A Vector Error Correction Analysis of International Price Dynamics in Ghana's Cocoa, Gold, and Crude Oil Markets

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ABSTRACT

The Vector Error Correction Model (VECM) on the dynamic interrelationships between the international prices of cocoa, gold, and crude oil in the context of Ghana were conducted. Summary statistics indicate that gold is observed to have the greatest stability in prices whereas crude oil has been most volatile. The unit root tests confirmed that in their original form all three commodities are non-stationary but become stationary after first differencing hence implying similar integration properties. The Johansen co-integration test identified two significant long-run relationships whereby crude oil greatly affects both gold and cocoa markets. The VECM (1) results confirm that long-term price movements are driven by oil price changes, while gold and cocoa prices promptly adjust to deviations from equilibrium. Short-run dynamics reveal a high degree of self-dependence in gold and cocoa prices, whereas oil price developments reflected the external influence of other commodity prices. Impulse Response Functions (IRF) show crude oil price shocks have persistent effects on cocoa prices, while their effects on gold prices fizzle out over time. FEVD suggests that gold and cocoa prices are, by and large, self-driven, and oil price shocks account for only 9.88% of variation in gold prices and 15.30% of fluctuations in cocoa prices. This indicates that global oil price shocks may feel lesser impact on Ghana's commodity markets than expected, while interrelationship between gold and cocoa seems stronger. The study, To mitigate the impact of oil price volatility on Ghana's key exports like cocoa, the government and private sector should adopt market stabilization policies such as commodity futures and options trading, invest in value-added processing, and implement macroprudential measure. In order to lessen the impact of fluctuations in oil prices on Ghana's main exports, such as cocoa, the public and private sectors should invest in value-added processing, implement macroprudential measures to lessen vulnerability to external price shocks, and adopt market stabilization policies like trading commodities futures and options to reduce vulnerability to external price shocks.

Keywords: Gold, Cocoa, Crude Oil, Co-integration, commodity markets

BACKGROUND

Ghana’s international trade relies heavily on cocoa, gold, and crude oil, which formed the backbone of the country's economic success. Export earnings from these three commodities remain vital to various aspects of government revenue, foreign exchange reserves, and overall economic stability (Obeng et al, 2023). Along with considering cocoa backbone to the Ghanaian economy, cocoa substantially was one of the foreign exchange earners of the country and brought millions of livelihoods to Ghanaians. Gold is another major exported commodity that has historically contributed to export revenue as well as foreign direct investment; more than that, Ghana has become an emerging actor in the global crude oil market, in recent times being endowed with massive reserves and production. But the volatility of international commodity markets creates serious issues for planning and trajectory of Ghana's growth (Oteng et al., 2024). However, the international prices of these commodities are subject to various factors, including global demand and supply

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dynamics, geopolitical tensions, exchange rates, and macroeconomic policies (Oteng et al., 2024; Larmin, 2022).

While a good number of past studies have looked at the individual dynamics of cocoa, gold, and crude oil prices in Ghana's economy, few indeed have provided a comprehensive analysis of their interconnected price movements. Most of the existing work is more focused on the exploration of these commodities in isolation without examining their joint impact on economic growth (Larmin, 2022). Larmin noted that the relationship between gold and oil prices remained hard to define, as their connections were time dependent and without clear theoretical justification. Barson et al. (2023), acknowledged the importance of the role of fluctuations in exchange rate levels on commodity prices but did not sufficiently consider the comovement of cocoa, gold, and crude oil prices in the Ghanaian context.

Hence, most analyses invest into aggregating effects of commodity prices on the broader economy, as gross domestic product (GDP) and not into a sector-specific study. For example, studies by Oteng et al. (2024) emphasized the wide ramifications crude oil price fluctuations have on the economy but did not disaggregate their effects on sectors like agricultural economy, which plays a critical role in food security and rural employment within Ghana. Also, while many other studies delved into how unconventional monetary policies such as quantitative easing (QE) affect commodity prices in emerging markets (Obeng et al., 2023), there was a lack of attention toward how these have evolved with regards to their impact on cocoa and gold and crude oil markets more specifically in Ghana.

This paper primarily provides an investigation into the interconnections of gold, cocoa, and crude oil price movements in Ghana with a focus on long-run equilibrium, short-run dynamics, and competition between global price shocks toward these commodity markets. The paper further presents the analysis into short-term responses and variance decomposition of commodity prices. Such analysis provides an insight on how shocks to certain commodities have effects on the others with time and the extent to which movement of price of each commodity is driven.

