_{ji,t}^g(J)}{N} \quad (42)$$

$$= \frac{\sum_{i,j=1,i\neq j}^{N}\tilde{\Phi}_{ji,t}^g(J)}{N-1} \quad (43)$$

Where $0 \leq C_t^g(J) \leq 1$

The decomposed form of (TCI) which is the pairwise connectedness index (PCI) estimates the connectedness of variables $i\ and\ j$

$$C_{ijt}^g(J) = 2\frac{\tilde{\Phi}_{ij,t}^g(J) + \tilde{\Phi}_{ji,t}^g(J)}{\tilde{\Phi}_{ii,t}^g(J) + \tilde{\Phi}_{ij,t}^g(J) + \tilde{\Phi}_{ij,t}^g(J) + \tilde{\Phi}_{jj,t}^g(J)} \quad (44)$$

$$where\ 0 \leq C_{ijt}^g(J) \leq 1$$

That is [0,1] shows the degree of two-sided interconnectivity between variables i and j that is veiled by the TCI. The reliable assumptions of the asymmetric shock and the variables used in the study utilize the $\Lambda P\Pi$ and the PCI, respectively. The magnitude of the $\Lambda P\Pi$ determines whether i and j have the same (OCA). Bootstrapping is used to calculate the average of each (OCA) measure and its confidence interval (Antonakakis et al., 2020; Diebold & Yilmaz, 2012).

Estimation Procedure

A QR calculates the conditional quantiles of a response variable given one or more predictor variables using the least absolute deviation estimation procedure (Koenker & Bassett, 1978). Thus, QR involves minimizing the total sum of absolute differences between the predicted values of the response variable and the observed values at a given quantile across all observations in the sample. A QR involves using an asymmetric absolute loss function, while

median regression is a special case of quantile regression that uses absolute error loss. These methods offer an alternative to ordinary least squares (OLS), which utilizes squared error loss. Quantile regression methods provide a more comprehensive understanding of the data and have additional benefits. Median regression is more resilient to outliers than OLS, while quantile regression estimators can be consistent even with weaker stochastic assumptions than OLS estimation allows (Koenker & Bassett, 1978).

Wavelet coherence uses a statistical estimation procedure called Monte Carlo simulation to determine the significance of the coherence estimates (Cazelles et al., 2008; Gouhier et al., 2013). This involves generating many surrogate data sets by randomly shuffling the time series data while preserving their autocorrelation structure. The wavelet coherence is calculated and compared to the original coherence estimate for each surrogate data set to obtain a distribution of coherence values under the null hypothesis of no correlation between the two time series data. The significance level of the original coherence estimate is then determined by comparing it to the distribution of coherence values obtained from the surrogate data sets. Monte Carlo simulation is a commonly used method for hypothesis testing in signal processing and time series analysis. It is used in Wavelet Coherence to provide a robust estimate of the coherence between two-time series data that accounts for the effect of noise and other random fluctuations (Asafo-Adjei et al., 2020; Boateng et al., 2022; Gouhier et al., 2013; Owusu Junior, Adam, et al., 2021).

The TVP VAR uses a Bayesian estimation procedure, specifically the Markov Chain Monte Carlo (MCMC) algorithm, to estimate the time-varying model parameters (Antonakakis et al., 2019). Bayesian estimation updates prior

beliefs about the model parameters based on observed data, using a prior distribution and likelihood to generate a posterior distribution. This allows for flexible modelling of time-varying relationships between multiple variables. The MCMC algorithm generates parameter samples from the posterior distribution, which can be used to estimate statistics of interest. Bayesian estimation with MCMC is a powerful and flexible method used in various fields, such as macroeconomic forecasting, financial econometrics, and climate modelling (Antonakakis et al., 2019; Balcilar et al., 2021).

Data Type and Sources

The study used secondary data gleaned from BoG economic database with specifics stated in Table 1, but the exchange rate and global economic policy uncertainty were extracted from (*USD GHS Historical Data - Investing.Com*, n.d.) and (*Economic Policy Uncertainty Index*, n.d.) websites respectively. The monthly data span from January 2007 to March 2022, having a total observation of 183. Using monthly data spanning from January 2007 to March 2022 in research on Ghana has several advantages, including adequate data availability, covering multiple economic cycles, aligning with policy changes, and consistency with data reporting practices in the country. The study period covers a year before the peak of the GFC in 2008, the Chinese Crash, the exiting of the United Kingdom (UK) from the European Union (EU) (BREXIT), the Ghana banking sector clean-up exercise and the COVID-19 pandemic, etc. All the variables are presented in Table 2.

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Table 2: Variable description and sources

Sources	Variable Name	Code
(*Commodity Prices – Bank of Ghana*, n.d.)	International Cocoa Price	Cocoa
	International Gold Price	Gold
	International Brent Crude Oil Price	Crude
(*Financial Soundness – Bank of Ghana*, n.d.)	Capital Adequacy Ratio	CAR
	Non-Performing Loans	NPL
	Return On Equity (ROE)	ROE
	Return On Assets (ROA)	ROA
	Core Liquid Assets to Total Assets	CLATA
	Core Liquid Assets to Short-term Liabilities	CLASL
	Credit to Deposits	CD
(*Interest Rates – Bank of Ghana*, n.d.; *Merchandise Trade Flows – Bank of Ghana*, n.d.; *Monetary Survey – Bank of Ghana*, n.d.; *Real Sector – Bank of Ghana*, n.d.; *USD GHS Historical Data - Investing.Com*, n.d.)	Inflation Rate	INF
	Monetary Policy Rate	MPR
	Broad Money	M2
	Composite Index of Economic Activity (Real)	CIEAR
	Exchange Rate	EXR
	Trade Balance	TB
(*Economic Policy Uncertainty Index*, n.d.)	Global Economic Policy Uncertainty	GEPU

Source: Author's Construct (2023)

Data Processing and Analysis

The data were gleaned from diverse sources and merged. The merging confirmed that all the variables have common dates to boost the reliability of the analysis. At the end of the merging, the logarithm of the variables was taken

to bring all the variables to a common scale. This was a convenient way of expressing some of the large numbers in some variables. There was also another cleaning of the log dataset for missing and invalid values. The study started with plotting the log values in groups and individual variables to provide the trend picture of the log variable. Descriptive statistics, a unit root test and a Heatmap of the correlation coefficients were also presented to provide thorough characteristics of the dataset. The inferential statistics were then presented chronologically to test the research hypotheses. All estimations were done using E-views 12 package and R statistical software.

Chapter Summary

The interconnectedness between commodities, BSFSI and macroeconomic variables has been well established theoretically; it is germane that a study provides more empirical intuition to these relationships. The chapter provides detailed backing for employing positivism, quantitative approach and explanatory designs to examine the research objectives. The study was situated in Ghana, a commodity-dependent country in West Africa. The data spanned from January 2007 to March 2022, covering three (3) commodity prices, seven (7) BsFSI, six (6) macroeconomic variables and a control variable. The study employed six inference statistics, four main techniques (Quantile Regression, Bi-wavelet, Partial wavelet, and TVP-VAR) and two robustness techniques (non-parametric causality test and Wavelet multiple). With these, the study can provide time, and frequency-based results for detailed discussion while overcoming the problem of non-stationarity, non-linearity, and asymmetry in variables and providing lead-lag relationships between the variables.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

The chapter systematically presents results and discussions that follow the research objectives. The research objectives are to (1) examine the effects of commodity prices on the BsFSI in Ghana; (2) determine the influence of macroeconomic variables on the relationship between commodity prices and BsFSI in Ghana; (3) assess the degree of connectedness among commodity prices, BsFSI and macroeconomic variables in Ghana. The study employed three (3) dominant commodity prices, seven (7) BsFSI, six (6) macroeconomic variables and one (1) control variable.

The chapter starts with preliminary and inferential statistics, discusses the results, and ends with a chapter summary. The research hypotheses are addressed by employing QR and causality test, bi-wavelet and PWc, and TVP-VAR connectedness and Wavelet multiple, respectively. These inferential statistics are employed because of their abilities to deal with non-linearity, non-stationarity and asymmetric characteristics present in the data and supported by the HMH and AMH.

Preliminary Statistics

Table 3 presents seven descriptive statistics for the raw values of the variables in the study. Raw values are more intuitive and easier to interpret than natural log values. Table 3 shows the behaviour of the variables in terms of performance, linearity, variability, distribution, normality and stationarity. Table 3 test results are left in two decimal places.

Table 3: Descriptive statistics of variables

	Mean	Max	Min	SD	SK	KT	JB
Cocoa	2565.68	3430.35	1607.72	403.46	0.03	2.20	4.90*
Gold	1314.69	1971.07	630.61	322.62	-0.04	2.45	2.39
Crude	76.84	134.79	26.63	25.50	0.28	1.97	10.44***
CAR	17.80	23.89	13.19	2.11	-0.05	2.50	2.00
CD	67.81	91.63	43.1	13.31	-0.26	1.95	10.43***
CLASL	31.23	36.67	24.19	2.74	-0.56	2.76	9.88***
CLATA	23.83	28.75	18.57	2.23	-0.41	2.61	6.20**
ROA	4.34	6.92	1.61	1.01	0.47	2.84	6.85**
ROE	22.80	34.01	7.32	5.03	0.09	2.92	0.31
NPL	14.73	23.45	6.14	4.20	-0.17	2.40	3.62
CIEAR	11.76	73.36	-10.47	13.66	2.07	7.72	300.37***
EXR	3.22	7.53	0.92	1.79	0.27	1.66	16.01***
GEPU	162.26	430.26	48.88	70.89	1.10	4.02	44.78***
INF	12.58	20.74	7.5	3.72	0.60	2.04	18.1***
M2	34473.60	108231.3	3348.73	29600.99	0.90	2.70	25.57***
MPR	17.07	26	12.5	3.92	0.99	3.05	30.09***
TB	1.00	1.07	0.84	0.04	-0.45	2.87	6.52**

Source: Author's Computation (2023)

*Note: [***, **, *] represents 1% significant level, 5% significant level and 10% significant level, respectively. Max, Min, SD, SK, KT, and JB are abbreviations for Maximum, Minimum, standard deviation, skewness, kurtosis, and Jarque-Bera.*

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Table 3 shows the mean values for the commodity prices at 2565.68, 1314.69, and 76.84, respectively, for cocoa, gold and crude, with a standard deviation of 403.46, 322.69 and 25.50. Similarly, the BsFSI variables' mean, and standard deviation ranged between 4.34-67.81 and 1.01-13.31, respectively. Also, the means of CIEAR (11.76), EXR (3.22), INF (12.58), M2 (34473.60), MPR (17.07), and TB (1.00). The standard deviation values in Table 3 shows that the variables are not highly dispersed except for crude, GEPU and M2, which had their standard deviation value close to half the value of their means. The differences in commodity prices can be attributed to the combination of supply and demand factors, global economic conditions, geopolitical events, weather-related events, and other market dynamics. In 2016, dry weather

conditions in West Africa increased cocoa prices. Global economic uncertainty, particularly following the 2008 financial crisis and the COVID-19 pandemic in 2020, led to increased demand for gold as a safe-haven asset, driving up prices. Geopolitical tensions, such as conflicts in the Middle East and tensions between the United States and Iran, have also impacted crude oil prices.

A CD ratio of 43.1% suggest that the banks were not lending enough to their customers, while a ratio above 91.63% may indicate that the bank is overly exposed to credit risk. A ROA value above 1% may suggest that the banking section is within the normal and boom profit-making conditions. A CAR of 13.19% is still considered acceptable, but it may indicate that banks are taking on more risk than necessary, while a ratio of 23% indicates that banks have a strong capital base, which can be used to absorb potential losses and support future growth. A CLATA ratio above 20% may indicate that the bank has a very strong liquidity position. An NPL ratio above 10% may suggest that the bank has a high level of credit risk and may struggle to collect on its loans, while a ratio below 5% may indicate that the bank has a low level of credit risk and is operating efficiently. A CLASL ratio of 24.19% (36.67%) may suggest that the bank is exposed (not exposed) to liquidity risk and may (may not) struggle to meet its short-term obligations.

From Table 3, CIEAR's mean value of 11.76 suggests a relatively stable but not particularly strong overall economic performance. The maximum value of 73.36 may indicate a period of rapid economic growth or a surge in economic activity, while the minimum value of -10.47 may suggest a contraction in the economy or a period of economic recession. The EXC mean of 3.22 suggests a relatively stable exchange rate. The maximum value of 7.53 may indicate a

period of cedi depreciation, low foreign exchange reserves, high inflation, or a decrease in demand for Ghanaian exports. In contrast, the minimum value of 0.92 may indicate a strong demand for Ghanaian currency. A GEPU's mean value of 430.26 may indicate a period of extreme global economic policy uncertainty, while the minimum value of 48.88 may indicate a relatively stable global economic policy environment.

Also, INF value of 20.74% may indicate a period of rapid inflation, while the minimum value of 7.5% may indicate a period of relatively low inflation. The M2 value of 108231.3 may indicate a period of rapid growth in the money supply. In contrast, the minimum value of 3348.73 may indicate a contraction in the money supply or a period of economic recession. An MPR value of 26% may indicate a period of tight monetary policy or efforts to curb inflation, while the minimum value of 12.5% may indicate looser monetary policy or efforts to stimulate economic growth.

The distribution of the dataset has positive and negative asymmetry (Royston, 1982). The kurtosis values show that the variables are either leptokurtic (positive kurtosis > 3) or platykurtic (negative kurtosis < 3), except MPR, which can be classified as mesokurtic (kurtosis = 3) (Joanes & Gill, 1998). From the Jarque-Bera statistics test, the study is not normally distributed for a majority of the variables (p-value < 0.05) (Jarque & Bera, 1980). The normality test confirms deviation from normality, with excess kurtosis indicating that most variables have flatter distribution and are broader than a normal distribution.

Table 4: Stationarity and linearity tests

	PP Statistics		KPSS Statistics		Linearity tests	
	Level	First Diff	Level	First Diff	TRS	KET
Cocoa	-3.35*	-11.39***	0.13*	0.06	1.88	12.04***
Gold	-2.10	-10.73***	0.19***	0.16	1.03	4.86**
Crude	-1.83	-7.72***	0.14**	0.09	5.26*	6.54**
CAR	-3.92**	-15.34***	0.10	0.04	24.00***	6.20**
CD	-1.82	-13.48***	0.18***	0.08	1.28	0.12
CLASL	-4.40***	-26.17***	0.35	0.31	6.14**	5.51**
CLATA	-4.14***	-26.02****	0.31	0.24	3.62	5.49**
ROA	-5.71***	-28.43***	0.23***	0.07	31.82***	2.51
ROE	-7.62***	-30.83***	0.15**	0.07	14.81***	4.87**
NPL	-1.68	-12.27***	0.12*	0.06	0.66	4.59**
CIEAR	-5.39***	-21.86***	0.09	0.03	2.81	2.14
EXR	-1.99	-11.79***	0.27***	0.06	12.59***	6.95***
GEPU	-4.91***	-19.57***	0.16**	0.05	3.20	8.12***
INF	-1.70	-9.25***	0.10	0.10	4.17	1.92
M2	-1.52	-19.40***	0.42***	0.10	3.27	6.14**
MPR	-1.58	-13.15***	0.24***	0.11	0.67	2.85
TB	-7.03***	-36.05***	0.10	0.10	1.97	2.99*

Source: Author's Computation (2023)

*Note: [***, **, *] represents 1% significant level, 5% significant level and 10% significant level, respectively. KPSS, PP, KET and TRS are abbreviations for Kwiatkowski-Phillips-Schmidt-Shin, Phillips–Perron test, Keenan's one-degree test and Teraesvirta's Neural Network test.*

A quick view at Table 4 shows that the first difference of all the variables are stationary based on Phillips–Perron test with the null hypothesis of non-stationarity, but the null is rejected for cocoa, CAR, CLASL, CLATA, ROA, ROE, CIEAR, GEPU and TB only at level (p-value < 0.10) (Phillips & Perron, 1988). On the other hand, the KPSS test, which has the null hypothesis of stationarity, is not rejected for CAR, CLASL, CLATA, CIEAR, INF and TB at levels and also for all the variables at the first difference (p-value > 0.10) (Kwiatkowski et al., 1992). The study also tested for linearity since most economic and finance data show trends of non-linearity. TRS test and Keenan's test with a null hypothesis of linearity suggest that most of the variables are non-linear (p-value < 0.05) (Keenan, 1985; Teräsvirta et al., 1993). However, the variables' non-stationarity, non-linearity and non-normality characteristics will

not affect the inferential statistics employed in the study (Antonakakis et al., 2019; Gouhier et al., 2013; Koenker, 2008).

Figure 5 displays the unconditional correlation matrix to provide insight into the relationship between the variables in the range of negative one to positive one, portending low and high association (Cohen, 1988). Places with high positive correlations are shown in dark blue, those with moderate positive correlations are in mid-blue, and areas with zero correlation are white. On the other hand, deep warm (brown) colours exhibit high negative connections. As the deep warm colour fades, so does the strength of the negative connections.

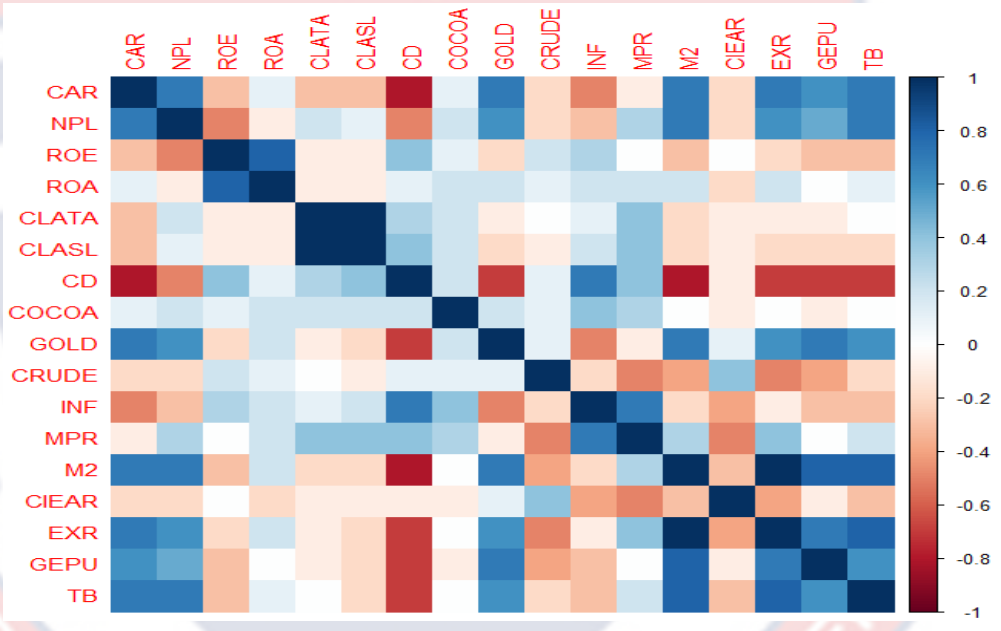


Figure 5: Heatmap of the correlation coefficients of the log series of commodity prices, BsFSI and macroeconomic variables.
Source: Author's Construct (2023)

Figure 5 shows the variables exhibit low, medium and high correlation, be it positive or negative. The weak relationship between the commodity prices indicates that there is no multicollinearity as such, they can be included in the QR estimation. A correlation coefficient of +/- 0.8 or higher usually indicates multicollinearity (Cohen et al., 2014; Gujarati & Porter, 2009). The positive relationship between EXR, GEPU, TB, CAR and NPL signifies that the

financial sector and macro-economy are interrelated, and their performance is often dependent on each other. Also, INF, CIEAR and MPR are negatively related to NPL and CAR. Figure 5 has provided insight into the interconnectedness among commodity prices, BsFSI and macroeconomic variables.

Results and Discussion

This section, in sequence, follows the research hypotheses of the study. The inferential statistics employed in the study handled the non-stationarity, non-linearity and non-normality characteristics of the dataset presented in Table 3 (Antonakakis et al., 2019; Koenker, 2008; Rhif et al., 2019). The techniques are also time and frequency estimations, which handle heterogeneous and adaptive characteristics of the variables postulated by HMH and AMH (Lo, 2004; Müller et al., 1993).

