Comovement between Commodities in Ghana, the Role of Exchange Rates

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Research Article

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Posted Date: September 23rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1903219/v1

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Comovement between Commodities in Ghana, the Role of Exchange Rates
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Abstract
This paper examines the relationship between commodity prices in Ghana and if any, the role of exchange rate on such relationship using wavelet analysis and monthly data from September, 2007 to March, 2021. We test for the robustness of the empirical findings using multiple wavelet analysis. We find that exchange rate plays an intrinsic role in the dynamic comovement of commodity prices with strong coherence at short and medium terms. The partial wavelet coherence analysis shows that exchange rate drives commodity interdependence. This study is of relevance to other developing export-dependent countries and the Ghanaian government in making strategic trade policies and to investors that are interested in these cross-sector commodities. Governments and investors that are privy to the intrinsic role of exchange rate on its dependent commodities can benefit from this study to diversify against exchange rate fluctuations and the implicit effect of inflation.

Keywords: Connectedness; Wavelet analysis; Export-dependent; Coherence; Ghana
1.0 Introduction

Commodity prices influence the economic growth and standard of living of developing or low-income countries (Addison et al., 2014) empirically identified as import-dependent with relatively low exports as compared to aggregate imports (Arezki et al., 2012). In such countries, commodity prices could affect the demand and supply of other currencies used for trading because implicitly, exchange rates determine trade levels (Ahmad et al., 2014). Frankel (2010) asserted that commodities prices might potentially affect exchange rates. If commodities are strategically positioned, would their prices predict exchange rate or otherwise, and/or are they interrelated? As stipulated also by Arezki et al. (2012), there are long term trade fluctuations in commodity prices that cause changes in exchange rate prices.

Commodity prices across countries should reflect the purchasing power parity (PPP) hypothesis of one price however, exchange rates have been more volatile than relative price levels (Stockman, 1980). PPP is reportedly a model-based criterion of nominal exchange rates (Qayyum, Khan & Zaman, 2004) and also defined by Dornbusch (1985) as the “inflation theory of exchange rates”. The PPP theory is most reflective in the long run where one can explore if changes in exchange rates produce changes in relative prices, and not fully reflected in differential inflation (Qayyum et al., 2004). As a price-based theory of exchange rate determination, the PPP focuses on changes in price levels, as the overriding determinant of exchange rates (Dornbusch, 1985; Nakorji et al., 2021).

There are a plethora of studies contributing to the literature that exchange rates are influenced by commodity prices noting their bi-directional causality (Arezki et al., 2012; Bashar et. al., 2013; Chen et al., 2003; Chen et al., 2014; Liu et al., 2020; Zhang et al., 2015; Salisu et al., 2018). Literature has also proven that there is comovement between exchange rates and commodity prices where both variables interdependently lead and lag at various time horizons (Chen & Rogoff, 2003; Chen et al., 2014; Salisu et al., 2018). As has been empirically proven, primary commodity prices predict exchange rate prices (Arezki et al., 2012) and in most export-dependent and developed countries (Haider et al., 2021). Also, Chen et al. (2010) speculate that volatility in “gold” prices predicts volatility in the exchange rate. On the contrary, Schaling et al. (2014) report that the prices of “oil” could not predict the Japanese yen and commodity prices quoted in Rand were respectively proven not to Granger cause exchange rates. and the comovement between exchange rates and commodity prices. There is also a surfeit of literature exploring the connectedness of commodity prices (Ai et al., 2006;
Bouri et al., 2021; Cai, Zhan & Chen, 2019; Frimpong et al., 2021; Pindyck & Rotemberg, 1988).

It has been reported that there is comovement between commodities in different production sectors or unrelated commodities attributable to macroeconomic variables and their past and current variables (Pindyck et al., 1988). Co-movement of excess commodity price returns reflects time-varying lead-lag relationships at various phase differences (Ohashi & Okimoto, 2016; Liu et al., 2020). With significant comovement in the short run as opposed to the long-run comovement (Chen et al., 2014; Sari, Hammoudeh & Soyta, 2010; Zhang et al., 2015; Ohashi et al., 2016). The varying comovement, however, does not affect the bi-directional granger causality that exists between commodities (Bashar & Kabir, 2013; Liu et al., 2020; Zhang et al., 2015).

In Ghana, there is barely any literature that assesses the comovement of commodities, and the role of exchange rate plays in such comovement. However, there is literature from Archer et al. (2022) and Boateng et al. (2022) who have used cocoa, crude oil and gold to analyse the asymmetric dependence between exchange rate and these commodity prices and the interconnectedness among the commodities and external shocks considering the real sector of Ghana respectively. Archer et al. (2022) showed that prices of crude oil (turbulent conditions) and cocoa (normal and extreme market conditions) cause appreciation in the Ghanaian Cedi. The findings from Boateng et al. (2022) also revealed that in the medium term, gold causes an increasing inflation rate but not cocoa and crude oil – from 2006 to 2011 – but in 2019, commodities were the leading variables and a negative relationship with inflation.