REVIEW OF LITERATURE

There is a plethora of research that examined factors influencing Ghana's economy, especially concerning commodity prices and macroeconomic stability. A significant portion analyzed the impact of gold and oil prices, foreign direct investment, exchange rates, and inflation on Ghana's GDP growth. Some sources explored the relationship between international commodity price shocks and fiscal imbalances, focusing on cocoa and gold exports and tax revenue. Other studies investigated the influence of macroeconomic variables like money supply, lending rates, and real GDP on Ghana's exchange rate. And there are papers that explored the impact of commodity price shocks on financial stability and analyze connectedness among financial variables.

The price dynamics of Ghana’s key export commodities—cocoa, gold, and crude oil—are closely influenced by both global and domestic factors, creating a complex and often unpredictable environment that significantly affects the country’s economic performance. As Ghana’s economy heavily relies on these exports, shifts in international commodity prices interact with exchange rates, monetary policy, and macroeconomic indicators to shape fiscal outcomes and growth. Studies using various econometric methods such as quantile regression, structural VAR, and VECM reveal that while crude oil and cocoa prices tend to influence the Ghana Cedi under certain conditions (Archer et al., 2022; Obeng et al., 2023), gold prices show weaker or no significant effects (Ameyaw, 2023). Additionally, commodity price volatility links strongly with banking stability and economic variables (Kyei et al., 2023), and national stabilization mechanisms provide only partial relief to producers (Tröster et al., 2019). Cocoa exports boost growth more than cocoa prices, especially in Ghana and Côte d'Ivoire (Ofori-Abebrese et al., 2017). Long-run oil prices are mostly driven by supply and demand, with speculation playing a minor role (Hammadache, 2011), and similar patterns of short-term price dynamics are seen in other markets like coconut and crude oil (Montaño &

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Cinco, 2023). This literature review aims to synthesize these findings, exploring how commodity price shifts affect Ghana's economy and highlighting policy responses, while identifying gaps for future research.

Ghana's economy is largely dependent on the export of cocoa, gold, and crude oil, which together form a major portion of the country's export revenue (Nunoo, 2016; Kyei et al., 2023; Oteng et al., 2024). This reliance on primary commodities makes the nation vulnerable to global price volatility. For instance, Nunoo (2016) emphasized how price shocks in the gold and cocoa markets have a direct impact on Ghana's fiscal balance, further affecting broader economic conditions. The country's susceptibility to price fluctuations is exacerbated by the concentration of export earnings in just a few commodities, underlining its exposure to external market conditions (Barson et al., 2023).

Research on the link between commodity price shocks and Ghana's economic growth presents mixed findings. While some studies, like Nunoo (2016) and Onomah (2019), argue that commodity price booms contribute to economic growth, others (e.g., Oteng et al., 2024) suggest a less straightforward relationship, pointing to instances where price hikes did not lead to proportional economic gains. Moreover, Ahene-Codjoe et al. (2022) underscore the critical issue of trade mispricing—particularly for gold and cocoa exports—which erodes Ghana's tax base and diminishes the revenue available for national development.

Cocoa, gold, and crude oil prices exhibit significant comovement due to shared global factors such as economic growth, inflation, and currency fluctuations. The interconnectedness of these markets is influenced by global investor sentiment and macroeconomic shifts, which drive price movements in sync across these commodities (Barson et al., 2023). The comovement is particularly evident in the context of exchange rates; Barson et al. (2023) found that Ghana's exchange rate fluctuations directly impact the coherence of commodity prices, particularly when the effects of global economic changes are factored in.

Understanding the comovement of these commodities is essential for both policymakers and investors, as it helps to anticipate periods of synchronized price shifts, which can have broad implications for Ghana's economy. For instance, Kyei et al. (2023) noted that commodity price comovements often respond to global economic trends, suggesting that Ghana's policymakers need to closely monitor international economic developments to better manage domestic outcomes.

The exchange rate between the Ghanaian cedi and major international currencies plays a crucial role in determining the domestic prices of both exports and imports, particularly cocoa, gold, and crude oil (Antwi et al., 2020). Exchange rate depreciation makes imports more expensive while lowering the price of exports, impacting the competitiveness of Ghana's commodities in global markets.