Hypothesis One: The effect of commodity prices on the BsFSI in Ghana

Analysis of results

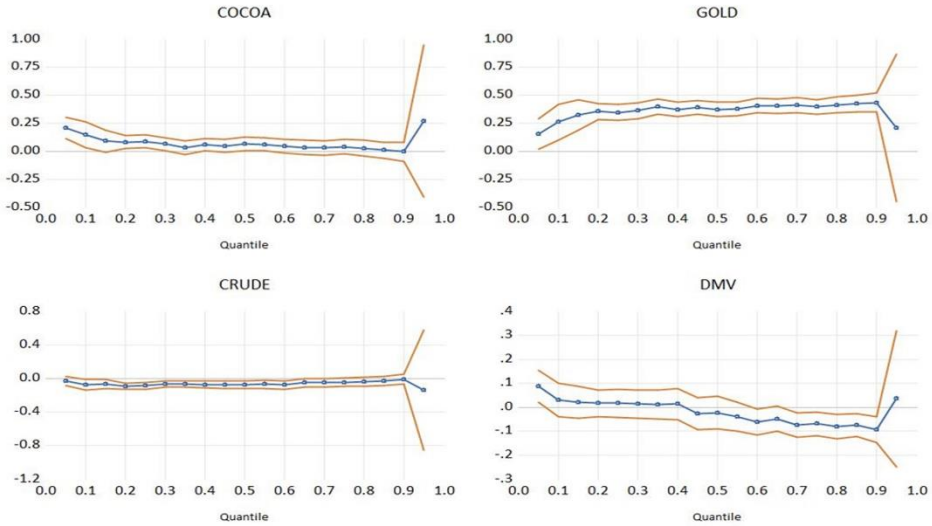
Hypothesis one was assessed using QR. The current study used 19 quantiles segregated as the slump market condition (lower quantiles; $0.05 \leq \tau \leq 0.35, where\ \tau\ increases\ by\ 0.05$, normal or stable market condition (intermediate quantiles; $0.40 \leq \tau \leq 0.65, where\ \tau\ increases\ by\ 0.05$ and the boom market condition (higher quantiles; $0.70 \leq \tau \leq 0.95, where\ \tau\ increases\ by\ 0.05$ (Barson, Owusu Junior, Adam, et al., 2022; Boateng et al., 2021; Bossman et al., 2022; Owusu Junior & Tweneboah, 2020). The study provides post-estimation tests on linear regression results in Table 7 in Appendix A to justify the reason for employing QR (Koenker, 2008). Breusch–Pagan test (Breusch & Pagan, 1979), White's General Test (White,

1980), Ramsey RESET Test (Ramsey, 1969), Non-constant variance test (Koenker, 1981), Breusch–Godfrey LM test (Godfrey, 1978), and Shapiro Test (Royston, 1982) on the linear regression results are also presented in Table 7 because violating the assumptions of linear regression can lead to incorrect inferences and incorrect predictions. The post-estimation results in Table 7 show that the linear regression is inappropriate for the dataset; linear regression assumptions were not adequately satisfied. The study then employs quantile regression to account for the problems identified (Archer et al., 2022; Boateng et al., 2021; Gök & Tiwari, 2022; Koenker & Bassett, 1978).

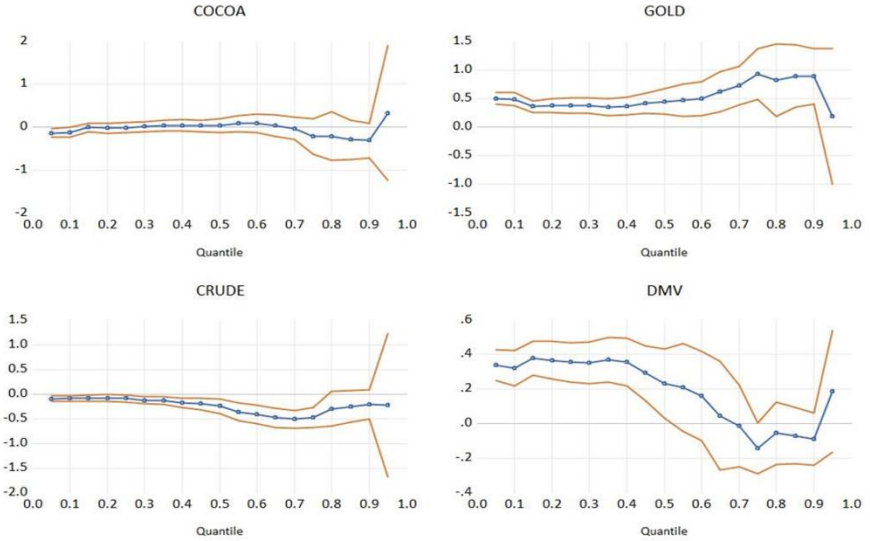
The results of the QR are presented graphically in Figure 6 and summarised in Table 8 (Appendix B) but discussed after the presentation of the results. The QR was estimated with no intercepts because the study does not consider the response variable's overall mean or baseline. The regression dependents are taken from the seven (7) BsFSI and presented under a 95% confidence interval. A dummy variable (before exporting 0, and since exporting 1) was introduced to capture the season when Ghana has not started exporting crude oil commercially. The researcher assumed that a dummy variable which accounts for the period before and during commercial crude oil exportation could better capture the dynamics of the problem and provide a more accurate QR analysis of the relationship between commodity prices and BsFSI.

From Figure 6, gold price significantly positively impacts CAR and NPL across all quantiles. Cocoa price also has a significant positive impact on CAR except for specific quantiles such as ($\tau = 0.35 \; and \; 0.6 - 0.95$).

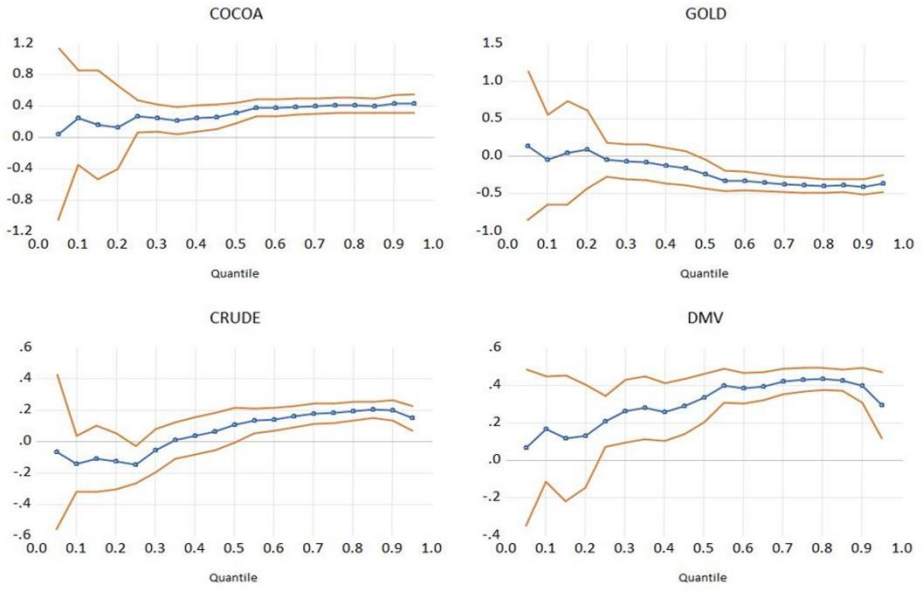
Quantile Process Estimates for CAR



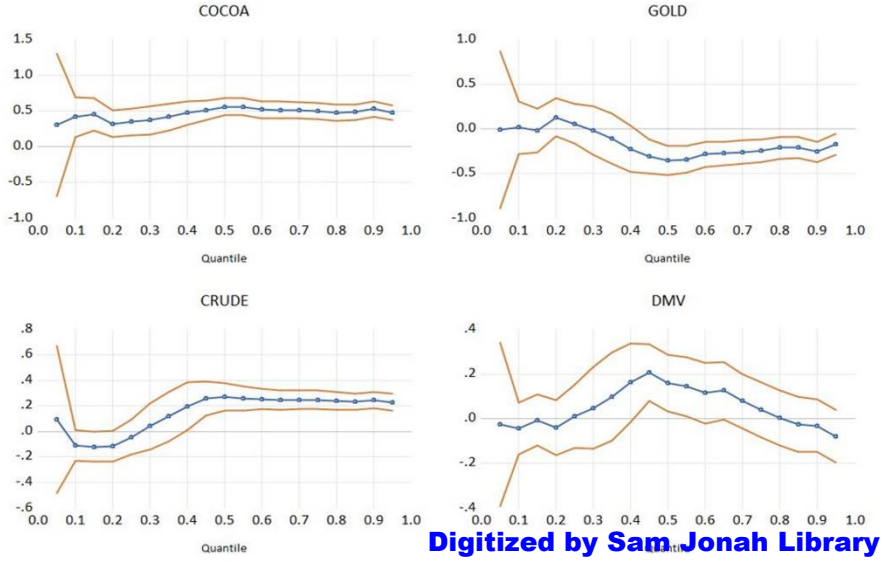
Quantile Process Estimates for NPL



Quantile Process Estimates for ROA



Quantile Process Estimates for ROE



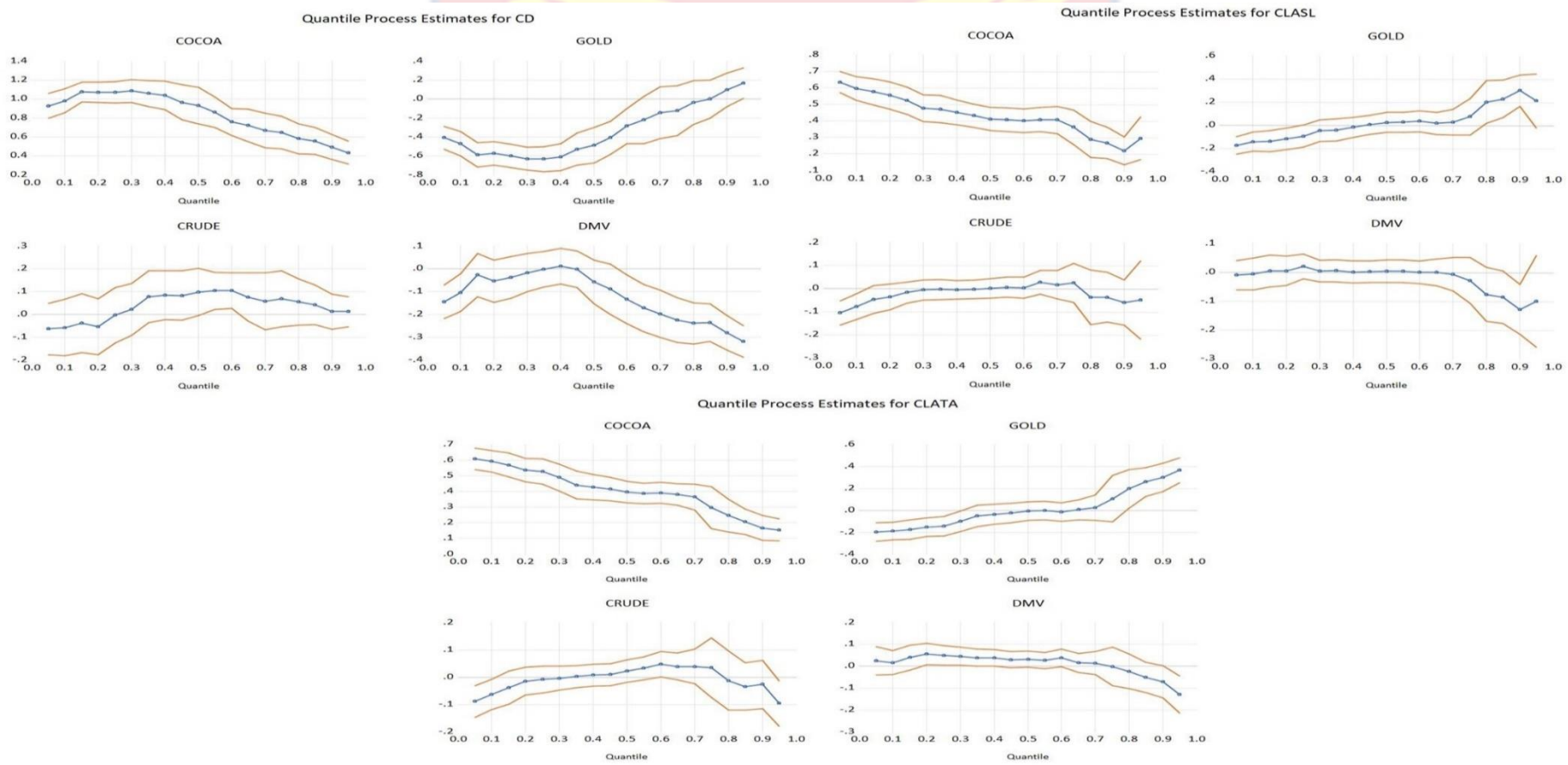


Figure 6: Graphical representation of quantile regression estimations
Source: Author's Construct (2023)
Note: Plots are shown with a Confidence interval of 95%. DVM is a dummy variable with 1 as when export of crude started and 0 as before crude oil export period in Ghana. For positive (negative) coefficients for DVM, it means that, the DVM was more (less) during commercial crude export than before crude oil export period ceteris paribus.

However, crude oil price was seen to have a significant negative impact on CAR in a slump and normal market conditions and insignificant at boom conditions ($\tau = 0.7 - 0.95$). Also, the cocoa price has a negative impact on NPL, but only significant in ($\tau = 0.05\ and\ 0.1$), whereas crude oil price significantly negatively affected NPL except for ($\tau = 0.80\ to\ 0.95$). The results notably showed that the CAR quantile coefficients of cocoa price were reducing across quantiles, but the opposite was seen in the gold price coefficients of CAR. A possible counterintuitive result is that gold prices negatively affect NPL in Ghana. The DMV coefficients were significant at boom conditions for CAR (negative) and slump conditions for NPL (positive). Thus, the CAR (NPL) was reduced (increased), by the coefficients during commercial crude exports than before ceteris paribus.

Cocoa price also has a significant positive impact on ROA in from ($\tau = 0.25\ to\ 0.95$) and a significant positive effect on ROE for all quantiles except ($\tau = 0.05$). The gold price significantly negatively affects ROA and ROE normal and boom conditions. Also, the crude oil price has a positive and significant impact on ROA in normal and boom market conditions but insignificant and negative in a slump. Similarly, crude oil price significantly positively affects ROE in normal and boom market conditions. The results show that the ROA and ROE quantile coefficients of cocoa prices trend upward from lower quantiles to high quantiles but saw a downward turn ($\tau = 0.2 - 0.3$). Also, crude price trended upward in the coefficients of ROA, but ROE reached a peak in ($\tau = 0.5$). Gold price coefficients were in descending order of the quantile values for both ROA and ROE. DMV has a positive and significant effect from ($\tau = 0.25\ to\ 0.95$) on ROA and ($\tau = 0.4\ to\ 0.55, 0.65$) on ROE.

Figure 6 shows gold price negatively impacts CD across all quantiles however insignificant in higher quantiles but affects CLATA only in a slump and boom market conditions. Cocoa price also has a significant positive impact on CD and CLATA for all quantiles. Moreover, crude oil prices have a significant positive impact on CD only in $(\tau = 0.55\ to\ 0.6)$ quantiles. Similarly, crude oil price only significantly negatively affects CLATA in $(\tau = 0.05, 0.1\ and\ 0.95)$. The results show that the CD quantile coefficients of cocoa price rose to the highest in $(\tau = 0.3)$ quantile and started reducing. The DMV was only significant in boom market conditions but at reducing values of negatives for CD while positive and significant for some selected quantiles of CLATA. Gold price coefficients on CD reduced to the lowest $(\tau = 0.3 - 0.35)$ and started rising.

Figure 6 shows that cocoa prices significantly positively impact CLASL, which trended downward until a sharp turn at the highest quantile. Whereas the coefficients of gold prices were positive and significant in some slump and boom conditions, crude prices were significant and negative in $(\tau = 0.05 - 0.1)$. The results showed some fluctuations in the trends. The DMV was only significant but negative at $(\tau = 0.9)$ for CLASL.

Post-estimation tests on quantile results

The study conducted post-estimation tests on the results in Figure 6 and presented in Table 11, Appendix D, to ensure the coefficients were not biased. The Joint Test of Equality of Slopes in Table 11 tests whether the quantile coefficients are equal without testing them individually. The null hypothesis of all the equality of slope tests was rejected for all the QR estimates (p-value <0.01) see Table 11, Appendix D. The results confirm that the coefficients differ

significantly across quantiles (Archer et al., 2022; Gök & Tiwari, 2022). The results also confirm that different market conditions provide different results for the banking sector, as posited by AMH (Lo, 2004).

The stationarity of the quantile residuals was estimated with Phillips–Perron test, as shown in Table 11, Appendix D, even though quantile regression assumes local stability in its estimates (Phillips & Perron, 1988). Figure 19 in Appendix E also presents a graphical Zivot-Andrews test for NPL to buttress the PP test (Zivot & Andrews, 1992). The results in Table 11 for the PP test show that most QR are stationary but could not capture the stationarity in NPL. As such, the unit root of NPL was tested with the Zivot-Andrews test, which has the statistical power to pinpoint structural breaks endogenously (Zivot & Andrews, 1992). The null hypothesis of unit root with a structural break(s) is rejected in all quantiles of NPL in Figure 19 in Appendix E. This settles that the quantile residuals for the study do not have a unit root and are less likely to bias the coefficients of QR estimates. The possible break points in the quantile can be attributed to the lingering impact of shocks (GFC, Ebola pandemic, commodity price slump, and COVID-19) experienced within the time period, which can change the dynamics of the residuals (Archer et al., 2022; Zivot & Andrews, 1992).

In order to have the best local power against departure from the linear autoregressive function in the direction of the square of the linear autoregressive function, Keenan's one-degree test for non-linearity is created (Keenan, 1985). Keenan's test in Table 11 in Appendix C has a null hypothesis of linearity, which is not rejected in most of the quantiles in the model except for ROA and ROE ($p - value > 0.1$). This affirms that the quantile residuals are linear, as

such, the QR model is robust to reveal the asymmetric dynamics of the BsFSI-commodity nexus across a diverse distribution of BsFSI (Keenan, 1985).

Robustness causality check for quantile results

The study employed Jeong et al. (2012) non-parametric causality test to explore the causality between the QR results, as shown in Figure 7 because the QR approach does not capture causality. The estimations are uni-directional because the test is a bi-variate test which does not violate its efficiency (Archer et al., 2022; Balcilar et al., 2021; Boateng et al., 2021). The results show that crude oil prices significantly cause all BsFSI, mostly in normal market conditions. Also, the results show that gold prices cause ROE, ROA, CLASL, and CLATA significantly, but mainly in a slump and normal market conditions. Similarly, NPL, ROE, ROA, CLATA, and CLASL are significantly caused by cocoa prices at normal market conditions. The study revealed insignificant causality between cocoa-CAR, gold-CAR, gold-NPL, cocoa-CD, and gold-CD.

Discussion of quantile regression results

The QR results showed a significant effect of commodity prices on the BsFSI at diverse quantiles to capture the AMH. The results corroborate the findings of a plethora of studies (Alodayni, 2016; Kinda et al., 2018; Miyajima, 2017; Miyajima et al., 2017; Mupunga & Ngundu, 2020; Okyere & Mensah, 2021). The results show that higher cocoa and gold prices increase foreign exchange earnings for Ghana, translating to more funds to banks for lending and investment (Kinda et al., 2018). This can improve Banks' CAR, which measures their ability to absorb losses. However, the decreasing (increasing) values of cocoa (gold) across QR show that the effect decreases (increases) as we move towards higher quantiles of the CAR. This implies a positive effect of cocoa

(gold) prices on the CAR is more pronounced for banks that have lower (higher) levels of CAR and becomes less(more) significant as banks become more financially sound (Abaidoo et al., 2021). Thus, banks that are less (more) financially sound are more reliant on lending to the cocoa(gold) sector or on cocoa (gold)-related collateral and therefore benefit more directly from increases in cocoa (gold) prices. As banks become more (less) financially sound, they diversify their lending portfolios and reduce (increase) their reliance on the cocoa (gold) sector, which reduce (increase) the impact of cocoa (gold) prices on their CAR (Okyere & Mensah, 2021).

Then again, the negative relationship between cocoa prices and NPLs can be explained as higher cocoa prices could lead to increased investment in the cocoa sector, increasing household employment and income (Boateng et al., 2022). This could result in reduced loan defaults and lower levels of NPL in the banking sector. Also, Suppose the gold price is high. In that case, the revenue generated from gold exports could lead to increased economic activity and higher loan demand in the mining sector, however, as firms are tempted to take on more debt to expand their operations. If the increase in international gold prices is not sustainable, these companies may not be able to repay their debts, leading to an increase in NPLs (Schwartz, 1995).