As a developing country, the Ghanaian government ought to know the impact of macroeconomic variables such as exchange rate on its commodities so that it can serve as a reference for policy-making and investment decisions. Also, the debate on the dominance of either commodity prices or exchange rates in predicting the other is still open (Sari et al., 2010; Owusu Junior et al., 2019). Thus, this literature seeks to explore the comovement of gold, cocoa and brent crude oil. Secondly, we examine the role exchange rate may have on these commodities by exploring its direct and controlled effect on their respective returns. This is because, if the commodities comove as stipulated by Pindyck et al. (1988), there would be a need to analyse if exchange rate initiatives the comovement between commodities.

Collins et al. (1980) assert that to have a reflective meaning to the relationship between exchange rates and commodity prices, one should use nominal exchange rates which capture inflation rates. The nominal exchange rates which are reflective of inflation have been
empirically proven to comove with commodity prices (Nakorji et al., 2021). For this study, nominal exchange rates and prices of gold, cocoa and crude oil are used based on the 2019 State of Commodity Dependence Report – which states that these three commodities are the most traded in Ghana. In the United Nations Conference on Trade and Development (UNCTAD) 2-year State of Commodity Dependence Report, commodity dependence is exclusively a developing country phenomenon. The report states that Ghana is dependent on the export of minerals, ore, and metals. However, its three leading commodity exports are in the sectors of agriculture, fuels, and metal; cocoa, brent crude oil and gold respectively. We use the Bivariate Wavelet and Partial Wavelet Coherence (PWc) to analyse the commodity comovement and if any, the role of exchange rate in such relationship. We adopt these techniques due to its uniqueness in decomposing data into localised time and frequency, for analysing the control external effects and suitable for working with non-stationary data (Bakas & Triantafyllou, 2018; Rouyer et al., 2008; Tweneboah et al., 2019; Owusu Junior et al., 2019). We also use the multiple wavelet coherence analysis to test the robustness of the findings (Oygur & Unal, 2020).

The findings from the biwavelet analysis show a dominant transmission from exchange rate to gold and crude oil only. But the dominating characteristics of the exchange rate give it a contagion effect on crude oil and gold just as cocoa has on exchange rate. The biwavelet analysis shows that the unrelated commodities comove depicting features of interdependence (Pindyck & Rotemberg, 1988). Thus, we went on ahead to explore the contribution of exchange rate on such comovement. The results subsequently prove the effect of exchange rate on commodity comovement because the strong coherence between the commodity prices no more exhibits comovement when exchange rate is controlled for. The multiple wavelet analysis shows that our findings are robust because the returns of the commodity prices as explanatory factors barely show and coherence at various frequencies. The dynamic comovement between commodities at different localized time and frequency is influenced by the structure of the market and participants theorized to set prices of commodities according to different market situations across heterogeneous markets (Müller, Dacorogna, Dave, Pictet, Olsen, & Ward, 1993; Patil & Rastogi, 2019). In a heterogeneous market, the Adaptive Market Hypothesis (AMH) reports that the differences that exist in market participants adjust over time because market efficiency is dependent on market conditions (Zhou & Lou, 2013).

The implications of this study would help government make effective policies that would put its exports in a strategic position in the global market. The interrelatedness of
exchange rate and commodity prices could be capitalized on by individual and firm producers who depend on imports for inputs, and investors who contribute to the balance of payment of the Ghanaian economy to diversify in the international markets. Also, to the government, when drawing up monetary (trade) policies and more importantly, as the government is taking measures to liberalize the structures of international trade through the African Continental Free Trade Area (ACFTA), the findings from this literature would be advantageous. The study also finds that the COVID-19 pandemic poses no threat to the comovement of commodity prices and exchange rate. Empirically, developing countries that are export-dependent on either gold, cocoa and or gold can also capitalize on these findings to make effective government decisions.

The rest of the paper is in Section 2 as the methodology; Section 3 on data description; Section 4 is on results and discussion and Section 5 presents the conclusion of the study.
2.0 Methodology

The study investigates the time-frequency comovement between exchange rates and commodity prices. The wavelet analysis is suitable for the study because of the non-stationarity, non-linearity and asymmetry of the data series used. Wavelet overcomes the non-stationarity effect by decomposing the times series data into time and frequency (Rouyer et al., 2008). Also, the wavelet analysis allows the simultaneous analysis of comovement at the frequency level and localised time between the exchange rate and commodity prices (Owusu Junior et al., 2019).

2.1 Bivariate Wavelet (Biwavelet)

The biwavelet technique is employed to assess the time-frequency comovements of our variables. The biwavelet can also be used to infer interdependence (low frequency) and or contagion (high frequency) (Frimpong et al., 2021; Gallegati, 2012).