Antwi et al. (2020) investigated the effects of macroeconomic factors on Ghana's exchange rate, including real GDP, inflation, money supply, and interest rates. They discovered that whereas inflation and the money supply had an indirect impact, real GDP had a direct one. This emphasizes how crucial exchange rate management is since even little swings can have a big impact on the local prices of important goods, which can impact producer profitability and overall economic stability.

The fluctuations in the price of crude oil have a significant impact on several areas of the Ghanaian economy, particularly transportation and agriculture (Oteng et al., 2024). Because of the nation's reliance on imported fuel, changes in oil prices are often passed on to other industries, increasing production costs and decreasing profitability, particularly in the agricultural sector. Oteng et al. (2024) emphasized how price rises disproportionately impact food commodities as opposed to animal goods, highlighting the asymmetric effects of oil price volatility on agricultural commodities. This vulnerability to variations in the price of crude oil draws attention to one of Ghana's main weak points. Food security and the livelihoods of farmers depend on policies that lessen the effects of changes in oil prices, especially in the agricultural sector. These industries could be protected from the volatility of the world's oil markets with the use of strategic interventions like subsidies or the encouragement of other energy sources.

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Monetary policy, particularly through instruments like open market operations, bank rates, and money supply management, plays a critical role in stabilizing Ghana's economy in the face of commodity price volatility (Barson et al., 2023). The Bank of Ghana's efforts to manage inflation through monetary policy have direct and indirect effects on commodity prices by influencing exchange rates and domestic inflation levels.

Obeng et al. (2023) examined the Granger causality relationships between money supply and the prices of cocoa, gold, and crude oil, finding significant correlations both in the short and long term. Their study suggests that changes in money supply influence commodity prices, and these relationships are critical for policymakers aiming to stabilize prices and control inflation.

Despite the extensive body of research on commodity price dynamics in Ghana, significant gaps remain that warrant further exploration. One key area involves the effectiveness of monetary policy in managing commodity price volatility. While several studies have explored the relationship between macroeconomic variables and commodity prices, there is limited in-depth analysis of which specific monetary policy instruments are most effective in mitigating the adverse effects of price fluctuations. Barson et al. (2023) and Obeng et al. (2023) highlight the critical role of money supply and inflation management in influencing commodity prices. However, more granular research is needed to assess the effectiveness of particular policy levels, such as interest rate adjustments and open market operations. Moreover, the optimal timing and targeting of these policy interventions remain underexplored (Nunoo, 2016), particularly in contexts where price shocks in cocoa, gold, and crude oil simultaneously affect multiple sectors of the Ghanaian economy.

Another area of concern is the lack of research on hedging and risk management strategies for businesses and investors in Ghana. Given the country's heavy reliance on cocoa, gold, and crude oil exports, price volatility poses substantial risks to the broader economy. While Ahene-Codjoe et al. (2022) and Oteng et al. (2024) underscore the vulnerability of key sectors to international price shocks, there is limited research on effective hedging mechanisms that can minimize this exposure. More work is needed to identify financial instruments or strategies that Ghanaian producers and investors can use to hedge against risks, ensuring economic stability even amid global price fluctuations (Barson et al., 2023).

The influence of global market structures and power dynamics on Ghanaian commodity producers also remains an underexplored field of study. Multinational corporations dominate the global commodity trade, often determining pricing and profit distribution. Ahene-Codjoe et al. (2022) and Oteng et al. (2024) indicate that trade mispricing and undervaluation of exports are significant issues in Ghana's gold and cocoa sectors. However, more research is needed to understand how the power imbalances in global markets impact Ghanaian producers, particularly in terms of pricing, profit margins, and long-term economic sustainability. Such research would shed light on the structural constraints that Ghanaian exporters face, and offer policy recommendations to enhance their bargaining power and profitability.

Technology and innovation also represent a critical gap in the literature. Although studies like Kyei et al. (2023) and Oteng et al. (2024) touch upon broader economic trends, there has been limited focus on how technological advancements could transform Ghana's commodity sectors. Research is needed to explore how innovations in agricultural techniques, mining technologies, or energy efficiencies could boost productivity, reduce operational costs, and increase the global competitiveness of Ghanaian producers. By improving production processes through technology, Ghana's cocoa, gold, and crude oil industries could become more resilient to price volatility and global competition.

A final gap involves the application of more sophisticated econometric models, such as Vector Autoregressive (VAR) models, to analyze the complex interrelationships between international commodity prices and macroeconomic variables. While existing studies often use traditional econometric approaches like standard regression models (Barson et al., 2023; Obeng et al., 2023), a VAR analysis would offer deeper insights into the lagged effects and feedback mechanisms between these commodity markets and their broader macroeconomic impacts. Therefore, further research utilizing VAR models is essential to better

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understand the dynamic interplay between international commodity prices and key economic indicators in Ghana.