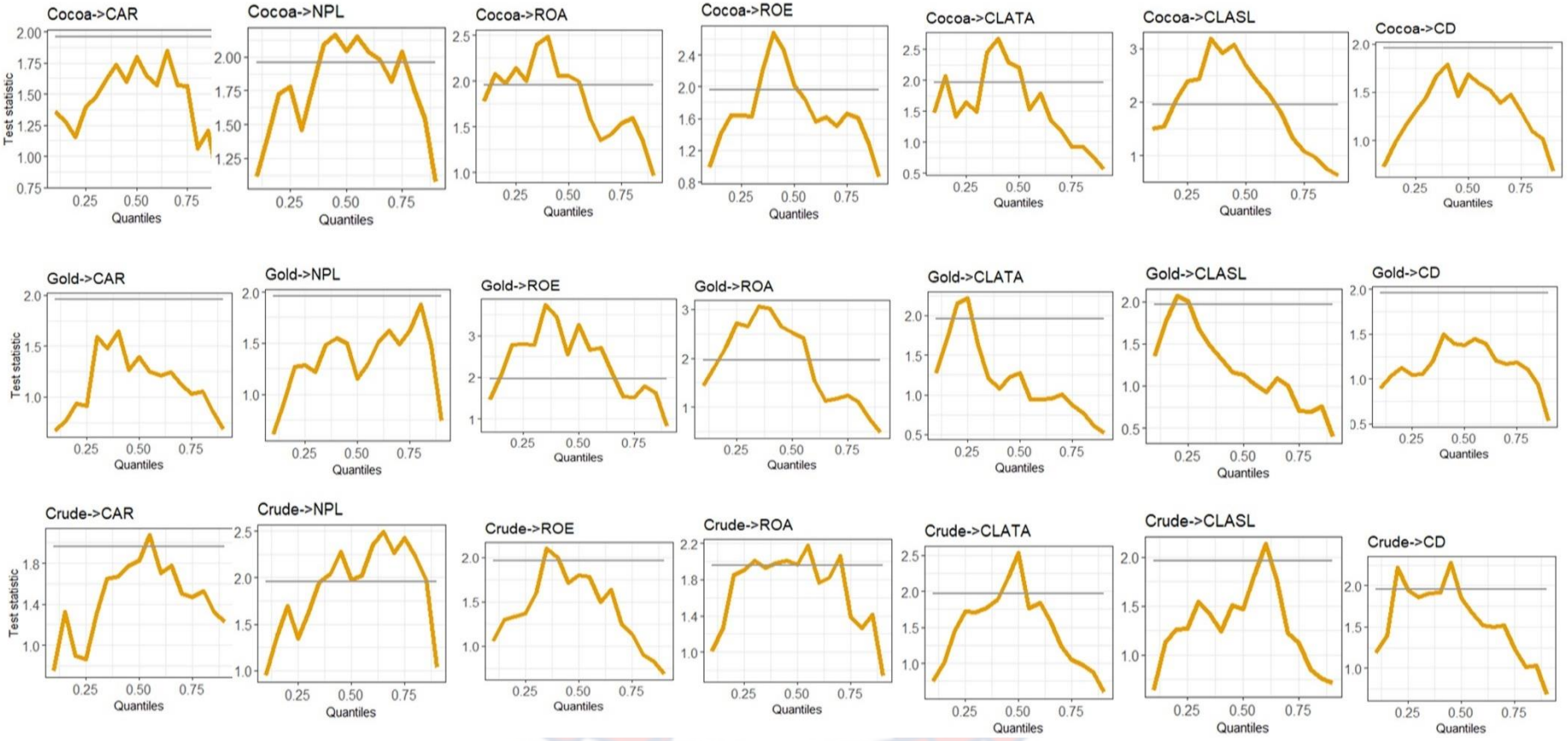


Figure 7: Robustness check by quantile causality
Source: Author's Construct (2023)
Note: The significance of the causality in quantiles is denoted by the region beyond a test statistic of 1.96.

The increment in crude oil prices is felt negatively in most sector sectors of the Ghanaian economy; as such, it is translated into an increment in transportation fees, food prices, etc. (Cantah, 2018; Zankawah & Stewart, 2019). That causes households to withdraw their savings at banks to smoothen their consumption. If the price increases continuously, more households will withdraw their savings hence a reduction in CAR (Abaidoo et al., 2021). Bank's ability to withstand crises is reduced, causing financial instabilities (Schwartz, 1995; Siklos, 2021).

However, when crude oil prices increase, countries like Ghana can experience increased government revenue, foreign exchange earnings, and economic growth in the long term. This can lead to increased loan demand in the crude oil sector, as businesses and consumers may have more capital to invest and spend. Banks may experience a higher level of loan demand, which can offset the negative impact of lower CAR. Additionally, higher revenues for businesses in the crude oil sector can lead to increased profitability for crude oil companies, reducing their risk of defaulting on loans.

The cocoa industry is a driver of economic activity in Ghana, particularly in rural areas (Okyere & Mensah, 2021). Thus, the cocoa industry performs well(worse), and it can lead to an increase(decrease) in economic activity, which can create(reduce) new business opportunities and increase(decrease) demand for credit (Abaidoo et al., 2021). Well performing cocoa industry would also increase the creditworthiness of businesses, which can lead to an expansion of credit by banks to meet the growing demand for credit from businesses involved in the cocoa industry, which can improve the CLASL and CLATA ratios (Miyajima et al., 2017). Additionally, higher revenue from cocoa exports can lead to improved bank profitability and,

therefore, higher ROE and ROA. Cocoa price increment causing bank profitability is also not startling as there are a lot of cocoa farmers in Ghana (Okyere & Mensah, 2021).

The negative effects that rising gold prices may have on CD, ROE, ROA, CLASL and CLATA are due to increased demand for foreign currency and a decrease in Ghanaian Cedi. It becomes more expensive for banks to borrow money from foreign sources, which can reduce the amount of credit available for lending to customers. This decrease in credit can also result in a decline in the profitability of banks, as there are fewer opportunities for banks to earn interest income from loans, and their assets become less valuable in foreign currency terms. The increased demand for foreign currency can lead to a decrease in the CLASL and CLATA of banks, as banks may need to use their liquid assets to obtain foreign currency to meet their obligations (Mupunga & Ngundu, 2020).

The null hypothesis is rejected in favour of the alternative; commodity prices significantly affect the BsFSI in Ghana. As such, a hedging strategy through commodity price insurance would help manage exposure to price volatility in the commodity markets. Also, forward contract strategies can be employed by market participants to meet market conditions because of the adaptive nature of the BsFSI. The government can use monetary policy tools such as adjusting interest rates and reserve requirements, fiscal policy tools such as taxation and spending, and diversification of the economy to influence the supply and demand of foreign currency and stabilize the exchange rate. This can help mitigate the effects of changes in commodity prices on the BsFSI in Ghana.

Hypothesis Two: Macroeconomic variables influence the relationship between commodity prices and BsFSI in Ghana

Analysis of results

The bi-wavelet examines the second hypothesis and PWc approaches. The bi-wavelet determines the co-movement between commodity prices and BsFSI in a time-frequency domain, whereas the PWc boons in the degree of distortion in the co-movements of commodity prices and BsFSI after controlling for macroeconomic variables.

Bi-wavelet results

The study presents 21 pairs of plots between commodity prices and BsFSI in Figure 8, with summary results in Table 5. In examining bi-wavelet plots, the direction of the arrows shows the phase difference. In-phase and anti-phase between commodity prices and BsFSI are seen from arrows in the right (→) and left directions (←). Also, the lead-lag is shown in the downward/upward pointing of the arrows. In that, left(right) arrows pointing down(up) (↙)(↗) indicate that the commodity price leads. Right-down-diagonal (↘) or left-up-diagonal (↖) arrows show that the BsFSI is leading.

The estimation uses Monte-Carlo simulation at 95% confidence bound, which is the red Cone of Influence (COI) to interpret the significance of the results. The results outside the COI are insignificant. The interdependence between the combined variables is embodied by the surface colour and the colour palette. The red(blue) pallets imply areas with major(minor) coherence. The short-, medium-, and long-term co-movements represent the average of high-frequency scales indicating short-term (less than 8 months), medium-

frequency scales known to be medium-term (corresponding to 8–32 months), and low-frequency scales are long-term (over 32 months).

Figure 8 shows a mixture of positive and negative high co-movement between commodity prices and BsFSI throughout the wavelet time scales. The highest interdependence is between cocoa and CD, whereas there was a low relationship between gold and CLASL. Figure 8 shows the interdependence between commodity prices and BsFSI intensified between 2013 and 2016 at medium-frequency scales which can be classified as a contagion effect. This period is known as the commodity price slump. The GFC did not affect most pairs, but the ones it affected saw a high co-movement within those eras (Gockel, 2010).

Gold had a positive and significant correlation with NPL same applies to crude and NPL, but insignificant co-movement exist between cocoa and NPL between the years of 2007 to 2010 in the medium term. Also, in the COVID-19 era and aftermath, the correlation between crude and ROA increased. In the long term, the results showed low correlations, i.e., cocoa-CAR, crude-NPL, cocoa-ROE, gold-ROE, cocoa-CLASL, and crude-CLASL, whereas high correlations were found in cocoa-CD, crude-ROE, cocoa-ROA, crude-NPL, crude-ROA, and cocoa-CAR. In short, the results show that it is essential to monitor the interdependence between commodity prices and BsFSI to identify potential risks and take appropriate measures. The summary of the results in Figure 8 is presented in Table 5

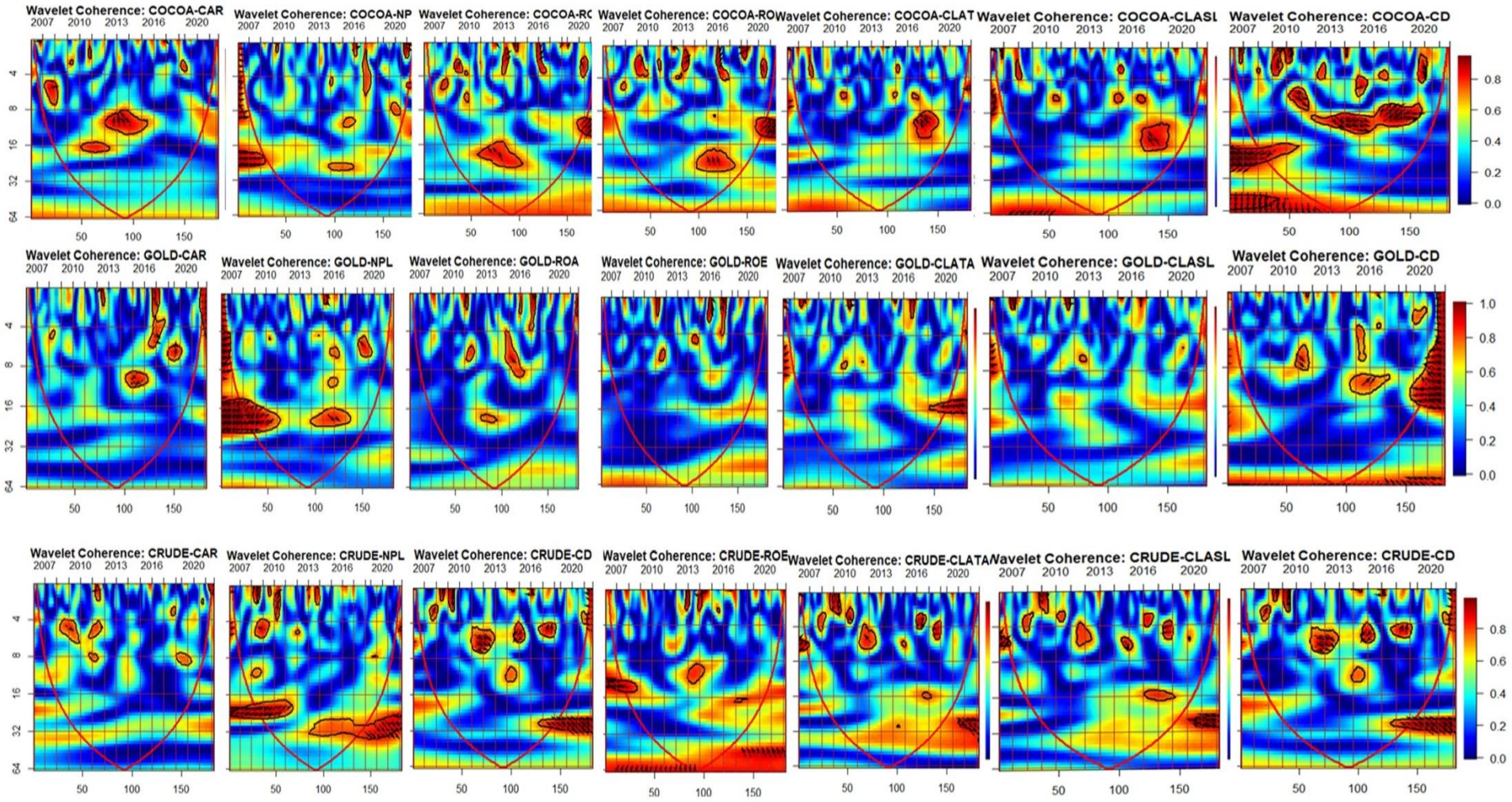


Figure 8: Bi-wavelet coherence between commodity prices and BsFSI
Source: Author's Construct (2023)

Table 5: Summary of Bi-wavelet results

First Variable	Time - horizon	Cocoa			Gold			Crude		
Second Variable		Phase	Lead/Lag	Relation	Phase	Lead/Lag	Relation	Phase	Lead/Lag	Relation
p	ST	In-phase	Indistinct	Contagion	In-phase	Lag	Contagion	Out-phase	Lag	Contagion
	MT	Indistinct	Lag	Contagion	Indistinct	Lead	Contagion	Indistinct	Indistinct	Not Applicable
	LT	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable
NPL	ST	In-phase	Lead	Contagion	Lead	Lag	Contagion	Out-phase	Lead	Contagion
	MT	Indistinct	Indistinct	Contagion	Indistinct	Lead	Interdependence	Indistinct	Lead	Contagion
	LM	Indistinct	Indistinct	Not applicable	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Contagion
ROA	ST	Indistinct	Lead	Contagion	Indistinct	Lag	Contagion	Indistinct	Indistinct	Contagion
	MT	Indistinct	Lag	Contagion	Indistinct	Indistinct	Not Applicable	Out-phase	Lead	Interdependence
	LT	Indistinct	Indistinct	Interdependence	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Contagion
ROE	ST	In-phase	Lead	Contagion	Indistinct	Lag	Interdependence	Out-phase	Indistinct	Contagion
	MT	Indistinct	Lag	Contagion	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Contagion
	LT	Indistinct	Indistinct	Interdependence	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Contagion
CLATA	ST	Indistinct	Indistinct	Not Applicable	In-phase	Lag	Contagion	Out-phase	Lag	Interdependence
	MT	Indistinct	Lag	Contagion	Out-phase	Indistinct	Not Applicable	Indistinct	Indistinct	Contagion
	LT	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable
CLASL	ST	Indistinct	Indistinct	Not Applicable	In-phase	Lag	Not Applicable	Out-phase	Lag	Interdependence
	MT	Indistinct	Lag	Contagion	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable
	LT	Indistinct	Indistinct	Interdependence	Indistinct	Indistinct	Not Applicable	Indistinct	Indistinct	Not Applicable
CD	ST	In-phase	Lag	Interdependence	Indistinct	Lag	Interdependence	Out-phase	Lead	Interdependence
	MT	Out-phase	Lead	Interdependence	Out-phase	Lead	Interdependence	Out-phase	Lead	Interdependence
	LT	Indistinct	Indistinct	Interdependence	Indistinct	Indistinct	Interdependence	Indistinct	Indistinct	Interdependence

Source: Author's Construct (2023)

Note: ST, MT and LT represent the average of high-frequency scales indicating short-term (less than 8 months), medium-frequency scales known as medium-term (corresponding to 8–32 months), and low-frequency scales are long-term, respectively.

Partial wavelet results

The results of the PWc are presented next from Figure 9-Figure 15. Six macroeconomic variables and a control variable are employed to partial out their effect in the nexus between commodity prices and BsFSI. The PWc analysis shows no phase difference and lead/lag variable (Gouhier et al., 2013). Each result from the macroeconomic variables is presented and analysed separately, but in all, the study presented 147 partial wavelet plots. However, each macroeconomic variable had 21 partial wavelet plots. A detailed discussion of the results is provided after the presentations.

The interpretation of the PWc follows that of a colour spectrum. The coherence between the commodity prices and BsFSI is presented after controlling for the macroeconomic variables. The red colour implies areas with high correlation, while the opposite is seen with blue. The short, medium and long-term co-movements represent the average of high-frequency scales indicating short-term (less than 8 months scale), medium-frequency scales known to be medium-term (corresponding to 8–32 months scale), and low-frequency scales are long-term (over 32 months scale), respectively (Gök & Tiwari, 2022; Kiviaho et al., 2014). The results reveal the characteristics of the market described by HMH and AMH (Lo, 2004; Müller et al., 1993).

Figure 9 shows that inflation significantly impacts the co-movement between commodity prices and BsFSI. Specifically, Figure 9 depicts that inflation reduced the coherence between cocoa and CAR in 2010-2013 and cocoa-ROE in 2016-2020 in the medium term while increasing the coherence between cocoa and CAR in the long term from 2016 upward. Also, the relationship between gold and NPL was reduced in the medium and long term.

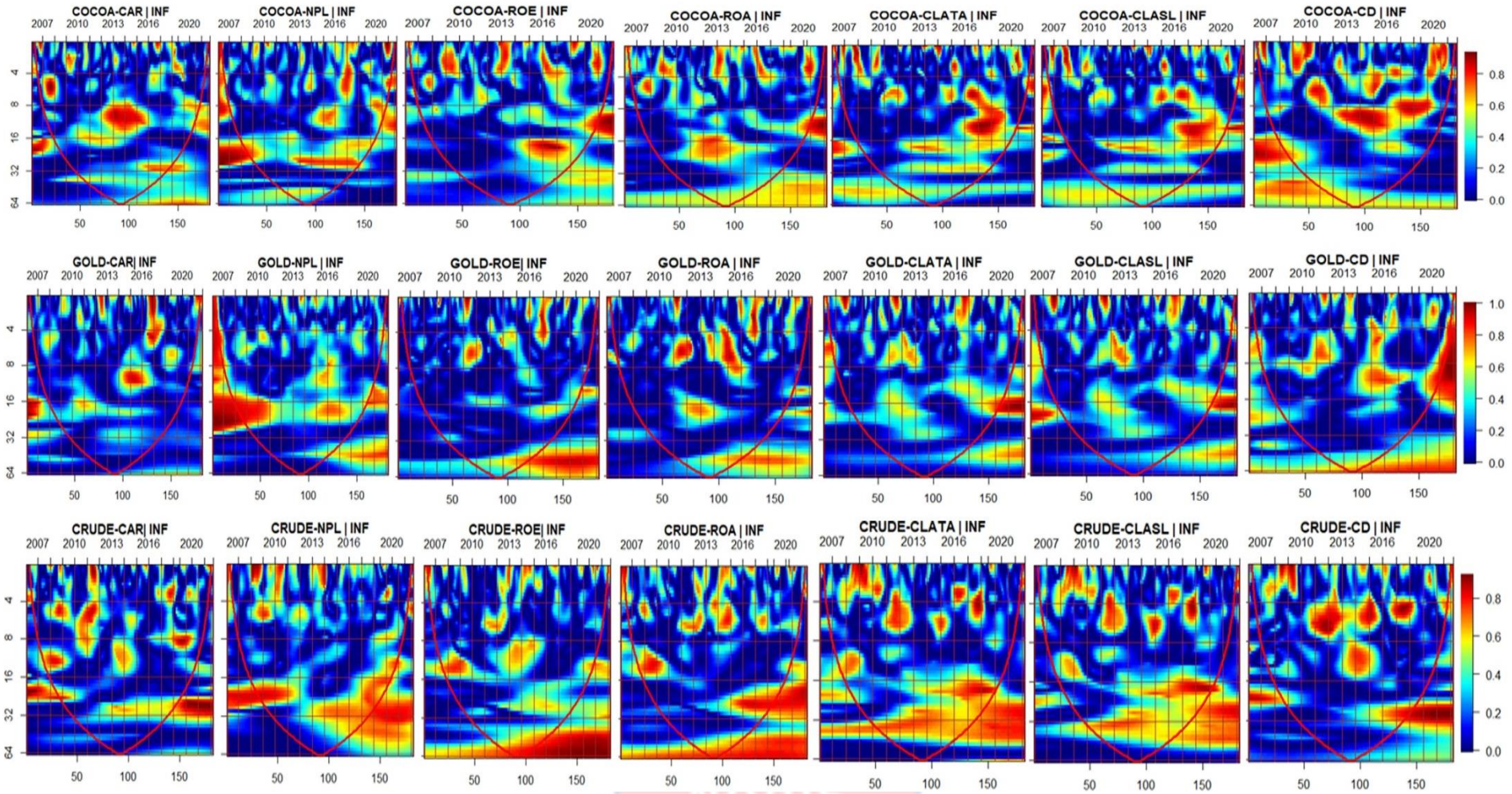


Figure 9: Commodity price and BsFSI co-movement, conditioned on INF.
Source: Author's Construct (2023)

Looking carefully at Figure 9, the nexus between gold and CAR, gold and ROE, and gold and CLATA was drastically reduced across all time horizons. In comparison, the study can posit that the nexus between crude and BsFSI had the most impact on headline inflation, followed by the cocoa and BsFSI, gold and BsFSI, and cocoa and BsFSI.