2.1.1 Continuous Wavelet Transform (CWT)

We adopt the Continuous Wavelet Transform (CWT) for better extraction feature (isolation and identification) purposes, data compression, best detects peaks and oscillations and to map the changing properties of non-stationary signals (Asafo-Adjei, Agyapong, Agyei, Frimpong, Djimatey, & Adam, 2020; Kuşkaya et al., 2009; Owusu Junior et al., 2019). The fundamentals of wavelet analysis comprise two factors: time or location ($\theta$) and frequency ($s$), expressed below:

$$\psi_{\theta,s}(t) = \sqrt{s^{-1}} \psi (t - \theta)(s^{-1}), \psi(\bullet) \in L^2 (R)$$

where $\sqrt{s^{-1}}$ is the standardisation factor, ensuring that the unit variance of the wavelet $|| \psi_{\theta,s}(t) ||^2 = 1$; $\theta$ is the location factor, offering the exact place of the wavelet coherence; and $s$ is the scale dilation factor, describing the overextended nature of the wavelet.

The Morlet wavelet can be expressed as below:

$$\phi^M (t) = \frac{1}{\pi^{1/4}} e^{i\omega_0 t} e^{-t^2/2}$$
where the dominant frequency of the wavelet is $\omega_o$. We set $\omega_o$ at 6 (Asafo-Adjei et al., 2020; Frimpong et al., 2021; Wu, Zhu, Xu, & Yang, 2020) to generate the tolerability of the Morlet function (Owusu Junior et al., 2019).

The time series $x(t)$ can be decomposed, based on a selected mother wavelet as;

$$W_x(\theta,s) = \int_{-\infty}^{\infty} x(t) \sqrt{s}^{-1} \psi \ast \left(\frac{t-\theta}{s}\right) dt$$

By protruding the specific wavelet $\psi(*)$ onto the chosen time series, we undoubtedly attain $W_x(\theta,s)$. Compatibly, the crucial benefit of a CWT is its flair to decompose and reconstruct the function $x(t) \in L^2(R)$

$$x(t) = \frac{1}{c_\varphi} \int_0^\infty \left[ \int_0^\infty W_x(i,s) \psi_{\theta,s}(t) d\theta \right] \frac{ds}{s^2}, s > 0$$

The CWT is a pre-requisite for investigating coherency (lead-lag) and phase difference between two time series.

2.1.2 Wavelet Transform Coherence (WTC)

The squared absolute value of a wavelet cross-spectrum normalization to a single spectrum of wavelet power is well known as the Wavelet Transform Coherence (WTC) (Torrence & Compo, 1998). Accordingly, the squared wavelet coefficient is defined as:

$$R^2(x,y) = \frac{|\lambda(s^{-1}W_{xy}(\theta,s))|^2}{\lambda(s^{-1}|W_x(\theta,s)|^2)\lambda(s^{-1}|W_y(\theta,s)|^2)}$$

where $\lambda$ is a smoothing factor, which balances resolution and significance, and $0 \leq R^2_{xy}(\theta,s) \leq 1$. A wavelet coherence near 0 specifies a weak or no relationship, whereas a figure near to 1 depicts a strong co-movement between the variables (Asafo-Adjei et al., 2020; Mensi, Rehman, & Vo, 2020; Owusu Junior et al., 2019). The bias in the wavelet power spectrum and wavelet cross-spectrum is removed by the standardization function (Frimpong et al., 2021; Wu et al., 2020). For a precise significance level of the WTC, the Monte Carlo procedure would be used for simulation; the theoretical distribution of the WTC coefficient is unidentified (Torrence et al., 1998).
2.1.3 WTC Phase Difference

The wavelet transforms coherence phase difference indicates the disruptions in the fluctuation of the observed time series. Following Bloomfield et al., (2004) and Torrence et al. (1998) the phase difference between \(x(t)\) and \(y(t)\) is characterised as below

\[
\Omega_{xy}(\theta, s) = \tan^{-1}\left(\frac{\Im\{S^{-1}W_{xy}(\theta, s)\}}{\Re\{S^{-1}W_{xy}(\theta, s)\}}\right), \Omega_{xy} \in [-\pi, \pi]
\]  

where \(\Im\) and \(\Re\) are the imaginary and real operators respectively. In the wavelet coherence map, the directional arrows are used to differentiate diverse phase patterns of the wavelet coherence difference – \(x(t)\) and \(y(t)\) are in-phase (antiphase), the arrow points to the right (left); if the arrow points down (up), this implies that \(y(t)\) (or \(x(t)\)) is leading (Asafo-Adjei et al., 2020; Frimpong et al., 2021; Wu et al., 2020). Also, \(|\Omega_{xy}| < \frac{\pi}{2}\) indicates that the two phase move in-phase and vice-versa respectively (Owusu Junior et al., 2019).