The international price dynamics of Ghana's key export commodities—cocoa, gold, and crude oil—are shaped by a complex web of global and domestic factors. The interdependence of these commodities and the influence of exchange rates, global economic conditions, and monetary policy present significant challenges for Ghana's economic stability. While existing research provides valuable insights into these dynamics, further investigation is needed to understand the interdependence and dynamics among these key commodities, given their significant role in Ghana's economic stability. By enhancing understanding in this area, stakeholders can better navigate the volatile commodity markets and promote sustainable economic growth in Ghana.

METHODS OF DATA ANALYSIS

Source of Data

The study utilizes latest monthly data on the international prices of cocoa, gold, and crude oil obtained from the Bank of Ghana (BoG) website. The data spans from January 2014 to April 2023.

Stationarity

To ensure the validity of results from the analysis, stationarity checks were conducted using the Augmented Dickey-Fuller (ADF) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test.

The ADF test assesses the presence of a unit root in a time series data, using the model:

$$\Delta \boldsymbol{Y_t} = \boldsymbol{\alpha} + \boldsymbol{\beta t} + \boldsymbol{\gamma Y_{t-1}} + \sum_{i=1}^{p} \boldsymbol{\delta_i}\, \boldsymbol{\Delta Y_{t-i}} + \boldsymbol{\varepsilon_t} \quad \text{.....(1)}$$

where $\boldsymbol{Y_t}$ is the variable of interest, $\propto$ is a constant, $\boldsymbol{\beta}$ is the coefficient on time trend, $\boldsymbol{\gamma}$ is the coefficient of lagged $\boldsymbol{Y}$, and $\boldsymbol{\varepsilon_t}$ is the error term.

The KPSS Test tests the null hypothesis that a time series is stationary around a deterministic trend.

Optimal Lag Length Selection

To determine the appropriate lag length for the VECM model, selection criteria such as the Akaike Information Criterion (AIC), Schwarz Bayesian Criterion (SBC), and Hannan-Quinn Criterion (HQC) were employed.

Johansen's Co-integration Test

The Johansen co-integration test was used to determine the presence of a long-run equilibrium relationship among the variables. The test employs the trace statistic:

$$\boldsymbol{\lambda_{trace}} = -\boldsymbol{T} \sum_{i=r+1}^{n} \boldsymbol{In}\,(\mathbf{1} - \boldsymbol{\lambda_i}) \quad \text{.....(2)}$$

and the maximum eigenvalue statistic:

$$\boldsymbol{\lambda_{max}} = -\boldsymbol{T}\, \boldsymbol{In}(\mathbf{1} - \boldsymbol{\lambda_{r+1}}) \quad \text{.....(3)}$$

where $\boldsymbol{\lambda_i}$ represents the estimated eigenvalues, and $\boldsymbol{T}$ is the sample size.

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Vector Error Correction Model Analysis

Given the presence of co-integration among the variables, a Vector Error Correction Model (VECM) was estimated to examine both short-run and long-run dynamics of the international prices of cocoa (COC), gold (GOL), and crude oil (OIL). The VECM model is specified as follows:

$$\nabla \boldsymbol{Y_t} = \boldsymbol{\pi Y_{t-1}} + \sum_{i=1}^{p} \Gamma_i \Delta \boldsymbol{Y_{t-i}} + \boldsymbol{\varepsilon_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

where $\boldsymbol{Y_t} = (\boldsymbol{GOL_t, COC_t, OIL_t})$ represents gold, cocoa and crude oil prices at time $\boldsymbol{t}$, $\Delta \boldsymbol{Y_t}$ repereants the first differenced of the variables, $\boldsymbol{\pi}$ is the co-integration matrix which captures the long-run relationships among the variables and $\boldsymbol{\pi = \alpha \beta'}$ where $\boldsymbol{\alpha}$ represents the speed of adjustment and $\boldsymbol{\beta}$ co-integrating vectors, Γ_i are the short-run adjustment parameters and $\boldsymbol{\varepsilon_t}$ is the vector of error terms.

VECM Model Stability Test and Residual Diagnostics

The stability of the estimated VECM model was checked using the Unit Circle Test, which requires all eigenvalues of the companion matrix to lie within the unit circle.