However, the coherence between the variables in the period of COVID-19 and its aftermath was maintained in Figure 9. Nonetheless, the impact of the GFC was not noticed in the partial wavelet results. Also, when the commodity prices slumped, the relationship between the variables was maintained, although the impact of inflation was noticed. In conclusion, the study can postulate that inflation significantly impacts the nexus between Commodity Price and BsFSI (Mupunga & Ngundu, 2020). Likewise, the impact of the GFC was indirect to the commodity prices nexus, which accounted for why it was reduced from the relationship (Balcilar et al., 2021). The study posits that policymakers should consider the impact of inflation when analysing the nexus between commodity prices and BsFSI and adopt measures to control inflation as it.

The following plots in Figure 10 present partial wavelet results from the monetary policy rate (MPR). Figure 10 shows that the MPR substantially impacts the co-movement between Commodity Price and BsFSI. Unambiguously, Figure 10 shows an increase in the coherence between cocoa and CAR in 2010-2016 in the long term, while bluer (cold) colours interpreted as low correlations are seen in the coherence of cocoa and the BsFSI across various horizons. Also, the relationship between gold and NPL was reduced in the medium and long term.

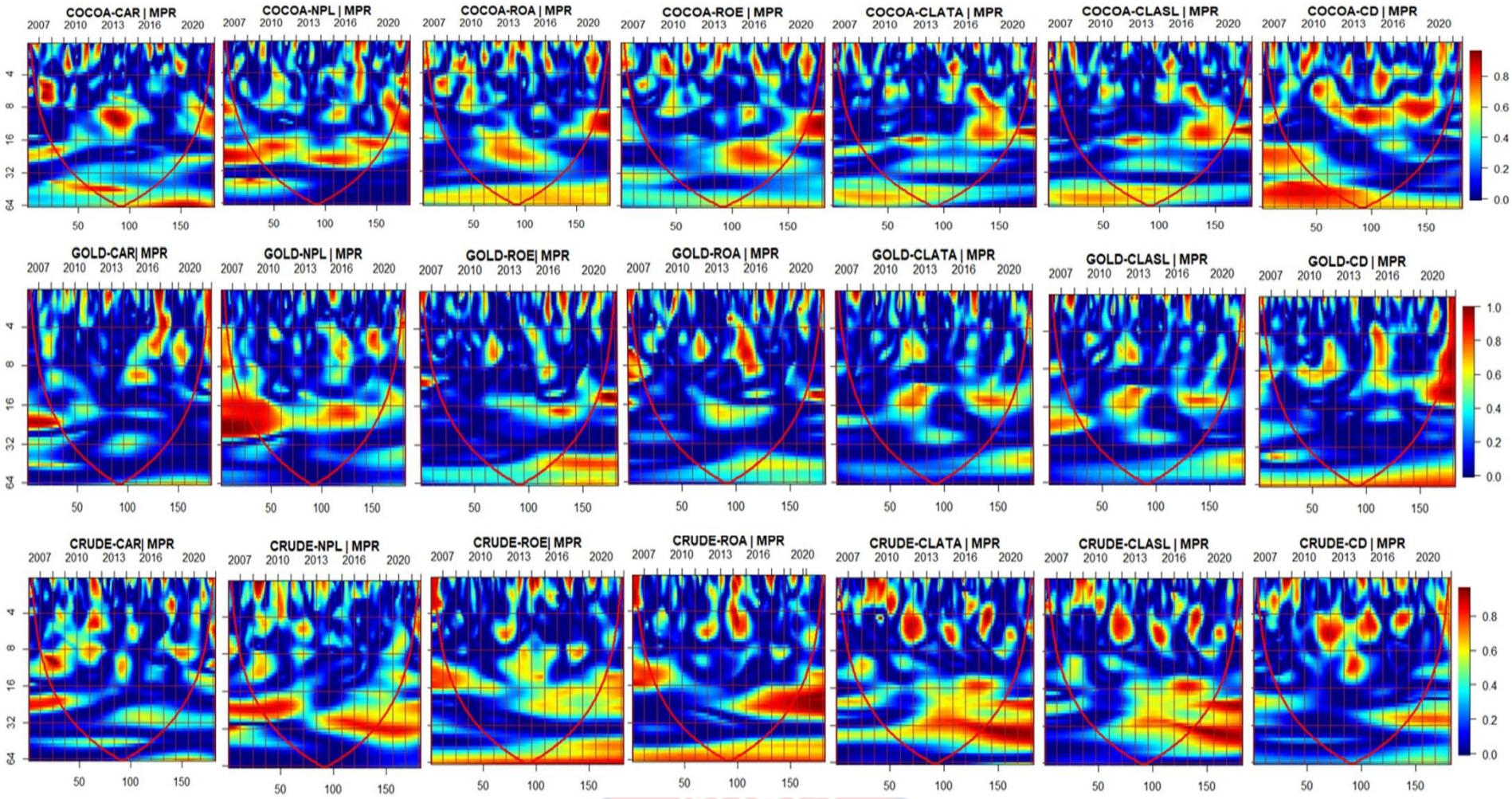


Figure 10: Commodity price and BsFSI co-movement, conditioned on MPR.
Source: Author's Construct (2023)

Similarly, there was a reduction in relationships between gold and BsFSI across all times and frequencies. Compared to Figure 8, the coherence between crude and the BsFSI was not significantly different. The study recorded a significant impact on gold and BsFSI, followed by the nexus between cocoa and BsFSI and crude and BsFSI.

Moving on to the economic events, the influence of the period of the GFC in 2008 and COVID-19 and its aftermath was seen in the plots (Ben Haddad et al., 2021). However, in the era of the commodity prices slump in 2014-2016, the co-movements between variables were like the magnitude in Figure 8. As such, the study concludes that the monetary policy rate partially impacts the nexus between commodity price and BsFSI; as such, it recommends that investors and traders consider the impact when making investment decisions. Also, the partial wavelet results in Figure 10 are not resistant to the impact of economic, political, or health shocks (Kinda et al., 2018; Lindgren et al., 1996). First, policymakers should take a proactive approach to monitor and manage the impact of monetary policy on commodity prices and financial stability. Second, policymakers should consider the impact of economic events on these relationships when designing policies. The plots in Figure 11 present partial wavelet results from a broad money supply (M2).

A careful look at Figure 11 shows the impact of the M2 on the nexus between commodity prices and BsFSI has reduced coherence except for some few relationships such as gold-CLATA in 2010-2013, gold-CLASL in 2010-2013, crude-CAR in 2016 and crude-CLATA in 2013-2016.

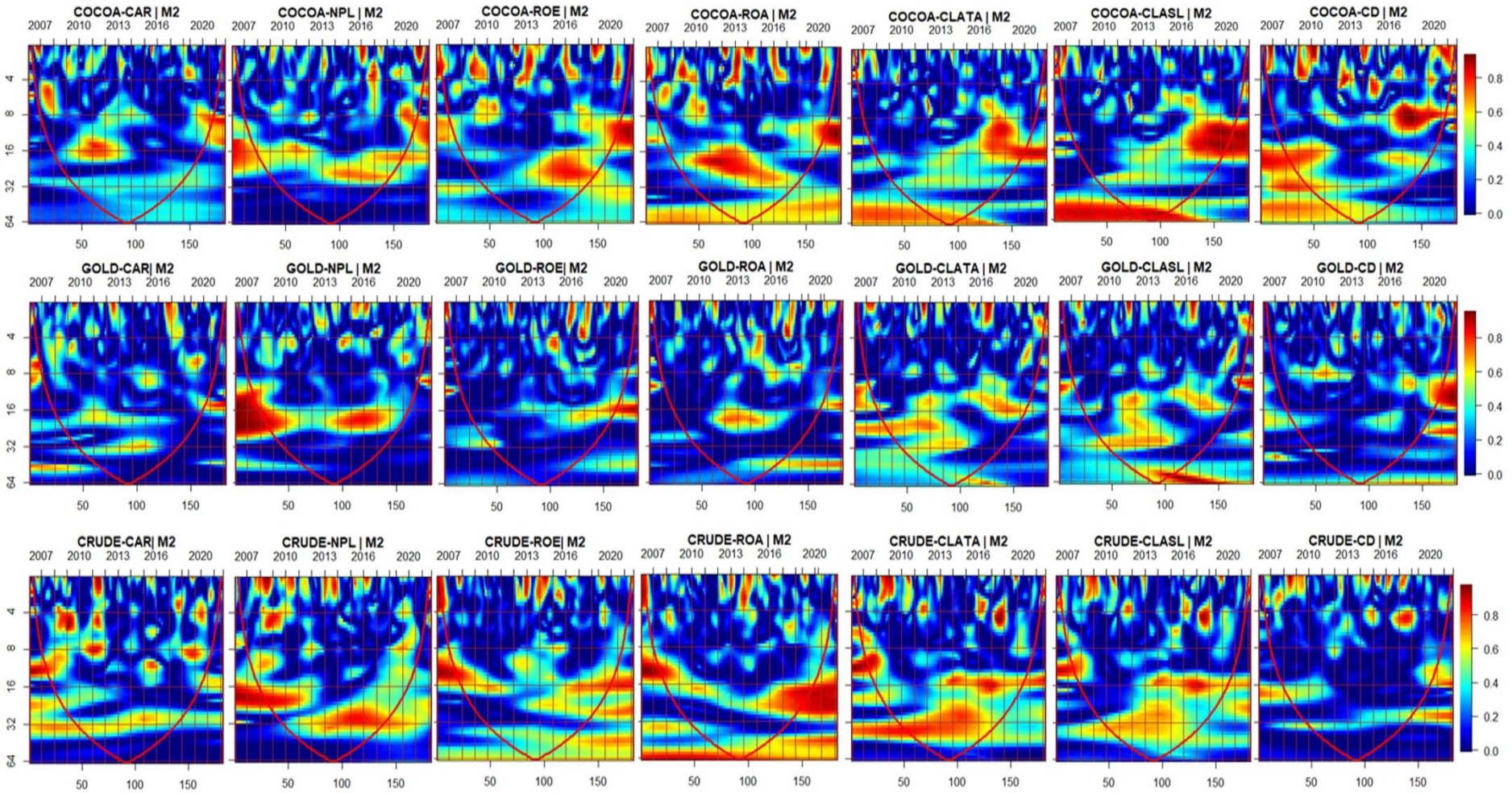


Figure 11: Commodity price and BsFSI co-movement, conditioned on M2.
Source: Author's Construct (2023)

Also, cocoa-ROA in 2013-2016, cocoa-CLATA in 2020 and cocoa-CLASL in 2020 saw an increase in their co-movements. The significantly changed co-movements are gold-ROE, gold-CAR, gold-NPL, cocoa-CD, and crude-CD. Also, the correlation between the variables in the long term has increased across the study's time horizon. The results show that the relationships relating to gold prices saw significant changes in the co-movements, cocoa prices and crude prices in descending order.

In 2013-2016, the results showed almost no correlation between cocoa-CAR, gold-ROE, and gold-CD. This means the highest integration from the commodity prices slump did not affect these nexuses. However, within these same periods in other plots in Figure 11, the study saw an increase or maintained correlation from Figure 8. Also, in the COVID-19 era, the study saw high correlations between plots such as cocoa-NPL, cocoa-ROE, cocoa-CLATA, cocoa-CLASL, and cocoa-CD in the short and medium term. Similar can be seen from crude-ROE, crude-ROA, crude-CLATA, and crude-CLASL in the long term. The nexus between commodity prices and BsFSI also increased in the GFC era in 2008, but mostly in the medium and long term. The results of M2 align with the findings of (Kinda et al., 2018; Mupunga & Ngundu, 2020).

The results of the partial wavelet of commodity prices and BsFSI conditioned on the exchange rate are presented in Figure 12. The results show that with exchange rate impacts the relationship between commodity prices and BsFSI, their correlation either increases or decreases but is never the same. This indicates the significant impact of the exchange rate on the correlation between the variables.

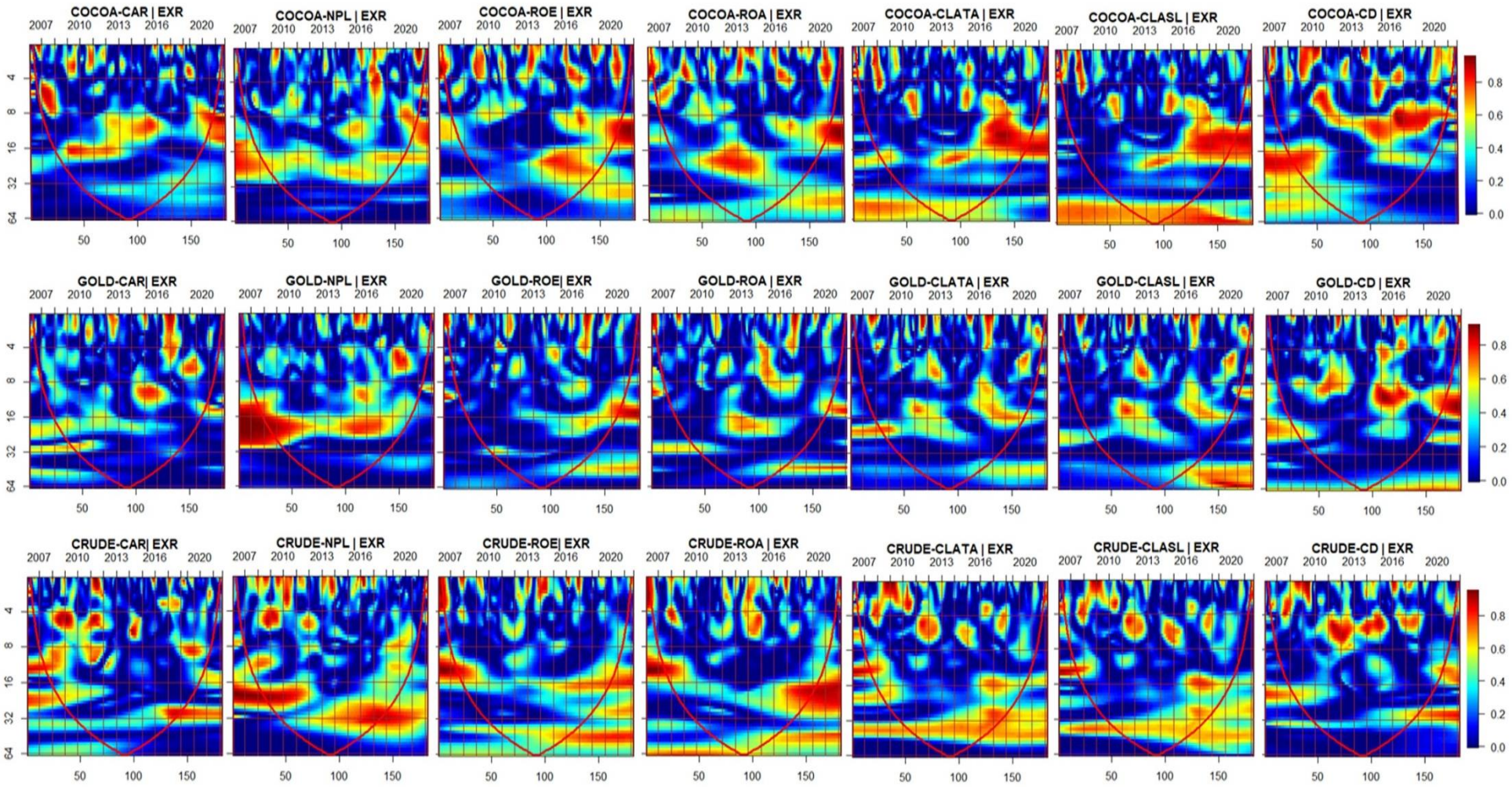


Figure 12: Commodity price and BsFSI co-movement, conditioned on EXR.
Source: Author's Construct (2023)

The most noticeable moments in the plots are cocoa-CAR within the medium term in 2009-2010, cocoa-ROE within the short to medium term 2016-2020, as well as cocoa-CLATA in 2016-2020 and cocoa-CLASL in 2016 in the medium term. Also, there was some remarkable correlation between gold and ROE, ROA, CLATA, and CD. Similar events are seen in crude-CLASL and crude-CLATA. The exchange rate affects the correlation of gold most, followed by cocoa and then crude.

The study saw the excruciating impact of the exchange rate on the relationship under study in the plots of Figure 12 at some known global events. First is the GFC, which peaked in 2008; the results show that the co-movements were reduced but not between cocoa-CD, gold-CAR, gold-NPL, cocoa-NPL, gold-CLATA, and all crude relationships. Also, the increase in co-movement in the Commodity price slump in 2014-2016 and COVID-19 in 2020 in the relationship between commodity prices and BsFSI was noticed in almost all the plots of Figure 12. These results are not surprising because of the influence of the exchange rate on commodity pricing (Barson, Owusu Junior, & Adam, 2022).

The plots in Figure 13 present partial wavelet results from a CIEAR. The following plots in the present partial wavelet results from CIEAR. This would provide more insight into understanding the co-movement between commodity prices and BsFSI. The results in Figure 13, which present the relationship between Commodity Price and BsFSI co-movement conditioned on CIEAR, are not significantly different from those in Figure 8.

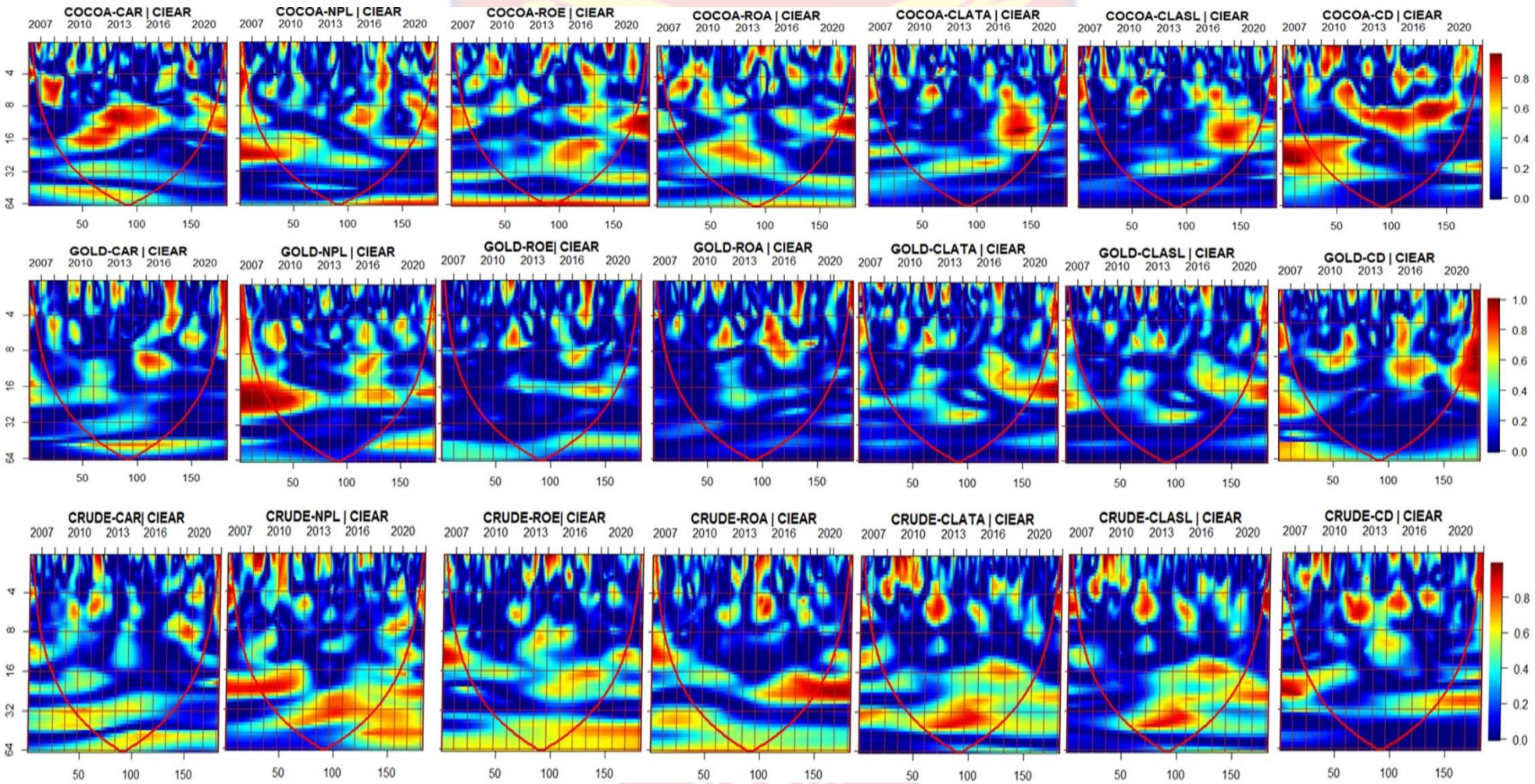


Figure 13: Commodity price and BsFSI co-movement, conditioned on CIEAR.
Source: Author's Construct (2023)

This is because CIEAR measures economic activities in the Ghanaian economy; hence increase in the relationship between commodity prices and BsFSI also increases economic activities. The results point to a few increments in the nexus between crude-CLATA, crude-NPL, and crude-CLASL in the long term.

