UNIVERSITY OF CAPE COAST

EMPIRICAL ANALYSIS OF THE EFFECT OF CRUDE OIL PRICE VOLATILITY ON INDUSTRIAL OUTPUT IN GHANA

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BY

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APRIL 2023

DECLARATION

Candidate's Declaration

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

Candidate's Signature: .... Date: ....

Name: Matilda Makafui Yabani

Supervisor's Declaration

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

Supervisor's Signature: .... Date: ....

Name: Prof. Omowumi O. Iledare

ABSTRACT

The industrial sector of Ghana is the second largest consumer of refined crude oil products. The industrial sector's output has exhibited significant volatility, with a GDP share of 19% in 2009 and 28.26% in 2021. A rising number of worldwide economies are particularly worried about the effect of crude oil price volatility on economic growth. Hence, this study investigated the impact of crude oil price volatility on industrial sector output in Ghana. The study employed monthly data from January 2001 to December 2020. The quantile regression, the causality in quantiles and bi-wavelet approaches were used to examine the relationship between crude oil price volatility and industrial sector output. The study’s empirical model results showed that there was a negative asymmetric impact of crude oil price volatility on industrial sector output at normal and boom economic conditions. Also, the study revealed significant causality between crude oil price volatility and industrial sector output mostly at stress and normal economic conditions of the industrial sector. The study further found negative significant short-term co-movements between crude oil price volatility and industrial sector output across time and frequency. The study recommended that policymakers should consider implementing petroleum price policies that can mitigate the negative effects of crude oil price volatility on the industrial sector output This includes establishing a Price Stabilization Fund which allows the government to save windfall gains during periods of high oil prices and release these funds to offset rising costs when prices fall. This helps stabilize domestic petroleum product prices, ensuring that industrial producers are shielded from sudden crude oil price fluctuations.

KEY WORDS

Bi-wavelet

Conditional Causality in quantile

Crude oil price

Industrial sector output

Quantile regression

Volatility

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DEDICATION

To my family: Emmanuel, Elizabeth, Perfect, and Samuel Yabani.

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LIST OF ACRONYMS

BoG	Bank of Ghana
CONS	Construction
EIA	Energy Information Administration
ELECT	Electricity
GDP	Gross Domestic Product
GSS	Ghana Statistical Service
IEA	International Energy Agency
IMF	International Monetary Fund
ISO	Industrial Sector Output
MFG	Manufacturing
MQ	Mining and Quarrying
OPEC	Organization of Petroleum Exporting Countries
OPV	Oil Price Volatility
ROVX	Realised Crude Oil Price Volatility
WS	Water and Sewerage

CHAPTER ONE

INTRODUCTION

Energy stands as a cornerstone of a nation's economic growth. Conferring to the Energy Information Administration (2021), petroleum is among the primary sources of energy that is utilized in the industrial sectors. In addition to a number of other important aspects, one of the most significant components in the production process of the global economy is crude oil. A rising number of worldwide economies are particularly worried about variations in crude oil price and how these may affect economic growth. These concern stems from the possibility that crude oil price changes may inhibit performance asymmetrically (Boateng, Adam & Owusu Junior, 2021; Mo, Chen, Nie & Jiang, 2019) and across time and frequency (Asafo-Adjei, Adam & Darkwa, 2021).

The largest economic sector of Ghana is typically the services sector (Ghana Statistical Service 2021). This sector encompasses a diverse variety of activities such as finance, tourism, telecommunications, retail, and more. It is important to Ghana's economy, accounting for a sizable amount of the nation's Gross Domestic Product (GDP), contributing roughly 45.19 percent in 2020 and 45.93% in 2021. The industrial sector of Ghana is the country's second largest economic area, contributing roughly 31.6 percent in 2020 and 28.26 percent in 2021 to Ghana's Gross Domestic Product respectively. In Ghana, the industrial sector is the second largest consumer of petroleum products, accounting for 9.1 percent of total petroleum product consumption in 2000 and rising to 466.4 Ktoe in 2019, accounting for 12.1 percent (Energy

Commission, 2021). Therefore, it is crucial to consider how the industrial sector of Ghana is affected by volatility of crude oil prices.

Background to the Study

Recent years have seen a resurgence of interest in the investigation of the effects of changes in oil prices on commercial performance, in part due to the rise and subsequent fall in crude oil prices that commenced in 2001, followed by another in 2008, after the subprime mortgage crisis. European prices for a barrel of Brent crude oil have fallen from $111 in July 2014 to less than $50 in January 2015. Recent events, like the Covid-19 outbreak, have caused oil prices to rise or fall throughout the world (Prabheesh et al., 2020). Supply disruptions that are detrimental to the economy and a decrease in oil usage came from social isolation measures, company closures, and personnel cuts in the oil industry caused by infection and quarantine restrictions (Prabheesh et al., 2020). Boateng et al. (2021) stated that the shocks from Covid-19 occurred at the same time as the failure agreement among OPEC and its partners to restrict world oil output. As a result of these factors, there was a change in the price of crude oil throughout the first and second quarters of 2020. As seen in Figure 1, the price of a barrel of Brent crude fell from $63.60 in January 2020 to $23.34 in April 2020.

***Figure 1*: The Trend in Average Monthly Brent Crude Oil Prices**.
Source: Bank of Ghana (2020)

According to Jiménez-Rodrguez and Sánchez (2005), the influence of fluctuating crude oil prices on economic development is relayed through supply and demand channels. This is the case even when supply and demand channels are not directly involved. Shocks to the price of oil can either raise or decrease production expenditures, which can lead to a drop in supply-side output quality. On the demand side, Jimenez-Rodriguez et al. (2005) claim that oil price shocks influence consumption of goods and services indirectly through their effect on disposable income. That is, a rise in the price of oil lowers consumers' disposable income, which in turn causes them to delay their purchases. It is possible that the pace of economic activity may decrease as a result of this condition. Furthermore, oil price shocks may heighten uncertainty about the economy's future prospects, prompting people to save as a cautious move, negatively impacting economic activity (Jimenez-Rodriguez et al., 2005). Because of this, the impact on economic growth will also be contingent on whether or not the nation is a net exporter or importer of crude oil. A surge in crude oil prices oil is good news for economies that rely on exports, and vice versa. (Jiranyakul, 2016).

The heterogeneous market theory (Müller et al., 1997) and the adaptive market hypothesis (Asafo-Adjei, Adam & Darkwa, 2021; Boateng et al., 2021; Li, Huang & Failler, 2022, etc.) suggest that the crude oil market is diverse and adaptable (Lo, 2004). In the opinion of Müller et al. (1997), players in the market are irrational, which might change market dynamics over short, medium, and long investment horizons. Lo (2004) argues that shifts in the dynamics of the market cause structural shifts in both time and frequency, and that this correlates to the adaptability of the market. It is essential, for this reason, to analyze the degree of quantile asymmetric nexus, time-varying co-movements and conditional causality associated with alterations in the value of crude oil.

The expansion of the economy of Ghana is susceptible to being significantly influenced by shifts in both the cost of crude oil and its overall availability in the country (Centre for Study of Africa Economies, 2014). According to Awunyo-Vitor et al. (2018), the Ghanaian economy is heavily dependent on imported crude oil and this demonstrates the crucial role that crude oil plays in the economy as a result of rising consumption. This is because Ghana is unable to produce enough of its own crude oil to meet the country's demand for petroleum products and electricity generation (Cantah & Asmah, 2015; Awunyo-Vitor et al., 2018). The Energy Commission (2021) argues that, despite recent finds, Ghana stays a crude oil importer. Ghana has generally sought to sell higher-grade oil while importing crude oil for economic reasons. In the year 2020, a total of 4,843 kilotonnes of crude oil were imported, the refineries utilized 461 kilotonnes for manufacturing petroleum products, while the remaining 382 kilotonnes were utilized to generate power. as shown in Figure 2.

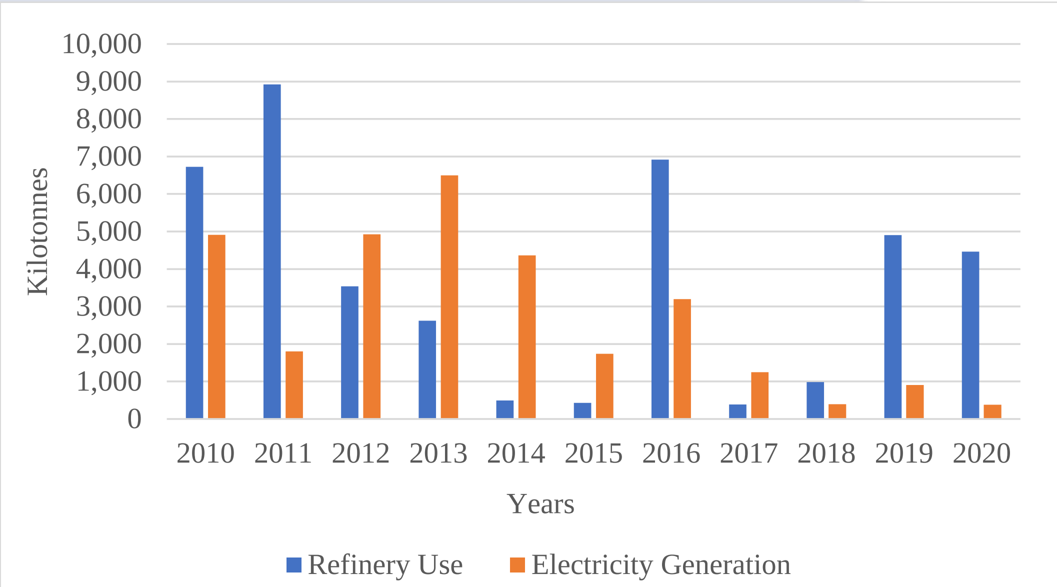

Figure 2: The Trend in Crude Oil Import in Ghana
Source: Energy Commission (2021)

Ghana's industrial sector is regarded as second largest contributor to the GDP of the country. Data for 2019 from the Ghana Statistical Service, (2020) revealed a growth rate of 6.4 percent, compared to 10.6 percent in 2018. The highest growth rate for 2019 was 7.6 percent in the service sector, followed by 6.4 percent in industry and 4.6 percent in agriculture. The service sector continues to be the most important sector. Its GDP share climbed from 47 percent in 2018 to 48.2 percent in 2019. The sectors GDP growth rate, on the other hand, increased from 2.7 percent in 2018 to 7.6 percent in 2019 (Ghana Statistical Service, 2020) as shown in Figure 3.

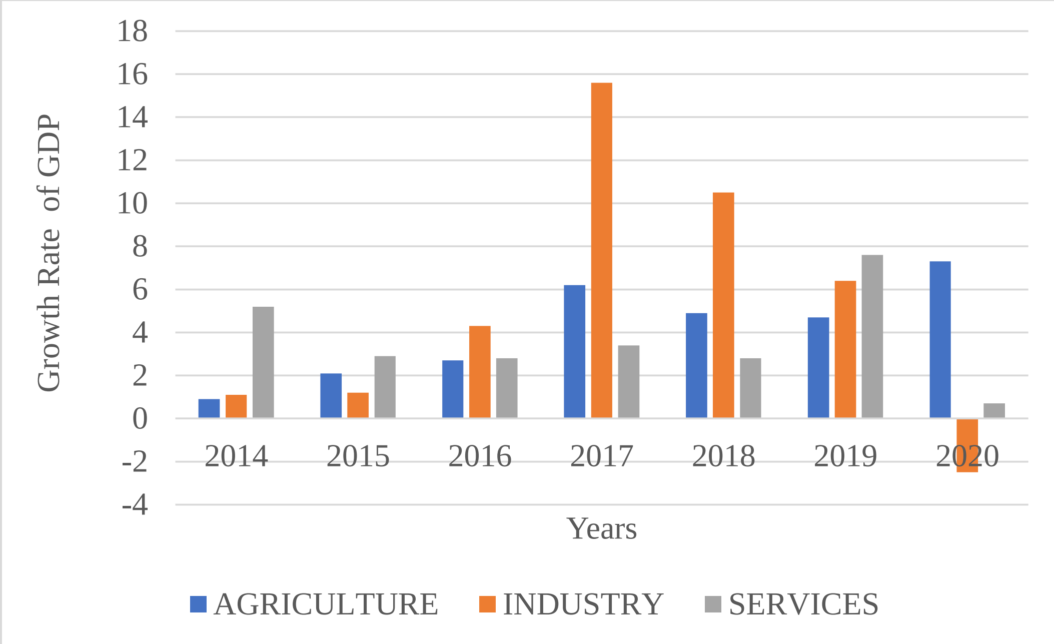

Figure 3: Growth rate of GDP for Agriculture Sector, Industrial Sector and Services Sector**.**
Source: Ghana Statistical Service (2020).

The industrial sector, with a 29.88 percent GDP share in 2020, saw its growth rate decrease from 6.4 percent in 2019 to a negative growth rate of 2.5 percent in 2020 (Ghana Statistical Service, 2020). The industrial sector of Ghana experienced a negative growth rate in 2020, primarily due to the disruptive repercussions of the COVID-19 epidemic. Lockdowns, supply chain disruptions, reduced demand, global economic slowdown, and financial constraints contributed to the contraction, affecting industries reliant on both domestic and global markets. Additionally, the decline in oil prices and labor force challenges further compounded the sector's challenges (Ghana Statistical Service, 2021; World Bank, 2020). The sector is made up of five subsectors, namely; manufacturing, mining and quarrying, construction, water and sewerage, and electricity. The Energy Information Administration (2021), asserts fuel is one of the primary sources of energy that is utilized in the commercial and manufacturing sectors. In the manufacturing industry, crude oil and products derived from petroleum are put to use as a means of energy, as feedstock or as unprocessed goods in the production of a wide variety of intermediate and end-user goods, including plastics, polyurethane, and solvents. Refineries, for example, use crude oil to make gasoline, kerosene, gas oil, and other fuel oils, among others (Energy Information Administration, 2021). Because crude oil is a main source of energy for the industrial sector, fluctuations in its price may have an effect on the percentage of GDP that the industrial sector contributes.

As a result, it is essential to investigate the impact that the fluctuation in the price of crude oil has on the industrial sector. The current study specifically explores their asymmetry, causality, as well as time and frequency nexus in order to support optimal resource management decisions. Asymmetric analysis is used to understand how different economic variables or factors affect a particular sector, such as the industrial sector in this case, during different phases of their fluctuations. In the context of the effect of crude oil price fluctuations on the industrial sector of Ghana, asymmetric analysis is employed to examine whether the sector responds differently to upward price swings compared to downward movements in crude oil prices.

This approach is informed by the recognition that economic agents often react differently to both beneficial and detrimental shifts in key factors. For example, during periods of rising crude oil prices, industries may face higher production costs, which could lead to decreased profitability and reduced output. On the other hand, when oil prices decline, industries might experience cost savings, potentially resulting in increased production and economic growth. This uneven response to positive and negative changes is known as asymmetric behavior. This is done in consideration of the shifts that occur in both crude oil prices and the industrial sector. The asymmetric relationship will be answered through the quantile regression approaches as adopted by prior literature (Adebayo, Rjoub, Akinsola & Oladipupo, 2022; Archer, Owusu Junior, Adam, Asafo-Adjei & Baffoe, 2022; Barson, Owusu Junior, Adam & Asafo-Adjei, 2022; Demir, Pesqué-Cela, Altunbas & Murinde, 2022) to divulge the economy's conditions in terms of stress, normal and boom. On the other hand, the bi-wavelet approach which examines co-movements and lead-lag nexus between time series data across time and frequency would be employed (Armah, Amewu & Bossman, 2022; Asafo-Adjei, Adam & Darkwa, 2021; Singh, Bansal & Bhardwaj, 2022).

Statement of the Problem

Energy is a crucial factor in the national economic development and sustainable progress of any nation, including Ghana (Awunyo-Vitor et al., 2018; Mukhtarov, Humbatova, Mammadli & Hajiyev, 2021). A growing number of countries throughout the world are becoming more concerned about the asymmetric, causality and time-frequency varying effect of unstable oil prices on economic growth (Asafo-Adjei, Adam & Darkwa, 2021; Boateng, Adam & Owusu Junior, 2021; Ftiti et al., 2016; Mo et al., 2019). The rising oil prices have been a major challenge for both local businesses and the global economy (Cantah & Asmah, 2015; Boateng et al., 2021).

In Ghana, consumers of petroleum products including firms bear the full cost of petroleum use, and the increased prices have led to significant problems for businesses. These problems include increased transportation and production costs, reduced profitability, and the need for cost-cutting measures such as layoffs and reduced production. The downward review of the Special Petroleum Tax (SPT) incorporated into Ghana's Petroleum Price Build-Up (PBU) and the revision and neutralization of the Price Stabilization and Recovery Levy (PSRL) has an impact on rising petroleum prices for consumers in Ghana (Tsatsu, 2022). This was intended to lessen the impact of rising crude oil prices. However, the downward review was unable to stop the price of petrol from rising by more than 38% between January 2017 and June 2019 to sell at Ghs5.25 per litre. Also, from June 2019 to March 2022, fuel costs would rise by 64.15%, leading to an increase in price from GHS 5.25 to GHS 8.618.

This is extremely concerning and detrimental to all economic actors, notably the industrial sector, whose operations substantially depended on fuel consumption. The Chief Executive Officer (CEO) of the Association of Ghana Industries (AGI), Seth Twum Akwaboah, described the business environment as challenging in the country. In his view, utility tariffs have increased, fuel prices have increased, the policy rate has increased – leading to high interest rates, high levels of inflation, depreciation of the cedi, and a variety of businesses have been forced to cut production (The Business and Financial Times, 2022).

Statistics on petroleum product consumption by sectors from the Energy Commission (2021) as shown in Figure 4 revealed that the transportation sector utilized 1,148.2 Ktoe of petroleum products in 2000, accounting for 79.9 percent of total petroleum products consumed in the economy. In 2019, this grew to 2,950.7 Ktoe, accounting for 77.2 percent of total petroleum product consumption. The industrial sector is the second largest user of petroleum products, accounting for 9.1% of total consumption in 2000 and rising to 466.4 Ktoe, representing 12.1 percent (Energy Commission, 2021). Hence, the rise in consumption of petroleum products in light of the corresponding increase in crude oil price would exacerbate the impact of price volatility on industrial sector output. Accordingly, with this level of consumption, the industrial sector output at various economic situations may be vulnerable to crude oil price volatility.

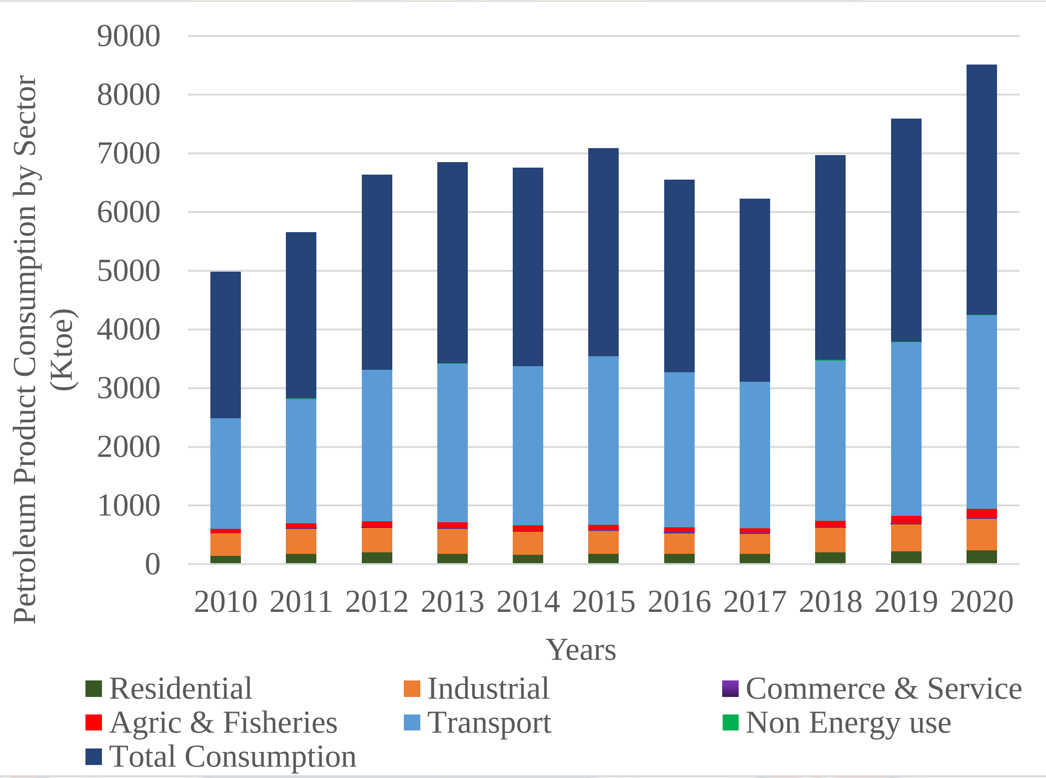

Figure 4: The Trend in Petroleum Product Consumption by Sectors (Ktoe)
Source: Energy Commission (2021)

Policies by the Government of Ghana to cut subsidies on petroleum products could cause fluctuations in petroleum products prices (Adjei-Mantey & Takeuchi, 2023; Kojima, 2016). This can further lead to adverse influence on the output of the industrial sector asymmetrically depending on the size and growth of the industries. The reduction in subsidies on petroleum products in periods such as 2013 and 2015 led to an eventual increase in production cost of firms which dwindled output. For example, the government of Ghana in 2015 set aside US$12.5m for subsides, compared with the US$150m in 2014 (Economist Intelligence, 2015).

Many theoretical and empirical studies have been conducted on the topic of the relationship between fluctuations in oil prices and economic growth. These studies used a variety of perspectives and methods, but they mostly focused on developed economies (Burakov, 2016; Koirala and Ma, 2020; Humbatova, 2019; Le & Chang, 2015; Mo, Chen, Nie & Jiang, 2019; Yazdani & Noor 2015). However, there are few references to Ghana and other developing countries (Ogunsakin & Oloruntuyi, 2017; Cantah & Asmah, 2015; Dogah, 2015; Donkor, 2018; Lin, Wesseh, & Appiah, 2014).

The vast majority of these studies provide evidence that supports a negative link between fluctuations in the price of crude oil and economic growth, however some of these studies also challenged the validity of the negative association (Mgbame & Donwa, 2015). The few studies on crude oil price dynamics conducted in developing countries have not focus the discussions on the industrial sector (Asafo-Adjei, Adam & Darkwa, 2021; Boateng et al., 2021; Boateng et al., 2022; Dramani & Frimpong, 2020; Kassem, Khoiry & Hamzah, 2019). For instance, Asafo-Adjei, Adam and Darkwa (2021) and Boateng et al. (2021) explored the impact of fluctuations of crude oil price on stock returns in Africa but did not focus on the industrial sector. In addition, Boateng et al. (2022) investigated the influence of crude oil price on the real sector of Ghana.

Nonetheless, studies conducted on the impact of crude oil price volatility on industrial sector output (Abdulkareem & Abdulkareem, 2016;

Ahmed et al., 2017; Aimer, 2016; Akalpler et al., 2018; Al-Risheq, 2016; Al-Sasi et al., 2017; Awunyo-Vitor et al., 2018; Eksi et al., 2011; Hau, Zhu, Huang, and Ma, 2020; Iganiga et al., 2021; Ogunsakin et al., 2017; Riaz et al., 2016; Yu et al., 2022; Zhang et al., 2022) employ methodologies that do not account for diverse economic conditions of the industrial sector. In this regard, prior studies have not yet addressed the quantile asymmetric and conditional causality effects of crude oil price volatility on diverse economic conditions of industrial sector output.