2.2 Partial Wavelet (PWc)

Partial Wavelet Coherence is a technique in wavelet analysis similar to the partial correlation which is considered effective for measuring the correlation between two time series \((x(t)\) and \(y(t)\)) after controlling for and removing the influence of time series \(z(t)\). PWc helps in solving the problem of “untainted” correlation between two time series on wavelet coherence by eliminating the impact of the third effect (Frimpong et al., 2021; Mensi et al., 2020; Wu et al., 2020). For this study, the partial wavelet coherence is used to eliminate the effect of exchange rate on commodity prices; cocoa, crude oil and gold. This would help find the real correlation and interconnectedness of these commodities if any.

The coherence among \(x(t)\), \(y(t)\), \(x(t)\) and \(z(t)\) and \(y(t)\) and \(z(t)\) is transcribed as:

\[
R(x, y) = \frac{\lambda[W(x,y)\times \lambda[W(x)\times \lambda[W(y)]]]}{\sqrt{\lambda[W(x)]\times \lambda[W(y)]}}
\]  

\[
R^2(x, y) = R(x, y)\times R(x, y)^* 
\]  

(7 i)  

(7 ii)
Following Frimpong et al (2021), Mensi et al (2020), Wu et al (2020), Wu and Wu, (2020), PWc can be designated using an equation analogous to the partial correlation squared, as

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

(7 vi)

where $R_p^2(x, y, z)$ ranges from 0 to 1. This section employs $x$ and $y$ to mean the commodity price returns while $z$ denotes the exchange rate index. Monte Carlo methods are used to estimate the level of significance of the PWc. A low $R_p^2$ region observed where a high $R^2$ region indicates that time series $y$ does not have a significant influence on $x$ instead, the time series $z$ dominates the variance of $x$. If there is no difference between $R_p^2$ and $R^2$, both $y$ and $z$ have a significant influence on $x$.

3.0 Data Source and Data Description

The study uses monthly returns covering the period of September 2007 to March 2021 after the data was cleaned for missing data (matched with trading dates of both data sets). The sample size is relatively large while complementing the data used with its span (Bakas et al., 2018; Chen et al., 2010; Chen et al., 2014; Owusu Junior et al., 2019) and nature (Pindyck, 2004). The data set is quoted in the USD/GHS for exchange rate and for the commodity prices as for Cocoa (USD/Tonne), Gold (USD/Ounce) and Brent Crude Oil (USD/Barrel). These commodity prices were gleaned from the Bank of Ghana Economic Indicators website (https://www.bog.gov.gh/economic-data/commodity-prices) and motivated from the UNCTAD (2019) which records that these goods are strategically positioned in the Ghana trade sector while the data on exchange rate was extracted from YahooFinance (https://finance.yahoo.com/quote/GHS=X?p=X&tsrc=fin-srch).
The frequency of the data series is motivated by the monthly available data of commodity prices which has no records from the periods of July to December, 2019. The data on exchange rate is available from 2007 as such, the authors gleaned the data for the study from September 2007 to March 2021. As shown, the study was based on monthly returns of \( r_t = \ln P_{t-1} - \ln P_t \), where \( r_t \) is the continuously compounded return, \( P_t \) and \( P_{t-1} \) are current and previous index correspondingly.

Figure 1 presents the graphical presentation of exchange rates and commodity prices. In Panel A, the commodity prices are reflecting a rising trend and are rightly skewed. Though the magnitude of the trend is unpredictable, all commodity prices are rising indicating comovement between the commodity prices. The fluctuations in the trends reflect the unsteadiness of the commodity prices making it a risky investment. In Panel B, the exchange rate trend series look quite stationary until the early part of 2019 and 2020. The normality test confirms the non-stationarity of the data series using ADF and KPSS tests. Also, the trends show time varying volatility clustering, which is in line with the stylized facts of most financial assets (Adam & Owusu Junior, 2017).
Figure 1: Plots of commodity prices and returns.
Note: The trend of the prices of crude oil and cocoa depict a similar movement. Though the trend of gold prices is fluctuating, it depicts an opposite trend when compared to the prices of crude oil and gold as and when they are rising and dropping.