On the other side, there was a reduction in crude-ROA, cocoa-CAR, cocoa-NPL, gold-ROE, and gold-ROA. Comparing the impact on various commodity prices nexuses, a careful look shows that gold correlations were affected most in all time horizons, followed by cocoa nexuses and crude connections. The impact of Covid 19 was noticed throughout the plots; hence there was a high correlation from 2020 onward. BsFSI shows a significant measure of a healthy CIEAR. Hence, weakening CIEAR would affect banks' projects, firms, and household borrowing, and governments cannot settle their debts (Kinda et al., 2018; Lindgren et al., 1996; Mupunga & Ngundu, 2020). The central Bank of Ghana should consider implementing policies that ensure financial stability, particularly during economic downturns caused by factors such as the Covid 19 pandemic.

The plots presenting partial wavelet results from trade balance are grouped in Figure 14. A careful look at Figure 14 shows that the effect of the trade balance on the nexus between commodity prices and BsFSI has reduced their correlations. None of the plots in Figure 14 was left out of the effect of TB; however, the increase or decrease in the correlation is dependent on the variables involved. The significantly changed co-movements are gold and CLATA, gold-ROA, gold-NPL, cocoa-CD, crude-NPL, crude-ROE, and crude-CAR.

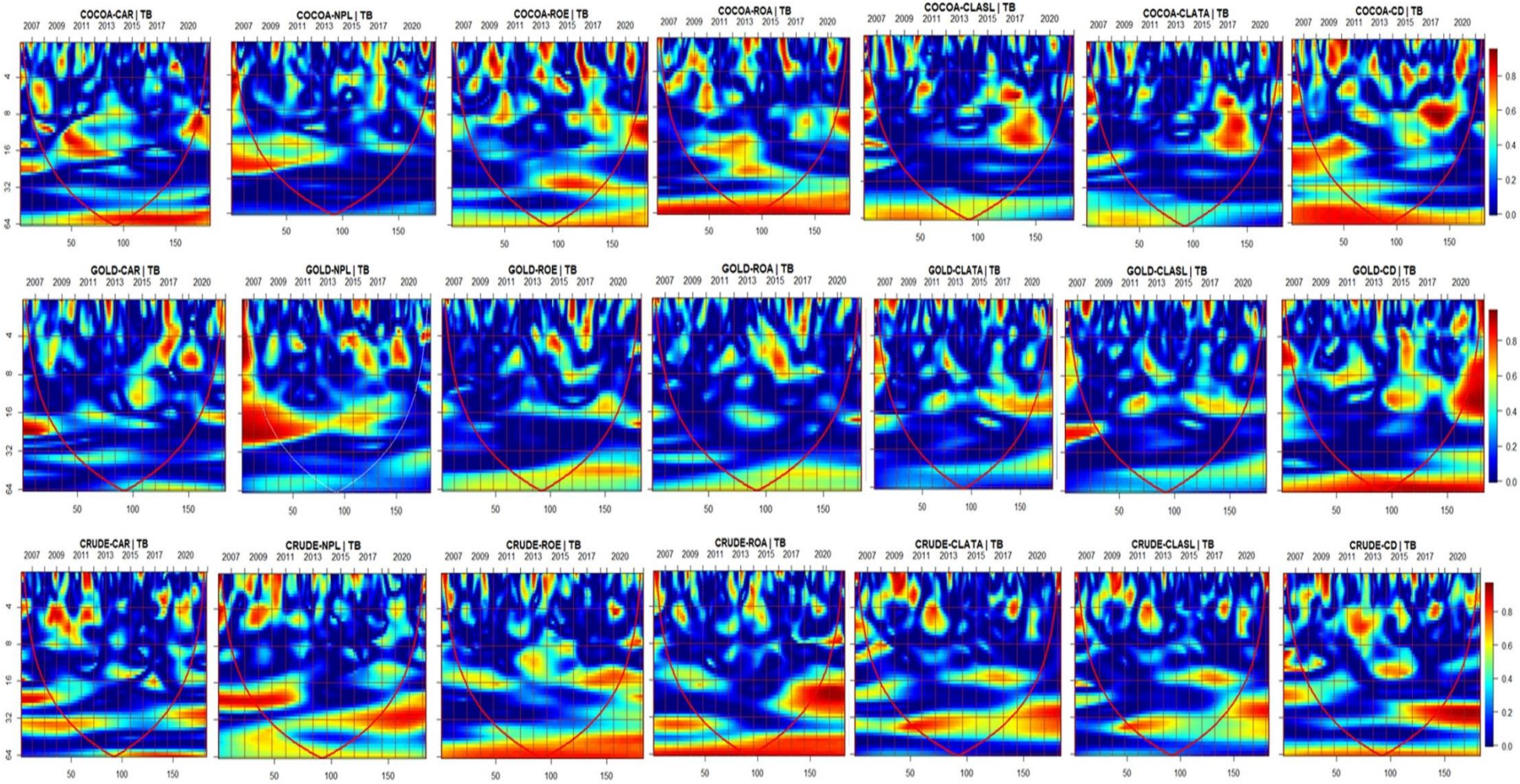


Figure 14: Commodity price and BsFSI co-movement, conditioned on TB.
Source: Author's Construct (2023)

Also, the correlation between the variables in the long term has increased across the study's time horizon. The results show that the relationships relating to cocoa prices saw significant changes in the co-movements, crude prices, and gold prices.

In 2013-2016, the results showed almost no coherence in the plots except commodity prices and CD. This means the highest integration from the commodity prices slump did not affect these nexuses. Also. in the COVID-19 era, the study saw high correlations among plots. The nexus between commodity prices and BsFSI also increased in the GFC era in 2008, but mostly in the medium and long term, except for gold-ROE and gold-ROA (Guzman, Medina & Soto, 2014; Tahar et al., 2021). Trade balance changes contribute to commodity prices' effect on BsFSI (Agarwal et al., 2016). Policies to promote export diversification and macroeconomic stability can help reduce the impact of trade balance and commodity price fluctuations on the economy.

The following plots present partial wavelet results from GEPU, which are used as a control for the analysis. This would provide insight into the co-movement between commodity prices and financial soundness indicators. Figure 15 presents the partial wavelet coherence analysis after the effect of GEPU has been controlled and eliminated from either combination of commodities: Commodity Price and BsFSI. The results in Figure 15 showed that the co-movements within the red COI indicate a significantly low correlation across different time horizons and wavelet scales compared to the results in Figure 8 (Boateng et al., 2022).

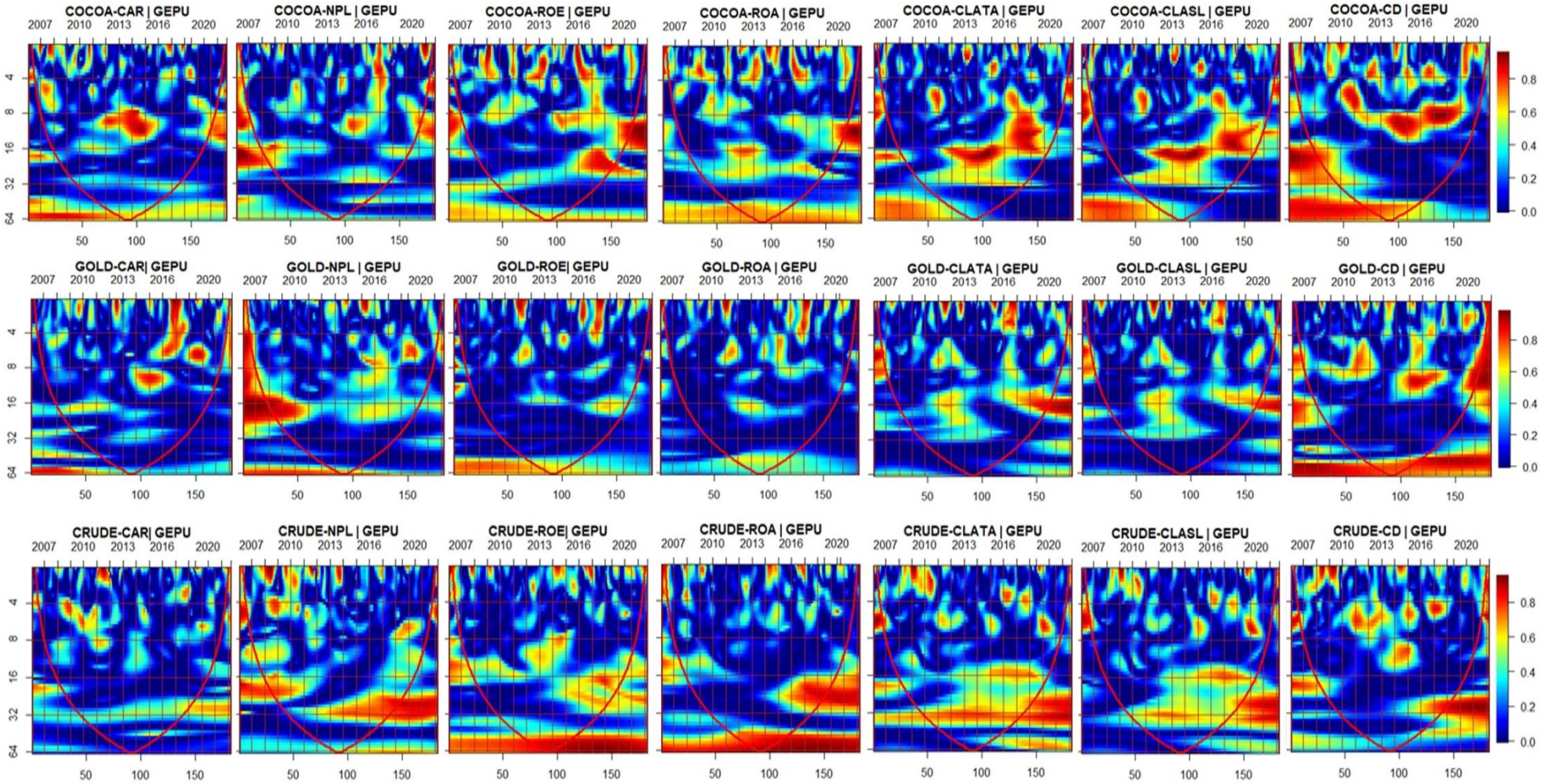


Figure 15: Commodity price and BsFSI co-movement, conditioned on GEPU.
Source: Author's Construct (2023)

This implies that external shocks significantly influence commodity prices in the time and frequency domain, as Frimpong et al. (2021) indicated when agricultural commodities were considered. This may distort the BsFSI due to the adverse impact on international commodity prices.

Discussion of bi-wavelet and partial wavelet results

The study employed bi-wavelet and partial wavelet to examine the time-frequency dimensions of the problem under study and found high co-movements between commodity prices and BsFSI, following the HMH and AMH (Lo, 2004; Müller et al., 1993). The results from the bi-wavelet are like the quantile results of hypothesis one but in time and frequency. The study corroborates previous studies' findings that asymmetric and time-based behaviour of households and firms causes the relationship between commodity prices and commodity-dependent countries' financial soundness to be supported by the AMH and the HMH (Archer et al., 2022; Asafo-Adjei, Boateng, et al., 2021; Barson, Owusu Junior, & Adam, 2022; Boateng et al., 2021; Lo, 2004; Müller et al., 1993). The findings support a plethora of studies, such as Abaidoo et al. (2021) and Sheefeni (2015), who employed diverse econometric techniques, yet a similar conclusion; there is a significant relationship between commodity prices and BsFSI.

The results from the partial wavelet show that macroeconomic variables significantly influence the relationship between commodity prices and BsFSI in Ghana, as shown in the theories from the monetarist's view and financial fragility (Abaidoo et al., 2021; Gospodinov & Jamali, 2018; Hau et al., 2020; Jena, 2017; Labys & Maizels, 1993). Specifically, it was noticed that the exchange rate has the most significant impact on the relationships (Archer et al.,

2022; Jena, 2017), followed by M2 (Antwi et al., 2020), inflation (Boateng et al., 2022), and monetary policy rate (Gospodinov & Jamali, 2018). CIEAR had the most negligible significant impact on the co-movement between the variables, which aligns with the findings of Boateng et al. (2022), who found that the Bank of Ghana CIEAR has a meagre impact on the co-movements between commodity prices. What accounted for the low impact could be that CIEAR is limited in accessing the economic activity of Ghana.

The results show that partialing out inflation reduces the correlation between commodity price and BsFSI (Boateng et al., 2022). The results are in line with Schwartz's hypothesis, which posits that a persistent rise in the price of commodities causes financial sector instability (Abaidoo et al., 2021; Bordo & Wheelock, 1998; Schwartz, 1995). Hence, with steady inflation in an economy, the impact of the commodity price on the BsFSI will be minimized. As such, in the price increment of commodities, governments should monitor their inflation rate so that the impact on the BsFSI will not escalate.

On monetary policy instruments such as M2 and monetary policy rate, the results showed a significant effect of M2 and monetary policy rate on the relationship between commodity price and BsFSI (Abaidoo et al., 2021; Bordo & Wheelock, 1998; Gospodinov & Jamali, 2018). Noticeably, partialing out monetary supply increases the correlations between the variables, whereas the monetary policy rate reduces the co-movement between the variables. Hence, it corroborates the notion of Monetarists that asymmetrical and unpredictable monetary policy announced by the central bank without a corresponding consideration to the possible trade-offs amid economic growth and inflation rate

causes instability in the financial sector (Friedman & Schwartz, 1963; Vo et al., 2019).

The results show that exchange rate and trade balance impact the relationship between commodity prices and BsFSI; thus, exchange rate fluctuations can impact business competitiveness in international markets across time-frequency (Kinda et al., 2018; Mupunga & Ngundu, 2020). As a result, exchange rate movements can increase the comovement between commodity prices and BsFSI. The most noticeable moments are the exchange rate's significant effect on the variables' correlation in the medium term (Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022). Hence, policymakers can strengthen Ghana's exchange rate to address changes in the relationship between commodity prices and BsFSI. Also, a decrease in trade balance reduces an economy's economic activities. The Financial fragility approach to instability holds that financial instability unswervingly is connected business cycle's peak and trough (Abaidoo et al., 2021; Borio & Drehmann, 2009, 2011).

Lastly, the results showed the GEPU significantly impacted the relationship between commodity prices and BsFSI most in the long term. This could be because the commodity price is determined mostly by international demand and supply (Asafo-Adjei et al., 2020; Boateng et al., 2022). Drawing from the results and discussions, the study rejects the null hypothesis in favour of the alternate; macroeconomic variables influence the relationship between commodity prices and BsFSI in Ghana. This is in line with a plethora of studies (Abaidoo et al., 2021; Babihuga, 2007; Gangelhoff, 2015; Kinda et al., 2018; Miyajima, 2017; Mohammed, 2021; Mupunga & Ngundu, 2020; Sheefeni, 2015). The study posits that policymakers and implementers consider

diversifying the economy by developing other sectors, such as manufacturing and services, which can reduce the country's reliance on commodity exports and minimize the impact of price volatility in these markets. Also, effective fiscal management, including maintaining a healthy fiscal balance and using fiscal buffers, can help stabilize the economy in the face of commodity price shocks.

Hypothesis Three: Ghana has a significant degree of connectedness among commodity prices, BsFSI, and macroeconomic variables.

Analysis of results

The current study employed TVP-VAR connectedness and wavelet multiple techniques to examine the degree of connectedness among commodity prices, BsFSI, and macroeconomic variables in Ghana. TVP-VAR connectedness presents time-varying connectedness among the variables in light of specific events, while wavelet multiple results are frequency-dependent (Antonakakis et al., 2020; Gouhier et al., 2013). The average connectedness from the TVP-VAR connectedness of the variables is presented in Table 6. Table 6 shows the impact of each variable (commodity prices, banking sector financial soundness, and macroeconomic variable) on the forecast error variance of the whole model. The central diagonal values are from the variables' own contribution of a distinctive impact, while others' contributions to TO and FROM are shown in off-diagonal values.

Table 6 shows that the degree of connectedness among commodity prices, BsFSI, and macroeconomic variables is higher, with a total connectedness index (TCI) percentage value of 68.36%.

Table 6: Average total connectedness for commodity prices, BsFSI, and macroeconomic variables

	CAR	NPL	ROE	ROA	CLATA	CLASL	CD	Cocoa	Gold	Crude	INF	MPR	M2	CIEAR	EXR	GEPU	TB	**FROM**
CAR	22.47	15.08	0.53	0.56	0.66	1.03	9.5	0.05	7.82	1.16	6.5	0.49	11.37	1.45	9.47	6.02	5.82	77.53
NPL	10.24	26.53	4.02	0.21	0.69	0.14	6.52	1.35	10.1	1.74	1.78	2.48	11.01	0.55	9.94	6.62	6.08	73.47
ROE	2.89	8.36	33.5	25.95	0.23	0.14	7.52	0.28	1.22	4.42	3.23	0.4	2.43	0.03	1.84	5.05	2.51	66.5
ROA	0.95	0.27	30.3	47.79	0.27	0.41	0.4	2.15	3.17	1.38	1.2	2.74	3	1.96	3.3	0.53	0.17	52.21
CLATA	2.25	0.78	0.39	0.5	37.71	35.11	1.66	11.38	1.54	0.06	1.36	3.88	0.58	1.18	0.26	1.14	0.2	62.29
CLASL	3.37	0.37	0.27	0.58	33.24	36.26	4.04	8.87	0.89	0.55	2	3.24	1.83	0.6	0.89	2.22	0.77	63.74
CD	10.54	6.96	3.53	0.76	0.78	1.59	19.92	0.71	9.96	0.31	9.27	2.36	10.94	0.11	8.11	8.26	5.89	80.08
Cocoa	1.18	1.26	0.26	0.91	3.77	3.49	8.3	46.61	0.68	1.01	13.37	10.08	1.12	0.75	0.33	6.43	0.44	53.39
Gold	8.76	9.68	0.49	0.75	0.16	0.89	12.9	0.92	25.4	0.38	5.42	0.61	10.94	0.91	7.79	8.74	5.28	74.6
Crude	0.54	1.28	0.84	0.11	1.77	2.42	0.15	0.52	1.56	43.66	3.97	16.02	6.41	4.81	9.73	4.72	1.49	56.34
INF	9.07	3.75	2.32	1.16	0.59	1.01	14.48	3.39	7	1.55	30.94	14.94	1.69	3.12	0.36	3.14	1.49	69.06
MPR	0.83	1.42	0.75	3.2	3.28	2.98	4.25	3.69	0.3	9.54	19.18	36.28	3.37	4.17	6.44	0.02	0.31	63.72
M2	8.11	8.38	0.66	0.71	0.24	0.67	10.03	0.02	9.05	2.97	1	1.65	19.91	1.17	19.26	8.52	7.67	80.09
CIEAR	0.76	0.84	1.32	5	0.05	0.06	0.61	1.31	0.47	5.94	9.31	11.15	4.7	49.64	7.62	0.18	1.04	50.36
EXR	6.75	7.36	0.48	1.03	0.17	0.49	8.21	0	7.28	4.61	0.16	3.18	20.79	1.89	21.75	7.55	8.28	78.25
GEPU	6.3	6.62	2.55	0.53	0.3	0.64	12.04	0.45	10.39	3.37	2.86	0.04	13.68	0.08	11.89	22.73	5.54	77.27
TB	10.02	7.34	1.07	0.22	1.19	2	12.75	0.05	10.78	1.35	1.4	0.45	14.65	0.5	12.73	6.66	16.84	83.16
TO others	82.55	79.74	49.79	42.18	47.39	53.07	113.37	35.14	82.21	40.35	82.02	73.7	118.52	23.3	109.96	75.79	52.99	1162.07
Inc. own	105.03	106.27	83.29	89.97	85.11	89.33	133.29	81.75	107.61	84.02	112.96	109.98	138.43	72.94	131.7	98.52	69.83	**TCI**
NET	5.03	6.27	-16.71	-10.03	-14.89	-10.67	33.29	-18.25	7.61	-15.98	12.96	9.98	38.43	-27.06	31.7	-1.48	-30.17	**68.36**
NPDC	5	6	11	10	14	13	5	9	7	9	8	7	0	12	2	7	11	

Source: Author's Computation (2023)

Note: The first seven (7) variables are BsFSI, the following three (3) commodity prices, and the last seven (7) are the macroeconomics variable TCI, NET and NPDC denote Total Connectedness Index, net directional connectedness and net pairwise directional connectedness respectively. Positive net values represent net transmitters, whereas negative net values show net receivers.