Also, considering the degree of heterogeneity and adaptability of the crude oil market in relation to economic growth, prior studies that have used the industrial sector output as proxy have failed to assess the time-frequency nexus between the variables in a developing country context. The inclusion of a time-frequency nexus analysis in this study holds significant policy implications for both the industry and public policy debate. The time-frequency analysis allows for a detailed examination of how the relationship between crude oil price volatility and industrial sector output evolves over different time scales. This information is crucial for policymakers, industry leaders, and stakeholders in making informed decisions. For instance, understanding how the impact of crude oil price fluctuations varies across short-term and long-term periods can guide the development of targeted policies that address immediate shocks as well as long-term sustainability. Moreover, this nuanced analysis can aid in the formulation of adaptive strategies to mitigate the adverse effects of oil price volatility on the industrial sector, enhancing the resilience of the sector in the face of changing market conditions.

The unique contribution of this study lies in its focus on the developing country context of Ghana and the specific examination of the industrial sector's response to crude oil price volatility using a time-frequency nexus analysis. While prior studies have often used the industrial sector's output as a proxy without considering the intricate temporal dynamics, this study delves into the time-frequency relationship between crude oil price fluctuations and sectoral output. This approach acknowledges the heterogeneity and adaptability of the crude oil market and its interaction with the industrial sector in a developing economy, offering insights that can guide policy decisions tailored to Ghana's unique circumstances. Furthermore, the study contributes to the broader global understanding by examining these dynamics in the context of a developing country, potentially providing valuable insights for other economies facing similar challenges and opportunities. The emphasis of this study compliments these studies by looking at the effect of crude oil price volatility on the output of the industrial sector in Ghana. This sector is the nation’s second largest user of refined crude oil products and it is important to evaluate its vulnerability to crude oil price fluctuations.

Empirical analysis is performed on the vulnerabilities of the aggregated and the disaggregated stages of the industrial sector output to crude oil price volatility. Comparison can therefore be made between the outcomes of the aggregated and disaggregated levels of industrial sector output. This is needed to decipher the extent to which the sub-sectors reflect the overall sector for policy decisions in the management of resources in the country. This is relevant because, oil price volatility does not affect all sectors equally (Taghizadeh-Hesary, Rasolinezhad, & Kobayashi, 2015). That is to say, certain business sectors are more severely affected than others leading to asymmetric and heterogeneous nexus. The subsectors of the industrial sector, including manufacturing, construction, mining and quarrying, water and sewerage, and electricity, are likely to be affected differently by crude oil price volatility due to their inherent characteristics and dependencies. The manufacturing sector is intricately tied to crude oil prices as it relies on petroleum products both as raw materials and energy sources. Fluctuations in oil prices can significantly impact production costs, particularly for industries dependent on plastics, chemicals, and transportation-related products. During periods of high oil prices, manufacturing industries could experience cost escalation, potentially leading to reduced profitability and increased consumer prices. Conversely, lower oil prices might offer cost relief for these sectors, potentially stimulating production and economic growth. Construction activities are closely linked to the costs of transportation, machinery, and energy, which can be heavily influenced by oil prices. Higher oil prices can lead to increased costs for construction materials and equipment, potentially causing delays and cost overruns in projects. Lower oil prices, however, could mitigate some of these cost pressures, potentially benefiting the construction industry.

The mining and quarrying sector can be affected by oil price volatility through its impact on transportation costs, as well as energy-intensive mining processes. Increased oil prices could drive up operational costs, affecting profit margins in mining and quarrying activities. On the other hand, lower oil prices might ease cost pressures, allowing the sector to maintain or even expand its operations. While Water and Sewerage sector is not as directly tied to oil prices as others, it does have some energy and operational costs related to transportation and equipment maintenance. Depending on the extent of these dependencies, fluctuations in oil prices could influence the sector's operational expenses. The electricity sector's operations are affected by both the cost of fuel used for power generation and the broader energy market dynamics. Higher oil prices can lead to increased fuel costs for thermal power plants, potentially impacting electricity prices and supply reliability. Conversely, lower oil prices might provide cost relief for the energy sector, which could translate into more stable electricity prices and availability.

In summary, the diverse dependencies of these subsectors on petroleum products, energy, and transportation costs create varying degrees of vulnerability to crude oil price volatility. This lies in the fact that each subsector's operations and cost structures interact differently with changing oil prices, leading to asymmetric impacts. A comprehensive analysis of these subsectors will provide valuable insights for policy decisions and resource management strategies, ensuring a targeted and effective approach to addressing the heterogeneous effects of oil price fluctuations across Ghana's industrial landscape. The paper addresses these issues in this context, the quantile asymmetric, causality and time- and frequency-dependent impact of crude oil price volatility on industrial sector output. It is against this backdrop that the study investigates the quantile asymmetric, causality and time- and frequency-dependent impact of crude oil price volatility on industrial sector output.

Purpose of the Study

The purpose of this study is to investigate the effect of crude oil price volatility on industrial sector output in Ghana.

Research Objectives

The specific objectives include:

1. Estimate the asymmetric relationship between realised crude oil price volatility and industrial sector output.
2. Determine the conditional causality of realised crude oil price volatility to industrial sector output.
3. Analyse the responsiveness of the industrial sector output to realised crude oil price volatility across time and frequency.

Research Questions

The study is guided by the following research questions;

1. What is the asymmetric relationship between realised crude oil price volatility and industrial sector output?
2. What is the conditional causality of realised crude oil price volatility to industrial sector output?
3. What is the responsiveness of the industrial sector output to realised crude oil price volatility across time and frequency?

Significance of the Study

This research attempts to examine the effect that variations in the price of crude oil have on the production of the industrial sector. Ghana, as a nation heavily dependent on oil imports for both its industrial processes and energy requirements, remains exposed to the variations of global crude oil price fluctuations. The findings of this study hold substantial significance, offering valuable insights into the extent to which crude oil price volatility influences industrial output within the country. This empirical knowledge can serve as a vital resource for policymakers and industry stakeholders, enabling them to make informed decisions concerning resource allocation, investment strategies, and effective risk management practices in a dynamic economic environment.

Delimitations

The purpose of the study was to investigate how the output of Ghana's industrial sector was affected by the fluctuation in the price of crude oil, which in this case, realised crude oil price volatility. Five sub-sectors in the industrial sector of Ghana were utilised. These were mining and quarrying, manufacturing, electricity, water and sewerage, construction. The industry sector average was also included in this study for further inferences. In the study, researchers utilised a monthly time series data set that covered the period starting in January 2001 and ending in December 2020. This area was selected due to data accessibility. The study employed the quantile regression bi-wavelet, and conditional causality in quantile approaches.

Limitations

The research did not concentrate on the whole economy. As crude oil is thought to be one of the key sources of energy, it is possible that it will have an effect on other parts of the economy. This study focuses solely on the industrial sector. Another drawback is the lack of monthly data on industrial sector output; the only information available was on a quarterly basis. In

Eviews-10, the method developed by Chow and Lin (1971) was applied in order to produce the monthly series. Because there are no restrictions on the sub-periods that can be used when disaggregating data with this approach, there are no issues to the reliability of the findings when employing it.

Also, the quantile regression technique used in this study only considers the quantiles of the industrial sector output as the dependent variable. Hence, the study is not able to reveal quantile-on-quantile effects of both dependent and independent variables. However, application of the quantile regression approach is ideal in controlling for other macroeconomic factors relative to the quantile-on-quantile technique which is limited to only two variables. Furthermore, despite the fact that the conditional causality in quantile approach examines causality between two variables, it is able to investigate causality for relationships that are non-linear. The bi-wavelet on the other hand shows the interconnectedness between two variables without controlling for a third variable, as in the case of partial wavelet approach. However, it is a useful tool which examines the interconnectedness of two variables across time and frequency indicating leading and lagging variables.

Organisation of the Study

There are five chapters in the research. The study's introduction, problem statement, purpose, goals, and questions are all covered in the first chapter along with its importance, constraints, and organizational structure. The second chapter summarizes empirical findings from earlier studies that are relevant to this research and evaluates the literature on crude oil prices and their impacts on different economic sectors. The methodology of the study, the research design, the research technique, and data processing and analysis are all outlined in Chapter Three. The findings of the empirical investigation are explained in Chapter Four. The last chapter presents the study's findings, conclusions, and suggestions.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter covers reviews on the effect of crude oil price volatility on the industrial sector's output. The study's underlying ideas, a conceptual framework for oil price volatility, industrial output, and a review of pertinent empirical research are explored in this chapter.

Theoretical Review

The theoretical linkages among the variables are presented to highlight some relevant hypotheses such as heterogenous and adaptive market hypotheses. the theoretical linkages among the variables are presented to highlight some relevant hypotheses such as heterogenous and adaptive market hypotheses. As a first illustration, the symmetric/linear association growth theory is presented. Next, the theoretical linkages among the variables are presented to highlight some relevant hypotheses such as heterogenous and adaptive market hypotheses.

The symmetric/linear relationship growth theory

Proponents of the symmetric/linear connection theory of growth (Hamilton, 1983; Hooker, 1986) argue that fluctuations in the growth rate of production are caused by fluctuations in oil prices (Taofik, 2018). Their arguments were based on what occurred in the oil market and how it affected the economies of oil exporting and importing nations between 1948 and 1972. Hooker (2002) conducted extensive empirical research between 1948 and 1972 and found that oil price changes significantly influenced production growth. According to Taofik (2018), Laser (1987) supports the notion that there is a symmetric link between the volatility of oil prices and economic growth. A rise in oil prices would inevitably lead to a drop in GDP, whereas the impact of a drop in oil prices on GDP is equivocal due to the fact that its influence differs from nation to nation (Taofik, 2018).

According to Eagle (2017), there are few inputs that have both symmetrical and asymmetric effects on the performance of the macroeconomy including oil. This means that changes in the price of oil can cause unanticipated repercussions on economic growth. He was of the belief alterations in the price of oil stifle growth through a variety of routes, such as increases in production costs and anticipation of higher inflation. In addition, he asserted that a rise in the price of oil can result in improvements to a nation's transportation and production levels as well as the stability of its financial system. It is against this backdrop that this study examines the asymmetric nexus between crude oil volatility and performance of the industrial sector.

Theoretical channels of the influence of crude oil price volatility on industrial output

According to Bugshan (2021), volatility in oil prices affects industrial output through three pathways, namely: output level, monetary policy, and market value. The consequences of an increase or reduction in the price of oil for the trajectory of output level are different for each economy. These implications might be positive or negative. An increase in the price of oil has a negative impact on the output of nations that import oil since it leads to greater production costs and reduces the buying power of consumers, both of which work to lower output. This connection is supported by the findings of empirical studies conducted in industrialized markets that are net importers of oil (Bilgin, Gozgor & Karabulut, 2015; Tang, Wu & Zhang, 2010). A plausible explanation for this could be that increased volatility makes forecasting future economic growth and demand in markets more difficult; as a result, businesses postpone investment (Henriques & Sadorsky, 2011).

As indicated, monetary policies are another pathway through which oil price volatility (OPV) affects industrial output (Bugshan, 2021). The increased cost of production caused by a rise in the price of oil will be passed on to customers in the form of higher prices. As a direct consequence of this, the rate of inflation in the nation will accelerate. As a standard response, the Central Bank will boost interest rates in order to combat the inflationary pressure. This will have two ramifications. First, the discount rate for expected future cash flows will increase (Cologni & Manera, 2008). Also, the higher cost of corporate financing will cause project investment to be delayed (Henriques & Sadorsky, 2011; Phan, Tran & Nguyen, 2019).

According to Basher and Sadorsky (2006) and Bugshan (2021), the nature of an industry's operations determines whether OPV will have a favourable or adverse impact on future cash flow. Profits and stock prices for oil companies would benefit from a rise in the price of oil. Oil and gas companies gain from increasing oil prices because their profit margins expand. Yet, sectors dependent on oil for their production are expected to see a decline in profits. This is because of the direct correlation between rising oil prices and higher production costs (Bugshan, 2021).

Another potential mechanism is through changes in demand. Volatility in crude oil prices can impact consumer and business confidence, leading to changes in consumption patterns and investment decisions (Henriques & Sadorsky, 2011). For instance, when crude oil prices increase, consumers may reduce their demand for goods and services that require high energy use, leading to a decline in demand for related products and services (Sorrell, 2015). Moreover, businesses may delay or cancel investment decisions in new projects or equipment that require high energy consumption (Ang, 1992). This could lead to a decline in economic growth in the industrial sector.

Accordingly, the impact of the fluctuations in crude oil prices on industrial output becomes heterogeneous and adaptive across time and frequency due to the behavioral intentions of investors which would alter in response to the changes in the market’s dynamics (Cornell, 2018; Owusu Junior et al., 2021). The heterogeneous market hypothesis (Müller et al., 1997) and the adaptive market hypothesis (Boateng et al., 2021; Li, Huang & Failler, 2022) suggest that the crude oil market is diverse and adaptable. Therefore, the effect of crude oil price on economic growth might not be the same across economic conditions of stress, normal and boom as well as time and frequency.

Müller et al. (1997) argue that market participants are irrational, which might change market dynamics over short, medium, and long investment horizons. Lo (2004) argues that shifts in the dynamics of the market cause structural shifts in both time and frequency, and that this correlates to the adaptability of the market. Hence, the markets become nonlinear, asymmetric and nonstationary (Owusu Junior et al., 2021). This demands empirical methods that can decipher the nexus between fluctuations in crude oil and industrial output. In this regard, the current study explores the asymmetric as well as time and frequency co-movements between crude oil price volatility and industrial output using the quantile regression and bi-wavelet approaches respectively.

Conceptual Review

Oil price volatility

Volatility in prices is a common economic process that occurs almost every day within any given financial year. According to Lin et al. (2013), the term "price volatility" describes the degree to which prices go up or down over a period of time. In a well-functioning market, prices are indicative of present and forecasted supply and demand situations, as well as variables that may have a substantial impact on them. In situations where market prices change often within extremely short time intervals, then it can be concluded that there is high price volatility for that particular product (Chen and Hsu, 2012). Thus, an economy is described as having low price volatility when market prices are fairly stable for longer periods. There can be volatility in the prices of all economic goods, including gold, timber, cocoa, coffee, and cashew.

According to the findings of Ogiri, Amadi, Uddin, and Dubon (2013), volatility is the measure of the propensity of oil prices to rise or decrease abruptly within a period of time, such as a day, a month, or a year. This tendency may be seen in the context of crude oil price volatility. According to Lee (1998), which is referenced in Mgbame et al. (2015), volatility is defined as the standard deviation in a given time, and volatility has an instantaneous negative and big influence on economic development. In a nutshell, volatility may be defined as the degree to which the price of a commodity fluctuates over time (increase and fall). Oil price volatility can have huge repercussions for businesses and the global economy. (Council on Foreign Relations, 2016).

Historically, the international commerce of crude oil has been crucial to the development of the global economies (Taofik, 2018). One of the few production inputs that may potentially create a recession is oil (Hamilton, 2009; Tverberg, 2012). Oil price volatility stifles growth via a variety of mechanisms, ranging from increased production costs to inflation expectations (González and Nabiyev, 2009). Oil price shocks over the past few decades have dampened global economic expansion (Tang, Wu, & Zhang, 2010). As oil supplies were interrupted by a succession of political events in the Middle East in the 1970s and 1980s, prices dropped throughout the world (Tang et al., 2010). According to Awunyo-Vitor, Samanhyia, and Bonney (2018), the decades of the 1970s and 1980s made it abundantly evident how reliant developed economies are on crude oil.

Major economies like the United States and the United Kingdom have seen slowing growth, rising unemployment, and rising prices across board. Several industrialized economies went through the stagflationary period (Awunyo-Vitor et al., 2018). After the initial interruption, several more events have occurred, each of which has reduced crude oil output and increased prices. These incidents include the Iraq-Iran War in 1978, the Gulf War in

1990, the Asian Economic Crisis in 1977, the Iraq War in 2003 (Tunyo, Armah, Cantah, & Suleman, 2021), and the COVID-19 Pandemic (Boateng et al., 2021; Boateng et al., 2022; Prabheesh, Padhan, & Garg, 2020). Therefore, more evidence-based research must understand the effects such volatilities can have on industrial sector output in the long-run and short-run.

Industrial sector output

Ghana's industrial sector has experienced significant growth and transformation over the past few decades (Ackah, Adjasi & Turkson, 2016; O'Neill, 2022; Tunyo et al., 2021). This can be seen in the sector’s contribution to GDP, own-growth, sub-sectors, ability to offer employment, coupled with the challenges thereof. The industrial sector in Ghana comprises several sub-sectors, including manufacturing, construction, water and sewerage, electricity, and mining and quarrying (Ghana Statistical Service, 2020). The manufacturing sector is the largest sub-sector and includes food and beverages, textiles and garments, and pharmaceuticals. Figure 5 shows the growth rates of the sub-sectors of the industrial sector.

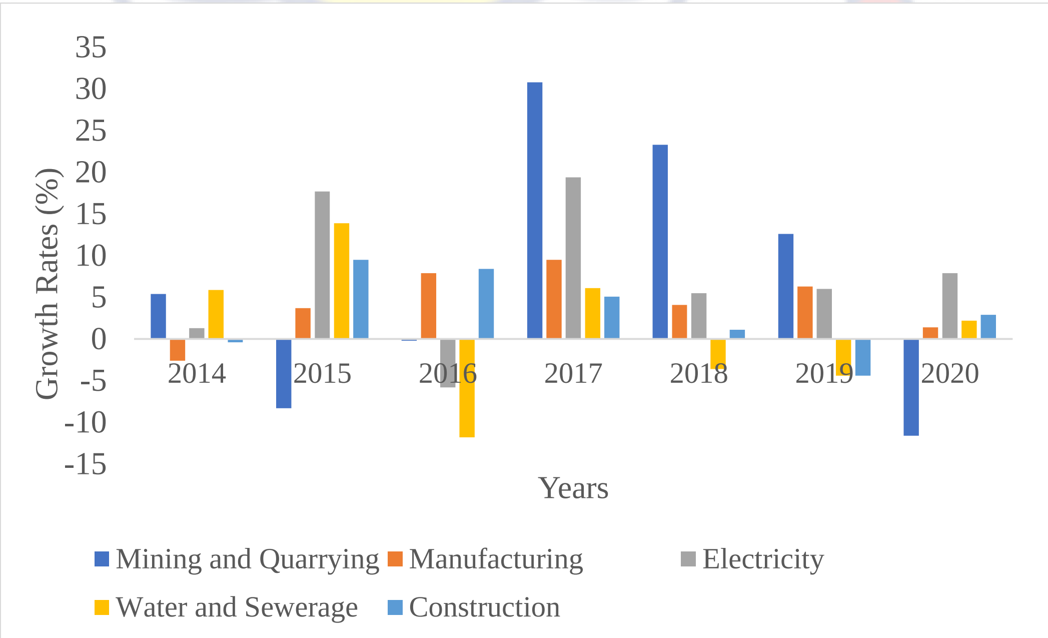

Figure 5: Growth Rate of the Sub-sectors of the Industrial Sector
Source: Ghana Statistical Service (2020)

From Figure 5, the manufacturing sector was the least performing sub-sector in 2014 followed by the construction sector. During this period, water and sewerage sector was the highest performing, followed closely by mining and quarrying. However, in 2015 and 2020, the growth rates of the mining and quarrying sector were the lowest despite its maximum growth from 2017 to 2019. Almost all the sub-sectors record a negative growth rate at particular years suggesting that the output of the industrial sector has experienced rapid variations over time.

The industrial sector faces several challenges, including inadequate infrastructure, limited access to finance, and low levels of technology and innovation (Ackah, Adjasi & Turkson, 2016; Ghana Statistical Service, 2020; Tunyo et al., 2021). These challenges have hindered the sector's ability to compete internationally. In conclusion, while Ghana's industrial sector has shown promising growth, there is still room for improvement to fully realize its potential and address the challenges it faces.

Relationship between industrial sector output and crude oil price volatility

Crude oil is a key input cost for many industries, particularly those that rely on transportation and manufacturing (Al-Risheq, 2016). When the price of crude oil rises, it can increase the cost of inputs for these industries, which can reduce profitability and potentially lead to lower production levels (Boateng et al., 2021). On the other hand, the price of crude oil can also impact consumer spending patterns, as higher oil prices can lead to higher prices for goods and services across the economy (Phan, Tran, Nguyen & Le, 2020). If consumers are forced to spend more on essentials like gasoline and heating oil, they may have less disposable income available to spend on other goods and services, which can in turn impact demand for industrial goods (Okwu, Akpa, Oseni, & Obiakor, 2020).

The price of crude oil is also closely tied to macroeconomic factors like inflation, interest rates, and global economic growth (Asafo-Adjei et al., 2020; Asafo-Adjei, Boateng et al., 2021; Boateng et al., 2022; Kasongwa, & Minja, 2022). For example, if the global economy is experiencing a period of rapid growth, demand for crude oil may increase, which can drive up prices. Conversely, if interest rates rise, it can lead to a decrease in demand for oil and other commodities, which can lead to lower prices.

Additionally, geopolitical events like conflicts, natural disasters, and trade disputes can also impact the price of crude oil (Gong, Feng, Liu & Xiong, 2023; Zhang, Wang, Xiao & Zhang, 2023). For example, if there is a disruption in oil supply due to a natural disaster or geopolitical conflict, it can lead to a sudden spike in prices that can impact the industrial sector. In summary, the relationship between crude oil price volatility and industrial sector output is complex, with many different factors at play. The price of crude oil can impact input costs, consumer spending, macroeconomic factors, and geopolitical factors, all of which can in turn impact the output of industrial sectors in various ways.

Conceptual Framework

This section shows the study's conceptual framework. The sustainable progress of any country is built on a number of elements, one of which is energy, and Ghana is no exception. In addition to a number of other important aspects, crude oil is one of the most important components in the production process of the global economy. Crude oil price volatility describes the degree to which prices go up or down over a period of time. Crude oil price volatility has the tendency of affecting output of industrial sector as it serves as one of the inputs of industrial production.

Based on literature, some other macro-economic variables which could affect industrial output were included in the framework as control variables (Abokyi et al., 2018; Al-Risheq, 2016; Iganiga, Anyanwu, Ikubor, & Ojima, 2021). They include energy consumption, foreign direct investment, and interest rate. Industrial output may also be affected by the energy consumed as energy serves as one major input of industrial production. According to Abokyi et al. (2018), the unpredictable electricity power supply is regarded as the number one issue affecting the industrial sector in Ghana. Because of this, energy consumption is incorporated into the model as a control variable.

Interest rates also have the tendency to affect industrial output. Butler (2022) opined that lower interest rate spurs growth while higher interest rate reduces spending and investment, causing a reduction in industrial output. Most industries in Ghana finance their businesses through loans from banks and may be vulnerable to interest rates. Interest rate is therefore included in the model as a control variable. Foreign direct investment (FDI) can be described as an ownership stake in a foreign company or project made by an investor, company, or government from another country. Iddrisu, Adam, and Halidu (2015) looked at the impact of FDI on Ghana's industrial sector's output from 1980 to 2013. According to the report, foreign direct investment significantly improves Ghana's industrial sector's output over time. This justifies the inclusion of FDI as a control variable in the model.