Table 1

<table>
<thead>
<tr>
<th>Descriptive Summary</th>
<th>EXR</th>
<th>Brent Crude Oil</th>
<th>Cocoa</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.0117</td>
<td>-0.0006</td>
<td>0.0049</td>
<td>0.0016</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>0.5279</td>
<td>0.1030</td>
<td>0.0376</td>
<td>0.0582</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.1312</td>
<td>-0.9192</td>
<td>0.1292</td>
<td>-0.0559</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>73.3183</td>
<td>4.8055</td>
<td>0.1762</td>
<td>1.0214</td>
</tr>
<tr>
<td>Normtest W</td>
<td>0.1469***</td>
<td>0.9003***</td>
<td>0.9948</td>
<td>0.9839*</td>
</tr>
<tr>
<td>ADF</td>
<td>-8.2290***</td>
<td>-5.3930***</td>
<td>-4.7733***</td>
<td>-4.7928***</td>
</tr>
<tr>
<td>KPSS</td>
<td>0.0190</td>
<td>0.0485</td>
<td>0.3525</td>
<td>0.1297</td>
</tr>
</tbody>
</table>
Correlation Matrix of Returns

<table>
<thead>
<tr>
<th></th>
<th>EXR</th>
<th>Brent Crude Oil</th>
<th>Cocoa</th>
<th>Gold</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXR</td>
<td>1.0000</td>
<td>-0.1460</td>
<td>0.0954</td>
<td>-0.1223</td>
</tr>
<tr>
<td>Brent Crude Oil</td>
<td>-0.1460</td>
<td>1.0000</td>
<td>0.2752**</td>
<td>0.2179*</td>
</tr>
<tr>
<td>Cocoa</td>
<td>0.0954</td>
<td>0.2752**</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>-0.1223</td>
<td>0.2179*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB: (**), (*) represent significance at 1%, 5% and 10% respectively. The H₀ for ADF and PP tests is unit root and KPSS is no unit root. The return series show that there is unit root.

Table 1 presents the descriptive statistics and the correlation matrix of the monthly price returns of the exchange rate and the commodity prices. The average returns for all the variables are positive but for crude oil implicitly exhibiting the lowest average returns; averagely, exchange rate has the highest returns and for the commodity prices, cocoa has the highest returns. The average returns also reflect the skewness of the data series in the same manner, aside crude oil and gold which are negatively skewed. The kurtosis measures also reflect that while exchange rate and crude oil are leptokurtic, cocoa and gold are platykurtic. The skewness and the kurtosis measures of the data reflect its non-stationarity property which the study tests using the Augmented Dickey Fuller (ADF) and the KPSS which both confirm that at 1% significant level, we fail to reject the null hypothesis that the data is not stationary.

The Pearson’s unconditional correlations of the data series gives an introductory acumen into the data set. The correlations between gold and crude oil and between cocoa show significance at 5% and 10% respectively with co-efficients between 0.1 and 0.3. Though the positive degree of correlation is relatively low, the commodity returns reflect abilities to comove. The correlation between the exchange rate and the commodity prices are averagely of the same magnitude but show a negative relationship. What role would the exchange rate play on commodity prices if there is a negative linear correlation? Does the positive correlation between the commodity returns indicate comovement?

4.0 Results and Discussion

To analyse the comovement, magnitude of coherence, interdependence or dominancy in a particular time and frequency, one needs to understand how to read the plots presented in Figures 2 and 3. The phase difference is reflective in the arrows’ movement: arrows moving in the same direction (in-phase) and in opposite direction (anti-phase). The interdependence shows the ability of a variable to either lead or lag at a particular frequency and a dominating variable is said to have a contagion effect on the other. An arrow pointing up (down) and in the right (left) direction shows that the first variable leads and otherwise, the variable lags. The
Monte-Carlo simulation at 95% confidence bound, – Cone of Influence – show that there is diversification in the blue pallets and in the red pallets, right pointing arrows are risky but diversification is possible when the arrows are pointing towards the left. Also, in the red pallets, the magnitude of the coherence (lead-lag relationship) is reflective in the top (high) and bottom (low) frequencies, and left (beginning) and right (end) scales (Mensi et al., 2020; Owusu Junior et al., 2019).

The wavelet factors are set at $l_j, j = 1 \ldots 4$ associated to the 0-4 months (short term), 4-8 months (medium term), 8-16 months (medium term) and 16 months and above (long term) (Gallegati, 2008; Hamrita & Tirifi, 2011).
Figure 1: Biwavelet coherence between respective commodity prices.
4.1 From Figure 1, the monthly returns of cocoa and crude oil show little comovement at the 95% confidence level however, there is strong comovement at the cycles of the various frequencies at which there is coherence. At the 0–16-month cycles, there is interdependence between the variables in diagram (a). At the 0–4–8–16-months cycle, for the latter part of 2008, there is a right arrow moving downwards and a left arrow moving upwards interpreting that the first variable lags. However, at the 0–4–8-month cycle, the arrow is moving right and upwards showing that cocoa is leading. At the coherence levels of measure, there is strong comovement between the variables.