Thus, 68.36% of forecast error variance within the model is from interactions among the variables. while the remaining 31.64% is idiosyncratic impacts of forecast error variance. This provides empirical evidence to support the assertion that commodity prices, BsFSI, and macroeconomic variables are highly interconnected and significantly influence each other's dynamics (Abaidoo et al., 2021). Thus, a decline in international gold prices may affect the profitability of banks that have lent money to the mining industry. This could lead to a deterioration in the BsFSI, which could affect macroeconomic variables such as CIEAR and exchange rates. Similarly, changes in macroeconomic conditions, such as a rise in MPR, could affect the demand for loans to the cocoa sector, which could the international prices of cocoa and the BsFSI of Ghanaian banks that have invested in cocoa (Kinda et al., 2018).

Also, Table 6 points out that 8 variables are net transmitters. Net transmitters are the drivers of interconnectedness, i.e., they influence other variables rather than being influenced by others. In descending order, the net transmitters are M2, CD, EXR, INF, MPR, Gold, NPL, and CAR. In contrast, the net receivers are TB, CIEAR, Cocoa, ROE, Crude, CLATA, CLASL, ROA and GEPU. The dominance of M2, CD and EXR in transmitting shocks to other variables in the system confirms some previous studies (Mupunga & Ngundu, 2020). Also, TB as a major shock recipient is not surprising as TB measures the difference between merchandise exports and imports in Ghana. Intuitively, the TB is heavily affected by macroeconomic variables such as EXR, M2 and INF (Antwi et al., 2020). Also, Gold as a transmitter indicates that it can affect other variables through interdependence and contagion effects during crises as Gold is a store of value (Boateng et al., 2022).

Figure 16 displays a dynamic total connectedness among the variables under study while bringing economic, political, and health shocks to life over the study period. Figure 16 also shows the patterns of change of each variable in the model over time. Thus, either from a net receiver to a net transmitter or otherwise. Figure 16 shows that the TCI value fluctuates over the study period, averaging 68.36%. The dashed line from left to right in Figure 16 shows events that also brought kink in the TCI curve. The dash lines follow from the Eurozone Debt crisis recession on 30th August 2013, when the Eurozone officially emerged from the recession that plagued the European migrant crisis in the early days of September 2015, BREXIT on 16th June 2016, the disruption of the China Crash in 2016, Ghana banking sector clean-up peaked in 1st August 2018, COVID-19 pandemic as declared as a Public Health Emergency of International Concern (PHEIC) by World Health Organization on 30th January 2020 and COVID-19 peak 11th March 2020.

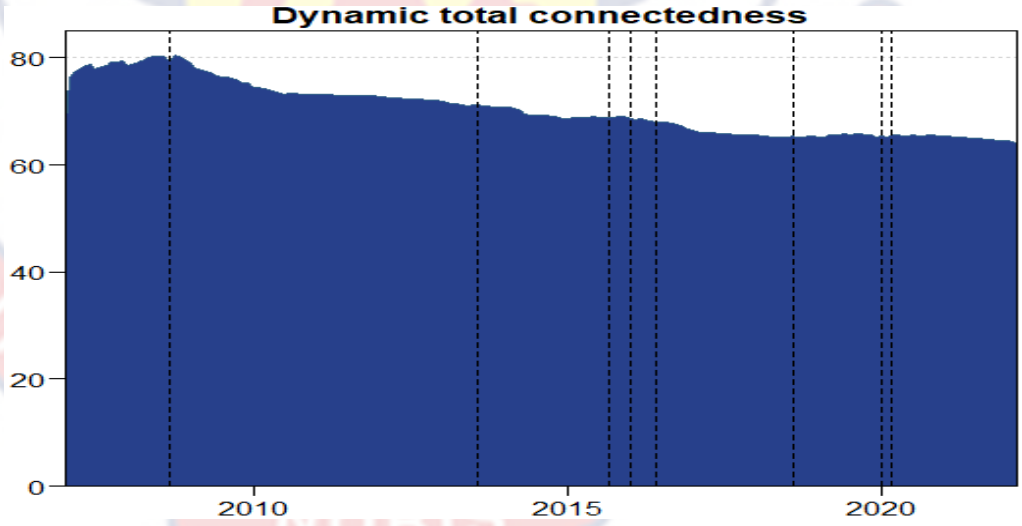


Figure 16: Dynamic total connectedness among commodity prices, BsFSI and macroeconomic variables

Source: Author's Construct (2023)

The results show that the variables respond to GFC, geopolitics or pandemic (Naser, 2019; Yang et al., 2022). Mainly after crises, some of the

relationships among the variables experience contagion effects, causing a rise in the degree of connectedness, as shown in Figure 16; such events push the TCI upward. Hence, the TCI experiences many peaks that overlap with diverse crises in the study period. The TCI started a little below 80% in 2007 but reached its highest of 80% during the peak of the GFC on 1st September 2008, as emphasised by the dashed lines. The impression of the GFC has been well-established in the literature (Asafo-Adjei, Adam, et al., 2021; Owusu Junior, Adam, et al., 2021; Ramlall, 2018). The conclusions are that commodities (crude oil and cocoa) were adversely affected. At that time, there were significant systemic risks present, and commodity price uncertainty grew.

Figure 17 eventually assumes the variables are either net transmitting or net receiving. It is noticed that each of the variables under examination with positive values corresponds to the role of a net transmitter, whereas negative values represent a net receiver. Figure 20 in Appendix F shows that except CAR, NPL, CD, Gold, M2, and EXR, the other variables show little to no change over time and have a transmission rate of shocks exceeding 100% interdependence. On the other hand, Cocoa, ROE, and ROA have the lowest transmission rates of shocks over time see Figure *21* in Appendix G. During falling commodity prices (2014-2016), contagion is observed through shocks transmitted by Cocoa, INF, and GEPU. This is also evident during specific crisis periods marked by dashed lines.

Figure 17 shows that some variables have; (1) a persistent role in the system that is either a net transmit or net receiver through the study period or (2) changing role, which can be either a net transmitter or net receiver depending on the time period. Figure 17 confirms that M2, EXR, CD, NPL, and Gold are

the persistent net transmitters in the model. The findings on EXC and Gold as transmitters are consistent with other studies (Archer et al., 2022; Barson, Owusu Junior, & Adam, 2022; Boateng et al., 2022). On the other hand, the persistent net receivers are CIEAR, ROA, ROE, CLASL, CLATA, cocoa and crude. Most BsFSI as receivers is not surprising because the financial sector is prone to shocks (Asafo-Adjei, Boateng, et al., 2021; Diaconu & Oanea, 2014; Ghosh, 2010).

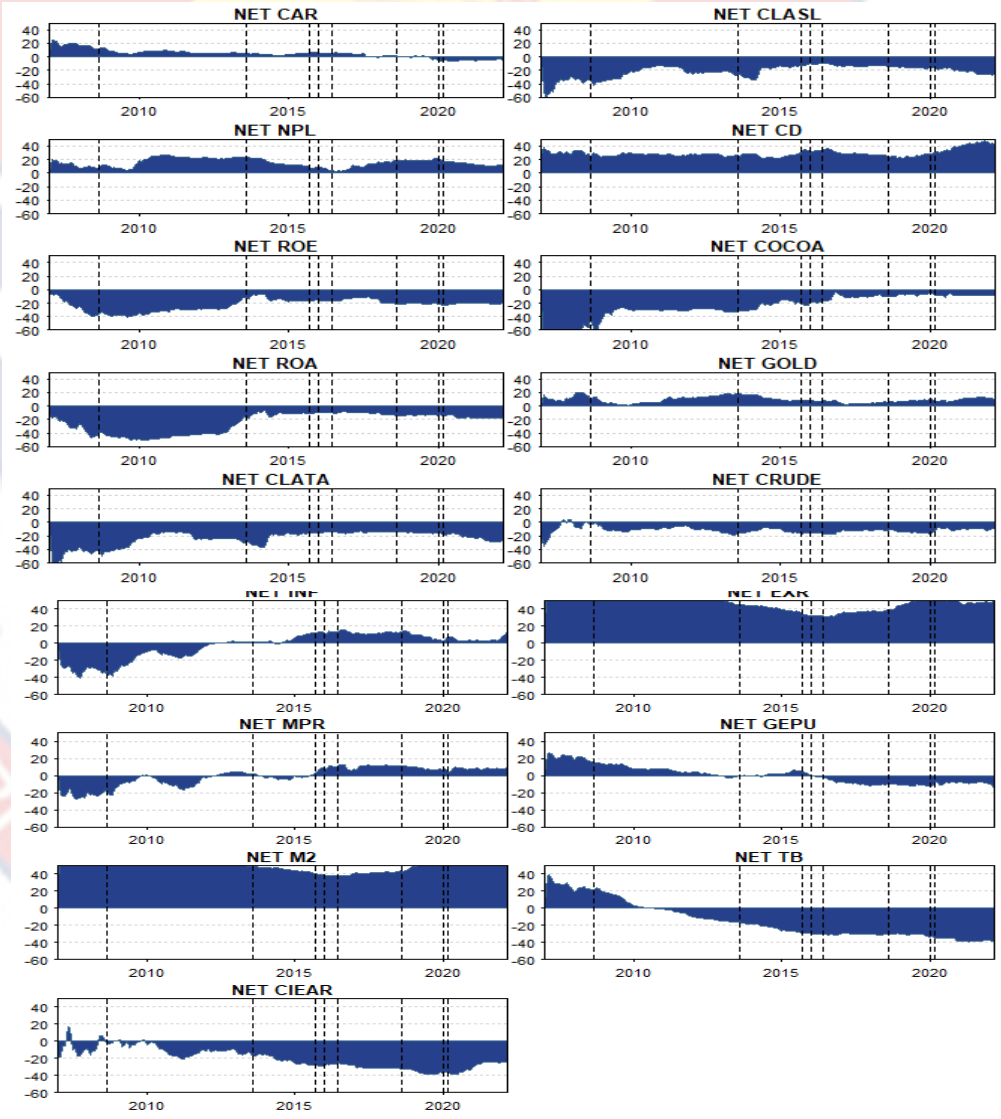


Figure 17: Net connectedness among commodity prices, BsFSI, and macroeconomic variables
Source: Author's Construct (2023)

The remaining variables assume both roles over time, with either net transmitting or net receiving dominating. Hence, policy implications focusing on these should critically observe, considering the shocks they transmit or receive among the system of the variables. Except for some nets directional connectedness that reveals contagion during crises, for instance, INF, MPR and TB. From 2007 to the peak of the GFC in 2008, it can be noticed that cocoa was a net receiver (up to -60%) from the model. The results bring to light the interconnectedness among the variables under study. The model's macroeconomic variables are mostly net transmitters, whereas the FSI and commodity prices are primarily net receivers.

Robustness check from wavelet multiple correlation and wavelet multiple cross-correlations

The TVP VAR connectedness was tested with a different model as a robustness check. Hence the study employed wavelet multiple correlation and cross-correlation to reveal the variables' composite connectedness in a frequency-dependent manner. The results are presented over short-medium and long-term time horizons. WMC and WMCC address the difficulty of estimating interdependency pairs wisely. WMC and WMCC are presented in Figure 18. However, the numerical coefficients are presented in Appendix F in Table 9 and Table 10.

Figure 18 shows that the study's variables are continuously integrated across all time horizons. The interconnected among the variables are independent of lead/lag variables. The level of interdependence can be seen in 0.999942 for the WMC, with lower and upper bounds as 0.999767 and 0.999985, respectively, in Table 9. There is a continuous rise in multiple

correlation values over the horizon. Thus, log values of one variable can be explained by the remaining variables to a degree of about 99.9942% from monthly, leading up to scale 16 months of interdependence (Owusu Junior, Adam, et al., 2021).

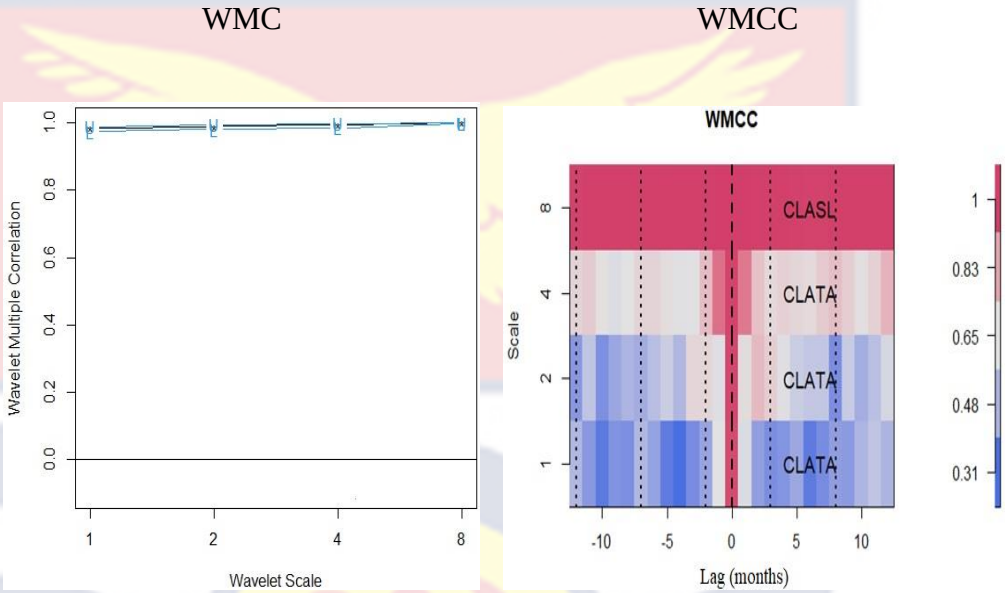


Figure 18: Wavelet multiple correlations and Wavelet multiple cross-correlations between commodity prices, BsFSI, and macroeconomic variables
Note: U-upper limits (at 95% confidence interval)

WMCC coefficients are accessible in Table 10 in Appendix F, portraying four wavelet scales. The variable with the capacity to lead or lag all other variables is indicated by one listed on a scale. It suggests that it has the highest value in the linear combination of all the variables at the various scales at that scale. The WMCC, which determines the most important variable at a given wavelet scale to act as either a leading (first-mover to respond to shocks) or lagging (last-variable to respond to shocks after the other variables) variable, have economic implications because they reveal the degree of patterns of behaviour across multiple variables. Table 10 in Appendix F and Figure 18 show CLATA and CLASL are the dominant frequencies. This indicates that

CLASL has a long-term effect on the variables in the model. This highlights the tenets of the Monetarist View of Financial Instability, which is the "illiquidity of money markets" (Friedman & Schwartz, 1963).

Discussion of TVP VAR connectedness results

The study employed an inferential technique that allowed the study to assess the interconnectedness among commodity prices, BsFSI, and macroeconomic variables in Ghana while taking notice of major economic, political, and health events over the study sample period. The results also confirm high connectedness among commodity prices, BsFSI and macroeconomic variables, as confirmed by other studies (Abaidoo et al., 2021; Kinda et al., 2018; Mupunga & Ngundu, 2020). The idea of net transmitters and receivers in the model provides evidence of who drives the model, as Kinda et al. (2018) found that macroeconomic variables transmit the adverse impact of commodity price slump on BsFSI.

The results indicate that broad money supply and exchange rate transmit shock to the model's other variables. This corroborates the findings of Abaidoo et al. (2021), who posit that disproportionate government involvement through unnecessary expansionary monetary policy, with corresponding policy reversals and rapid taking away of excess money by a central bank can warrant financial instability in the long run. Also, Barson et al. (2022) found that the exchange rate drives commodity prices in Ghana. Similarly, several studies have found a significant impact of exchange rates and money supply on macroeconomic variables (Chuku & Simpasa, 2018; Jena, 2017; Kung'u, 2017; Owusu Junior et al., 2018; Salisu et al., 2018). Hence, the dominancy of broad money supply and exchange rate in the model is unsurprising.

The fluctuating nature of the dynamic connectedness holds that TCI values are influenced by economic, political, and health shocks. As found in the literature that commodity prices received a spillover effect from the GFC (Balcilar et al., 2021; Ben Haddad et al., 2021). Also, the results showed that the commodity price slump in 2014-2015 adversely affected the BsFSI of Ghana, just as in Algeria (Gangelhoff, 2015). As such, shocks in the model increase the variables' connectedness (contagion) but return to normal (interdependence) after the persistence of the shock is reduced, corroborating the findings of (Antonakakis et al., 2020; Jebabli et al., 2014; Kinda et al., 2018). In effect, the study can posit a high degree of connectedness among commodity prices, BsFSI, and macroeconomic variables in Ghana. Also, results from Wavelet multiple showed that CLATA and CLASL have the potential to lead or lag. This is in line with Monetarists' View on financial instability, which is linked to the liquidity of the money market (Vo et al., 2019).

Additionally, the model connectedness provides an overview of the degree of connectedness among the variables and the net transmitters and results in the model providing an opportunity for policy implementation. Policymakers and practitioners can fall on these to develop policies that capture the variables' nature. The study found that M2, CD, EXR, INF, MPR, Gold, NPL, and CAR are net transmitters in the model, while the net receivers are TB, CIEAR, Cocoa, ROE, Crude, CLATA, CLASL, ROA and GEPU. Ghana, as an exporter of cocoa, gold and crude oil, changes in international prices can affect the country's export revenues and overall economic growth (Cantah, 2018). High (low) international prices can increase(decrease) the country's export revenues

and boost (slow) economic growth, contributing to the financial stability of the country.

Sequel to this discussion, the study supports the hypothesis that Ghana has a significant degree of connectedness among commodity prices, BsFSI, and macroeconomic variables. The interconnectedness of the variables in the model follows in calendar times and intrinsic times (Antonakakis et al., 2020). The results provide more eye-opening grounds for the government, BoG and policymakers to formulate and implement efficient and effective monetary policies, inflation targets, bank reserve requirements, and price stabilization policies to enhance the BsFSI. Also, household confidence would be enhanced to reduce the problem of panic withdrawal in the event of a global shock.

Chapter Summary

The chapter presents the results of the analysis techniques and discussions of the study concerning the research hypotheses. The chapter started with preliminary statistics that provided an overview of the variables and justifiable reasons for employing the inference statistics. The study employed QR and non-parametric causality test, Bi-wavelet and PWc, TVP-VAR connectedness and Wavelet multiple for objectives one, two and three, respectively. The results showed significant effects of commodity prices on Ghana's BsFSI. Secondly, the study found that macroeconomic variables influence the relationship between commodity prices and BsFSI, and lastly, there is a high degree of connectedness among the study variables.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Introduction

The final chapter captures the summary, conclusions and recommendations. The summary entails the research process and the summary of key findings based on the research hypothesis. The conclusions drawn from the findings are linked to theoretical, practical and policy decisions. The chapter subsequently presented recommendations based on the findings and conclusions. Lastly, suggestions for further studies are provided.

The study examined the interconnectedness among commodity prices, BsFSI and macroeconomic variables in Ghana. Therefore, the specific research objectives are to:

1. examine the effects of commodity prices on the BsFSI in Ghana;
2. determine the influence of macroeconomic variables on the relationship between commodity prices and BsFSI in Ghana;
3. assess the degree of connectedness among commodity prices, BsFSI and macroeconomic variables in Ghana.