Overall, the conceptual framework posits that fluctuations in crude oil prices can have a significant impact on the output of the industrial sector. When crude oil prices are high, the cost of production for the industrial sector firms increases, leading to a decrease in profitability and output. On the other hand, when crude oil prices are low, the industrial sector firms can benefit from lower production costs and increased profitability. The control variables play a role in mitigating the impact of crude oil price volatility on the industrial sector. Higher levels of energy consumption can increase the vulnerability of the industrial sector to crude oil price volatility, whereas foreign direct investment can provide the sector with additional resources and funding to mitigate the effects of volatility. Interest rates can also influence the industrial sector's output by affecting the cost of borrowing for firms. Figure 6 presents a conceptual framework that shows the relationship between crude oil price volatility and industrial output.

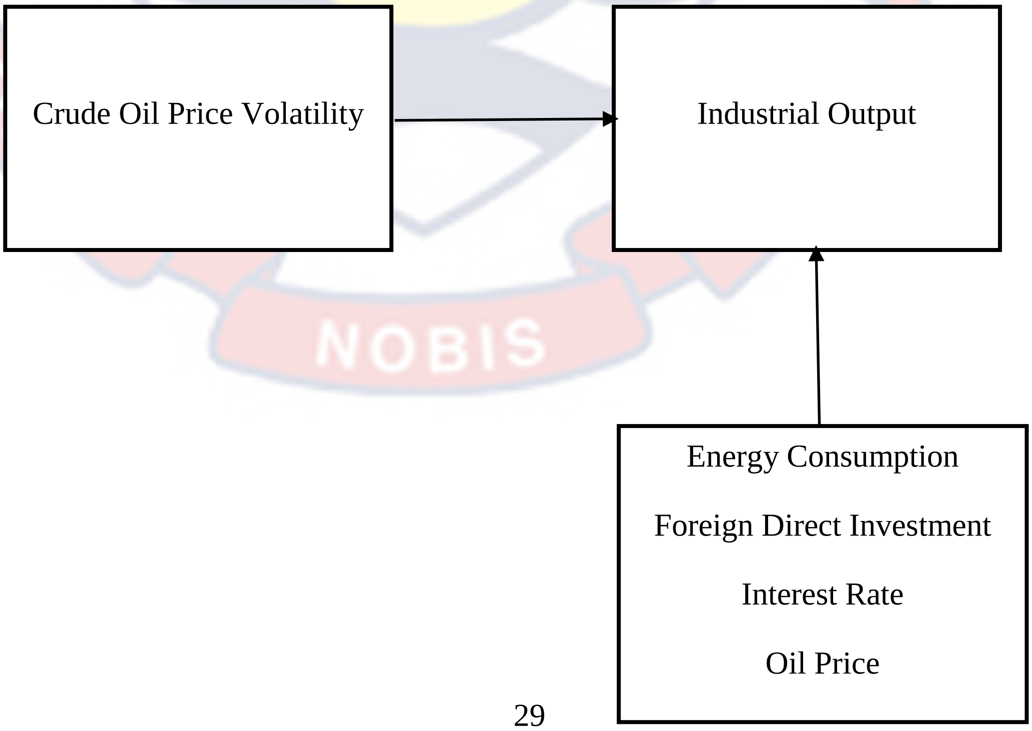

Figure 6: Conceptual Framework
Source: Author's Construct (2023)

Empirical Review

There is a plethora of research available on the effects of fluctuations in the price of crude oil. The vast majority of these research focused on the effect that fluctuating crude oil prices have on economic development, whereas just a small number of studies looked at the impact of other macroeconomic factors.

Asymmetric nexus

Abdulkareem and Abdulkareem (2016) conducted a comprehensive analysis of macroeconomic and oil price volatility within the context of Nigeria. They employed Generalized Autoregressive Conditional Heteroskedasticity with Mean (GARCH-M), Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH), and Threshold Generalized Autoregressive Conditional Heteroskedasticity (TGARCH), while considering different time frames, including daily, monthly, and quarterly data. Their investigation unveiled that all the examined macroeconomic variables, encompassing real gross domestic product, interest rates, exchange rates, and oil prices, exhibited pronounced levels of volatility. Notably, the asymmetric models (TGARCH and EGARCH) outperformed the symmetric models (GARCH (1 1) and GARCH-M) in their ability to predict volatility trends. This research underscored the significant impact of oil price fluctuations on the overall economic instability of Nigeria. Consequently, the

Nigerian economy proved susceptible to both internal factors, such as the instability of interest rates and real GDP, and external factors, including fluctuations in exchange rates and oil prices.

Hau, Zhu, Huang, and Ma (2020) conducted an original investigation into the relationship between the volatility of crude oil prices and China's agricultural commodity futures. They employed a unique quantile-on-quantile regression technique to explore the heterogeneous dependence between these two variables. To estimate the conditional volatility, the researchers utilized a dynamic model with time-varying parameters and stochastic volatility. Their findings revealed diverse dependencies between crude oil price volatility and agricultural futures volatility across various quantiles. Notably, as agricultural volatility increased in higher quantiles, the spillover of absolute volatility also grew, indicating a heightened interdependence. This interplay of volatility exhibited differences in response to market conditions, distinguishing between turbulent and stable market environments. Furthermore, the study highlighted those extreme quantiles of oil volatility, whether exceptionally high or low, exerted a substantial impact, while the behavior of agricultural volatility remained unaffected during normal oil market conditions. Moreover, the research unveiled the persistence of volatility dynamics over time, emphasizing the substantial variations in the influence of volatility on returns.

In 2016, Al-Risheq conducted a comprehensive study examining the influence of oil prices and various other significant factors on manufacturing output across 52 developing nations. The study employed a fixed effects model to analyse data spanning from 1970 to 2012. The study's findings revealed a noteworthy and adverse relationship between high oil prices and industrial production. It was evident that elevated oil prices had a substantial detrimental impact on the manufacturing sector. Consequently, the author concluded that emerging nations, heavily reliant on oil imports, are particularly vulnerable to negative oil price shocks. Such shocks pose a significant threat to both industrial production and overall economic growth in these countries (Al-Risheq,2016).

In addition, Ahmed, Osama Daudpota, and Kashif (2017) used data from July 2005 through June 2015 using vector auto-regression modeling approaches to explore the influence of fluctuations in oil prices on production at the industrial level. Results revealed that high oil price volatility (OPV) was associated with a significantly higher likelihood of adverse effects on industrial performance. The study showed that the interaction between OPV and industrial performance was mediated by the effects of inflation. That is, whenever there was high volatility in oil prices, it resulted in high inflation rates, which made it difficult for industries to meet their target output or productivity level. Hence, supporting the claim that OPV has a considerable short- to medium-term influence on industrial productivity.

In a similar context, Iganiga, Anyanwu, Ikubor, and Ojima (2021) conducted an investigation into the relationship between oil price fluctuations and industrial production levels in Nigeria. The study aimed to uncover both the symmetric and asymmetric impacts of oil price fluctuations on the Nigerian industrial sector, utilizing two distinct modeling approaches: the Autoregressive Distributed Lag (ARDL) model for linear effects and the Nonlinear Autoregressive Distributed Lag (NARDL) model for nonlinear effects. According to the short-term linear ARDL model, the research indicated that higher oil prices tend to positively affect the output of the building and overall industrial production. Conversely, these elevated oil prices were found to have a negative influence on the efficiency of the manufacturing subsector. On the other hand, the long-term nonlinear analysis revealed that oil price shocks, whether increases or decreases, had diverse and distinct effects on the industrial sector and its constituent components. Specifically, a surge in oil prices was associated with a decline in both aggregate industrial production and the manufacturing index. Conversely, the data suggested that the output in the building and construction sector experienced some growth during such price spikes. Moreover, a long-term decrease in oil prices was linked to an increase in industrial production levels.

Similarly, a group of researchers in Pakistan delved into the repercussions of oil price volatility (OPV) on the nation's overall manufacturing output, as outlined by Riaz, Sial, and Nasreen in 2016. In their study, the authors employed both the EGARCH-in-Mean model and the ARDL regression model to analyse monthly time series data spanning from 2001 to 2011.The results of their investigation unveiled a non-linear relationship between fluctuations in oil prices and the quantity of manufactured goods produced in Pakistan. Initially, the country's manufacturing production exhibited an uptick in response to heightened oil price volatility. However, the study identified a critical juncture where manufacturing production began to dwindle even as OPV continued to increase.

In 2022, Ahmad, Iqbal, Khan, Han, Vega-Muñoz, and Ariza-Montes conducted a comprehensive analysis examining the macroeconomic repercussions of crude oil shocks across South Asian countries, including Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. The study encompassed time series data spanning from 2000 to 2020 and employed two distinct analytical models: the impulse response function and the vector autoregression model. The research outcomes underscored the remarkable sensitivity of macroeconomic indicators to even minor fluctuations in oil prices, emphasizing the significant impact these shifts can exert on the socio-economic landscape of a region. Notably, the variance decomposition analysis revealed that each nation in the South Asian region responded uniquely to crude oil price fluctuations. These diverse responses were reflective of the specific macroeconomic fundamentals, independent policy measures, sectoral structures, and inherent national disparities prevalent within each country (Ahmad et al., 2022).

Conditional causality evidence

Ogunsakin and Oloruntuyi (2017) conducted research in Africa to investigate the link between OPV and the macroeconomic performance of two of the continent's top net oil producing countries (Angola and Nigeria). The research looked at quarterly data covering the years 1990 to 2014 and applied the E(GARCH), the Granger Causality test and the Structural Vector Autoregressive (SVAR). The rate of growth of the GDP the currency rate, foreign interest, and the price of oil in the globe. The variables of interest were the inflation rate, the domestic real interest rate, and the amount of money in circulation. According to the findings, the fluctuation in oil prices has a relatively insignificant effect on the rates of growth of both nations' gross domestic products (Ogunsakin and Oloruntuyi 2017).

In 2018, Awunyo-Vitor, Samanhyia, and Bonney conducted a study in Ghana aimed at investigating the direct relationship between oil price fluctuations and economic development. The research employed various statistical tests, including the unit root test, the Johansen co-integration test, and the Granger causality test, to analyze data gathered from 1970 to 2012. The study's findings revealed an inverse correlation between oil price shifts and economic growth, suggesting that increases in oil prices tend to be associated with decreases in economic development. However, when viewed across a much broader time frame, the influence of fluctuating oil prices on economic development was found to be statistically insignificant. Furthermore, the Granger causality test identified a unidirectional cause-and-effect relationship, indicating that rising oil prices had a causal impact on expanding economies. In summary, the research indicated that oil price fluctuations have a minimal impact on the growth of the Ghanaian economy. Consequently, it underscored the importance of pursuing measures to promote economic growth that are independent of oil price fluctuations (Awunyo-Vitor et al., 2018).

In 2011, Eksi, Izgi, and Senturk conducted a study assessing the effects of crude oil price volatility on industrial production in select Organisation for Economic Co-operation and Development (OECD) nations. The research drew its conclusions from the analysis of monthly time series data covering the period from 1997 to 2008, employing both the Granger causality test and the Johansen co-integration approach. The study's results unveiled a significant short-term causal relationship between crude oil prices and industrial production in all examined countries, except for France. Interestingly, in the case of France, the causality was observed to run from industrial production to oil prices in the short term. Furthermore, for the United States, an error correction mechanism was employed, revealing a long-term causal relationship from oil prices to industrial production. These findings collectively suggest that fluctuations in crude oil prices do indeed exert an impact on the industrial production index in these studied nations.

Akalpler and Bakar (2018) evaluated the influence of variations in oil prices on economic development between 1981 and 2015.To analyze this relationship, they utilized both the Granger causality test and VECM. Their findings demonstrated a positive association between the true effective exchange rate and the price of oil and growth in the economy, but a negative correlation between government expenditure and inflation. Additionally, they found that changes in oil prices had a causal effect on economic growth and the exchange rate, while changes in the exchange rate had a causal effect on inflation. Through variance decomposition analysis, they observed that OPV was the largest driver of variation in economic growth and exchange rates, whereas the exchange rate was the main trigger of variability in inflation, followed by oil prices.

Al-Sasi, Taylan, and Demirbas (2017) conducted a study on how "fluctuations in oil prices affect GDP of the United Arab Emirates (UAE). The aim of the research was to identify in what way oil prices changes influence macroeconomic indicators in the UAE. They employed several procedures including Ordinary Least Squares (OLS), ARDL, Augmented Dickey-Fuller (ADF), and Granger causality methods to analyze the effect of oil prices on the UAE's economic development from 2001 to 2020. This study revealed there was a direct correlation between oil price changes and UAE's GDP in both the immediate and long-term. Consequently, if the essential corrective efforts are not implemented, a drop in oil prices might represent a long-term danger to the UAE's economic security.

Time and frequency nexus

Yu, Guo, and Chang (2022) conducted a study "examining the relationship between oil price volatility and economic performance during the COVID-19 and financial crises of 2007-2008. They employed time and frequency domains simultaneously to look into how shifts in oil prices affected macroeconomic performance during these crises. By using Wavelet analysis, the researchers explored the interconnection between oil price shocks and economic activities during these crises They suggested that during financial crises, both the economy and oil prices exhibited considerable strength, but the COVID-19 epidemic resulted in substantial instability in the economy. During both crises, the analysis found a substantial link with the price of oil and economic activity, illustrating the severe impact that an increase in oil prices may have on economic activity.

In 2019, Mo, Chen, Nie, and Jiang conducted a comprehensive investigation into the influence of crude oil prices on the economic growth of the BRICS nations, which include Brazil, Russia, India, China, and South Africa. Their study employed a wavelet-based quantile-on-quantile method, enabling them to dissect the data into different investor horizons and assess the overall effects across various quantiles. The research outcomes revealed that the impact of crude oil prices on economic growth varied significantly among these countries, fluctuating across different time periods and quantile levels.

These variations stemmed from disparities in oil policies and economic development strategies unique to each nation. Specifically, in the BRICS countries, the study identified a positive effect of crude oil prices on economic growth. However, this positive effect weakened during periods of high oil prices in Brazil and Russia, and it diminished over time in India. In China, the research unveiled a positive impact in the short and medium term, followed by a subsequent negative influence. Interestingly, in the long run, higher crude oil prices were found to stimulate economic growth in China. Furthermore, the study highlighted distinct dynamics in South Africa, where a negative effect of crude oil prices on economic growth was observed in the short term. Nevertheless, over time, a positive effect re-emerged, although it gradually waned (Mo et al., 2019).

Zhang, Mou, and Ye (2022) conducted research on the effect of international crude oil price fluctuations on China's industrial sector, focusing specifically on dynamic jumps. To achieve this, they used the asymmetric Autoregressive Moving Average- Exponential Generalized Autoregressive Conditional Heteroskedasticity (ARMA-EGARCH) model to examine the features of global price swings and integrated the jump element into the Autoregressive Moving Average- Exponential Generalized Autoregressive Conditional Heteroskedasticity-X (ARMA-EGARCH-X) model to explore the effects of sudden fluctuations on the country’s industrial sector over time. The researchers grouped abrupt increases in oil prices based on different oil market conditions and assessed the asymmetrical impact of the shocks. Their results indicated that global oil price fluctuations display volatility concentration that is characterized by asymmetry and dynamic jumps. The study found that oil price jumps had an adverse effect on returns in China's industrial sector, but a favorable impact on its volatility at the overall level.

Empirical review on Ghana

Dadzie, Nambie, and Obobi (2023) studied the link between the volatility of Ghana's petroleum and commodities prices. The main objective was to establish an empirical framework to understand the direction of this impact. Drawing on the existing literature on time series analysis, the research explored the ADF, Granger causality, co-integration, vector autoregressive (VAR), and vector error correction models to assess the connection between the volatility in petroleum energy prices and the chosen commodity variables. Findings revealed a significant and enduring connection between petroleum price volatility and commodity prices in Ghana over 2011 to 2022period. According to a single equation error correction model, shocks in petroleum energy prices led to increases in the prices of grains, meat, and cooking oil in both the short and long term. Additionally, the analysis of impulse response functions and variance decomposition indicated the presence of both short-term and long-term associations between these variables.

Nchor, Klepá, and Adamec (2016) investigated the evolving connection between oil price shocks and crucial macroeconomic indicators in the economy of Ghana. For this, they used Vector Autoregressive (VAR) and Vector Error Correction (VECM) models. The inflation rate, and real GDP growth rate in the and the real effective exchange rate were all factors addressed. The study emphasized the asymmetric effects of oil price shocks, suggesting that favorable and unfavorable oil price fluctuations had an influence on the chosen macroeconomic indicators. The study's empirical findings demonstrated that both linear and non-linear variations in oil prices have negative effects on Ghana's macroeconomic indicators. Positive oil price shocks, in particular, were found to have a greater impact than negative shocks to government spending, inflation, and the real effective exchange rate. Industry value added and imports, on the other hand, responded more strongly to negative oil price shocks. “Positive oil price shocks accounted for approximately 30 percent of the fluctuations in government spending, 5 percent in imports, 6 percent in industrial value added, 17 percent in inflation, and 2 percent in the real effective exchange rate in the long run. Conversely, negative oil price shocks resulted in roughly 8 percent of changes in government expenditure, 20 percent in imports, 8 percent in inflation, and 2 percent in the real effective exchange rate over time” (Nchor et al., 2016).

Dramani and Frimpong (2020) investigated "the effects of underlying changes in crude oil prices on the stability of Ghana's macroeconomic indicators" (Dramani and Frimpong, 2020). They developed a structural vector autoregressive model to decipher the causes of crude oil market variations. Their goal was to determine how these shocks affected macroeconomic variables, and some specificbilateral exchange rates in Ghana. They also investigated the extent to which the detected shocks influenced the levels of food and non-food prices. The study's findings revealed that shocks related to the supply and demand for oil dynamics had a substantial impact on Ghana's real GDP. Furthermore, the observed shocks had a significant impact on the bilateral exchange rate between Ghana and the Euro. Furthermore, the findings implied that very shock examined in the study had a substantial impact on both food and non-food inflation. This means that oil market disruptions have a negative impact on inflation, hurting both food and non-food costs in Ghana (Dramani and Frimpong, 2020).

Oteng-Abayie, Dramani, Sulemana, and Adusah-Poku (2023) did research titled "The Asymmetric Impact of Oil Price Shocks on Demand for Goods and Services in Ghana." Their study sought to observe the differential impacts of favourable and unfavourable changes in oil prices on overall demand and its diverse constituents spanning from 1970 to 2015. For their analysis, they used a nonlinear ARDL framework. According to the study's results, shocks in oil prices within the Ghanaian context had a persistent and asymmetric influence on overall demand and its constituent parts. More precisely, a positive oil price shift had a larger positive impact on overall demand than an unfavourable one from a fall in oil prices. When the various components of aggregate demand were examined, this trend was similar, with investment expenditures (0.662) having the most noticeable influence. Based on the study's suggestions, the research implications imply that policymakers should consider diversifying their approach to energy consumption. Rather than just exporting crude oil, government should promote processing and domestic use of the commodity. Furthermore, the study recommends that policymakers use hedging tactics and price-smoothing approaches to reduce the volatility of oil prices (Oteng-Abayie et al., 2023).

In a similar manner, Appiah, Oduro, and Benn (2020) conducted research on the empirical examination of the influence of oil consumption and price on Ghana's growth. The study gathered annual time series data, commencing in 1980 and extending up to 2016, and the researchers used the Augmented Dickey-Fuller (ADF) test, the Johansen Cointegration test, and the

Ordinary Least Squares (OLS) estimate process. Real GDP per capita, the amount of crude oil used, the price of crude oil, and the amount spent by the government are the variables that are utilized. Based on the study's results, there exists a correlation that is both positive and a noteworthy statistical relationship was identified between the oil price and long-term growthnevertheless, there is a correlation that is a substantial relationship between crude oil usage and long-term GDP growth. (Appiah et al., 2020).

Chapter Summary

The chapter reviewed literature on crude oil price volatility and industrial output. The theoretical review presented hypotheses that explain how the volatile nature of oil prices might have a ripple effect on the economy. In addition, the empirical review demonstrated the models that were utilized by other researchers, as well as the empirical findings about the effect that fluctuations in the price of crude oil have on countries and the gap that exists as summarised in Table 1. The study therefore, intends to consider the industrial sector of Ghana, the second highest contributor to the country’s GDP and the second highest consumer of refined crude oil products to determine how crude oil price volatility may affect its output.

The current study addresses theoretical, methodological and empirical gaps in line with the nexus between crude oil price volatility and industrial sector output. Theoretically, the nexus between crude oil price volatility and the industrial sector output can be heterogeneous and adaptive (Asafo-Adjei, Adam & Darkwa, 2021), in line with the heterogeneous market hypothesis (Müller et al., 1997) and the adaptive market hypothesis (Lo, 2005). However, prior studies conducted on the impact of other macroeconomic factors on the performance of the industrial sector failed to address the extent to which the nexus is heterogeneous and adaptive (see, Humaira et al., 2019; Iganiga et al., 2021; Jiranyakul, 2016; Tunyo et al., 2021) thereby revealing their asymmetric outcomes. This is because these studies employ methodologies that do not account for the heterogeneous and adaptive behaviours of the industrial sector output.

Overall, existing studies that have investigated the impact or effects of OPV have looked at it concerning macroeconomic indicators. The academic literature on economics is replete with research that investigate the connection between OPV and economic growth without limiting their focus to a particular sector of the economy. To the best of my knowledge, the topic on the impact of OPV on Ghana's industrial sector is almost entirely absent from the relevant body of academic research. As a result, this creates a gap, which in turn makes it necessary to do this research.

Hence, the current study utilises the quantile regression approaches as adopted by prior studies (Adebayo, Rjoub et al., 2022; Archer et al., 2022; Barson et al., 2022; Demir et al., 2020) to divulge the conditions of the market in terms of stress, normal and boom. It also employs the bi-wavelet approach which explores co-movements and lead-lag nexus between time series data across time and frequency (Armah, Amewu & Bossman, 2022; Asafo-Adjei, Adam & Darkwa, 2021; Singh, Bansal & Bhardwaj, 2022). Therefore, the purpose of this study is to bridge the knowledge gap by investigating the effects of OPV on industrial sector output in particular, measuring the asymmetric relationship between crude oil price volatility and industrial sector output, determining the time and frequency connectedness between crude oil price volatility and industrial sector output, and the conditional causality from crude oil price volatility to industrial sector output. Table 1 presents summary and gaps in literature.