The ARCH effect test was conducted to check the presence of autoregressive conditional heteroscedasticity in the residuals.

Impulse Response and Variance Decomposition Analysis

Impulse response analysis was conducted to assess how a shock to one variable propagates through the system over time. The impulse response function (IRF) helps understand the dynamic impact of shocks to cocoa, gold, and crude oil prices on each other.

Variance decomposition was used to assess the contribution of each variable to forecast error variance over different time horizons. This analysis helps in understanding the extent of interdependence among the variables.

RESULTS AND DISCUSSIONS

Summary Statistics

The descriptive statistics for gold, cocoa, and crude oil prices are summarized in **Table 1** below. Gold prices exhibit an average value of $1457.9000 with a median of $1317.9000, suggesting a slightly right-skewed distribution where occasional high prices pull the mean upward. Cocoa prices have a mean of $2572.9000 and a median of $2513.9000, indicating relative symmetry in the price distribution. Crude oil prices show an average of $67.3800 and a median of $63.97, implying that extreme values did not significantly distort the central measure.

The standard deviation of gold prices (275.4600) suggests moderate price fluctuations, while cocoa prices exhibit a higher standard deviation (361.5300). However, the coefficient of variation (C.V.) shows that gold prices (0.1889) and cocoa prices (0.1405) are relatively stable compared to crude oil (0.3174), which is more volatile. This indicates that crude oil prices experience frequent and significant changes, possibly due to geopolitical factors and supply-demand shocks.

Gold and crude oil prices exhibit positive skewness, implying a greater likelihood of extreme high prices than extreme low prices. In contrast, cocoa prices show a nearly symmetrical distribution with skewness close to zero (0.1618). The negative excess kurtosis values for all three commodities indicate platokurtic distributions, meaning they have fewer extreme outliers compared to a normal distribution.

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Table 1: Descriptive Statistics of Commodity Prices

Variable	Count	Mean	Std.	Min	max	C.V	Skewness	Ex. Kurtosis
GOL	112	1457.9000	275.4600	1069.4000	2000.7000	0.1890	0.5342	-1.3068
COC	112	2572.9000	361.5300	1904.6000	3313.8000	0.1405	0.1618	-0.7680
OIL	112	67.3756	21.3867	26.6300	117.2200	0.3174	0.5621	-0.4100

Stationarity Test

The Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test were conducted to assess the stationarity of Gold (GOL), Cocoa (COC), and Oil (OIL) prices. In **Table 2,** the results from the ADF test indicate that all three variables (GOL, COC, and OIL) are non-stationary at their original state, as their test statistics fail to reject the null hypothesis of unit root at the 5% significance level (*p*-values > 0.05). The KPSS test, which has a null hypothesis of stationarity, further confirms non-stationarity at original levels, as the test statistics exceed the critical values at the 5% level.

After first differencing as in **Table 3** below, all three variables become stationary, as evidenced by the ADF test statistics, which are now significant at the 1% and 5% levels (*p*-values < 0.05). The KPSS test statistics also confirm stationarity after first differencing, with values significantly lower than their critical thresholds. This confirms that gold, cocoa, and crude oil prices are integrated of order one, $I(1)$, and become stationary after first differencing.

Table 2: Augmented Dickey-Fuller (ADF) and KPSS Test Results

Variable	ADF Test (Constant Only)	ADF Test (Constant & Trend)	KPSS Test (Constant & Trend)
	Test Statistic	P-Value	Test Statistic
GOL	-1.2417	0.6585	-1.2123
COC	-2.7051	0.0763	-3.1854
OIL	-2.4715	0.1252	-2.4578

Table 3: ADF and KPSS Test Results after first Differencing

Variable	ADF Test (Constant Only)	ADF Test (Constant & Trend)	KPSS Test (Constant & Trend)
	Test Statistic	P-Value	Test Statistic
GOL	-3.4383	0.0097	-3.5331
COC	-9.0484	<0.0001	-9.0442
OIL	-4.407	0.0001	-4.9889

Johansen Co-Integration Test

The Johansen co-integration test (unrestricted trend) was conducted to determine the presence of a long-run relationship between international prices of Ghana's cocoa, gold, and crude oil markets. The test results provide insights into how these commodities interact over time and whether their prices move together in equilibrium despite short-term fluctuations. In **Table 4**, the Trace Test and Lmax Test results indicate that there are at least two co-integrating relationships (Rank = 2), given that the test statistics for rank 0 and rank 1 are statistically significant at the 5% level (*p*-values < 0.05). This confirms that the prices of cocoa, gold, and crude oil in Ghana exhibit a long-run equilibrium relationship, implying that shocks to one market may have lasting effects on the others.