The study employed a positivist philosophy, quantitative approach and explanatory design based on the nature of the research objectives. The study used major export commodities (cocoa, gold and crude oil) in the Ghanaian economy. This study employed monthly data of three (3) commodity prices, seven (7) BsFSI and six (6) macroeconomic variables in Ghana. The study also used GEPU as a control variable. The monthly data spanned January 2007 to March 2022 to include some major economic, political and health events, with an observation of 183. The study employed six inference statistics, four main

techniques (QR, Bi-Wavelet, PWc, and TVP-VAR connectedness) and two robustness techniques (non-parametric causality test and Wavelet multiple). With these, the study can provide time and frequency-based results for detailed discussion while dealing with non-linearity, non-stationarity and asymmetric characteristics projected by HMH and AMH. A dummy variable (1 as commercial crude export period and 0 as not exporting period from Ghana) was introduced in the QR estimation.

Summary of Findings

The summary of the findings is presented per hypothesis as follows:

In hypothesis one, the study found significant effects of commodity prices on the BsFSI of Ghana. The gold price significantly and positively impacts CAR and NPL across all quantiles. Whereas cocoa and crude prices significantly positively and negatively impact some specific quantiles. Also, the study found that cocoa price significantly positively impacts CD and CLATA for all quantiles, but the same cannot be said for gold and crude prices. The gold price negatively impacts CD across all quantiles but affects CLATA only in a slump and normal market conditions. The crude oil price positively impacts CD in normal and boom market conditions. Still, it is significant at only some normal market quantiles and significantly affects CLATA negatively in slump market conditions. Cocoa price positively impacts ROA and ROE across all quantiles, whereas gold price negatively affects ROA and ROE. Also, crude oil prices significantly positively and negatively impact ROA and ROE in specific quantile conditions. The result shows that cocoa prices significantly positively impact CLASL, but crude and gold prices were significant and negative in some market conditions.

The causality results show that crude oil prices significantly cause all BsFSI, mostly in normal market conditions. Also, the results show that gold prices cause ROE, ROA, CLASL, and CLATA significantly, but mainly in a slump and normal market conditions. Similarly, NPL, ROE, ROA, CLATA, and CLASL are significantly caused by cocoa prices at normal market conditions. The study noticed insignificant causality between cocoa and CAR, gold and CAR, gold and NPL, cocoa and CD, and gold and CD. The results support the AMH.

The second hypothesis found that macroeconomic variables significantly influence the relationship between commodity prices and BsFSI in Ghana. However, the influence of the specific variables employed in the study depends on the type of commodity, BsFSI, and time and frequency domain. Specifically, it was noticed that the exchange rate has the most significant impact on the relationships, followed by M2, inflation, and monetary policy rate. In contrast, CIEAR had the most negligible significant impact on the co-movement between the variables. Also, the findings showed that economic events have a significant role in the relationship. The results confirmed the significance of HMH and AMH employed in the study.

The final hypothesis holds a significant degree of connectedness among commodity prices, BsFSI, and macroeconomic variables in Ghana. The study grouped the variables in net transmitters and receivers from the findings. The results showed that in descending order, the net transmitters are M2, CD, EXR, INF, MPR, Gold, NPL, and CAR, while net receivers are TB, CIEAR, Cocoa, ROE, Crude, CLATA, CLASL, ROA and GEPU. The findings also revealed the lead/lag potential of BsFSI in the interconnectedness.

Conclusions

The study's general conclusion is that there was a high level of interconnectedness between commodity prices, BsFSI and macroeconomic variables in Ghana. However, the degree of influence depended on the time and frequency domain of the variables. The specific conclusions were based on each research hypothesis:

On the first hypothesis, the study concluded that commodity (cocoa, gold and crude oil) prices significantly affect Ghana's BsFSI. The specific impact noticed depends on the financial soundness indicator as well as the condition of the market. The findings attained in the study for gold and crude may be counterintuitive, but cocoa was expected because Ghana is export-dependent on these commodities. Thus, an increase(decrease) in cocoa price would increase(decrease) foreign exchange earnings for Ghana with an increase(decrease) in CD, ROE, ROA, CD CLATA and CLASL, while decreasing (increasing) NPL, particularly for those at lower quantiles. As banks become more financially sound, their reliance on the cocoa sector decreases, and the impact of cocoa prices on their BsFSI diminishes.

Also, higher gold prices can lead to revenue, overborrowing and overinvestment in the gold mining sector, which could increase NPL if increased prices are not sustainable. Banks with higher CAR or NPL are more sensitive to changes in gold prices. Furthermore, rising gold prices can decrease credit available for lending and bank profitability while decreasing the value of bank assets and increasing their risk of insolvency. Also, the increase in crude oil prices negatively affects the BsFSI of Ghana. This is not surprising because the increase in crude oil prices affects the cost of living in Ghana's economy

positively. As such high crude oil prices mean high transport fees, food prices and so on; hence there would be a reduction in the marginal propensity to save, reducing the BsFSI of Ghana.

Hypothesis two concluded that macroeconomic variables significantly influence the relationship between commodity prices and BsFSI in Ghana. The exchange rate significantly impacted the relationships, followed by M2, inflation, and monetary policy rate. In contrast, CIEAR had the most negligible significant impact on the co-movement between the variables. This is because fluctuations in exchange rate cause export revenue to increase or decrease, thereby causing significant changes in commodity prices and the banking sector's financial soundness. Also, M2 increases(decreases) the money in circulation, which affects investment decisions. Inflation is also directly related to commodity prices, causing changes in the relationship with financial soundness. Also, the findings showed that economic events have a significant role in the relationship.

On the third hypothesis, the study concluded that Ghana's degree of connectedness among commodity prices, BsFSI and macroeconomic variables was high; however, there is interdependence and contagion effect in benign market conditions and after global economic, political and health shocks. The TCI values were high in the era of the GFC. Also, there was a kink in the curve of TCI in the period of commodity price slump in 2014-2016. Accordingly, connectedness intensifies with increases in uncertainties during specific economic events but plummets into low levels of uncertainties right after these major events. M2, CD, EXR, INF, MPR, Gold, NPL, and CAR. are net transmitters identified in the model, while TB, CIEAR, Cocoa, ROE, Crude,

CLATA, CLASL, ROA and GEPU are net receivers. The study concludes that changes in any of these variables are likely to impact the others in the network significantly.

Recommendations

The study recommends that government policy ingenuities consider the specific characteristics of commodity prices, BsFSI, and macroeconomic variables, as well as the time and frequency of market conditions. The specific recommendations of the study presented are drawn from the hypothesis.

The study recommends that the intricate relationships unveiled between commodity prices and various BsFSI underscore the need for dynamic risk management strategies within the banking sector. Particularly in the context of cocoa, as a critical export for Ghana, policy measures should be tailored to bolster the sector's resilience, given its influence on foreign exchange earnings. The counterintuitive impact of gold prices suggests the importance of cautious lending practices in sectors experiencing revenue surges due to commodity price hikes.

A prudent approach in managing NPL is imperative to prevent overborrowing and potential insolvency risks, especially among banks with higher CAR. Additionally, as the study illuminates the adverse effect of crude oil price increases on the banking sector, policy interventions focusing on mitigating inflationary pressures arising from elevated oil costs could contribute to maintaining financial stability. These insights advocate for a proactive stance in managing the intricacies of commodity price impacts on the banking sector, tailoring strategies to the specific conditions of the market and BsFSI, ultimately

fostering a resilient financial landscape for sustainable economic growth in Ghana.

Based on the second hypothesis' findings, the study recommends that given the critical role of export revenue sensitivity to fluctuations in the exchange rate, it becomes imperative for policymakers and financial institutions to closely monitor and manage exchange rate movements, as they cascade into notable changes in both commodity prices and the robustness of the banking sector. Similarly, the discernible influence of M2 underscores the importance of managing money supply dynamics, as its fluctuations significantly influence investment decisions and, subsequently, the financial health of the banking sector. Furthermore, recognizing the direct correlation between inflation and commodity prices, strategies to manage and stabilize inflation take on added significance in maintaining a stable and resilient banking sector.

Importantly, while CIEAR demonstrated a comparatively modest impact, this insight remains valuable for informing holistic policy measures that consider a spectrum of macroeconomic variables. Ultimately, these findings reinforce the interconnected nature of economic events and their profound role in shaping the relationships between commodity prices, financial soundness, and the broader economic landscape. As such, stakeholders are urged to leverage these insights to craft proactive strategies that enhance the resilience of both the banking sector and the overall macroeconomic environment, fostering sustainable economic growth and stability in Ghana.

The study recommends from the third hypothesis that these insights carry significant implications for policymaking and risk management. In the context of the SDGs, particularly SDG 8 and SDG 17, these findings underscore

the necessity of fostering resilient economic systems that can absorb shocks and disruptions. By enhancing the understanding of how these variables interconnect and respond to various stimuli, policymakers and stakeholders can make more informed decisions to ensure stable economic growth, job creation, and global collaboration. Strengthening the robustness of financial institutions and building partnerships across sectors become vital components of safeguarding against potential vulnerabilities and promoting sustainable economic development in Ghana and beyond.

Suggestions for Further Studies

Further studies can examine the adaptive relationship between commodity prices and BsFSI by employing quantile-on-quantile regression. Similarly, the impact of macroeconomic variables on the relationship between commodity prices and BsFSI can be assessed with different estimation techniques, such as Quantile time-varying parameter VAR (QTVAR), to provide additional insight into the conditional distribution of variables. Studies using other economies would also provide grounds to enhance the generalizability and relevance of the findings and contribute to advancing research on the topic.

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APPENDICES

Appendix A

Table 7: Linear regression results and post-estimation tests

variable	. stat	CAR	CD	ROE	ROA	CLASL	CLATA	NPL
COCOA	Estimate	0.065**	0.860***	0.504***	0.372***	0.453***	0.419***	-0.019
	Std Err	[0.029]	[0.051]	[0.074]	[0.067]	[0.033]	[0.033]	[0.077]
GOLD	Estimate	0.379***	-0.403***	-0.233***	-0.291***	-0.011	-0.027	0.503***
	Std Err	[0.034]	[0.060]	[0.086]	[0.078]	[0.039]	[0.039]	[0.090]
CRUDE	Estimate	-0.075***	0.094***	0.177***	0.083*	-0.007	0.012	-0.217***
	Std Err	[0.020]	[0.035]	[0.050]	[0.045]	[0.023]	[0.023]	[0.052]
DMV	Estimate	-0.031	-0.087**	0.069	0.341***	-0.008	0.03	0.178***
	Std Err	[0.021]	[0.038]	[0.054]	[0.049]	[0.024]	[0.025]	[0.056]
	R2	0.999	0.999	0.995	0.981	0.999	0.999	0.992
	AIC	-356.678	-148.146	-16.073	-53.338	-306.432	-305.625	-1.243
	Post-estimation test for the linear regression.							
	BP	5.1371	24.563***	1.5724	3.5905	24.427***	34.638***	40.519***
	White	17.844**	64.269***	13.302*	9.8162	39.239***	42.585***	68.653***
	Reset	5.3439***	64.7***	6.5707***	5.6082***	58.094***	32.507***	48.587***
	Ncv	5.719919**	11.82962***	0.1868158	3.799968*	23.65271***	14.13126***	6.284485**
	BG- LM	129.74***	156.86***	60.498***	67.224***	128.3***	127.57***	171.05***
	Shapiro	0.99111	0.98223**	0.94229***	0.94889***	0.98785	0.98144**	0.94496***

Source: Author's Computation (2023)

*Note: [***, **, *] show significance levels at 1, 5 and 10 per cent, respectively. BP-Breusch–Pagan test, White-White's General Test, Reset-Ramsey RESET Test, Ncv-Non-constant variance test, BG-LM-Breusch–Godfrey LM test, Shapiro Test.*

Appendix B

Table 8: Asymmetric relationship between commodity prices and BsFSI

	CAR								NPL							
	CF	SE	CF	SE	CF	SE	CF	SE	CF	SE	CF	SE	CF	SE	CF	SE
τ	COCOA		GOLD		CRUDE		DMV		COCOA		GOLD		CRUDE		DMV	
0.05	0.21***	0.05	0.16**	0.07	-0.02	0.03	0.09**	0.03	-0.14***	0.05	0.50***	0.05	-0.09**	0.03	0.34***	0.05
0.1	0.15**	0.06	0.26***	0.08	-0.07**	0.03	0.03	0.04	-0.12**	0.06	0.49***	0.06	-0.09***	0.03	0.32***	0.05
0.15	0.09*	0.05	0.32***	0.07	-0.06**	0.03	0.02	0.03	-0.001	0.05	0.36***	0.05	-0.09***	0.03	0.38***	0.05
0.2	0.08***	0.03	0.36***	0.04	-0.09***	0.02	0.02	0.03	-0.02	0.06	0.38***	0.06	-0.08**	0.03	0.36***	0.06
0.25	0.09***	0.03	0.35**	0.04	-0.09***	0.02	0.02	0.03	-0.02	0.06	0.38***	0.07	-0.09**	0.04	0.35***	0.06
0.3	0.06**	0.03	0.36***	0.04	-0.06***	0.02	0.01	0.03	0.02	0.06	0.37***	0.07	-0.13***	0.04	0.35***	0.06
0.35	0.03	0.03	0.40***	0.03	-0.06***	0.02	0.01	0.03	0.04	0.06	0.35***	0.07	-0.13***	0.04	0.37***	0.07
0.4	0.06**	0.03	0.37***	0.03	-0.07***	0.02	0.01	0.03	0.05	0.07	0.37***	0.08	-0.18***	0.05	0.36***	0.07
0.45	0.05*	0.03	0.39***	0.03	-0.07***	0.02	-0.03	0.03	0.03	0.07	0.41***	0.09	-0.20***	0.06	0.29***	0.08
0.5	0.07**	0.03	0.37***	0.03	-0.07***	0.02	-0.02	0.03	0.03	0.08	0.45***	0.12	-0.25***	0.08	0.23**	0.10
0.55	0.06**	0.03	0.38***	0.03	-0.07***	0.02	-0.04	0.03	0.08	0.10	0.47***	0.14	-0.36***	0.09	0.21	0.13
0.6	0.04	0.03	0.41***	0.03	-0.07***	0.03	-0.06**	0.03	0.09	0.11	0.50***	0.15	-0.41***	0.10	0.16	0.13
0.65	0.03	0.03	0.40***	0.03	-0.05**	0.03	-0.04*	0.03	0.04	0.13	0.62***	0.18	-0.48***	0.10	0.05	0.16
0.7	0.04	0.03	0.42**	0.03	-0.05*	0.02	-0.07***	0.03	-0.03	0.13	0.73***	0.17	-0.51***	0.09	-0.01	0.12
0.75	0.04	0.03	0.40***	0.03	-0.04*	0.02	-0.07***	0.02	-0.21	0.21	0.93***	0.22	-0.48***	0.10	-0.14**	0.07
0.8	0.03	0.04	0.41***	0.04	-0.04	0.03	-0.08***	0.03	-0.21	0.29	0.82***	0.32	-0.30*	0.18	-0.06	0.09
0.85	0.01	0.04	0.43***	0.04	-0.03	0.03	-0.08***	0.02	-0.29	0.24	0.89***	0.28	-0.25	0.16	-0.07	0.08
0.9	-0.003	0.04	0.43***	0.04	-0.007	0.03	-0.09***	0.03	-0.31	0.21	0.89***	0.25	-0.21	0.15	-0.09	0.08
0.95	0.27	0.35	0.21	0.34	-0.14	0.36	0.04	0.14	0.33	0.80	0.19	0.60	-0.23	0.74	0.18	0.18

Table 8 continued

	CD								CLASL							
τ	COCOA		GOLD		CRUDE		DMV		COCOA		GOLD		CRUDE		DMV	
0.05	0.93***	0.07	-0.41***	0.06	-0.06	0.06	-0.14***	0.04	0.63***	0.03	-0.17***	0.04	-0.11***	0.03	-0.01	0.03
0.1	0.98***	0.06	-0.47***	0.07	-0.06	0.06	-0.10**	0.04	0.60***	0.04	-0.14***	0.04	-0.08***	0.03	-0.01	0.03
0.15	1.07***	0.05	-0.59***	0.07	-0.04	0.07	-0.03	0.05	0.59***	0.04	-0.14***	0.05	-0.05	0.03	0.004	0.03
0.2	1.07***	0.05	-0.57***	0.06	-0.05	0.06	-0.05	0.05	0.55***	0.04	-0.12**	0.05	-0.04	0.03	0.01	0.03
0.25	1.07***	0.06	-0.60***	0.06	-0.003	0.06	-0.04	0.05	0.52***	0.04	-0.09*	0.05	-0.02	0.02	0.02	0.02
0.3	1.08***	0.06	-0.63***	0.06	0.02	0.06	-0.02	0.04	0.48***	0.04	-0.05	0.05	-0.01	0.02	0.004	0.02
0.35	1.06***	0.07	-0.63***	0.07	0.08	0.06	-0.001	0.04	0.47***	0.04	-0.04	0.05	-0.003	0.02	0.01	0.02
0.4	1.04***	0.08	-0.61***	0.07	0.08	0.05	0.01	0.04	0.45***	0.04	-0.02	0.04	-0.005	0.02	0.001	0.02
0.45	0.97***	0.09	-0.53***	0.09	0.08	0.06	-0.001	0.04	0.43***	0.04	0.004	0.04	-0.002	0.02	0.003	0.02
0.5	0.93***	0.10	-0.49***	0.10	0.10*	0.05	-0.06	0.05	0.41***	0.04	0.03	0.04	0.002	0.02	0.004	0.02
0.55	0.86***	0.08	-0.41***	0.09	0.10**	0.04	-0.09	0.06	0.41***	0.04	0.03	0.04	0.01	0.02	0.004	0.02
0.6	0.76***	0.07	-0.28***	0.09	0.11***	0.04	-0.13**	0.05	0.40***	0.04	0.04	0.05	0.01	0.02	0.001	0.02
0.65	0.72***	0.09	-0.22*	0.13	0.08	0.05	-0.17***	0.05	0.41***	0.04	0.02	0.05	0.03	0.03	0.001	0.02
0.7	0.67***	0.09	-0.14	0.14	0.06	0.06	-0.20***	0.05	0.40***	0.04	0.03	0.06	0.02	0.03	-0.006	0.03
0.75	0.65***	0.09	-0.12	0.13	0.07	0.06	-0.22***	0.05	0.36***	0.05	0.08	0.08	0.03	0.04	-0.03	0.04
0.8	0.58***	0.08	-0.03	0.12	0.05	0.05	-0.24***	0.05	0.29***	0.06	0.20**	0.09	-0.04	0.06	-0.08	0.05
0.85	0.56***	0.07	-0.001	0.10	0.04	0.04	-0.24***	0.04	0.27***	0.05	0.23***	0.08	-0.03	0.06	-0.09*	0.05
0.9	0.49***	0.07	0.10	0.09	0.01	0.04	-0.28***	0.04	0.22***	0.04	0.30***	0.07	-0.06	0.05	-0.13***	0.04
0.95	0.44***	0.06	0.17**	0.08	0.01	0.03	-0.31***	0.04	0.30***	0.07	0.21*	0.12	-0.05	0.09	-0.10	0.08