In diagram (b), the phase difference shows frequencies that are in-phase and anti-phase while some arrows comove. In the years 2013 and 2015, the upward arrows move right and left respectively in the 4-8 band and sharper than those recorded in 2008. Empirically, this shows interdependence as cocoa leads in 2013 (4-8 band) and lags in 2018 in the medium term (8-6 band). But in 2016, the short term cycle, the arrows move left ways and points downwards depicting strong comovement; cocoa is leading. In the cycle of 8-16, cocoa is leading in the years of 2015, 2016, 2017 and 2018 at the end of the cycle with strong coherence. There is also a strong comovement at the low frequency between the band of 16–32-month cycle of diagram (c). Irrespective of this comovement, there is no lead-lag relationship between the variables but the fact that the variables are in-phase mean that there could be risk transfer to the other because they move in the same direction.

Empirically, Frimpong et al. (2021) show that there is an array of strong coherence in the comovement between agricultural commodities (particularly, oats, maize, soya bean and wheat) at different time-frequencies. Also, Ai et al (2006) stipulate that commodity prices comove and this is attributable to supply factors influencing their prices. Cai et al. (2019) also show a strong comovement between commodity sectors where there is interdependent relationship (lead-lag) in the sectors of agriculture-energy and agriculture-metals. These findings show the robustness of the empirical assertion of Pindyck et al. (1998) that, “the prices of largely unrelated raw commodities have a persistent tendency to move together”.

The findings from this paper confirms the empirical finding because, the time-frequency of diagrams (a), (b) and (c) show that there is comovement with varying effects of interdependence and contagion between the price returns of gold, cocoa and crude oil which are respectively in the minerals sector, agricultural and oil sector. The ability of the commodities to have interdependency makes it possible for investors to diversify. The findings from this study is in line with literature from Mehmet, Gabauer and Umar (2021) who assert
that commodities such as crude oil have transmittable effects on other commodities. In diagram a, crude oil prices have a dominant leading effect on cocoa (agriculture-energy commodities; Cai et al., 2019) in the short run though averagely, there is interdependency. Contradictory to, Umar, Gubareva, Naeem and Akhter (2021) who find that oil prices are granger caused by commodities such as wheat, cattle and grains. The findings in diagram (c) show no lead-lag relationship however there is strong coherence between crude oil returns and gold returns. As in Bouri, Lucey, Saeed, and Vo (2021) who assert that there exists comovement between commodity prices with strong instability among energy-metals and a modest connectedness between agricultural commodities.

Empirically, our findings show that there is cross-commodity connectedness between gold, crude oil and cocoa. Just as stipulated by Pindyck et al. (1998), the cross-comovement of these commodities could be attributed to the joint effects of their respective lag constructs, present values and macroeconomic variables such as inflation, interest rates and exchange rates. For this assertion, we control and eliminate the effect of the nominal exchange rates used which is inclined to variations in inflation to see if indeed the comovement between commodities hold or if the assertion by Pindyck et al. (1998) is true. Also, in the cone of influence bound, there is weak comovement between either combination of commodities in the years 2020 and early part of 2021 in either the short-, medium- or long-term frequencies. This weak comovement shows that the COVID-19 pandemic which has resulted in global financial crisis (Chen & Yeh, 2021) does not influence the comovement between commodity prices.
Figure 2: Partial wavelet coherence; EXR controlled.
Figure 2 presents the partial wavelet coherence analysis after the effect of exchange rate has been controlled and eliminated from either combination of commodities: cocoa-crude, cocoa-gold and crude-gold. Empirically, the PWc analysis shows no phase difference (Hu & Si, 2020). At the COI, there is no comovement in either of the combinations as the diagrams (a), (b) and (c) show absent coherence between the various combinations of the variables which had depicted cross-comovement in Figure 1. This implies that exchange rates are important drivers in the comovement of commodity prices making the findings in Figure 3 robust (comovement between exchange rates and commodity prices) and as well, the robustness of Pindyck et al. (1998).
Figure 3: Wavelet analysis of EXR and commodity prices
In diagram (a), the variables are in-phase depicting cyclical effects and possibility of contagion because the arrows ultimately depict that exchange rate is leading with very strong comovements at the 0–8-month cycle. At high frequencies of the heatmap, the short term and middle term – 0-4 and 4-8 cycles – respectively, you see strong comovement between the variables. In the 4-8 cycle, there is an in-phase movement of arrows depicting the cyclical effects that exists between both variables. The rightwards moving arrows are pointing upwards indicating that EXR (Exchange rate) is leading in most part of the late 2007, through out to the middle terms of 2008 and 2009.

The same leading effects is recorded at the short-term bands of late 2010 and the very short time before the COVID-19 pandemic broke out in 2019 with left moving downward arrows. In this wavelet analysis, the cyclical effect reflects the contagion effect that exists in the ability of exchange rate to transfer risk to the commodity prices of cocoa making it risky and not viable for diversification purposes. The comovement between EXR and Cocoa in diagram (b) at the 5% significance level, show that only at the 0-4 months cycle do they show strong comovement. However, in 2016, EXR is lagging and at 2019, though the arrows are anti-phase, there is no lead-lag relationship but diversification is possible.