Table 1: Summary and Relevance

Author(s)	Title/Topic	Method	Findings/Recommendations
		Global	
Zhang et al. (2022)	How do dynamic jumps in global crude oil prices impact China's industrial sector?	ARMA-EGARCH-X	The study did not consider the conditional causality of oil price on industrial production
Al-Sasi et al. (2017)	The impact of oil price volatility on economic growth.	ADF, OLS, ARDL, and Granger causality methods	The study did not consider time and frequency connectedness between oil price and industrial production
Mo et al. (2019)	Visiting effects of crude oil price on economic growth in BRICS countries: fresh evidence from wavelet-based quantile-on-quantile tests	wavelet-based quantile-on-quantile method	The study was not sector specific. Hence, did not consider the impact of oil price shocks on the subsectors of the industrial sector
Hau, Zhu, Huang, and Ma (2020)	Heterogeneous dependence between crude oil price volatility and China's agriculture commodity futures: Evidence from quantile-on-quantile regression.	time-varying parameter stochastic volatility in mean model	The study focused solely on agriculture and did not consider the impact of oil price shocks on the industrial sector
Ahmed et al. (2017).	Oil price shocks and industry level production using vector autoregression: Empirical evidence from Pakistan.	Vector auto -regression model	The study did not consider the impact of oil price shocks on the subsectors
Eksi et al. (2011)	Reconsidering the relationship between oil prices and industrial production: Testing for cointegration in some of the OECD countries.	Vector auto-regression model	The outcome of a comparative study across multiple countries is limited by its generalized nature, and may vary significantly when each country is examined individually.
Riaz et al. (2016)	Impact of oil price volatility on manufacturing production of Pakistan	EGARCH-in-Mean and the Autoregressive distributed lag regression model	The study did not consider the conditional causality of oil price volatility on manufacturing production

8	Yu et al. (2022)	Oil prices volatility and economic performance during COVID-19 and financial crises of 2007–2008	Wavelet Approach	The study did not consider the quantile asymmetric relationship between oil price fluctuations and economic growth
9	Ahmad et al. (2022).	Macroeconomic effects of crude oil shocks: Evidence from South Asian countries	Impulse response function and the vector auto-regression models	The outcome of a comparative study across multiple countries is limited by its generalized nature, and may vary significantly when each country is examined individually.
		Africa		
10	Akalpler et al. (2018)	The impact of oil price instability on economic growth: Evidence from Nigeria.	Vector Error Correction model and the Granger causality test	The study did not consider time and frequency connectedness between oil price and industrial production
11	Abdulkareem and Abdulkareem (2016)	Analysing oil price-macroeconomic volatility in Nigeria	GARCH models (GARCH-M, EGARCH and TGARCH)	The study did not consider time and frequency connectedness between oil price and industrial production
12	Iganiga et al. (2021)	Oil Price Shocks and Industrial Output in Nigeria; is The Relationship Linear?	Autoregressive distributed lag (ARDL)	The study did not consider time and frequency connectedness between oil price shocks and industrial output
13	Aimer (2016).	The effects of fluctuations of oil price on economic growth of Libya.	Vector error correction model	The study did not consider the quantile asymmetric relationship between oil price fluctuations and economic growth
14	Ogunsakin et al. (2017)	Oil price volatility and macroeconomic performance in two top net oil producing countries in Africa.	Structural Vector Autoregressive (SVAR), the E(GARCH), and the Granger Causality test.	The study did not focus on a particular sector, hence did not consider the impact of oil price shocks on the industrial sector
15	Al-Risheq (2016)	The impact of oil prices on industrial production in developing countries.	Fixed effects model	The study did not consider the conditional causality of oil price on industrial production

		Ghana		
16	Dadzie et al. (2023)	Impact of petroleum energy price volatility on commodity prices in Ghana.	Augmented Dickey Fuller, Granger causality, co-integration, vector autoregressive, and vector error correction models	Omission of a discussion of the broader socio-economic implications resulting from the significant and enduring relationship found between petroleum energy price volatility and commodity prices in Ghana
17	Nchor, Klepáč, and Adamec (2016)	Effects of oil price shocks on the Ghanaian economy	Vector Autoregressive (VAR) and Vector Error Correction (VECM)	The study did not consider the quantile asymmetric relationship between oil price fluctuations and economic growth
18	Dramani and Frimpong (2020)	The effect of crude oil price shocks on macroeconomic stability in Ghana	Structural vector autoregressive model	The study did not consider time and frequency connectedness between oil price and industrial production
19	Oteng-Abayie, Dramani, Sulemana, and Adusah-Poku, (2023)	The asymmetric impact of oil price shocks on the demand for goods and services in Ghana	Nonlinear ARDL	The study primarily focuses on the overall aggregate demand and its constituent parts, including investment expenditures, but it does not delve deeply into how these oil price shocks affect the industrial sector's output or production.
20	Awunyo-Vitor et al. (2018)	Do oil prices influence economic growth in Ghana? An empirical analysis.	The unit root test, the Johansen co-integration test, and the Granger causality test	The study did not focus on a particular sector, hence did not consider the impact of oil price shocks on the industrial sector

Source: Author's Construct (2023)

CHAPTER THREE

RESEARCH METHODS

Introduction

This section provides a comprehensive account of the research methodology, including the research paradigm, approach, and the empirical model specification. Also, this section describes the variables, the associated variable measurements, data sources, and the model estimation methodology.

Research Philosophical Perspectives or Paradigm

Holden and Lynch (2004) state that philosophical perspectives serve as the underlying structures that encompass all academic research. The research paradigm is a comprehensive framework that incorporates fundamental theories, crucial topics, and high-quality research methodologies for obtaining solutions (Hennink, Hutter, and Bailey 2020; Cameron 2009). The two primary philosophical stances in social science are known as ontology and epistemology (Ormston, Spencer, Barnard, & Snape, 2014). Epistemology is the study of how knowledge is recognized within a certain field. In addition to these moderate approaches, positivism and interpretivism represent two poles in the field of epistemology. The positivist school of thought in science accepts as true only objective claims.

The positivist model ensures the researcher and the respondent are kept at arm's length from one another in the pursuit of value-free results (Ormston, Spencer, Barnard, & Snape, 2014.). Not only that, but literature often links positivist paradigms with quantitative research methods (Smith, 1983).

Quantitative research has a large focus on numbers and enables the creation and testing of hypotheses. The Positivist paradigm also follows the deductive approach, which looks at a particular theory, formulates a hypothesis from that theory, and then tests the hypothesis to approve or disprove the theory (Slevitch, 2011). Because of its emphasis on numerical data and its desire to test hypotheses based on theoretical models, this study adheres to the positivist paradigm of epistemology.

Research Design

A study's research strategy may be affected by the research design chosen for the investigation as a whole. The research design is the framework for the study and the starting point from which all other decisions regarding the study, its execution, and its results will be made (Kothari, 2004). Saunders et al. (2012) identify three primary types of research studies: descriptive studies, exploratory studies, and explanatory studies. This study took on an explanatory research strategy since its goal was to assess the influence of one or more independent factors on a second, more important variable. A crucial part of the process of creating and validating theoretical models is using causal research design. This study is based on a causal research design since its authors set out to ascertain whether or not the effect of crude oil price volatility differs across different industries and whether or not there is a temporal and/or spatial correlation between the two.

Research Approach

Research can be characterized as quantitative, qualitative, or a combination of the two. A qualitative work applies to studies that concentrate on naturally occurring phenomena and in natural settings. It draws conclusions about mathematically inappreciable occurrences based on intuitive and perceptual observations. Blending quantitative and qualitative methods into a single strategy is what the mixed approach is all about. It explains the research challenge from both the quantitative and qualitative vantage points in depth (Creswell, 2013). In order to draw conclusions about the course of action of a phenomenon, the mixed research technique combines elements of qualitative and quantitative methodologies (Creswell & Clark 2011). To do this, the current study takes a quantitative approach and attempts to measure the correlation between its independent variables.

The focus of the quantitative method is on quantitative measurement and the use of numerical analysis of data for elucidation purposes. As the collected data can be simply analyzed with common statistical tools, a quantitative methodology will be used for the study. Meanwhile, the quantitative strategy makes use of numerical and measurable data in its strategies, measurements, and designs (Simon, Lee, Cottrell & Verleysen, 2007). In addition to proper measurement of the variables under study, the design relies on the concepts of demonstration, substantiation, and confirmation verifiability. The study is purely quantitative. This is because it deploys quantitative variables both dependent and independent to study the effect of crude oil volatility on the output of the industrial sector and time and frequency connectedness of the industrial sector and crude oil prices volatility.

Data Sources

The study analyzed the effect of crude oil price volatility on the output of Ghana's industrial sector using secondary data for the period of time spanning from 2001 to 2020. The data were in the form of a monthly time series. The price of crude oil, the output of industry, mining and quarrying, manufacturing, oil and gas, construction, water and sewage, and electricity are some of the elements that are taken into account. The research also adjusted for other variables, such as the amount of energy consumed, foreign direct investment, and interest rate. The Energy Commission, the Bank of Ghana (BOG), the International Monetary Fund (IMF), the Ghana Statistical Service (GSS), and the World Bank's database of World Development Indicators (WDI) were the sources of the data.

Theoretical Model Specification

The research creates a theoretical model of the relationship between crude oil price volatility and industrial sector production. using “the symmetric/linear relationship theory of growth” (Hamilton, 1983; Hooker, 1986). This theory argues that fluctuations in oil prices causes changes in economic growth (Taofik, 2018). That is, a surge in the price of oil would therefore lead to a drop in GDP (Taofik, 2018). Based on this theory, the current study presents a theoretical framework of how the price of oil affects economic growth as follows;

$$Y = f(OP) \tag{1}$$

where Y is economic growth, and OP is oil price.

The study follows prior literature to analyse the effect of volatility in oil price on growth (Aimer, 2016; Akalpler et al., 2018; Al-Sasi et al., 2017). Oil price volatility is a measure of how much oil prices change over time, whereas oil price is the actual level of prices at a particular point in time (Taofik, 2018). Higher oil price volatility means that oil prices are more unstable and subject to larger fluctuations, while lower oil price volatility indicates greater stability and predictability in oil prices (Chang, Baloch, Saydaliev, Hyder & Dilanchiev, 2022). Hence, equation 1 can be modified as;

$$Y = f(ROVX) \tag{2}$$

where Y is output, and ROVX is realised crude oil price volatility.

Empirical Model Specification

Estimation Techniques

Based on empirical literature, the effect of crude oil price volatility on the output of the industrial sector was specified using econometric techniques taking into consideration market and economic situations, and time and frequency connectedness. This is relevant to divulge the heterogeneous and adaptive behavior of the market and performance. In this regard, the quantile regression, the conditional causality-in-quantiles test and wavelet approaches are employed.

Quantile regression model

The study used the quantile regression approach to examine the relationship between time series data. It shows the effect of one variable (independent variable) on the conditional distribution of another variable (dependent variable). This technique is applicable when the time series data is not normally distributed, and hence, the coefficient from the mean equation of the Ordinary Least Square (OLS) technique would not be reliable (Koenker & Bassett, 1978). Hence, quantile regression is adopted to assess the asymmetric effect of one variable on the quantiles of another variable. The quantile regression model is shown as

$$Y_t = \beta_0(\theta) + \beta_1 X_t(\theta) + \mu_t(\theta) \tag{3}$$

where Y denotes output of the industrial sector at time t, X_t represents realised crude oil price volatility at period t. Moreover, θ is the θth quantile of the regressors and β represents parameters to be estimated at each quantile.

Existing studies such as Adebayo, Rjoub, Akinsola and Oladipupo (2022), Archer, Owusu Junior Adam, Asafo-Adjei and Baffoe (2022), Barson, Owusu Junior, Adam and Asafo-Adjei (2022), Boateng, Adam and Owusu Junior (2021), Demir, Pesqué-Cela, Altunbas and Murinde (2020), among others made use of the quantile regression approach. The quantile regression technique, introduced by Koenker and Bassett in the 1970s, models the conditional quantile of a response variable as a linear function of the explanatory variables, in contrast to the traditional practice of using only the conditional mean. This approach yields more reliable estimates in the presence of outliers in the response variable. Moreover, quantile regression provides a detailed understanding of the impact of the independent variable on the response variable.

Examining correlations between realised crude oil volatility and returns on output of the industrial sector occurred across 19 different quantiles, ranging from the 0.05^{th} to the 0.95^{th} quantile. These quantiles were chosen in order to determine whether changes in the price of realised crude oil would also affect the industrial sector's output. Hence, based on the quantiles of the study, three varying economic conditions are used. They are stress (0.05-0.35), normal (0.40-0.65) and boom (0.70-0.95) as advocated by prior studies (Adebayo et al., 2022; Archer et al., 2022; Demir et al., 2020).

As a result, estimates using quantile regression are more robust to outliers in the response measurement. In addition to this, quantile regression provides a more in-depth look at a regressand's dependence on an independent variable. In other words, it comprehensively describes and characterizes the data by displaying the effects of the regressor on the explanatory variable over the range of the dependent variable. To illustrate how the two variables are related, this is done. In most cases, the equation that best describes the quantile regression model is as follows:

$$Y_t(\theta|\mathrm{X}) = \beta(\theta)X_t' + \mu_t(\theta) \qquad (4)$$

where β_θ represents the vector of unknown parameters related with the θth quantile. The quantile regression minimizes $\Sigma_t\ \theta|\mu_t| + \Sigma_t\ (1-\theta)|\mu_t|$, as a result, the sum provides the asymmetric penalties $\theta|\mu_t$ for underprediction and $(1-\theta)|\mu_t|$ for overprediction. The optimization problem outlined below can be used to determine the coefficient or the quantile estimator.

$$\min \sum_{t\epsilon\{Y_t\geq X'_{t\,\theta}\}}^{n} \theta|\ Y_t - X_t'\beta\ | + \sum_{t\epsilon\{Y_t< X'_{t\,\theta}\}}^{n} (1-\theta)|\ Y_t - X_t'\beta\ | \qquad (5)$$

where Y_t is the dependent variable and X_t is a K by 1 vector of regressors.

Examining correlations between realised crude oil volatility and returns on output of the industrial sector occurred across 19 different quantiles, ranging from the 0.05th to the 0.95th quantile. These quantiles were chosen in order to determine whether changes in the price of realised crude oil would also affect the industrial sector's output. Hence, based on the quantiles of the study, three varying economic conditions are used. They are stress (0.05-0.35), normal (0.40-0.65) and boom (0.70-0.95) as advocated by prior studies (Adebayo et al., 2022; Archer et al., 2022; Demir et al., 2020).

Empirical objective one

This objective estimates the asymmetric relationship between realised crude oil price volatility and industrial sector output. After controlling for interest rate, energy consumption, crude oil price and foreign direct investment, the equation can be specified as;

$$Output_t = \beta_0(\theta) + \beta_1 OP_t(\theta) + \beta_2 ROVX_t(\theta) + \beta_3 EC_t(\theta) + \beta_4 int_t(\theta) + \beta_5 FDI_t + +\mu_t(\theta) \quad (6)$$

where Output_t denotes industrial sector output at time t, ROVX_t represents realised crude oil price volatility at period t. Again, OP, int, EC and FDI are the control variables representing crude oil price, interest rate, energy consumed and foreign direct investment respectively. Moreover, θ is the θth quantile of the regressors and β represents parameters to be estimated at each quantile.

Nonlinear causality-in-quantiles approach

The study utilizes the nonlinear causality-in-quantile approach as suggested by Balcilar, Gupta and Pierdzioch (2016) to explore the causality between two variables. Hence, to assess causality at diverse distributions of a variable for time series data that are non-normally distributed and non-linear, the causality-in-quantile test is preferred (Archer et al., 2022; Hammoudeh & Roubaud, 2019; Jena, Tiwari, Jeong, Härdle & Song, 2012). The study tests that y_t is not caused by x_t at various θ-quantile based on the lag-vector of $\{y_{t-1}, \dots, y_{t-p}, x_{t-1}, \dots, x_{t-p}\}$ if

$$Q_\theta(y_t | y_{t-1}, \dots, y_{t-p}, x_{t-1}, \dots, x_{t-p}) = Q_\theta(y_t | y_{t-1}, \dots, y_{t-p}) \quad (7)$$

Nonetheless, x_t causes y_t in the θ-quantile based on $\{y_{t-1}, \dots, y_{t-p}, x_{t-1}, \dots, x_{t-p}\}$ if

$$Q_\theta(y_t | y_{t-1}, \dots, y_{t-p}, x_{t-1}, \dots, x_{t-p}) \neq Q_\theta(y_t | y_{t-1}, \dots, y_{t-p}) \quad (8)$$

where $Q_\theta(y_t | \cdot)$ represents the θ-quantile of y_t. It must be noted that the conditional quantiles of y_t, $Q_\theta(y_t | \cdot)$ rely on t whereas the quantiles range between 0 and 1.

By defining the vectors $Y_{t-1} = (y_{t-1}, \dots, y_{t-p})$, $X_{t-1} = (x_{t-1}, \dots, x_{t-p})$, and $\gamma_{t-1} = (X_t, Y_t)$. Hence, functions $F_{yt|\gamma_{t-1}}(y_t|\gamma_{t-1})$ and $F_{yt|Y_{t-1}}(y_t|Y_{t-1})$ are the conditional distribution functions of y_t conditioned on vectors γ_{t-1} and Y_{t-1} correspondingly. Accordingly, as indicated by Jena et al. (2019), the causality-in-quantile hypothesis regarding equations (9) and (10) can be shown as:

$$H_0: P\{F_{yt|\gamma_{t-1}}\{Q_\theta(Y_{t-1})|\gamma_{t-1}\} = \theta\} = 1 \quad (9)$$

$$H_1: P\{F_{yt|\gamma_{t-1}}\{Q_\theta(Y_{t-1})|\gamma_{t-1}\} = \theta\} < 1 \quad (10)$$

Equation (9) (H_0 – Null Hypothesis):

Where:

P {} represents the probability.

F(yt|γ(t-1)) is a conditional probability distribution of variable yt given γ(t-1).

Qθ(Y(t-1) |γ(t-1)) is another conditional probability distribution of variable Y(t-1) given γ(t-1).

θ is a parameter.

Equation 9 is essentially stating the null hypothesis (H_0). It's saying that the probability of the event F(yt|γ(t-1)) Qθ(Y(t-1) |γ(t-1)) being equal to θ is equal to 1. Suggesting that there is no significant relationship or difference between the two conditional probability distributions F(yt|γ(t-1)) and Qθ(Y(t-1) |γ(t-1)).

Equation (10) (H_1 - Alternative Hypothesis):

Where:

P {} represents the probability.

F(yt|γ(t-1)) is, once again, a conditional probability distribution of variable yt given γ(t-1).

Qθ(Y(t-1) |γ(t-1)) is the conditional probability distribution of variable Y(t-1) given γ(t-1).

θ is a parameter.

Equation 10 is the alternative hypothesis (H1). It suggests that the probability of the event F(yt|γ(t-1)) Qθ(Y(t-1) |γ(t-1)) being equal to θ is less than 1. This implies that there is evidence to suggest that there might be a significant relationship or difference between the two conditional probability distributions F(yt|γ(t-1)) and Qθ(Y(t-1) |γ(t-1)).

Empirical objective two

This objective determines the conditional causality of realised crude oil price volatility to industrial sector output.

The study tests that $Output_t$ is not caused by $ROVX$ at various θ-quantile based on the lag-vector of $\{Output_{t-1}, \dots, Output_{t-p}, ROVX_{t-1}, \dots, ROVX_{t-p}\}$ if

$$Q_\theta(Output_t | Output_{t-1}, \dots, Output_{t-p}, xROVX_{t-1}, \dots, ROVX_{t-p}) = Q_\theta(Output_t | Output_{t-1}, \dots, Output_{t-p}) \quad (11)$$

Nonetheless, $ROVX_t$ causes $Output_t$ in the θ-quantile based on $\{Output_{t-1}, \dots, Output_{t-p}, ROVX_{t-1}, \dots, ROVX_{t-p}\}$ if

$$Q_\theta(Output_t | Output_{t-1}, \dots, Output_{t-p}, ROVX_{t-1}, \dots, ROVX_{t-p}) \neq Q_\theta(Output_t | Output_{t-1}, \dots, Output_{t-p}) \quad (12)$$

where $Output_t$ denotes industrial sector output at time t, ROVX_t represents realised crude oil price volatility at period t.

Bi-wavelet model

The bi-wavelet approach is presented to find out the time and frequency connectedness between two time series data. This approach is necessary in deciphering the calendar time and horizon (short, medium and long-terms) resource management decisions are useful depending on the kind of directional connectedness between two time series data. Since the bi-wavelet is non-parametric bivariate, it is impossible to control for any other variable. Also, this method can be used irrespective of the assumption(s) about the time series data.

Torrence and Compo (1998) define the wavelet transform coherence (WTC) as the normalization of the squared cross-absolute spectrum. The squared wavelet coherence is denoted as

$$R^2(x, y) = \frac{|\rho(s^{-1} W_{x.y}(i,s))|^2}{\rho(s^{-1}|W_x(i,s)|^2)\rho(s^{-1}|W_y(i,s)|^2)} \quad (13)$$

where x and y shows co-movements between two variables, ρ is a smoothing factor and the square difference ranges from 0 and 1, wherein a value near to 0 indicates a poor co-movement, whereas a number close to 1 indicates a significant co-movement. The WTC phase difference depicts the oscillation's disruptions. Bloomfield, McAteer, Lites, Judge, Mathioudakis, and Keenan (2004) analyze the phase difference between x(t) and y(t).

$$\emptyset_{xy}(\text{i}, s) = tan^{-1}\left(\frac{\Im\{S(s^{-1}W_{xy}(\text{i},s))\}}{\Re\{S(s^{-1}W_{xy}(\text{i},s))\}}\right) \quad (14)$$

where $\Im$ and $\Re$ stand for imaginary and real operators, respectively.

In graphical terms, the arrows pointing to the right (left) represent in-phase (out-of-phase) time series. A downward-pointing arrow suggests that the second time series trails the first by $\pi/2$, whereas an arrow pointing upward indicates that the first time series trails the second by $\pi/2$. Places with a lot of co-movements are shown by a red (warm) while areas with fewer co-movements are indicated by a blue (cool). An extended methodology of the bi-wavelet approach can be found in the works of Armah, Amewu and Bossman (2022), Asafo-Adjei, Adam and Darkwa (2021), Singh, Bansal and Bhardwaj (2022), among others.

Empirical objective three

This objective quantifies the responsiveness of the industrial sector output to realised crude oil price volatility across time and frequency.

$$R^2(ROVX, Output) = \frac{\left|\rho(s^{-1}W_{ROVX.Output}(\text{i},s))\right|^2}{\rho(s^{-1}|W_{ROVX}(\text{i},s)|^2)\rho(s^{-1}\left|W_{Output}(\text{i},s)\right|^2)} \quad (15)$$

where $ROVX$ and $Output$ shows industrial sector output and realised crude oil price volatility.

Variable Descriptions and Sources of Data

Table 2 presents codes, names of variables, unit of measurement, data sources and a priori. The variables listed in the table below were used to analyse the nexus between crude oil price volatility and industrial sector output in Ghana.

Table 2: Description of Variables, Units, and Sources of Data

Codes	Variable	Unit of Measurement	Data Source	Expected Sign
SO	Industrial Sector Output	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
OP	Crude Oil Price	International Brent crude oil price – Monthly average	Bank of Ghana (BOG) 2001-2020	
ROVX	Crude Oil Price Volatility	was measured using the realised crude oil price volatility extracted using the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model.	GARCH process in EViews 2001-2020	-
MFG	Manufacturing Subsector	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
MQ	Mining and Quarrying Subsector	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
ELECT	Electricity Subsector	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
CONS	Construction Subsector	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
WS	Water and Sewerage Subsector	measured as the value-added output in millions of cedis (GH)	Ghana Statistical Service (GSS) 2001-2020	NA
EC	Energy Consumed	measured as kilotonnes of oil equivalent	Energy Commission 2001-2020	+
FDI	Foreign Direct Investment	Foreign direct investment, net inflows (BoP, current)	World Development Indicators (WDI) 2001-2020	+
NT	Interest Rate	measured as the average commercial bank lending rate.	Bank of Ghana (BOG) 2001-2020	+

Source: Author's Compilation (2023)

Data Processing and Analysis

The Chow and Lin (1971) extrapolation technique was used in conjunction with the E-Views statistical package to produce the monthly time series for the industrial sector, the manufacturing sub-sector, the mining and quarrying sub-sector, the construction sub-sector, the water and sewage sub-sector, the electricity sub-sector which were available in quarterly form, and the foreign direct investment which was in an annual form. Because there are no restrictions on the sub-periods that can be used when disaggregating data with this approach, there is no danger to the reliability of the findings when employing it. Using monthly time series data for this study is justified as it aligns with the frequency of available data on crude oil prices and ensures that we can capture more detailed variations in both crude oil prices and industrial output over time, allowing for a more precise examination of the connection with crude oil price volatility and industrial output in Ghana. Additionally, the conversion of quarterly industrial output data to a monthly frequency allows for consistent temporal alignment and reduces potential data inconsistencies that might arise from using mismatched time intervals.