Table 8 continued

	CLATA								ROA							
τ	COCOA		GOLD		CRUDE		DMV		COCOA		GOLD		CRUDE		DMV	
0.05	0.61***	0.04	-0.20***	0.04	-0.09***	0.03	0.02	0.03	0.04	0.56	0.14	0.50	-0.06	0.25	0.07	0.21
0.1	0.59***	0.04	-0.19***	0.04	-0.06**	0.03	0.02	0.03	0.25	0.31	-0.04	0.31	-0.14	0.09	0.17	0.14
0.15	0.57***	0.04	-0.18***	0.04	-0.04	0.03	0.04	0.03	0.16	0.36	0.04	0.35	-0.11	0.11	0.12	0.17
0.2	0.54***	0.04	-0.15***	0.04	-0.01	0.03	0.06**	0.02	0.13	0.27	0.10	0.27	-0.12	0.09	0.13	0.14
0.25	0.53***	0.04	-0.14***	0.05	-0.01	0.02	0.05**	0.02	0.27***	0.10	-0.05	0.12	-0.15**	0.06	0.21***	0.07
0.3	0.49***	0.04	-0.10**	0.05	-0.004	0.02	0.04**	0.02	0.24***	0.09	-0.07	0.12	-0.06	0.07	0.26***	0.09
0.35	0.44***	0.04	-0.05	0.05	0.002	0.02	0.03**	0.02	0.22**	0.09	-0.08	0.12	0.018	0.06	0.28***	0.09
0.4	0.43***	0.04	-0.04	0.05	0.007	0.02	0.04*	0.02	0.24***	0.09	-0.12	0.12	0.04	0.06	0.26***	0.08
0.45	0.42***	0.04	-0.02	0.05	0.009	0.02	0.03	0.02	0.26***	0.08	-0.15	0.12	0.06	0.06	0.29***	0.07
0.5	0.40***	0.03	-0.01	0.04	0.02	0.02	0.03*	0.02	0.32***	0.07	-0.24**	0.10	0.11*	0.06	0.33***	0.07
0.55	0.39***	0.03	-0.001	0.04	0.03	0.02	0.03	0.02	0.37***	0.06	-0.32***	0.07	0.13***	0.04	0.40***	0.05
0.6	0.39***	0.03	-0.02	0.04	0.05	0.02	0.04**	0.02	0.38***	0.05	-0.34***	0.06	0.14***	0.04	0.39***	0.04
0.65	0.38***	0.03	0.01	0.05	0.04	0.02	0.01	0.02	0.39***	0.05	-0.35***	0.06	0.16***	0.03	0.40***	0.04
0.7	0.36***	0.04	0.03	0.06	0.04	0.03	0.01	0.03	0.40***	0.05	-0.37***	0.05	0.18***	0.03	0.42***	0.03
0.75	0.30***	0.07	0.11	0.11	0.04	0.06	-0.001	0.04	0.41***	0.05	-0.39***	0.05	0.18***	0.03	0.43***	0.03
0.8	0.25***	0.05	0.20**	0.09	-0.01	0.06	-0.02397	0.04	0.41***	0.05	-0.39***	0.05	0.20***	0.03	0.44***	0.03
0.85	0.21***	0.04	0.26***	0.07	-0.03	0.04	-0.05	0.04	0.42***	0.05	-0.39***	0.04	0.20**	0.03	0.43***	0.03
0.9	0.17***	0.04	0.30***	0.07	-0.03	0.05	-0.07**	0.04	0.43***	0.06	-0.41***	0.05	0.20***	0.03	0.40***	0.05
0.95	0.15***	0.04	0.37***	0.06	-0.10**	0.04	-0.13***	0.04	0.43***	0.06	-0.36***	0.06	0.15***	0.04	0.29***	0.09

Table 8 continued

	ROE							
τ	COCOA		GOLD		CRUDE		DMV	
0.05	0.31	0.51	-0.01	0.45	0.10	0.29	-0.03	0.19
0.1	0.41***	0.14	0.02	0.15	-0.11*	0.06	-0.04	0.06
0.15	0.45***	0.12	-0.02	0.12	-0.12**	0.06	-0.01	0.06
0.2	0.32***	0.10	0.13	0.11	-0.12*	0.06	-0.04	0.06
0.25	0.35***	0.10	0.06	0.11	-0.04	0.07	0.01	0.07
0.3	0.37***	0.10	-0.02	0.14	0.04	0.09	0.05	0.09
0.35	0.41***	0.09	-0.11	0.14	0.12	0.10	0.10	0.10
0.4	0.47***	0.09	-0.23*	0.13	0.20**	0.10	0.16**	0.09
0.45	0.51***	0.07	-0.31***	0.10	0.26***	0.07	0.21***	0.06
0.5	0.56***	0.06	-0.35***	0.08	0.27***	0.06	0.16**	0.07
0.55	0.56***	0.06	-0.34***	0.08	0.26***	0.05	0.14**	0.07
0.6	0.52***	0.06	-0.28***	0.07	0.25***	0.04	0.11	0.07
0.65	0.52***	0.06	-0.28***	0.07	0.25***	0.04	0.13**	0.07
0.7	0.51***	0.06	-0.26***	0.07	0.25***	0.04	0.08	0.06
0.75	0.50***	0.06	-0.24***	0.07	0.25***	0.04	0.04	0.06
0.8	0.48***	0.06	-0.21***	0.06	0.24***	0.04	0.004	0.06
0.85	0.49***	0.06	-0.29***	0.06	0.23***	0.03	-0.03	0.06
0.9	0.53***	0.05	-0.26***	0.06	0.24***	0.03	-0.03	0.06
0.95	0.47***	0.05	-0.17***	0.06	0.23***	0.03	-0.08	0.06

Source: Author's Computation (2023)

Note: Plots are shown with a Confidence interval of 95%

Appendix C

Table 9: Wavelet multiple correlations

Scale	WMC "lower"	Correlation	WMC "upper"
1	0.974527809	0.983154542	0.988876
2	0.980231916	0.989154973	0.994062
3	0.984720196	0.993755003	0.997454
4	0.999766627	**0.999941629**	0.999985

Source: Author's Computation (2023)

Table 10: Wavelet multiple cross-correlations

Scale	Localizations	Time Lag (months)	Leading/Lagging variable
1	0.9832	0	CLATA
2	0.9892	0	CLATA
3	0.9938	0	CLATA
4	0.9999	0	CLASL

Source: Author's Computation (2023)

Appendix D

Table 11: Stationarity of quantile residuals

Joint Test of Equality of Slopes							
	CAR	NPL	ROE	ROA	CLATA	CLASL	CD
τ	9.4658***	16.643***	2.6017***	3.1489***	3.2115***	3.663***	19.532***
Phillips-Perron Unit Root Test							
0.05	-2.06**	-1.39	-3.05***	-2.37**	-1.73*	-1.86*	-1.71*
0.1	-2.43**	-1.43	-4.00***	-3.44***	-2.12**	-2.20**	-1.81*
0.15	-2.87***	-1.54	-4.39***	-3.75***	-2.54**	-2.60***	-2.12**
0.2	-3.34***	-1.56	-4.82***	-4.33***	-2.93***	-2.89***	-2.15**
0.25	-3.43***	-1.59	-5.61***	-5.18***	-3.08***	-3.35***	-2.42**
0.3	-3.70***	-1.68*	-6.60***	-6.34***	-3.41***	-3.51***	-2.62***
0.35	-3.89***	-1.74*	-7.30***	-6.89***	-3.61***	-3.58***	-2.88***
0.4	-4.05***	-1.83*	-7.66***	-7.19***	-3.67***	-3.64***	-3.01***
0.45	-4.11***	-1.94*	-7.69***	-7.28***	-3.65***	-3.63***	-2.98***
0.5	-4.09***	-2.12**	-7.56***	-7.24***	-3.59***	-3.56***	-2.87***
0.55	-4.00***	-2.30**	-7.34***	-6.97***	-3.48***	-3.53***	-2.57**
0.6	-3.76***	-2.39**	-7.01***	-6.73***	-3.43***	-3.43***	-1.86*
0.65	-3.57***	-2.39**	-6.63***	-6.32***	-3.22***	-3.22***	-1.42
0.7	-3.29***	-2.37**	-6.24***	-5.95***	-2.91***	-2.98***	-1.06
0.75	-3.21***	-2.16**	-5.74***	-5.60***	-2.19**	-2.55**	-0.97
0.8	-2.88***	-1.66*	-5.34***	-5.44***	-1.74*	-1.75*	-0.60
0.85	-2.70***	-1.44	-4.91***	-5.16***	-1.43	-1.49	-0.32
0.9	-2.17**	-1.33	-4.32***	-4.46***	-1.09	-1.15	-0.01
0.95	-1.52	-1.27	-3.31***	-3.42***	-0.97	-1.06	0.13
Keenan's one-degree test for non-linearity							
0.05	7.19***	0.28	0.006	0.71	0.67	0.77	0.0004
0.1	3.99**	0.11	5.01**	4.31**	0.005	0.02	0.14
0.15	1.55	0.29	7.00***	7.02***	0.45	0.47	1.12
0.2	0.08	0.01	0.08***	9.61***	1.22	1.26	1.96
0.25	0.01	0.01	7.41***	10.93***	1.68	1.60	3.13*
0.3	0.003	0.14	4.49**	7.36**	1.17	1.03	3.57*
0.35	0.007	0.17	1.80	5.47***	0.24	0.79	2.89*
0.4	0.02	0.47	0.29	3.80***	0.04	0.25	2.00
0.45	0.39	1.18	0.06	1.87	0.001	0.01	0.52
0.5	0.88	1.73	0.57	0.30	0.18	0.10	0.08
0.55	1.73	1.26	0.53	0.10	0.34	0.19	0.20
0.6	2.66	0.97	0.23	0.05	0.48	0.37	1.30
0.65	3.62*	0.46	0.04	0.04	0.52	0.66	1.40
0.7	4.16**	0.26	0.07	0.05	0.72	0.74	1.40
0.75	4.09**	0.05	0.68	0.01	0.72	0.48	0.65
0.8	3.64*	0.64	1.81	0.00	0.32	0.10	0.29
0.85	2.95*	0.78	3.13*	0.09	0.12	0.02	0.11
0.9	1.23	1.04	4.27**	1.63	0.0001	0.02	0.03
0.95	2.00	3.17*	7.77**	6.85*	0.07	0.82	0.37

Source: Author's Computation (2023)

Note: [***, **, *] show significance levels at 1, 5 and 10 per cent, respectively.

Appendix E

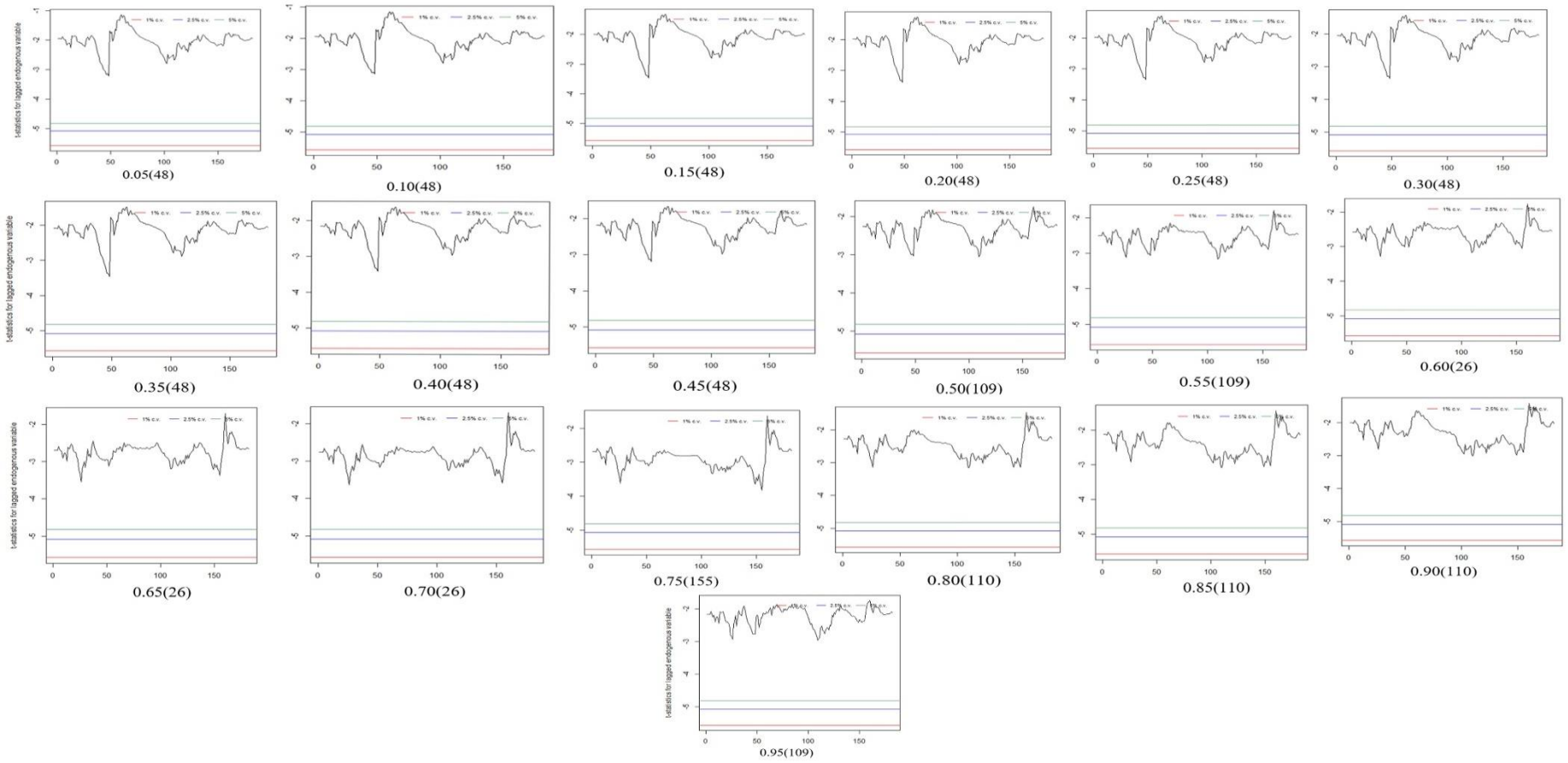

Figure 19: Zivot-Andrews Unit Root Test
Source: Author's Construct (2023)
Note: respective Quantile has a potential breakpoint position in the bracket

Appendix F

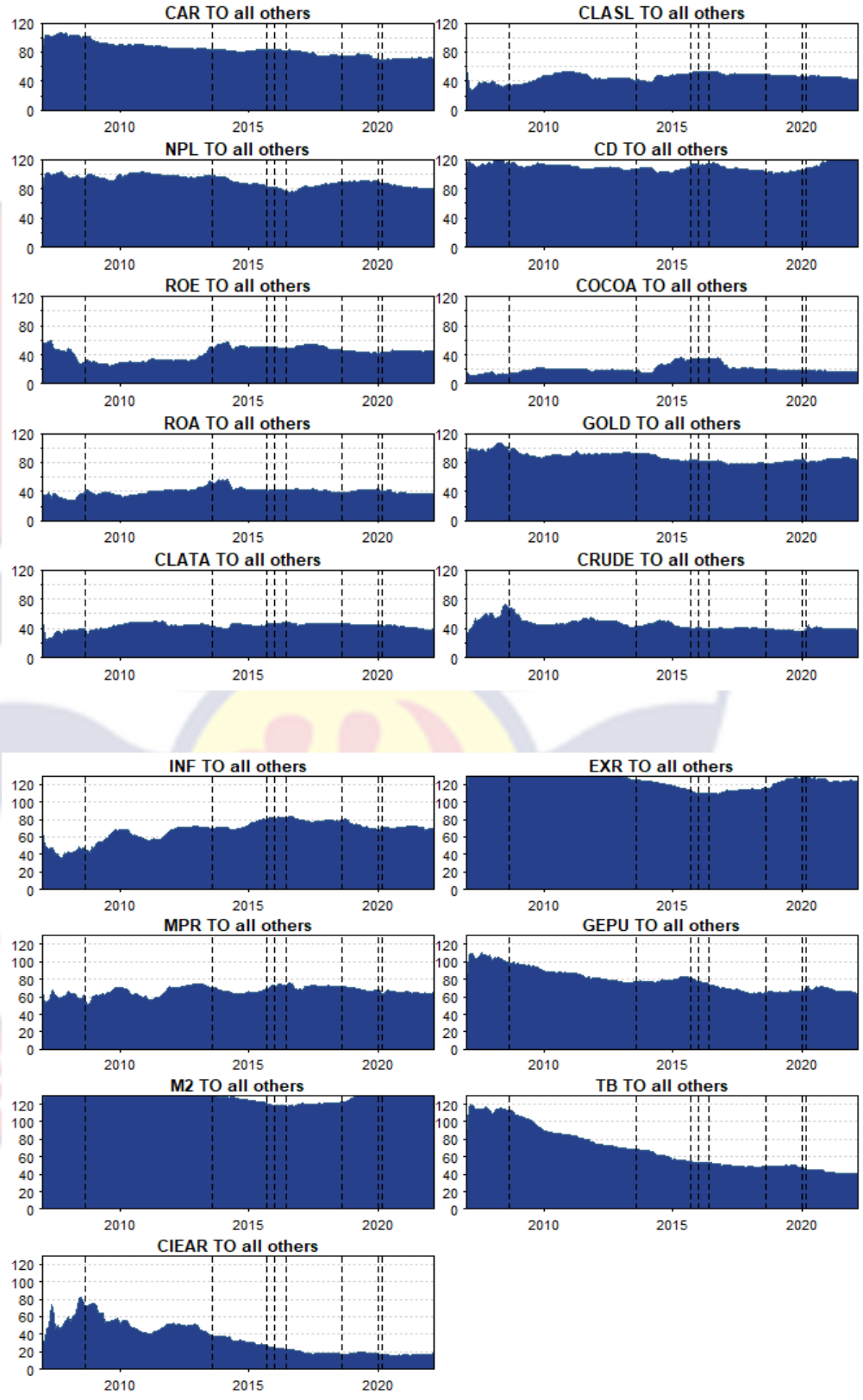

Figure 20: Directional connectedness TO others among commodity prices, BsFSI and macroeconomic variables
Source: Author's Construct (2023)

Appendix G

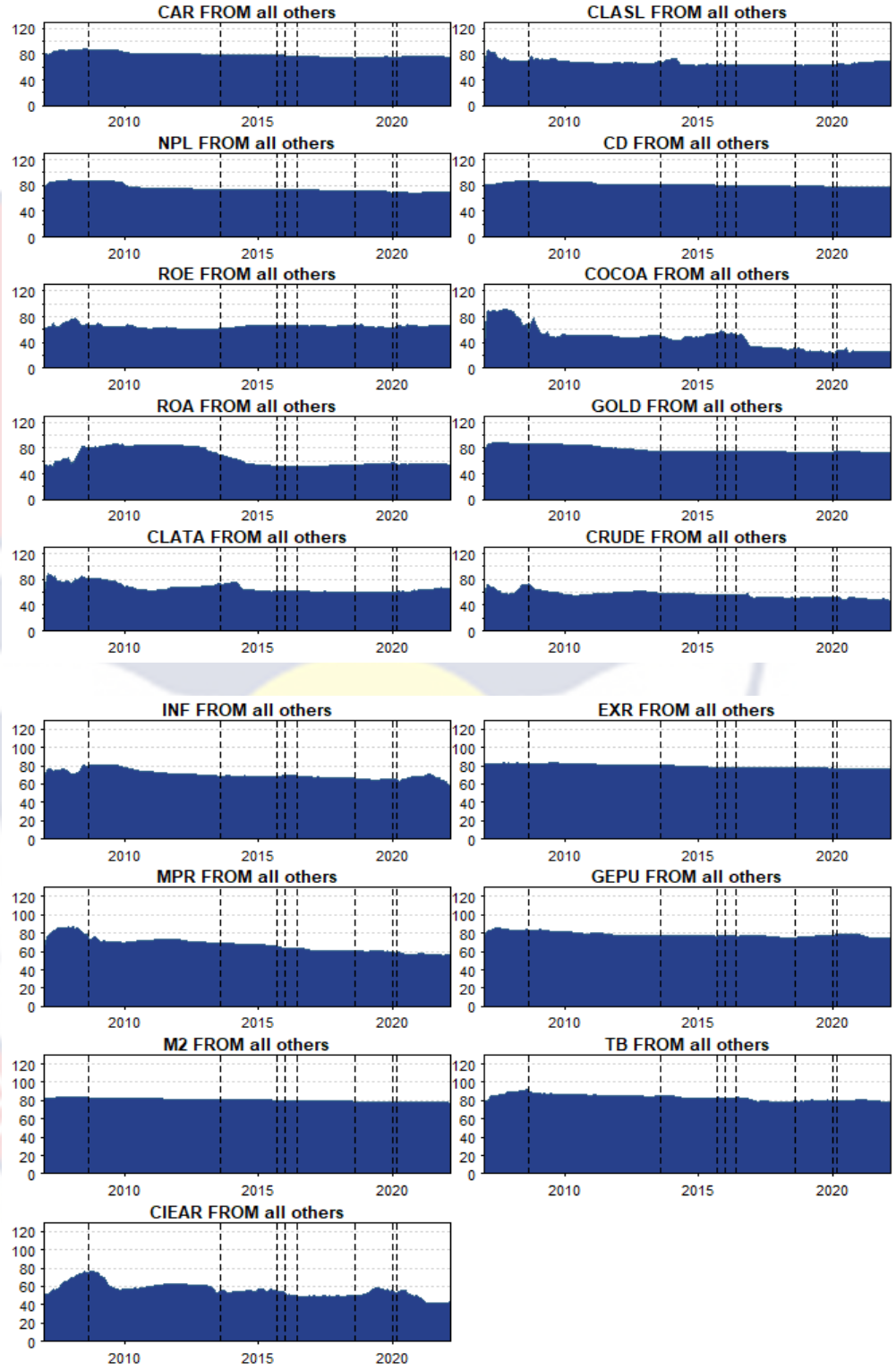

Figure 21: Directional connectedness FROM others among commodity prices, BsFSI and macroeconomic variables
Source: Author's Construct (2023)