The comovement between EXR and Crude oil show no interdependence because ultimately, exchange rate is leading. Between the band of 8-16, years 2008 and early 2009, for most part of 2013 and 2014, the arrows are right and pointing upwards showing that brent crude oil is lagging and has no effect on the returns of exchange rates. The arrows are moving leftwards and pointing downwards in the latter part of 2018 and most of 2019 however this does not read differently from the interpretation just given. Averagely, there is no interdependence between the variables but in the bands of 8-16 of years 2018 and 2019, diversification is possible. At the low frequencies, in the years of 2013 and 2014, in the long run, there is a weak comovement between exchange rate and crude oil where again, exchange rate is leading.

At the 95% confidence bound of the COI, as has been empirically proven, the analyses of the heatmaps in Figure 3 affirm literature that reports that the comovement between exchange rate and commodity prices is time varying (Bashar et al., 2013; Okashi et al., 2016) and dominantly, in the short and medium terms depicting a stronger correlation in the short term (Chen et al., 2014; Sadosky, 2000; Sari et al., 2010; Zhang et al., 2015). Moreso, at all significant levels of the comovement in this study, at the various localised frequencies, there is strong comovement. Averagely, the findings of the study show that indeed there is comovement
between EXR and commodity prices (Chen et al., 2003; Chen et al., 2014; Salisu et al., 2018; Acher et al., 2022). The comovement predominantly show that there is strong coherence between the variables where mostly EXR has a contagion effect on gold and crude oil. This means that the prices of gold and crude oil are influenced by exchange rate movements while cocoa prices have the ability of influencing exchange rates.

These findings are contradictory to literature that says that there is bi-directional causality (reflective when there is interdependence) between exchange rates and commodity prices. Looking at Table 3, there is mostly a contagion effect from exchange rate to commodity price returns. Schaling et al. (2014) report a bi-directional correlation and significant relationship between commodity prices and EXR. Bashar et al. (2013) also report a bi-directional causality between EXR and commodity prices however, in the very long run, EXR is determined by commodity prices. Zhang et al., (2015) also find that there is bi-causality comovement between exchange rates and commodity prices with effects of commodity prices on exchange rates been more dominant.

There is a magnitude of literature also supporting the argument that commodity prices predict EXR such as Haider et al. (2021) who stipulates that commodity prices better predict the prices of EXR in export-dependent countries; Liu et al. (2020) also reporting that in New Zealand, Canada, South Africa and Australia, commodity price returns can predict the returns of respective exchange rates; Chen et al., (2003) report that commodity prices of exports strongly affect the movement of floating real EXR for countries as Australia and New Zealand; and Scahling et al., (2014) also asserting that future and forward contracts of commodities may be important indicators of currency movements.

On the contrary to the extent of literature asserting that exchange rates are predictable by commodity prices, the findings from this study prove otherwise for gold and crude oil but not cocoa. Also, EXR is the leading variable depicting contagion effects. Our findings are in line with Trezzi, (2014) who reports that EXR lead commodity index prices in Australia; Kohlscheen, Avalos, and Schrimp (2017), who condemn the ability of commodity prices to predict or lead the coherence on EXR and Chen et al., (2010) professing that EXR have the robust predictability effect on commodity prices.

The ability of EXR to dominantly lead in diagrams (a) and (c) reflect the risk there is to investors and producers of gold and crude respectively. The EXR has the ability to transfer risk to gold and crude oil but not to cocoa which has a reverse action on EXR. However, in late 2010 for gold in the short and medium terms of most of 2018 and 2019 for crude oil,
diversification was possible in order to reduce risk. Where diversification is possible, investors could diversify against inflation (Pindyck et al., 1998) which is reflective in the EXR that is generally leading the comovement between commodities.

**Table 3: Summary on Wavelet Coherence**

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<tr>
<th>Biwavelet Analysis between Commodities</th>
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<tbody>
<tr>
<td>Cocoa-Crude Oil</td>
<td>Crude Oil</td>
<td>Interdependence</td>
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<tr>
<td>Cocoa-Gold</td>
<td>Cocoa</td>
<td>Contagion</td>
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<tr>
<td>Crude-Gold</td>
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<td>Interdependence</td>
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<th>Partial Wavelet Coherence Analysis</th>
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<tr>
<td>Cocoa-Crude Oil</td>
<td>EXR</td>
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<tr>
<td>Cocoa-Gold</td>
<td>EXR</td>
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<tr>
<td>Crude-Gold</td>
<td>EXR</td>
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<th>Biwavelet Analysis between EXR and Commodities</th>
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<tbody>
<tr>
<td>EXR-Gold</td>
<td>EXR</td>
<td>Contagion</td>
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<tr>
<td>EXR-Cocoa</td>
<td>Cocoa</td>
<td>Contagion</td>
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<tr>
<td>EXR-Crude Oil</td>
<td>EXR</td>
<td>Contagion</td>
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4.2 Robustness Test