The data was further processed using the natural logarithm of the time series data except for the realised crude oil volatility which was extracted in logarithmic returns through the GARCH (1,1) process. To aid in the descriptive analysis, the study employed charts such as minimum, maximum, median, mean, Kurtosis, Skewness, standard deviation (Std. Dev), Jarque-Bera statistic, Kwiatkowski–Phillips–Schmidt–Shin test (KPSS), Pearson's r and the Teraesvirta neural network (TRSNN) were used to find a correlation between the two variables. In particular, we utilize skewness and kurtosis to look at the distribution's overall symmetry (asymmetry) and peakedness (flatness), respectively.

Both the skewness and kurtosis are combined to assess normality of the data. This is hypothetically confirmed by the Jarque-Bera statistic based on the 5% significance level. The KPSS test was subsequently used to assess issues of stationarity. The Teraesvirta Neural Network (TRS) test was used to address linearity of the data. Correlation matrix is shown to ascertain the direction and magnitude of variables' connectivity as well as determine their degree of collinearity. The mean, standard deviation (Std. Dev), Kurtosis, Skewness,, Jarque-Bera statistic were estimated using the EViews -10 statistical software. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and the Teraesvirta Neural Network (TRSNN) method were analysed through the R programming statistical software.

The three research questions were answered using the quantile regression, conditional causality in quantiles and bi-wavelet approaches respectively. The quantile regression was used assess the effect of realised crude oil price volatility on varying economic conditions of the industrial sector (Adebayo et al., 2022). The economic conditions considered in this study as also supported by prior studies are stress, normal and boom economic conditions (Adebayo et al., 2022; Archer et al., 2022; Barson et al., 2022; Boateng et al., 2021; Demir et al., 2020). The causality in quantiles test was used to investigate the conditional causality from crude oil price volatility to industrial sector output. The bi-wavelet was also employed to examine the specific time and frequency (investment horizon of short, medium and long-terms) at which either crude oil or industrial sector variable leads/or lag the other. The main estimations were performed using the R programming statistical software.

Chapter Summary

This chapter detailed the research methods that were followed to complete the study. This study took a quantitative methodology, grounded on the positivist research paradigm. The study employed an explanatory research methodology because its researchers wanted to know how oil price volatility affected Ghana's industrial sector. This research made use of secondary data collected on a monthly basis from 2001 to 2020. The study quantitatively examined the influence of realised crude oil volatility on the industrial sector of Ghana. This effect was executed across economic conditions (stress, normal and boom) as well as time and frequency. For this reason, the quantile regression and bi-wavelet approaches were utilised as the study's estimation techniques. A preliminary data analysed was investigated to first assess the time series data in terms of normality, stationarity, and linearity justifying the use of robust techniques that could explain the dynamics of the nexus.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This research seeks to analyse the nexus between realised crude oil price volatility and industrial sector output at consolidated and segmented levels in Ghana. It employed five sub-divisions within Ghana's industrial sector, comprising mining and quarrying, manufacturing, electricity generation, water treatment, and construction. The industry sector aggregate was added in this study for further inferences. The findings of this study were presented in this chapter and discussion following a quantitative research methodology coupled with an explanatory research framework. Accordingly, the study employs a secondary source data between 2001 to 2020 which was a monthly time-series data. The chapter's organization is structured in the following manner: First, descriptive statistics of the monthly time series data is performed. Second, the main estimations are performed using the quantile regression, bi-wavelet and conditional causality in quantiles approaches.

Descriptive Statistics

The descriptive statistics is made up of realised crude oil price volatility (ROVX), crude oil price (OP), five industrial sector divisions and the industrial sector output. These were construction (CONS), electricity (ELECT), manufacturing (MFG), mining and quarrying (MQ), and water and sewerage (WS). The industry sector output (ISO) was also included. Four control variables were employed to supplement the quantile regression estimation. These are energy consumption (EC), foreign direct investment (FDI), interest rate (INT), and crude oil prices (OP). The variables used in the descriptive statistics are in natural logarithm with exception to the crude oil price volatility which is in its natural logarithmic returns extracted through the GARCH (1,1) model. The transformation of crude oil price volatility into natural logarithmic returns through the GARCH (1,1) model is crucial in this empirical analysis for several reasons. Natural logarithmic returns are preferred in financial and economic studies as they capture percentage changes in price, making them a more meaningful representation of asset price dynamics. Additionally, the GARCH (1,1) model specializes in modeling volatility, and expressing conditional variances as natural logarithmic returns facilitates the interpretation of volatility changes. Moreover, using natural logarithmic returns enhances the statistical properties and interpretability of the variable, ensuring that it aligns better with the assumptions required for accurate regression analysis in the study of its impact on industrial output in Ghana.

Minimum, maximum, median, mean, standard deviation (Std. Dev), skewness (SKS), kurtosis, Jarque-Bera, Kwiatkowski–Phillips–Schmidt–Shin test (KPSS) and Teraesvirta Neural Network (TRSNN) tests were performed to first ascertain the nature, distribution, stationarity and linearity of the time series data. Particularly, the skewness and kurtosis are respectively used to examine the degree of symmetry (asymmetry) and peakedness (flatness) of the distribution. Both the skewness and kurtosis are combined to assess normality of the data. Standard deviation values closer to zero indicates less dispersion within the dataset. Skewness values that are closer to zero denotes a symmetrical distribution, otherwise asymmetrical distribution (positively or negatively skewed). Also, kurtosis values between -0.5 and +0.5 suggests a mesokurtic distribution. On the other hand, Kurtosis values above 0.5 means a leptokurtic distribution, but a platykurtic distribution if less than -0.5.

This is hypothetically confirmed by the Jarque-Bera statistic with a null hypothesis of normality. The KPSS test is subsequently used to assess issues of stationarity with a null hypothesis of a stationary series. The Teraesvirta Neural Network (TRSNN) test is used to address linearity of the data with a null hypothesis of a linear relationship. All the hypothetical tests are assessed at the 5% significance level. The number of observations (N) of the variables are also presented in Table 3.

Table 3: Descriptive Statistics

	Min	Max	Median	Mean	Std. Dev.	SKS	Kurtosis	Jarque-Bera	KPSS	TRSNN	N
CONS	6.361	10.274	8.464	8.402	1.325	-0.192	1.499	24.023**	4.885**	97.861**	240
EC	6.326	7.299	6.811	6.772	0.227	-0.155	2.732	1.685**	4.236**	9.194**	240
ELECT	5.411	8.552	6.858	6.974	1.057	0.148	1.580	21.032**	4.859**	39.084**	240
FDI	17.892	22.079	21.677	20.953	1.356	-1.131	2.591	52.883**	3.465**	49.170**	240
INT	3.042	3.866	3.311	3.339	0.173	1.243	4.575	86.568**	2.238**	2.418	240
ISO	8.433	11.765	10.171	10.148	1.057	-0.029	1.614	19.249**	4.917**	58.151**	240
MFG	7.614	10.792	9.344	9.271	0.908	-0.081	1.857	13.317**	4.876**	3.311	240
MQ	7.404	10.768	9.040	9.029	1.127	0.100	1.527	22.092**	4.844**	31.942**	240
OP	2.911	4.888	4.128	4.066	0.492	-0.367	2.277	10.621**	1.504**	2.602	240
ROVX	0.004	0.167	0.007	0.011	0.017	6.932	58.950	33225.970**	0.265	11.906**	240
WS	4.809	8.113	6.351	6.368	1.042	0.150	1.625	19.812**	4.853**	11.710**	240

Source: Author’s Construct (2023)

*Note: The variables CONS, EC, ELECT, FDI, INT, ISO, MFG, MQ, OP, ROVX and WS represent Construction, Energy consumption, Electricity, Foreign Direct Investment, Interest rate, Industry Sector Output, Manufacturing, Mining and Quarrying, Crude oil price, Realised crude oil price volatility, and Water and Sewerage respectively. Also, **, and * denotes significance at 1% and 5% respectively. Min, Max, Std. Dev., SKS, KPSS, TRSNN, and N denote Minimum, Maximum, Standard deviation, Skewness, Kwiatkowski–Phillips–Schmidt–Shin test (KPSS), Teraesvirta Neural Network, and number of observations of the data respectively.*

Table 3 illustrates the minimum, maximum, median and mean values of the variables. FDI (min; 17.892, max; 22.079, median; 21.67, mean; 20.953) has the highest values for all four statistics (minimum, maximum, median and mean), indicating that it has the highest overall values compared to the other variables. ROVX has the lowest values (min; 0.004, max; 0.167, median; 0.007, mean; 0.011) for all four statistics, indicating that it has the lowest overall values compared to the other variables. This is not surprising because logarithmic returns were used for ROVX relative to the natural logarithm of the remaining variables. For most variables, the mean and median are relatively close, suggesting that the distribution of values is roughly symmetric. However, for INT, the mean is slightly higher than the median, suggesting that there may be some outliers on the high end of the distribution. The ranges between the minimum and maximum values vary widely across variables, from a narrow range of 0.163 (ROVX) to a wide range of 4.187 (FDI).

Furthermore, from Table 3, the standard deviation values closer to zero means that the data points of the variables are less disperse. For instance, a standard deviation value of 0.227 for EC, 0.173 for INT, 0.492 for OP and 0.017 for ROVX. The standard deviation values for these variables approaching zero illustrate that these variables are less dispersed. It is also observable that the variables are closer to symmetry as the skewness values approach zero except for ROVX, FDI and INT that depart from symmetry. The Kurtosis values for all variables above 0.5 indicates that the variables have a leptokurtic distribution. Since there is no simultaneous symmetry and mesokurtic distribution for each variable, they are considered not normally distributed. This is confirmed by the Jarque-Bera statistic with a null hypothesis of normality. Because the Jarque-Bera statistic for all the time series data are significant at the 1% level, the null hypothesis is rejected to mean that the series are not normally distributed.

Additionally, it can be seen from the KPSS test with a null hypothesis of a stationary series at a 1% level, the null hypothesis of the test is rejected except for ROVX. Hence, almost all the series are not stationary. Moreover, to investigate linearity of the variables, the Teraesvirta Neural Network (TRS) test with a null hypothesis of linearity is used. It can be confirmed that at the 1% level the null hypothesis of the series (except for INT, MFG and OP) is rejected. This indicates that most of the series are not linear. As shown, the non-normal distribution, non-stationary series and the non-linear series permit the application of the quantile regression and bi-wavelet approaches since they are robust in such circumstances as confirmed by prior studies (Adebayo et al., 2022; Archer et al., 2022; Armah, Amewu & Bossman, 2022; Demir et al., 2020; Singh, Bansal & Bhardwaj, 2022).

The time series presentation of the main variables for this study are presented in Figure 7. Since, ROVX obtained through the GARCH (1,1) model discussed in appendix A is in logarithmic returns, and the industrial sector output variables are in natural logarithm, the series are presented separately, and their patterns are observed across time.

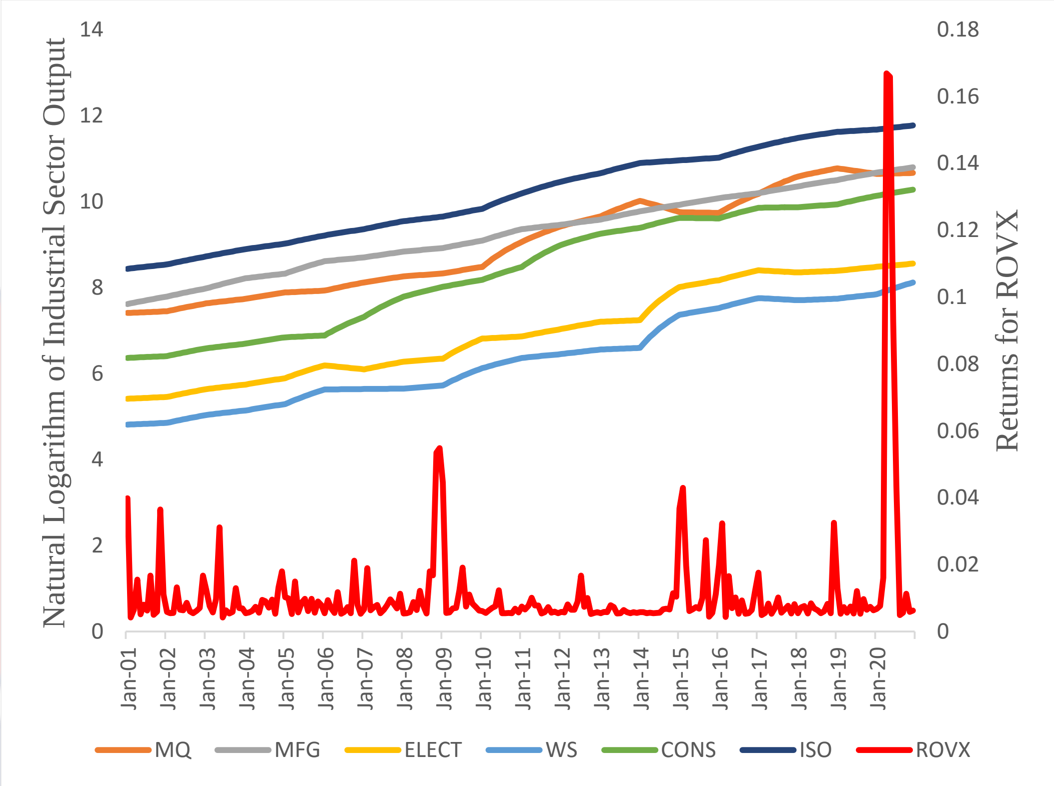

Figure 7: Time series plots of ROVX and Industrial Sector Output
Source: Author's Construct (2023)

Note: The variables, MQ, MFG, ELECT, WS, CONS, ISO, and ROVX represent Mining and Quarrying, Manufacturing, Electricity, Water and Sewerage, Construction, Industrial Sector Output, and Realised crude oil price volatility, respectively.

Figure 7 depicts observable shocks in ROVX over time, with major fluctuations during periods of economic crises, such as the 2008 Global Financial crisis, the British exit from the European Union (BREXIT) in 2016, and the COVID-19 Pandemic in 2020. In contrast, the natural logarithm of the industrial sector output trends upward, despite experiencing occasional downturns during these same crisis periods. Thus, an increase in crude oil volatility shocks can be observed with a decline in certain sub-sectors such as construction, manufacturing, and mining and quarrying. On the other hand, a rise in electricity and water and sewerage sector output can be observed during BREXIT. Additionally, Figure 7 illustrates a slight decline in the industrial sector output amidst the COVID-19 Pandemic. Therefore, to understand the potential opposing movements between crude oil volatility and some industrial sector outputs, inferential analysis must be performed to assess the susceptibility of the industrial sector to shocks from ROVX.

Correlation Matrix

The correlation matrix (see Appendix B) shows the level of relationship between the variables. The variables used in the correlation matrix are in natural logarithm with exception to the crude oil price volatility which is in its natural logarithmic returns. Direction and size of the relationship are both made clear. To assess potential issues related to multicollinearity, it is essential to conduct a correlation test. This test serves as a means to identify and address concerns arising from multicollinearity in the study's variables. It is recommended that the correlation coefficient between two independent (explanatory) values be less than 0.8, as suggested by prior research (Gujarati & Porter, 2009; Obite, Olewuezi, Ugwuanyim, & Bartholomew, 2020).

Interest rate is negatively correlated with all the variables (see Appendix B). The connection between crude oil price and the industrial sector is positive and significant. This implies that crude oil price is a possible predictor of the industrial sector and can be treated as part of the selected control variables. The realised crude oil price volatility (ROVX) is less connected to the industrial sector as shown from the magnitude of the correlation coefficients depicting weak correlations. This is not startling because the realised crude oil volatility forms part of the crude oil price as shocks which seldomly occur and might not entirely reflect the behavior of other markets across all economic conditions as well as time and frequency.

It must be noted that the high correlation values (above 0.8) between the dependent variables (industrial sector and sub-sectors) as well as between the dependent and explanatory variables (in the cases of CONS and EC; CONS and FDI; MFG and FDI) do not raise multicollinearity issues. Hence, multicollinearity becomes a problem when the explanatory variables are rather highly connected as advocated by prior studies (Nkrumah-Boadu, Owusu Junior, Adam, & Asafo-Adjei, 2022; Obite, Olewuezi, Ugwuanyim, & Bartholomew, 2020). Accordingly, the relationships between the explanatory variables with correlation coefficients less than 0.8 can be considered ideal with no issues of multicollinearity in the quantile regression model of this study.

The Asymmetric Relationship between Realised Crude Oil Price Volatility and Industrial Sector Output

Asymmetric Model Results

This section shows estimates from the quantile regression approach on the effect of realised crude oil price volatility (ROVX) on the industrial sector output. The industrial sector output includes the five divisions of the industrial sector (construction (CONS), electricity (ELECT), manufacturing (MFG), mining and quarrying (MQ), and water and sewerage (WS)) and the aggregated industrial sector output (ISO). Four control variables were employed to supplement the quantile regression estimation. These are energy consumption (EC), foreign direct investment (FDI), interest rate (INT) and crude oil price (OP).

Estimates are presented for 19 quantile (τ) distributions of industrial sector output from 0.05 through to 0.95. The lower quantile range of 0.05-0.35 (which represents stressful economic conditions), the middle quantile of 0.40-

0.65 (which represents normal economic conditions), and the higher quantile of 0.70-0.95 (which represents economic boom) are used to illustrate economic conditions of industrial sector output (see, Adebayo et al., 2022; Archer et al., 2022; Demir et al., 2020). The effect of realised crude oil price volatility (ROVX) on the economic conditions of the construction industry (CONS) is presented in Table 4.

Table 4:Quantile Regression Estimates (ROVX on CONS)

	Construction Sub-sector				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	-0.2142	0.3292	-0.8838	0.4430	0.6035***
0.10	-0.7599	-2.1002	-0.3254	-0.2283	0.6424***
0.15	-1.0577**	-4.8242	0.6048	-1.3345	0.5880***
0.20	-1.5771***	-6.5571	1.4963***	-2.7285***	0.6375***
0.25	-1.3201***	-6.0308	1.3928***	-2.7390***	0.6348***
0.30	-1.3184***	-6.3169	1.3426***	-2.7590***	0.6567***
0.35	-1.1205***	-6.0773	1.3764***	-2.8708***	0.6326***
Normal					
0.40	-1.0429***	-6.0172	1.3675***	-2.9213***	0.6319***
0.45	-1.0299***	-6.3005	1.3530***	-2.9455***	0.6408***
0.50	-0.9837***	-6.7112	1.4501***	-3.0548***	0.6208***
0.55	-0.9814***	-4.8618	1.4794***	-3.1215***	0.6231***
0.60	-0.9711***	-4.6634	1.3860***	-3.0530***	0.6422***
0.65	-0.8919***	-3.8564	1.2649***	-2.9357***	0.6494***
Boom					
0.70	-0.7955***	-4.0716*	1.4056***	-2.8595***	0.5770***
0.75	-0.7243***	-3.7101*	1.3453***	-2.6657***	0.5551***
0.80	-0.6658***	-3.3303**	1.2376***	-2.5742***	0.5660***
0.85	-0.6552***	-3.3506**	1.2067***	-2.5593***	0.5728***
0.90	-0.6036***	-3.0785*	1.1043***	-2.4660***	0.5836***
0.95	-0.4011***	-0.5511	1.0427***	-2.3587***	0.5498***

Source: Author's Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

As presented in Table 4, it is observable that the effect of ROVX on the output of the construction sub-sector is negative. Therefore, ROVX transmits negative shocks to the construction industry. The negative effect of

ROVX on boom economic conditions (quantiles 0.7-0.90) of the construction sub-sector output is significant. This implies that the realised crude oil volatility has a substantial effect on the construction sub-sector when the economic conditions are favorable. In other words, extreme good performance of the construction sub-sector attracts negative shocks from the realised crude oil. On the other hand, at stressed (quantiles 0.05-0.35) and normal economic conditions (quantiles 0.40-0.65) of the construction sub-sector, there is insignificant nexus between the construction sector and realised crude oil price volatility.

Moreover, from Table 4, the control variables have significant effects on the construction sector at most quantiles of the construction sector. For instance, rising crude oil prices have a depressing effect on construction sub-sector in down, steady, and up markets from quantiles 0.15 to 0.95. However, investors of the energy market and the construction sector may find the markets attractive with the quest of offering diversification benefits. On the other hand, energy consumption has a positive effect on the construction sub-sector from quantiles 0.20 to 0.95. Hence, inadequate energy supply is expected to push up crude oil price which will increase the production cost of the construction sub-sector, and thereby reducing output. Inadequate energy supply and inefficient energy consumption, as argued by Kassim and Isik (2020), mitigate industrial expansion, warranting cautious observation of the negative nexus at all quantiles.

The nexus between interest rate and the construction sub-sector is negative and significant for quantiles 0.20 to 0.95. Favorable growth in the construction sub-sector is correlated with increased energy consumption and foreign direct investment (FDI). Beji and Belhadj (2014) highlighted the long-term benefits of industrialization, including increased economic diversity, the spread of new technologies, lower unemployment rates, and higher living standards, thus the beneficial effect of energy consumption should come as no surprise. For this reason, the building sector is strongly reliant on the energy industry to keep its operations running smoothly. As noted from the construction industry, Table 5 also shows the effect of realised crude oil price volatility on the electricity sub-sector.

Table 5: Quantile Regression Estimates (ROVX on ELECT)

	Electricity Sub-sector				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	0.0815	-0.1055	1.0843**	-0.7164	0.0400
0.10	-0.1109	1.9656	1.5547***	-1.2656*	0.0150
0.15	-0.7880	-6.9583	1.6364***	-1.8243***	0.2198
0.20	-1.3559***	-5.6443	1.4172***	-2.1837***	0.4687***
0.25	-1.3244***	-6.1381	1.2174***	-2.1069***	0.5246***
0.30	-1.2737***	-6.1101	1.1056***	-2.0811***	0.5515***
0.35	-1.1798***	-6.7185	1.2664***	-2.2820***	0.5184***
Normal					
0.40	-1.1962***	-7.4064	1.2722***	-2.3521***	0.5343***
0.45	-1.2548***	-8.8669**	1.4359***	-2.5041***	0.5206***
0.50	-1.2681***	-6.4849	1.4576***	-2.4868***	0.5144***
0.55	-1.3300***	-6.9157**	1.4645***	-2.5122***	0.5298***
0.60	-1.3772***	-7.1541**	1.4132***	-2.4920***	0.5535***
0.65	-1.3797***	-6.9978***	1.4868***	-2.5557***	0.5419***
Boom					
0.70	-1.3680***	-7.2333***	1.5234***	-2.5885***	0.5342***
0.75	-1.4052***	-7.5121***	1.4799***	-2.5851***	0.5566***
0.80	-1.4380***	-8.3503***	1.5907***	-2.6227***	0.5362***
0.85	-1.3891***	-7.9962***	1.4728***	-2.5248***	0.5514***
0.90	-1.1655***	-6.6657**	1.2601***	-2.3081***	0.5461***
0.95	-0.9081***	-3.3960*	1.0088***	-2.1240***	0.5512***

Source: Author's Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

From Table 5, there is a negative significant effect of ROVX on electricity sub-sector at middle quantile (0.45, 0.55, 0.60 and 0.65) and upper quantile (0.70-0.95) respectively representing normal and boom economic situations. However, unlike the construction industry, the electricity sub-sector is susceptible to negative shocks from ROVX at normal market situations in addition to boom. That is, effect from the ROVX is crucial during normal and boom market situations of the electricity industry. Conversely, the electricity industry output is insulated against negative shocks from ROVX during stressed conditions of the electricity industry output. For investors, it is better to diversify or hedge against volatility in the electricity sub-sector by observing the ROVX with other comparable investible assets, for instance, the crude oil price.

Additionally, the control variables have significant effect on the electricity sub-sector at most quantiles as found for the construction sector. As a result, the electrical sector is negatively impacted by rising crude oil prices in all three economic conditions (stress, normal, and boom – quantiles 0.20-0.95). However, investors of the energy market and the electricity sub-sector may find the markets attractive with the quest of offering diversification benefits. This outcome is similar to that of the nexus between interest rate and the electricity sub-sector (quantiles 0.10-0.95). On the other hand, the growth of the electricity sub-sector is positively correlated with both the consumption of energy (quantiles 0.05-0.95) and the inflow of direct foreign investment (quantiles 0.20-0.95). Table 6 shows the results of the study's further investigation into the effect of crude oil price volatility on the manufacturing sub-sector.

Table 6: Quantile Regression Estimates (ROVX on MFG)

	Manufacturing Sub-sector				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	-0.1805	-1.3202	1.7648***	-1.3133***	0.0889
0.10	-0.3651	-1.5071	1.6406***	-1.3222***	0.1688**
0.15	-0.5948**	-4.9105	1.5962***	-1.4734***	0.2576**
0.20	-0.8929***	-3.8318	1.6406***	-1.8620***	0.3722***
0.25	-0.7961***	-3.4565	1.5424***	-1.7897***	0.3786***
0.30	-0.7196***	-3.1689	1.5170***	-1.7564***	0.3696***
0.35	-0.6377***	-3.0271	1.5405***	-1.7794***	0.3527***
Normal					
0.40	-0.6849***	-3.9943	1.5619***	-1.8428***	0.3688***
0.45	-0.6987***	-4.5195*	1.6469***	-1.8850***	0.3522***
0.50	-0.7030***	-4.8974**	1.7038***	-1.9204***	0.3417***
0.55	-0.6975***	-4.4918**	1.7789***	-1.9533***	0.3226***
0.60	-0.6856***	-4.1301**	1.7875***	-1.9589***	0.3193***
0.65	-0.6704***	-4.2188***	1.7939***	-1.9563***	0.3145***
Boom					
0.70	-0.6297***	-3.6708**	1.8029***	-1.9597***	0.3054***
0.75	-0.6328***	-3.4601***	1.7335***	-1.9260***	0.3241***
0.80	-0.6125***	-3.3732***	1.7039***	-1.8736***	0.3226***
0.85	-0.5830***	-3.3605***	1.7276***	-1.8721***	0.3095***
0.90	-0.5663***	-3.1841***	1.6368***	-1.7981***	0.3255***
0.95	-0.3948***	-2.4492***	1.6005***	-1.7295***	0.2949***

Source: Author's Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

From Table 6, ROVX has a negative influence on the manufacturing sub-sector output for the middle quantile (0.45-0.65) and upper quantile (0.70-0.95). Consequently, the influence is substantial. during normal and boom economic conditions of the manufacturing sub-sector output. This corresponds to the outcome on the electricity sub-sector where the sector output is susceptible to negative shocks from ROVX at normal market situations in addition to boom. Again, effect of the ROVX is crucial during normal and boom market situations of the manufacturing industry. Conversely, there is insignificant nexus at the lower quantiles (0.05 and 0.10). It can be ascertained that the influence of ROVX during stressed conditions of the manufacturing sub-sector output is not substantial. For investors, it is better to diversify or hedge against volatility in the manufacturing sub-sector by observing the ROVX with other comparable investible assets, for instance, the crude oil price.

Also, it is clear from Table 6 that the control variables have a significant influence on the output of the manufacturing sub-sector across the majority of quantiles, just as was shown for the building and power industries. An increase in the cost of crude oil has an adverse impact on industrial output under all market situations, including stress (0.15-0.35) normal (040-0.65) and boom (0.70-0.95) economic conditions. However, investors of the energy market and the manufacturing industry may find the markets attractive with the quest of offering diversification benefits. The correlation between interest rates and the manufacturing sub-sector is analogous to this finding (0.05-0.95). Meanwhile, the industrial sector does well when there is an increase in both energy consumption (quantiles 0.05-0.95) and FDI (quantiles 0.10-0.95). Table 7 provides a deeper dive into how realised crude oil volatility has affected the mining and quarrying sub-sector.

Table 7: Quantile Regression Estimates (ROVX on MQ)

	Mining and Quarrying Sub-sector				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	-0.1438	-0.6568	0.5940***	-0.1396	0.2460***
0.10	-0.2732	-1.7686	0.7655	-0.3059	0.2443***
0.15	-0.4767	-3.2958	1.0844	-0.7278	0.2516**
0.20	-1.1394***	-4.3880	2.0248***	-2.2172***	0.3294**
0.25	-1.1272***	-5.4421	1.7852***	-2.0602***	0.3877***
0.30	-0.8143***	-3.4737	1.9409***	-2.0838***	0.2867***
0.35	-0.7157***	-3.3871	1.9607***	-2.1444***	0.2747***
Normal					
0.40	-0.7218***	-6.0440	2.3518***	-2.6200***	0.2335***
0.45	-0.6593***	-6.0719	2.3553***	-2.6686***	0.2311***
0.50	-0.6466***	-6.4525	2.3452***	-2.7092***	0.2417***
0.55	-0.6938***	-6.9651*	2.3395***	-2.7043***	0.2534***
0.60	-0.6987***	-7.0970**	2.2778***	-2.6700***	0.2709***
0.65	-0.6626***	-5.6127**	2.2743***	-2.6883***	0.2700***
Boom					
0.70	-0.6289***	-5.6281***	2.2930***	-2.6758***	0.2566***
0.75	-0.4482***	-5.3095***	2.3194***	-2.6750***	0.2163***
0.80	-0.4363***	-5.3711***	2.1901***	-2.6377***	0.2533***
0.85	-0.3899***	-5.3097***	2.2539***	-2.6626***	0.2291***
0.90	-0.3430***	-5.8517***	2.3465***	-2.7128***	0.2001***
0.95	-0.3453***	-5.5080***	2.1769***	-2.5725***	0.2349***

Source: Author's Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

From Table 7, ROVX has a negative influence on the mining sub-sector output for middle quantile (0.55-0.65) and upper quantile (0.70-0.95) correspondingly for normal and boom economic conditions of the mining sub-sector output. The effect is significant during normal and boom economic conditions. This corresponds to the outcome on the electricity sub-sector where the sector output is susceptible to negative shocks from ROVX at normal market situations in addition to boom. Again, effect of the ROVX is crucial during normal and boom market situations of the mining sub-sector. On the contrary, the mining sub-sector output is protected against significant negative shocks from ROVX during stressed economic conditions of the mining sub-sector output as found for electricity and manufacturing sub-sector. For investors, it is better to diversify or hedge against volatility in the mining industry by noticing the ROVX with other comparable investible assets, for instance, the crude oil price.

From Table 7, as was found for the construction, electricity and manufacturing sub-sectors, the control variables also have a considerable effect on the mining sub-sector output at the majority of quantiles of the mining sub-sector. Hence, increases in the price of crude oil have a detrimental effect on the mining sub-sector output during times of stress (quantiles 0.20-0.35), normal (quantiles 0.40-0.65), and boom (quantiles 0.70-0.95) economic conditions of the mining sub-sector. However, investors of the energy market and the mining industry may find the markets attractive with the quest of offering diversification benefits. This result is comparable to the relationship between interest rates and the mining sector (quantiles 0.20-0.95). On the other hand, energy consumption (quantiles 0.05, 0.20-0.95) and foreign direct investment (quantiles 0.05-0.95) are positively correlated with the output of the mining sector. The influence of ROVX on water and sewerage sub-sector output is further presented in Table 8.

Table 8: Quantile Regression Estimates (ROVX on WS)

	Water and Sewerage Sub-sector				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	-0.1234	1.5999	1.5354***	-1.3521***	0.0079
0.10	-0.2071	0.5804	1.8395***	-1.6842***	-0.0189
0.15	-0.6921	-7.1092	1.6144***	-1.8905***	0.1905
0.20	-1.3150***	-5.4117	1.4659***	-2.3203***	0.4376**
0.25	-1.2510***	-6.2729	1.3506***	-2.2961***	0.4711***
0.30	-1.2475***	-6.6241	1.2712***	-2.3359***	0.5060***
0.35	-1.1489***	-7.1248	1.4380***	-2.5125***	0.4658***
Normal					
0.40	-1.0912***	-6.9703	1.4290***	-2.5203***	0.4609***
0.45	-1.2095***	-8.1569*	1.3979***	-2.5427***	0.5002***
0.50	-1.2525***	-6.6278*	1.4131***	-2.5444***	0.5050***
0.55	-1.2737***	-5.6783**	1.4411***	-2.5906***	0.5086***
0.60	-1.3246***	-6.2963**	1.4347***	-2.5819***	0.5210***
0.65	-1.3279***	-6.4035***	1.4752***	-2.6210***	0.5163***
Boom					
0.70	-1.3488***	-6.6066***	1.4640***	-2.6208***	0.5249***
0.75	-1.3821***	-6.8937***	1.4320***	-2.6275***	0.5443***
0.80	-1.4030***	-7.6637***	1.5393***	-2.6412***	0.5192***
0.85	-1.3874***	-7.4969***	1.4456***	-2.5667***	0.5364***
0.90	-1.1964***	-6.3528**	1.2547***	-2.3688***	0.5330***
0.95	-0.9047***	-3.2899*	0.9868***	-2.1664***	0.5343***

Source: Author’s Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

As presented in Table 8, ROVX has a negative influence on the water and sewerage sub-sector output at middle quantile (0.45-0.65) and upper quantile (0.70-0.95). The effect is significant during normal and boom market conditions. This corresponds to the outcome of the electricity, manufacturing and mining sub-sectors where the sub-sectors' output is susceptible to negative shocks from ROVX at normal market situations in addition to boom. Again, the effect of the ROVX is crucial during normal and boom market situations of the water and sewerage sub-sector output. On the contrary, the water and sewerage sub-sector output is protected against significant negative shocks from ROVX during stressed conditions of the water and sewerage sub-sector output as found for electricity, manufacturing and mining sub-sectors.

The control variables also have a significant effect on the output of the water and sewerage sector at the majority of quantiles of the water and sewerage sub-sector output, as indicated in Table 8, as was discovered for the construction, electricity, manufacturing, and mining sub-sectors. Hence, rises in the price of crude oil have a negative effect on the output of the water and sewerage sub-sector during stressful times (quantiles 0.20-0.35), normal (quantiles 0.40-0.95), and boom (quantiles 0.65-0.95). It is advisable to use caution when detecting the negative nexus at all quantiles because Kassim and Isik (2020) thought that a lack of energy supply and inefficient energy consumption posed a threat to industrial expansion. Investors in the energy market and the water and sewerage sub-sector, however, can find these sectors appealing due to the potential for diversification benefits.

After ascertaining the direct effect of ROVX on the five sub-sectors, the study proceeds to decipher the vulnerability of the aggregated industrial sector output to realised crude oil volatility. This is relevant for resource management decisions because it will save time and resources to observe the overall industry sector for shocks transmission from ROVX if the overall sector output corresponds to the five sub-sectors. It goes to reason that it is important to lay much emphasis on the overall industry sector output as the point of call in the examination of the vulnerability of the industrial sector if it strongly reflects the sub-sectors dynamics. This assertion is built on the theory of financial and economic integration where markets do not operate in isolated system as supported by extant literature (Asafo-Adjei, Adam, Arthur, Seidu & Gyasi, 2022; Osei & Adam, 2020; Owusu Junior, Adam, Asafo-Adjei, Boateng, Hamidu & Awotwe, 2021). Table 9 further details the effect of ROVX on the industrial sector output.

Table 9: Quantile Regression Estimates (ROVX on ISO)

	Industrial Sector Output				
T	OP	ROVX	EC	INT	FDI
Stress					
0.05	-0.1678	-0.9784	1.1609***	-0.6348**	0.2063***
0.10	-0.3700	-1.9970	1.1045**	-0.6794	0.2741***
0.15	-0.6084	-3.7062	1.4270**	-1.1141*	0.2892**
0.20	-1.1028***	-4.6935	1.8360***	-2.0152***	0.4106***
0.25	-1.0219***	-5.3889	1.6844***	-1.8634***	0.4267***
0.30	-0.8691***	-3.7828	1.6833***	-1.8761***	0.4029***
0.35	-0.6896***	-3.3872	1.7401***	-1.9223***	0.3627***
Normal					
0.40	-0.7398***	-5.9303	2.0758***	-2.3366***	0.3365***
0.45	-0.7304***	-6.1595	2.1161***	-2.3313***	0.3226***
0.50	-0.7425***	-6.2392**	2.0832***	-2.2899***	0.3300***
0.55	-0.7716***	-5.4500**	1.9698***	-2.2382***	0.3652***
0.60	-0.7304***	-5.5932***	1.9656***	-2.2384***	0.3602***
0.65	-0.7216***	-4.2822**	1.9216***	-2.2305***	0.3718***
Boom					
0.70	-0.7012***	-4.5606***	1.8381***	-2.1758***	0.3881***
0.75	-0.6150***	-3.7553***	1.7548***	-2.1239***	0.3918***
0.80	-0.5869***	-3.7896***	1.7470***	-2.1255***	0.3905***

0.85	-0.5906***	-3.9217***	1.7378***	-2.1102***	0.3930***
0.90	-0.5176***	-3.4465***	1.6154***	-2.0323***	0.4078***
0.95	-0.4215***	-3.0463***	1.5825***	-1.9735***	0.3920***

Source: Author's Construct (2023)

*Note: The variables OP, ROVX, EC, INT, and FDI represent Crude oil price, Realised crude oil price volatility, Energy consumed, Interest rate and Foreign Direct Investment respectively. It must be noted that τ signifies the quantiles of the distribution. Also, ***, ** and * denote significance at 1%, 5% and 10% respectively.*

From Table 9, ROVX has a negative significant effect on ISO at the middle quantile (0.50-0.65) and upper quantile (0.70-0.95) respectively for normal and boom economic conditions. This corresponds to the outcome on the electricity, manufacturing, mining and water and sewerage sectors representing four sectors out of five with greater susceptible to negative shocks from ROVX at normal and boom economic conditions. Again, effect of the ROVX can be found during normal and boom market situations of the overall industry output. On the contrary, the overall industry output is guarded against significant negative shocks from ROVX during stressed conditions of the overall industry output as found for the five sub-sectors.

The control variables (OP, EC, INT and FDI) are seen to have significant effects on ISO at varying quantiles. For instance, an increase in crude oil prices has a detrimental effect on the output of the industry at stress (quantiles 0.20-0.35), normal (quantiles 0.40-0.65), and boom (quantiles 0.70-0.95) economic conditions. Yet, due to the potential for gains from diversification, investors within the energy market as well asthe output of the broader industry may find these areas intriguing. This result is comparable to the connection between interest rates and the output of the entire industry (quantiles 0.05-0.95). The output of the total industry, on the other hand, is positively correlated with both energy consumption (quantiles 0.05-0.95) and foreign direct investment (quantiles 0.05-0.95).

Discussion of the asymmetric relationship between realised crude oil price volatility and industrial sector output

In response to the first research objective, realised crude oil price volatility has a negative influence on the five sub-sectors and overall industry output. However, the effect differs marginally across the sub-sectors. For instance, the electricity, manufacturing, mining and quarrying and water and sewerage sectors representing four sub-sectors out of five had greater susceptibility to negative shocks from realised crude oil price volatility at normal and boom economic conditions. This implies that industrial sub-sectors that rely heavily on oil may experience lower economic growth during normal and booming economic conditions of the industrial sector output. This can result in reduced investment levels and elevated unemployment rates, potentially triggering a cascading impact on the overall economy.

The study indicates that escalating oil prices result in heightened volatility in crude oil prices, negatively impacting the industrial sector's output due to higher production costsTherefore, the production costs of the industrial sector which depends heavily on oil would increase which lowers the sector's output. Additionally, oil price volatility can also affect consumer and business confidence, which can lead to changes in consumption and investment behavior. When oil prices are volatile, businesses may be less confident about the future, leading to lower levels of consumption and investment, thereby dwindling industrial sector output.

The detrimental impact of sudden crude oil price fluctuations on the industrial sector output is supported by prior studies such as Ahmed et al. (2017) using the VAR approach, and Zhang et al. (2022) in China. Conversely, Iganiga et al. (2021) found a positive effect of crude oil price shocks on construction sub-sector and the overall industrial sector but negative effect on the manufacturing sub-sector in Nigeria when the ARDL and NARDL were employed.

Accordingly, the effect of the realised crude oil price volatility can be found during normal and boom economic situations of the industrial sector output such as in the electricity, manufacturing, mining and water and sewerage sub-sectors. The effect of ROVX on the industrial sector output was seen to be insignificant mostly during stressed conditions. This is possible because when the industrial sector experiences stressful conditions, consumption of refined crude oil might not increase which mitigates the adverse effect of crude oil price volatility.

The results of this study hold practical significance for investors in the Ghanaian industrial sectors. It suggests that investors in the electricity, manufacturing, mining and quarrying, and water and sewerage sub-sectors may face greater risks from volatile crude oil prices during normal and boom economic conditions. The study's theoretical implications suggest that the effect of crude oil price volatility on the industrial sectors is not uniform across quantiles. This finding aligns with earlier research (Dawar, Dutta, Bouri, and Saeed, 2021; Zhu, Guo, You, and Xu, 2016; Hamdi, Aloui, Alqahtani, and Tiwari, 2019), demonstrating that the impact of fluctuations in crude oil prices on the economy can differ based on the prevailing oil price levels. This suggests that the relationship between crude oil price volatility is asymmetric thereby violating the symmetric/linear relationship growth theory.

The Conditional Causality of Realised Crude Oil Price Volatility to Industrial Sector Output

Conditional Causality Model Results

This section presents the outcome on the conditional causality in mean as a way of confirming causality from ROVX to the industrial sector output. Since the approach is bivariate, causality can only be ascertained from ROVX to the industrial sector output with no control variables considered. Explanations of the quantiles from this approach is similar to the quantile regression technique only that the quantile regression does not depict causality. Similarly, the lower quantile ranges from 0.05-0.35 (stressful), the middle quantile from 0.40-0.65 (normal), and the higher quantile from 0.70-0.95 (boom) are used to illustrate economic conditions of industrial sector output (see, Adebayo et al., 2022; Demir et al., 2020).

In the conditional causality in quantile results, the test statistics correspond to the vertical axis with the quantiles presented on the horizontal axis in each plot. It is observable from the 5% significance level in connection with the critical value of 1.96 as illustrated by the horizontal solid line in the causality results. To illustrate significance at specific quantiles, the yellow curve should be above the 1.96 solid line before the null hypothesis (a change in ROVX does not cause a change in industrial sector output) can be rejected. Figure 8 presents the conditional causality in quantile between ROVX and the construction sub-sector output.

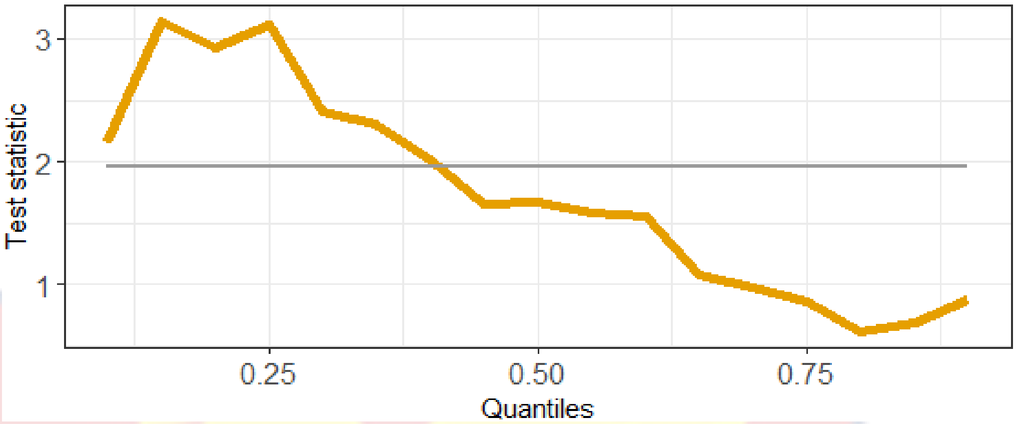

Figure 8: Quantile Causality in Mean from Realised Crude Oil Volatility to the Construction Sub-sector Output
Source: Author's Construct (2023)
Note: The variables CONS, and ROVX represent Construction sub-sector and Realised crude oil price volatility.

From Figure 8, it is evident that fluctuations in realised crude oil price volatility (ROVX) effect the output of the construction sub-sector at economic stress, as depicted by the lower quantiles (0.05-0.35). This highlights the conditional causality between ROVX and the construction sub-sector output. The construction sub-sector is one of the critical economic sectors that can be directly impacted by fluctuations in oil prices. For instance, changes in oil and gas prices can affect construction costs, transportation expenses, and demand for construction projects, which ultimately impact the output of the construction sub-sector. Figure 9 presents the conditional causality in quantile between ROVX and the electricity sub-sector output.

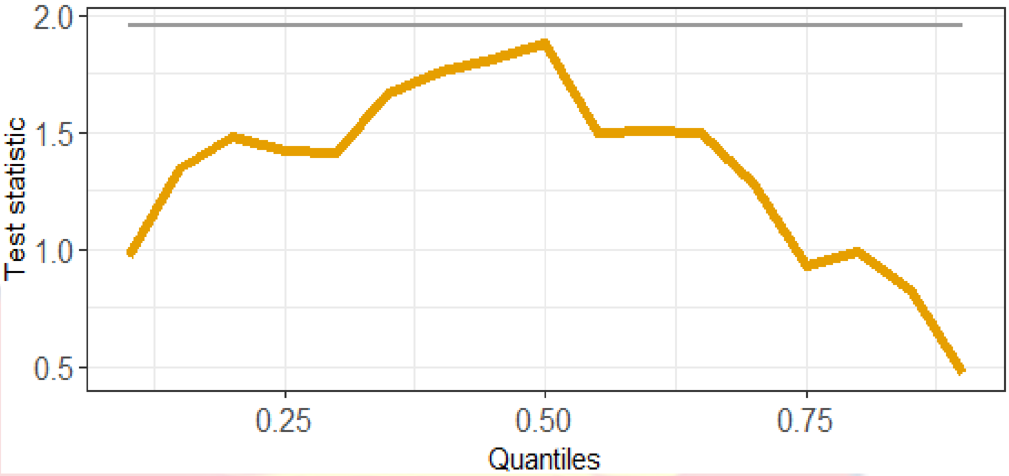

Figure 9: Quantile Causality in Mean from Realised Crude Oil Price Volatility to the Electricity Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ELECT, and ROVX represent Electricity sub-sector and Realised crude oil price volatility.