Using the biwavelet (direct effect) and PWc (controlled effect) analyses, we find that the role of exchange rate is very intrinsic in the dynamic comovement of commodity prices. The direct effect of exchange rate is pretty dominant in determining commodity price returns and is evidently reflected when exchange rate is controlled for. As this is the first study of its kind in Ghana, we conduct a robustness test. We specify the use of the multiple wavelet analysis of Oygur et al. (2020) which is an n-dimensional coherence analysis suitable for exploring the structure of the dynamic relationship between commodity price returns. Oygur et al. (2020) define the blue and red shaded regions in the heatmap as low and high power coherence, respectively.

From Figure 4, we find a low power coherence among the commodities to exchange rate at respective frequencies in diagrams (a), (b) and (c) due to the dominance of the blue pallets. The low power coherence shows that none of the combinations in commodities can manipulate changes in exchange rate (EXR). Also, diagram (d) shows deepening red shades in the heatmap at the 4-8–month cycle in years 2007 to 2011. However, dominantly, the blue pallets show that the commodities as explanatory variables do not capture the effect of EXR. We find that our results are robust. Specifically, we observe that the direct and controlled effect of exchange rate from Table 3 reflect the dominance of EXR in the connectedness of the commodities.
Figure 4: Multiple Wavelet Analysis
5.0 Conclusion

The paper uses wavelet coherence analysis to analyse the role of exchange rate on the dynamic comovement of commodity prices. The study contributes to literature by reporting findings that probably settles the debate on whether commodity prices are predicted by exchange rates or if exchange rates move commodity prices. The wavelet coherence analysis adopted in this study help analyse the comovement between commodity price returns at localised time-frequencies. We control for exchange rate effect and its direct effect on the strong coherence that empirically exists in the commodity prices. We use monthly data from Ghana; motivated by the report from UNCTAD (2019), identifying that Ghana is export-dependent on cocoa, brent crude oil and gold.

Setting the frequencies at month cycles of 0-4 (short-term), 4-8 and 8-16 (medium terms) and at 16 and above for long term, we report strong coherence between the cross-comovement of commodity prices, and between exchange rates and commodity prices. The analysis shows that in the short-term, cocoa leads against exchange rate in 2016 though exchange rates lead against gold both in the short term and medium term for the years 2010 and 2008 to 2009 respectively and also against crude oil in the medium band of 8–16-months. Dominantly, the comovement between exchange rates and commodity prices is recorded in the short to medium terms with strong coherence and possess the ability to diversify. However, exchange rate comoves the price returns of gold and crude oil with contagion effects depicting its ability to transfer risk to these commodities. The same relationship is however been transmitted from cocoa to exchange rates.

The ability of exchange rate to dominate and lead commodity prices possess another concern of whether commodity prices comove due to the ability of exchange rate to pass contagion effects to their prices. We find that commodity prices comove as they interdepend on each other making it less risky to invest in those commodities. In Figure 1, cocoa dominates in the medium terms for years 2008 and 2009 (4–8-month cycle) and 2015 to 2018 (8–16-month cycle) and in year 2016, dominates in the short term. Also, for the years 2008, and 2015 and 2009, crude oil leads the prices of cocoa in the short term and medium term (8–16-month cycle) respectively. However, crude oil and gold interdepend on each other as there is a strong comovement in the long term. Also, we find that the COVID-19 pandemic does not influence the comovement between commodity prices.

As the commodity prices are showing series of comovement, when the effect of exchange rate is controlled for, there is absence of coherence and comovement at either
combination of the commodities. This means that commodity prices are driven by exchange rates which also show variations due to inflation. This shows robustness in the findings of the comovement between exchange rates and commodity prices. Empirically, as the exchange rates have been proven in this study to have contagion effects on commodity prices, it is just about right for commodity prices to be driven by exchange rate irrespective of their interdependence. The interdependence of the commodity prices however makes it suitable to hedge against inflation. Also, we show that exchange rates play an important role in the dynamic comovement of commodity prices which we empirically prove to be robust using the multiple wavelet analysis.

The implication of this study is very important to the Ghanaian government and any developing export-dependent economy in relation to how to make policies concerning exchange rate. Just as the economies are trying to deepen the economic integration between African countries through the African Continental Free Trade Area, member countries must make effective policies that seeks to strengthen their respective currencies and also equilibrise the Balance of Trade of respective countries. Countries that know the interdependence and the drivers of their currencies, would be able to make effective decisions that would promote economic growth and increase standard of living of its citizens.

Funding
No funding was provided.

Data Availability Statement
The data in relation to the findings of this study are available upon request.

Conflicts of interest
We declare that there is no conflicts of interest.
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https://www.researchgate.net/publication/271294107