From Figure 9, it is evident that there is no causal relationship between realised crude oil price volatility (ROVX) and the output of the electricity sub-sector, regardless of the economic conditions of the electricity sub-sector output. This indicates that ROVX does not drive the electricity sub-sector output at varying quantiles, all other things held constant. This can be traced from the yellow curve below the 1.96 solid line which indicates that the null hypothesis (a change in ROVX does not cause a change in industrial sector output) is not rejected. The electricity generation in Ghana is sourced from a variety of energy resources, encompassing hydroelectric power, natural gas, and renewable energy. While crude oil might play a role in the energy sector, its impact may be diluted by the presence of other dominant energy sources.

The results from Figure 9 suggest that the electricity sub-sector may not be as vulnerable to causality from crude oil price volatility as other economic sectors. Figure 10 presents the conditional causality in quantile between ROVX and the manufacturing sub-sector output.

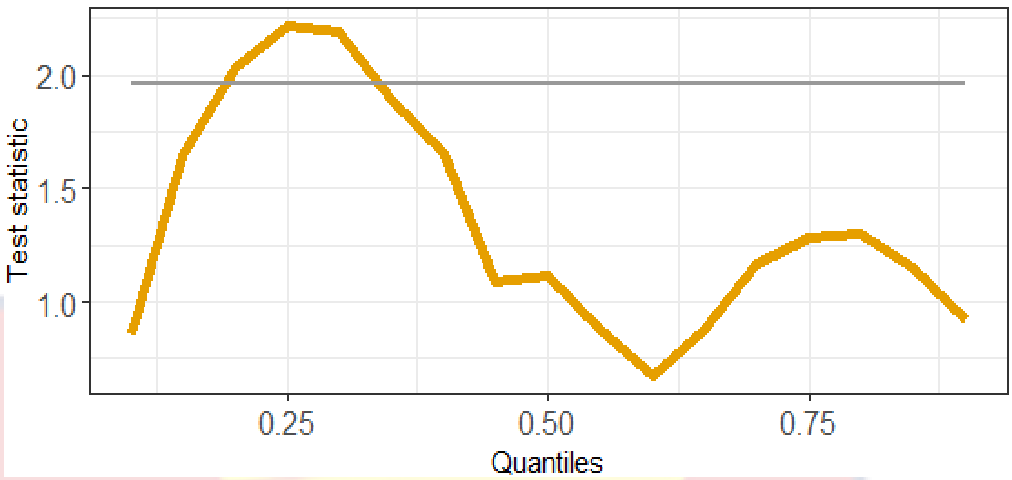

Figure 10: Quantile Causality in Mean from Realised Crude Oil Price Volatility to the Manufacturing Sub-sector Output
Source: Author's Construct (2023)

Note: The variables MFG, and ROVX represent Manufacturing sub-sector and Realised crude oil price volatility.

Figure 10 demonstrates that realised crude oil price volatility (ROVX) has a causal relationship with the output of the manufacturing sub-sector at economic stress, as represented by the lower quantiles (0.2-0.35). This implies that ROVX has the potential to cause the manufacturing sub-sector's output at only the lower quantile, all other things held constant. The manufacturing sub-sector's production is a pivotal component of the economy, and it is vulnerable to changes in the volatility of crude oil prices. The manufacturing sector relies heavily on petroleum products as raw materials and energy sources, making it vulnerable to changes in oil and gas prices. Figure 11 presents the conditional causality in quantile between ROVX and the mining and quarrying sub-sector output.

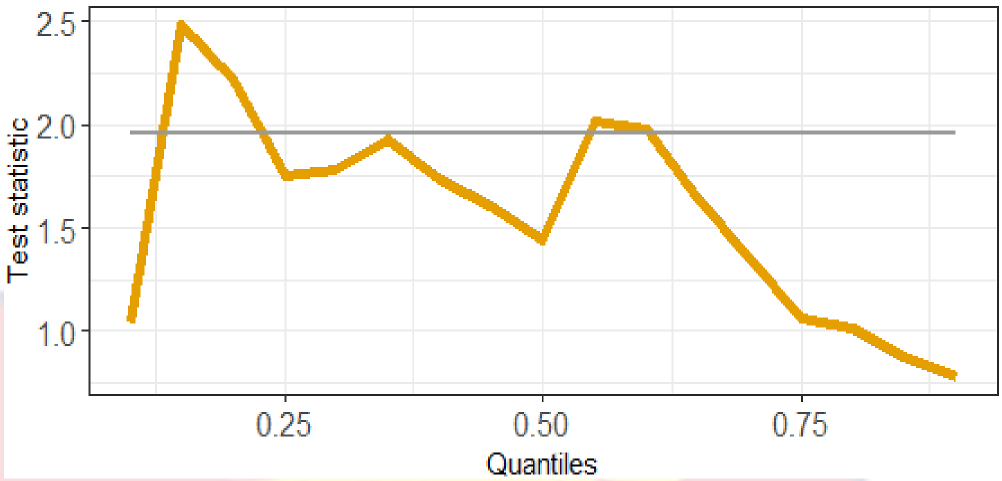

Figure 11: Quantile Causality in Mean from Realised Crude Oil Price Volatility to the Mining and Quarrying Sub-sector Output
Source: Author's Construct (2023)

Note: The variables MQ, and ROVX represent Mining and quarrying sub-sector and Realised crude oil price volatility.

Figure 11 indicates that there is a causal relationship between realised crude oil price volatility (ROVX) and the output of the mining and quarrying sub-sector from the yellow curve above the 1.96 critical solid line. The significant causality can be found at the lower (0.1-0.2) and middle quantiles (0.55-0.6) representing stressed and normal economic conditions. This implies that ROVX can drive the output of the mining and quarrying sub-sector at varying quantiles, holding all other things constant. The fact that this causality is most pronounced in the lower quantiles, representing stressed economic conditions, suggests that the mining and quarrying sub-sector is particularly sensitive to changes in crude oil prices during times of economic uncertainty. This sensitivity can be linked to a multitude of factors, including increased production costs and reduced demand for raw materials in turbulent economic environments (Humssi, Petrovskaya, and Abueva, 2022). Figure 12 shows the conditional causality in quantile between ROVX and the water and sewerage sub-sector output.

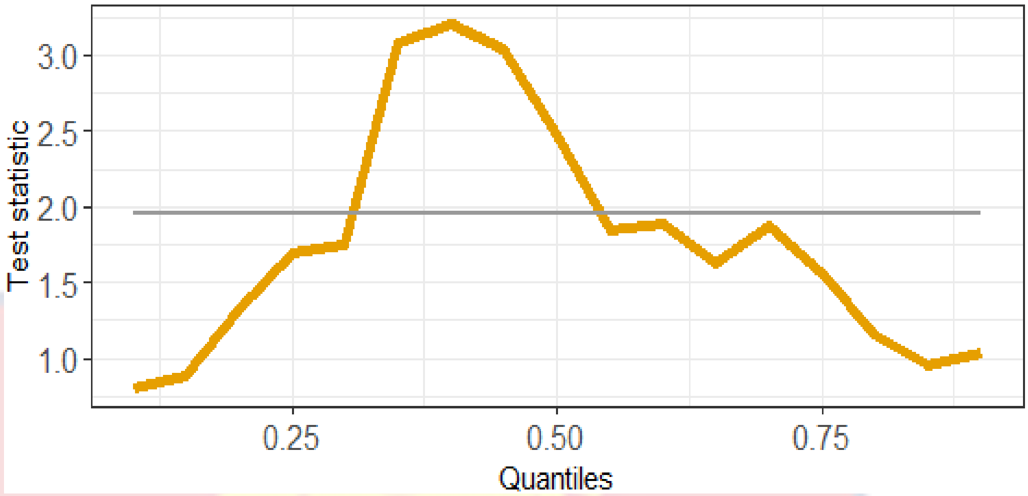

Figure 12: Quantile Causality in Mean from Realised Crude Oil Price Volatility to the Water and Sewerage Sub-sector Output
Source: Author's Construct (2023)

Note: The variables WS, and ROVX represent Water and Sewerage sub-sector and Realised crude oil price volatility.

From Figure 12, it is clear that there exists a causal connection between the observed fluctuations in realized crude oil price volatility (ROVX) and the output of the Water and Sewerage sub-sector. The significant causal nexus can be observed from the yellow curve above the 1.96 critical solid line in Figure 12. This relationship is observed at the middle quantiles (0.3-0.55), representing stressed to normal economic conditions. This implies that ROVX can drive the Water and Sewerage sub-sector output at varying quantiles, holding all other things constant.

Hence, variations in oil price volatility can exert substantial impacts on the Water and Sewerage sub-sector's output. In times of elevated oil prices, the Water and Sewerage sub-sector can experience increased costs for energy and raw materials, leading to reduced profitability. Conversely, low oil prices can lead to decreased demand for water treatment services, resulting in lower revenues for the sector. Figure 13 shows the conditional causality in quantile between ROVX and the industrial output.

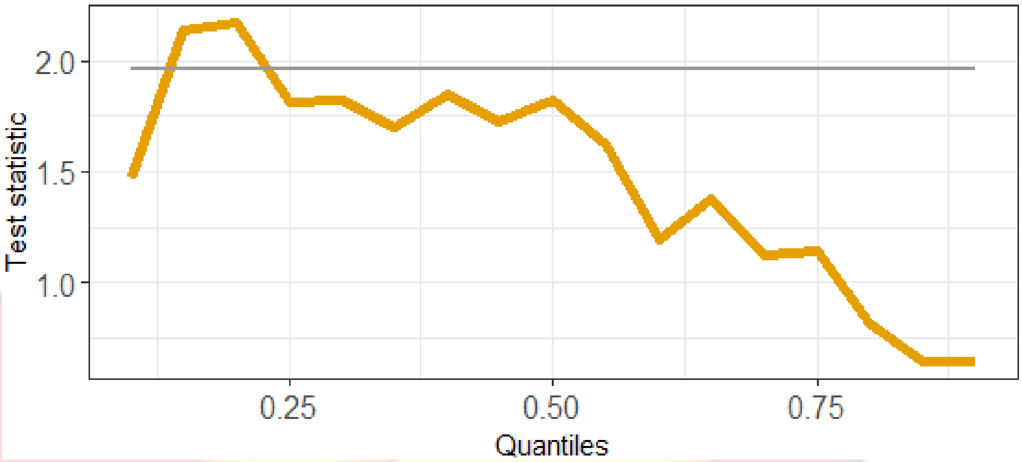

Figure 13: Quantile Causality in Mean from Realised Crude Oil Price Volatility to Industrial Sector Output
Source: Author's Construct (2023)

Note: The variables ISO, and ROVX represent Industrial sector output and Realised crude oil price volatility.

From Figure 13, it is evident that the realised crude oil price volatility (ROVX) has a causal relationship with the output of the Industrial sector, specifically at the lower quantile (0.1-0.2) representing stressful economic conditions. This implies that ROVX can drive the Industrial sector output at only the lower quantile, holding all other things constant. The Industrial sector comprises various sub-sectors that depend on oil and gas products as inputs for production and operations. These sub-sectors include manufacturing, mining and quarrying, and construction, among others. Hence, fluctuations in oil prices can have a significant effect on the Industrial sector's output. In times of elevated oil prices, the Industrial sector can experience increased costs for energy and raw materials, leading to reduced profitability. Conversely, low oil prices can lead to decreased demand for the Industrial sector's products and services, resulting in lower revenues for the sector.

Discussion of the conditional causality of realised crude oil price volatility to industrial sector output

The findings presented on the conditional causality between ROVX and industrial sector output showed that ROVX drives most of the industrial sector output at lower and middle quantiles representing market stress and normal market conditions, respectively. The outcome implies that crude oil price volatility increases or decreases production costs, investors' confidence, and demand of oil products, among others, which determines output of the industrial sector. The pattern of causality to the output of the industrial sector is specific during stress conditions of the construction, manufacturing, mining and industrial sector output, but at normal economic conditions of the water and sewerage sector and manufacturing sector output. However, the insignificant causality between crude oil price volatility and industrial sector output at economic boom signifies that, variations in crude oil price volatility does not drive the industrial sector output. Hence, when the industrial sector is highly performing, the sector becomes less vulnerable to crude oil price volatility.

Considering the causal effect of ROVX on output of the industrial sector, outcome from this study corroborates the findings of Al-Sasi et al. (2017) in the setting of United Arab Emirates as well as the study of Akalpler et al. (2018) in Nigeria. Causality from ROVX to industrial macroeconomic fundamental of Ghana also supports the findings of Archer et al. (2022) on the vulnerability of exchange rate to crude oil price in Ghana. In addition to this, Asafo-Adjei, Adam and Darkwa (2021) discovered a substantial correlation between crude oil price and stock returns in Ghana. This result is consistent with the findings of Hau et al. (2020), who utilized crude oil price volatility and agricultural commodities in the context of China.

The Responsiveness of The Industrial Sector Output to Realised Crude Oil Price Volatility Across Time and Frequency

Time Frequency Connectedness Model Results

In response to the time and frequency connectedness between ROVX and industrial sector output, the bi-wavelet approach is employed. This approach is capable of extracting time and frequency dimensions of the nexus. The time dimension shows the calendar time whereas the frequency perspective divulges the timeframes for investment which encompass short-term, medium-term, and long-term horizons. The frequencies are denoted by scales represented on the vertical axis on the extreme left. The calendar times are shown on horizontal axis on top of the bi-wavelet plot. Following the studies of Asafo-Adjei, Boateng, Isshaq, Idun, Owusu Junior and Adam (2021), and Boateng, Asafo-Adjei, Addison, Quaicoe, Yusuf and Adam, (2022), the study considers the short-term as from scales 0-8, between scales 8 and 32 as medium-term and beyond scale 32 as long-term.

The study follows discussions by extant literature (Boateng, Asafo-Adjei, Addison, Quaicoe, Yusuf & Adam, 2022; Idun et al., 2022; Nkrumah-Boadu et al., 2022; Singh, Bansal & Bhardwaj, 2022) to help explain the results. In graphical terms, time series that are in-phase are denoted by arrows heading to the right (left) (out of phase). Arrows from the bi-wavelet plots geared toward left denote negative nexus whereas arrows inclined to the right show positive co-movements. To decipher the pattern of leading and lagging variables, diagonal arrows are used.

Hence, a left arrow pointing downward or a right arrow pointing upward suggests that the second variable lags (or the first variable leads) the first by $\pi/2$, whereas left arrow pointing upward or a right arrow pointing downward indicates that the first time series lags the second by $\pi/2$. In this case the first time series is ROVX whereas the second time series is the industrial sector output. Significant co-movements are denoted by regions in red (warm) colour whereas insignificant co-movements are shown in blue (cool) colour. This is pictorially highlighted by the colour bar and the corresponding magnitude of the nexus located on the right-side of each bi-wavelet plot. The time and frequency connectedness between ROVX and the construction sub-sector output is shown in Figure 14.

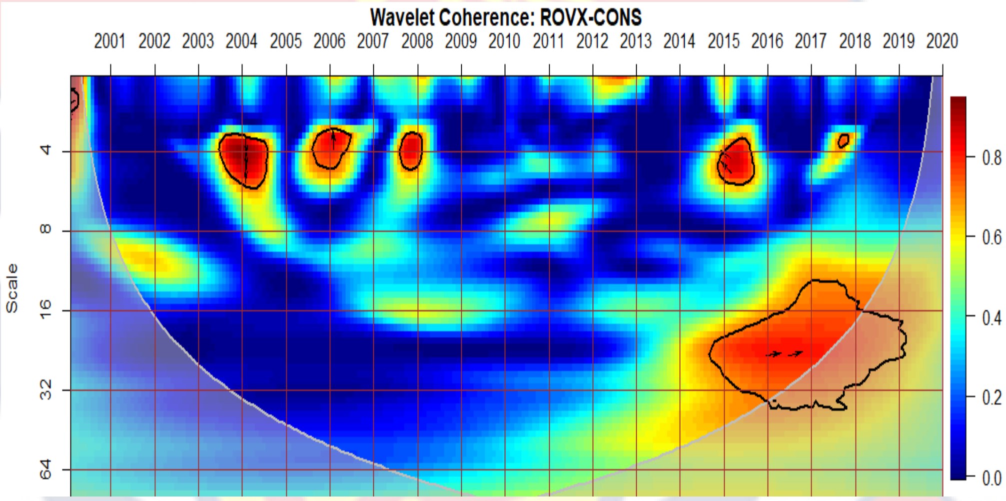

Figure 14: Co-movements between Realised Crude Oil Volatility and Construction Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and CONS represent Realised crude oil price volatility and Construction sub-sector output respectively

Figure 14 depicts the relationship between ROVX and the Construction sub-sector output over time and frequency, highlighting the extent of mutual dependence between the variables. The results from Figure 14 depicted by the warm (red) colours indicate significant co-movements between ROVX and Construction sub-sector output in the short-term (scales 2-6) during the periods of 2003-2008 and 2015-2016. Additionally, in the medium-term (scales 8-32) and early sections of the long-term (scales 32-40), strong co-movement is observed between 2015 and 2019. The correlation between ROVX and Construction sub-sector output shows a mix of positive (between 2016 and 2017 – scales 8-32) and negative (in 2015 – scales 2-6) nexus as indicated by the right and left pointing arrows respectively.

Notably, the negative co-movement between ROVX and Construction sector output during the short-term (scales 2-6) in 2015, has ROVX lagging. In contrast, in the medium-term (scales 8-32) between 2016 and 2017, ROVX drives Construction industry output. It is crucial to observe the dynamics of the Construction sub-sector output and its relationship with ROVX, especially during the short-term (scales 2-6), as they could be susceptible to shocks from ROVX. Figure 15 presents the time and frequency nexus between ROVX and the electricity sub-sector output.

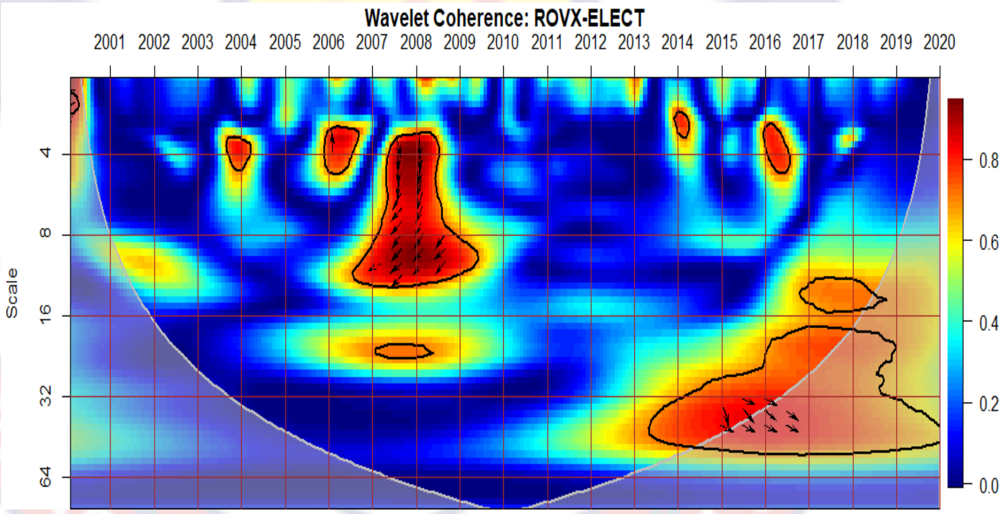

Figure 15: Co-movements between Realised Crude Oil Volatility and Electricity Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and ELECT represent Realised crude oil price volatility and Electricity sub-sector output respectively

Figure 15 highlights the relationship between ROVX and the Electricity sub-sector output. The short-term (scales 0-8) co-movements between ROVX and Electricity sub-sector output from 2003 to 2009 and from

2015 to 2017 are particularly strong. Additionally, the medium (scales 8-32) to long-term (32-50) interconnectedness between 2015 and 2019 is also strong as depicted by the red (warm) colour. Interestingly, both positive (right arrows) and negative (left arrows) relationships are observed between ROVX and Electricity sub-sector output.

In particular, the positive (right arrows) interconnectedness from Figure 15 between ROVX and Electricity sub-sector output from 2015 to 2016 in the long-term (scales 32-50), with ROVX lagging, is notable. This is denoted by the right-pointing arrows downward. However, a different outcome is found for the interconnectedness between ROVX and Electricity sub-sector output during the 2008 Global Financial Crisis. Specifically, negative (left arrows) co-movements exist between ROVX and Electricity sub-sector output, with ROVX leading the relationship in the short-term (scales 0-8) through to the medium-term (scales 8-14) between 2007 and 2010. ROVX leads because of the left-pointing arrows downwards. Figure 16 shows the time and frequency co-movements between ROVX and the manufacturing sub-sector output.

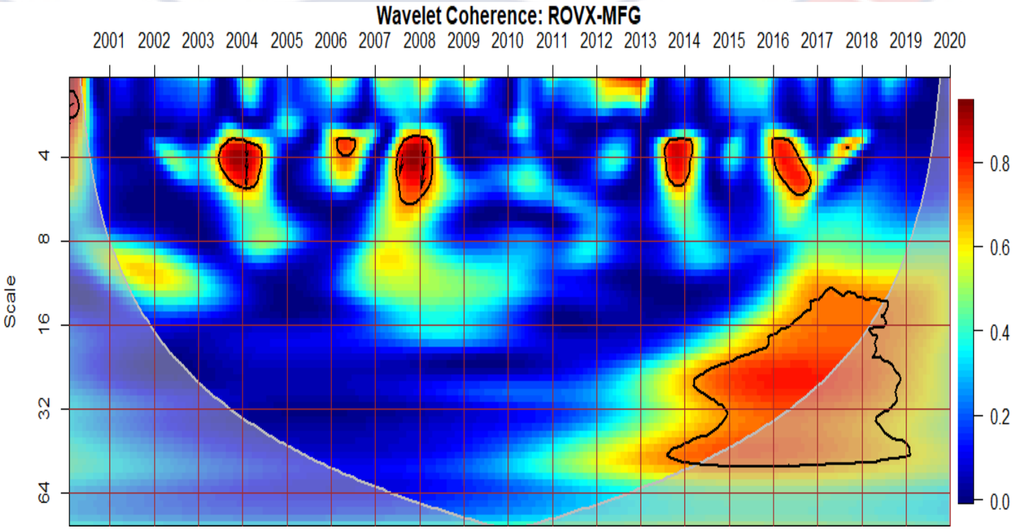

Figure 16: Co-movements between Realised Crude Oil Price Volatility and Manufacturing Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and MFG represent Realised crude oil price volatility and Manufacturing sub-sector output respectively

Figure 16 reveals the interconnectedness between ROVX and Manufacturing sub-sector output across time and frequency. The short-term (scales 0-6) analysis between 2003 and 2008, as well as between 2014 and 2017, reveals strong co-movements (shown in red colour) between ROVX and Manufacturing sub-sector output. In the medium-term (scales 12-16) and early sections of the long-term (scales 16-50), the interconnectedness is strongly depicted by the red colour, primarily between 2015 and 2019.

Specifically, there is neither negative nor positive connectedness between ROVX and Manufacturing sector output between 2015 and 2016 in the short-, medium-, and long-terms. On the other hand, ROVX drives (from the left-pointing arrows downwards) Manufacturing sub-sector output in the short-term (scales 2-6) between 2007 and 2009. The strong connectedness between 2007 and 2009 can be partially attributed to the 2008 Global Financial Crisis, which had a significant effect on the global economy and the oil and gas industry. Figure 17 illustrates the time and frequency co-movements between ROVX and the mining and quarrying sub-sector output.

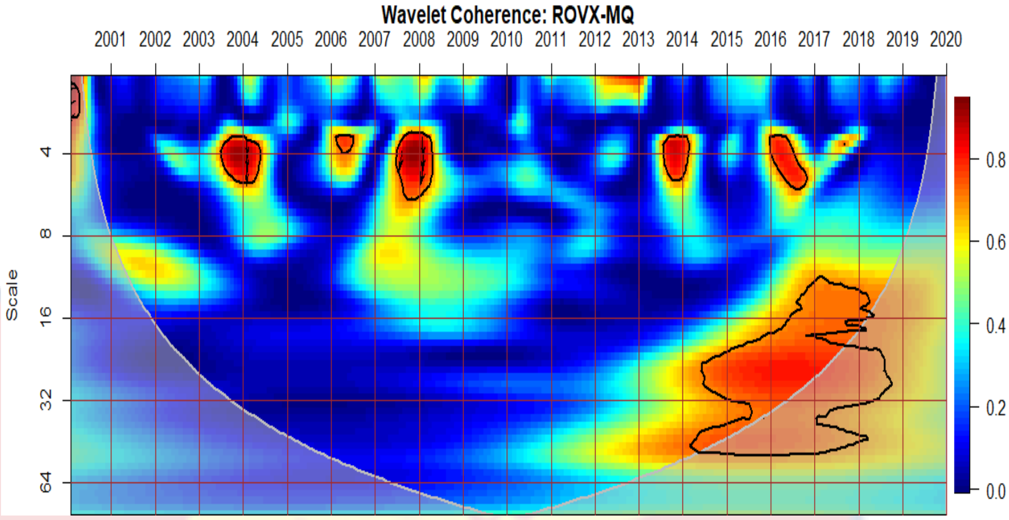

Figure 17: Co-movements between Realised Crude Oil Price Volatility and Mining and Quarrying Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and ELECT represent Realised crude oil price volatility and Mining and quarrying sub-sector output respectively

Figure 17 highlights the interconnectedness between ROVX and the Mining and Quarrying sub-sector. The short-term (scales 0-6) and medium-term (scales 12-16) co-movements show that there is a strong relationship (shown in red colour) between ROVX and the Mining and Quarrying sub-sector output, particularly during the periods between 2003 and 2008, and between 2015 and 2016.

Interestingly, there is neither negative nor positive connectedness between ROVX and Mining and Quarrying sector output between 2015 and 2016 in the short-term, medium-term, and long-terms. This outcome is similar to the manufacturing sector output. On the other hand, ROVX drives Mining and Quarrying sub-sector output in the short-term (scales 2-6) between 2007 and 2009. The strong interconnectedness observed between 2007 and 2009 can partly be attributed to the 2008 Global Financial Crisis, which had a significant effect on the global economy and the oil and gas industry. Figure

18 presents the time and frequency co-movements between ROVX and the water and sewerage sub-sector output.

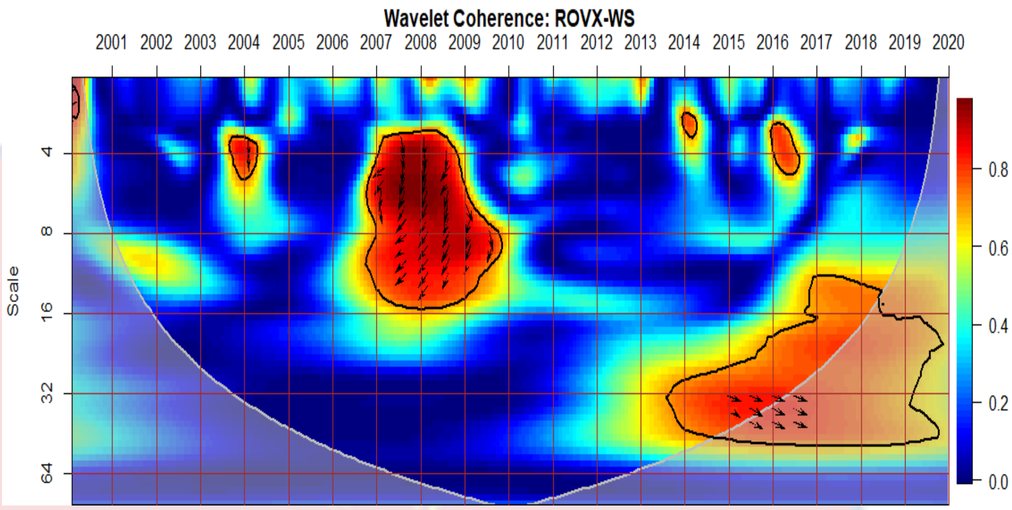

Figure 18: Co-movements between Realised Crude Oil Price Volatility and Water and Sewerage Sub-sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and WS represent Realised crude oil price volatility and Water and sewerage sub-sector output respectively

Figure 18 shows the interconnectedness between ROVX and Water and Sewerage sub-sector output over time and frequency. It is observed that there are strong co-movements (from the red colour) between ROVX and Water and Sewerage sub-sector output in the short-term (scales 0-8) between 2003 and 2010, as well as between 2015 and 2016. Also, in the medium-term (scales 8-16) strong co-movements can be found between 2007 and 2010, as well as the early sections of the long-term, the interconnectedness is strong between 2014 and 2019. The relationship between ROVX and Water and Sewerage sub-sector output is a mix of both positive and negative.

Notably, there is negative (left arrows) co-movements between ROVX and Water and Sewerage sector output between 2007 and 2010 in the short-term (scales 0-8) and medium-term (scales 8-16), with ROVX leading. ROVX leads at this point because of the left-pointing arrows downward. On the other hand, ROVX lags (from the right-pointing arrows downward) Water and Sewerage sub-sector output in the long-term between 2014 and 2019, which is similar to the Electricity sub-sector. It is suggested that the strong interconnectedness between 2007 and 2010 can partly be attributed to the 2008 Global Financial Crisis. In conclusion, the output of the Water and Sewerage sub-sector is closely related to ROVX, with a mix of positive and negative relationships. Figure 19 presents the time and frequency nexus between ROVX and the industrial output.

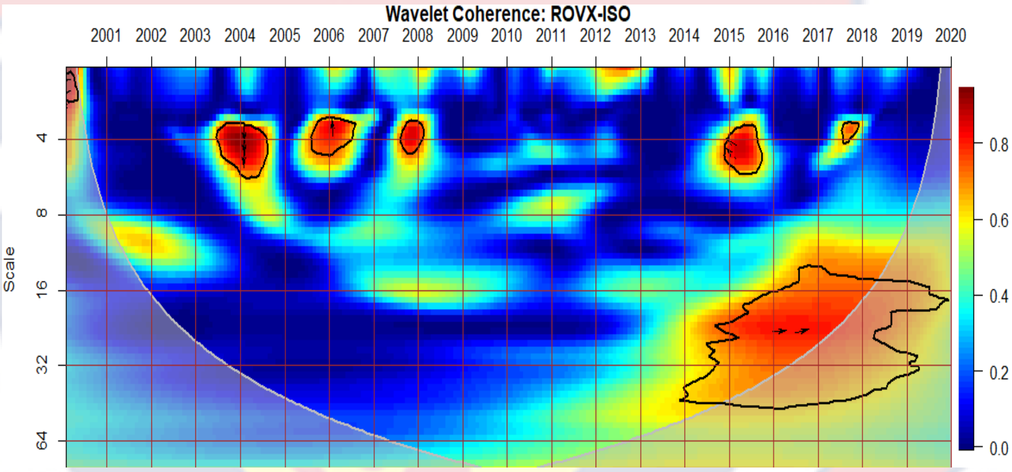

Figure 19: Co-movements between Realised Crude Oil Price Volatility and Industrial Sector Output
Source: Author's Construct (2023)

Note: The variables ROVX and ISO represent Realised crude oil price volatility and Industrial sector output respectively

Figure 19 shows the relationship between ROVX and the industrial sector output. It indicates strong negative (left arrows) co-movements (from the red colour) in the short-term (scales 2-6) between 2003 and 2009, and between 2015 and 2016, which is consistent with the patterns observed in the sub-sectors. Similarly, there is strong co-movement between the variables in the medium-term (scales 14-16) and long-term (scales 32-50), between 2014 and 2019. During this period, there exist right-pointing arrows which indicates positive nexus between ROVX and the industrial sector output. It is important to note that the industrial sector encompasses a wide range of activities, including manufacturing, construction, mining, and quarrying, among others.

Therefore, the pattern of co-movements observed in the industrial sector is similar to that of the sub-sectors, reflecting the interconnectedness between the ROVX and the broader economy. Generally, as revealed in the medium-term, and long-terms co-movements are strong for the output of the sub-sectors spanning important crises such as the BREXIT in 2016, banking sector financial crisis in 2017 that occurred in Ghana as well as the COVID-19 pandemic. This highlights the effects between the realised crude oil volatility and the industrial sector output. It can therefore be said that interconnectedness between realised crude oil volatility and the industrial sector are susceptible to crises which should be observed with caution by resource managers.

Discussion on the responsiveness of the industrial sector output to realised crude oil price volatility across time and frequency

The study found significant short-term correlations between the volatility of crude oil prices and industry sector output between 2003 and 2008 as well as between 2015 and 2016. Beyond 2014, the interconnectedness was significant in the medium-term and the early parts of the long-term. Between 2007 and 2010, there were specifically negative co-movements between realised crude oil volatility and the output of the electricity sub-sector as well as between realised crude oil price volatility and the output of the water and sewerage industry, with realised crude oil price volatility leading the relationship. The 2008 Global Financial Crisis can be partially attributed for the significant co-movements between 2007 and 2010. The time and frequency connectedness between ROVX and industrial sector output provides that the nexus is adaptive and heterogeneous which corroborates the results by Mo et al. (2019), Riaz et al. (2016) in Pakistan, Yu et al. (2022), and Zhang et al. (2022) in China.

It should be emphasized that, prior to 2014, the co-movements were primarily negative, with the productivity of the industrial sector being caused by the realised volatility of crude oil. The output of the industrial sector shows a similar pattern of causation with the realised volatility of crude oil price at particular intervals and frequencies. As seen in the medium- and long-term interconnectedness, the industrial sector has performed successfully despite significant crises like the BREXIT in 2016, the Ghanaian banking sector financial crisis in 2017, and the COVID-19 pandemic. This highlights the effects between the realised crude oil volatility and the industrial sector output. It can be established that co-movements between realised crude oil volatility and the industrial sector are susceptible to crises which should be observed with caution by resource managers.

The interconnectedness between the variables is not strong across all times and frequencies but they are rather time and frequency specific. This addresses the heterogenous nature and adaptive behaviors of the markets in responds to the heterogeneous market hypothesis (Müller et al., 1997) and the adaptive market hypothesis (Lo, 2004). This is in consonance with the outcomes revealed by extant literature (Asafo-Adjei et al., 2021; Boateng, Asafo-Adjei, Addison, Quaicoe, Yusuf & Adam, 2022; Boateng et al., 2021; Li, Huang & Failler, 2022). The weaker co-movements shown in blue colour (cold colour) are areas where crude oil volatility and the industrial sector output are less connected. Accordingly, the industrial sector output is insulated against adverse shocks from the reaslised crude oil volatility.

The results of this research carry significant implications for existing policies in the Ghanaian context, particularly those related to petroleum subsidies. The study highlights the negative effect of realised crude oil volatility on the output of the industrial sector, particularly the electricity, manufacturing, mining, and water and sewerage sub-sectors. This implies that policies that aim to reduce subsidies on petroleum products may cause an increase in production costs and a decline in the output of these sub-sectors.

For instance, the reduction in subsidies by the Ghanaian government on petroleum products in periods such as 2013 and 2015 led to an eventual increase in production cost of firms which dwindled output. The government of Ghana in 2015 set aside US$12.5m for subsides, compared with the US$150m in 2014 (Economist Intelligence, 2015). This reduction in subsidies may have had a negative effect on the output of the industrial sector, particularly the sub-sectors identified in this study.

Chapter Summary

The study quantitatively examined the effect of realised crude oil price volatility on the industrial output of Ghana. For this reason, the quantile regression, nonlinear conditional causality in quantile and bi-wavelet approaches were utilised as the study's estimation techniques. It was revealed that realised crude oil price volatility has an asymmetric, causal influence and time-frequency effect on industrial sector output. Categorically, the nexus between realised crude oil price volatility and the industrial sector output is asymmetric, heterogenous and adaptive.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This research investigates the effect of crude oil price volatility on industrial sector output in Ghana. Results, interpretations, conclusions, recommendation and suggestions for further study are summed up and discussed in this chapter. The empirical analysis looked at the asymmetrical connection between crude oil price volatility and the industrial sector, and the causality from crude oil price volatility to quantiles of the industrial sector output. The study also evaluated how the output of the industrial sector is related to the volatility of the price of crude oil in terms of both time and frequency.

Using monthly data from January 2001 through December 2020, quantile regression, conditional causality and bi-wavelet techniques were applied to estimate the responsiveness of the industrial sector output to realised crude oil price volatility. The variables for the study include, crude oil price volatility, manufacturing subsector, mining and quarrying subsector, water and sewage subsector, construction subsector, electricity subsector and industrial sector outputs, respectively. Other control variables included were energy consumption, foreign direct investment, and interest rate.

Summary of Findings

The research discovered from the first research objective that realised crude oil price volatility has a significant adverse effect on the industrial sector and its sub-sectors, particularly during normal and boom economic conditions. The electricity, manufacturing, mining, and water and sewerage sectors were found to be more susceptible to negative shocks from crude oil price volatility. The study underscores the importance of the asymmetric relationships between crude oil prices and industrial sector output, which, imperatively makes more effective resource management and policy decisions in the Ghanaian context and beyond.

Furthermore, the second objective looked at the causal relationship between crude oil price volatility and industrial output. The study revealed that the output of the sub-sectors of the industrial sector in Ghana is significantly affected by ROVX, especially during periods of market stress and normal market conditions. At such times, the effect of ROVX on construction, manufacturing, mining, and overall industrial sector output is significant. Additionally, the water and sewerage sub-sector output and the manufacturing sub-sector output are susceptible to shocks from the ROVX during normal market conditions.

Finally, the third objective analysed the responsiveness of industrial output to crude oil price volatility across time and frequency. The study found a notable correlation between the volatility of crude oil prices and the output of the industrial sector in Ghana. Prior to 2014, the co-movements were mostly negative, with realised crude oil price volatility causing a decline in industrial sector output. However, beyond 2014, the interconnectedness was significant over an extended period, both medium term and long term, indicating the industrial sector's resilience to crises like the COVID-19 pandemic and the Ghanaian banking sector financial crisis in 2017. The negative interconnectedness between realised crude oil price volatility and the electricity and water and sewerage industries from 2007 to 2010, with crude oil volatility leading the relationship, can be partially ascribed to the 2008 Global Financial Crisis.

Conclusions

In the first place, the instability of oil prices has a detrimental consequence on the output of the electricity sub-sector, as well as the manufacturing sub-sector, the mining and quarrying sub-sector, both in the normal and boom economic conditions. At the period of heightened market stress, however, these subsectors are shielded from the potentially damaging effects of volatility in the price of crude oil. However, volatility in the price of crude oil has negative effect on the construction sub-sector only during economic conditions characterized by a boom state; and during economic conditions characterized by a stressful situation, the subsector is shielded from the price shock. The volatility of the price of crude oil also has a negative effect on the overall output of the industrial sector.

From the second research objective, the findings highlight the conditional nexus between the ROVX and the industrial sector output. Causality is prominent during stress conditions of the construction, manufacturing, mining and industrial sector output, but at normal economic conditions of the water and sewerage sector and manufacturing sector output. However, when the industrial sector is highly performing, the sector is less susceptible to fluctuations in crude oil price instability.

Finally, this research also analysed the time and frequency connectedness of industrial output and crude oil price volatility. An intense adverse correlation in the volatility of crude oil prices and construction, electricity, water and sewerage, manufacturing and mining and quarrying sectors was obtained. The construction, electricity, water and sewerage, manufacturing, and mining and quarrying sectors are highly sensitive to shifts in oil price volatility. As crude oil price volatility increases, these sectors tend to experience decreased industrial output, which suggests that these industries are vulnerable to fluctuations in crude oil prices. It can be concluded that fluctuations in crude oil prices can exert substantial spillover effects on the industrial output, indicating that they are closely linked to the dynamics of the oil market.

Recommendations

Considering the results obtained from the first research objective, it is imperative for policymakers and resource managers in the industrial sector to develop robust contingency plans that account for different economic scenarios. These plans should include strategies to maintain stable output during periods of crude oil price volatility, including market stress and normal market conditions. Furthermore, policymakers should encourage industrial producers to enter into forward contracts or engage in hedging strategies to lock in stable prices for their energy needs. This can be supported through partnerships with financial institutions and commodity markets, allowing industries to mitigate the risk of sudden price spikes which could otherwise lead to higher costs and lower profits.

Secondly, policymakers should prioritize the establishment of strategic oil reserves to address supply-side shocks resulting from Ghana's dependence on crude oil imports. These reserves would serve as a buffer against sudden disruptions in global oil supply, reducing supply risks and stabilizing the country's reaction to global oil price variations. Simultaneously, the government should promote and incentivize industries to diversify their energy sources beyond fossil fuels. Encouraging the adoption of renewable energy, energy efficiency measures, and alternative fuels can reduce dependence on volatile oil prices.

In light of the third research's findings, the government should consider implementing petroleum policies to mitigate the negative effects of crude oil price volatility on the industrial sector. This includes establishing a Price Stabilization Fund which allows the government to save windfall gains in times of elevated crude oil prices and release these funds to offset rising costs when prices fall. This helps stabilize domestic petroleum product prices, ensuring that industrial consumers are shielded from sudden price fluctuations. The government could establish upper and lower price bands for fuel to help prevent extreme price fluctuations. When prices approach the upper band, the government can temporarily reduce taxes to stabilize prices, while it can increase taxes when prices fall towards the lower band. This approach maintains price stability for the industrial sector. Also, the government can consider targeted fuel subsidies that focus on protecting vulnerable industries within the industrial sector. By providing subsidies to specific industries facing significant cost increases due to oil price volatility, the government can minimize the adverse effects on industrial output while managing fiscal resources more efficiently.

To conclude, the government should establish a dedicated unit within the Ministry of Energy and Petroleum tasked with monitoring and analyzing crude oil price movements to effectively track and respond to oil price swings and their influence on industrial production. This unit should regularly assess the potential impact of price changes on the industrial sector and recommend timely policy adjustments. Additionally, the government should enhance transparency and information sharing with stakeholders, including industry players and the public, to ensure informed decision-making and promote confidence in the management of oil-related challenges.

Suggestions for Further Studies

Future research on the empirical examination of the impact of crude oil price volatility on the Ghanaian context should expand its scope beyond the industrial sector to encompass various sectors such as finance, digital technology, healthcare, tourism, and education. It should also consider the forward-looking nature of implied crude oil price uncertainty, derived from options markets, to better understand how businesses and investors perceive and react to potential oil price fluctuations. Comparative studies with neighbouring countries, examination of policy implications, long-term effects, regional variations, and the inclusion of additional macroeconomic indicators are also recommended. Furthermore, researchers can explore the environmental and social of variations in oil price levels on Ghana's sectors to offer a more thorough insight into multifaceted impacts.

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APPENDICES

APPENDIX A

The realised crude oil price volatility was extracted in logarithmic returns through the Generalized Autoregressive Conditional Heteroskedasticity (GARCH (1,1)) model. The GARCH model is a suitable choice for computing crude oil price volatility in this study because it explicitly accounts for the time-varying and non-constant nature of volatility in financial and commodity markets, allowing us to capture the dynamic and evolving characteristics of crude oil price fluctuations, which are essential for a comprehensive empirical analysis of their impact on industrial output in Ghana. The GARCH (1,1) model is a time series model commonly used in finance to estimate the volatility of financial assets. It is an extension of the Autoregressive Conditional Heteroskedasticity (ARCH) model, which allows for the conditional variance to be dependent on lagged values of the squared residuals. The development of the Generalized ARCH (GARCH) model aimed to address the difficulties faced by ARCH models.

Similar to the ARCH model, the GARCH model employs a weighted mean of past squared residuals, but its weights gradually decrease rather than becoming zero. According to the model, the most effective method for predicting the next period's variance involves a weighted combination of the long-term average variance, the predicted variance for the current period, and the most recent squared residual, which represents new information for the current period (Lux, Segnon, & Gupta, 2015). Existence of volatility from the data is also ascertained.

$\sigma^2{}_t = \omega + \alpha r^2{}_{t-1} + \beta\sigma^2{}_{t-1}$ (16)

where:

$\sigma^2{}_t$ is the conditional variance of the return's series r at time t.

ω is a constant representing the long-run average of the conditional variance.

r_t is the logarithmic returns,

α is the coefficient measuring the impact of the squared returns of the previous period ($r^2{}_{t-1}$) on the current period's conditional variance (σt^2).

β is the coefficient measuring the impact of the past period's conditional variance ($\sigma^2{}_{t-1}$) on the current period's conditional variance ($\sigma^2{}_t$).

To calculate the monthly realised volatility (A_t), by taking the square root of the sum of squared returns over a month:

$A_t = \sqrt{(\sum(r_i - \mu)^2)}$ (17)

where i ranges from 1 to n, and n is the number of returns in the period, and μ is the average return of the return's series r

The estimated conditional variance, $\sigma^2{}_t$, to the realised volatility, A_t, to assess the accuracy of the GARCH (1,1) model in capturing the volatility of the return's series.

The study shows the GARCH (1,1) model to estimate the volatility of crude oil price. This can be presented as

$\sigma^2{}_t = \omega + \alpha OP^2{}_{t-1} + \beta\sigma^2{}_{t-1}$ (18)

where:

OP_t is the logarithmic returns of crude oil price

$\sigma^2{}_t$, ω, α and β is as defined previously.

To calculate the monthly realised volatility ($ROVX_t$), by taking the square root of the sum of squared returns over a month:

$$ROVX_t = \sqrt{(\sum(OP_i - \mu)^2)} \qquad (13)$$

where i ranges from 1 to n, and n is the number of returns in the period, and μ is the average return of the returns series OP

APPENDIX B

Table 10: Correlation Matrix

	CONS	ELECT	ISO	MFG	MQ	WS	ROVX	EC	FDI	INT	OP
CONS	1.000										
ELECT	0.975**	1.000									
ISO	0.992**	0.986**	1.000								
MFG	0.985**	0.985**	0.996**	1.000							
MQ	0.983**	0.975**	0.994**	0.983**	1.000						
WS	0.973**	0.999**	0.986**	0.987**	0.974**	1.000					
ROVX	0.119	0.131*	0.124	0.138*	0.112	0.136*	1.000				
EC	0.913**	0.902**	0.921**	0.929**	0.909**	0.910**	0.186**	1.000			
FDI	0.830**	0.751**	0.795**	0.809**	0.754**	0.751**	0.011	0.769**	1.000		
INT	-0.638**	-0.608**	-0.667**	-0.705**	-0.641**	-0.625**	-0.101	-0.661**	-0.716**	1.000	
OP	0.451**	0.313**	0.414**	0.417**	0.399**	0.314**	-0.259**	0.403**	0.760**	-0.612**	1.000

Source: Author's Construct (2023)

*Note: The variables CONS, EC, ELECT, FDI, INT, ISO, MFG, MQ, OP, ROVX and WS represent Construction, Energy consumption, Electricity, Foreign Direct Investment, interest rate, Industrial sector output, Manufacturing, Mining and Quarrying, Crude oil price, Realised crude oil volatility, and Water and Sewerage respectively. Also, **, and * denotes significance at 1% and 5% respectively.*