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Table 4: Trace Test and Maximum Eigenvalue (Lmax) Test

Rank	Eigenvalue	Trace Test	p-value	Lmax Test	p-value
0	0.27166	57.587	0	31.381	0.0008
1	0.1664	26.206	0.0006	18.018	0.0105
2	0.079375	8.1876	0.0042	8.1876	0.0042

The co-integrating equations, represented by the β coefficients, describe the equilibrium relationship among the three commodity prices.

$$\beta = \begin{bmatrix} 0.0265 & -0.0431 & -0.0689 \\ -0.0225 & 0.0192 & -0.0120 \\ 0.3325 & 0.3409 & -0.1561 \end{bmatrix}$$

The renormalized beta values suggest that gold prices have a relatively higher weight in the long-run equilibrium relationship. Crude oil prices (d_OIL) have the highest impact on the co-integrating vectors, confirming that fluctuations in oil prices significantly affect both cocoa and gold prices in Ghana.

The α coefficients, or adjustment parameters, represent how quickly each commodity price returns to equilibrium after a short-term shock. Cocoa prices (d_COC) exhibit the strongest adjustment speed, particularly in the first and second cointegrating equations. This suggests that cocoa prices in Ghana react more rapidly to disequilibria in the long-run relationship. Gold prices (d_GOL) have a relatively slow adjustment, indicating that price deviations from equilibrium take longer to correct. Crude oil prices (d_OIL) show minimal adjustment, suggesting that external market forces (such as global oil supply shocks) influence them more than internal corrections.

$$\alpha = \begin{bmatrix} -7.9711 & 14.9130 & 14.9060 \\ 54.1850 & -41.2190 & 30.0580 \\ -4.6287 & -0.7775 & 0.0637 \end{bmatrix}$$

The long-run matrix below, which combines the adjustment and co-integration vectors, provides additional insights: The diagonal values suggest that gold and cocoa markets have stronger internal price dependencies compared to crude oil. The off-diagonal values indicate interactions among the markets, with cocoa and gold prices responding strongly to each other, while crude oil plays a relatively smaller role in the price adjustments of gold and cocoa.

$$\begin{bmatrix} -1.8809 & 0.2881 & 0.1074 \\ 1.1384 & -2.3741 & -0.7275 \\ -0.0935 & 0.0886 & -1.8139 \end{bmatrix}$$

Lag Order Selection

The lag selection criteria—Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Criterion (HQC)—were used to determine the most appropriate lag order for the VECM model. The results in **Table 5** indicate that Lag 1 is optimal, as it minimizes all three criteria (AIC = 32.4354, BIC = 32.8286, HQC = 32.5944).

The Likelihood Ratio (LR) test values show that increasing the lag order does not significantly improve model fit beyond Lag 1, as the *p*-values remain relatively high until Lag 12, where a sharp decline is observed (p = 0.0000). However, using too many lags risks overfitting, increasing parameter estimation errors, and reducing model efficiency.

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Table 5: Lag Selection Results

Lag	Log-Likelihood	p(LR)	AIC	BIC	HQC
1	-1590.6	—	32.4354*	32.8286*	32.5944*
2	-1588.3	0.8724	32.5713	33.2004	32.8259
3	-1585.4	0.7685	32.6955	33.5605	33.0454
4	-1581.7	0.5851	32.8015	33.9025	33.2469
5	-1575.3	0.1746	32.8546	34.1915	33.3955
6	-1572.8	0.8375	32.9863	34.5591	33.6227
7	-1567.6	0.323	33.0636	34.8723	33.7954
8	-1562.7	0.3628	33.1459	35.1906	33.9732
9	-1556.3	0.1716	33.1984	35.4789	34.1211
10	-1549.9	0.1739	33.2514	35.7678	34.2695
11	-1542.7	0.1057	33.2867	36.0391	34.4004
12	-1524.7	0	33.1052	36.0935	34.3143

(Note: The optimal lag is denoted by *.)

VECM (1) Model Results

The estimated co-integration equations describe the equilibrium relationships among gold, cocoa, and crude oil prices in Ghana:

$$GOL = 1.000 + 0.000\, COC - 50.2830\, OIL$$

$$COC = 0.000 + 1.000\ GOL - 44.0980\, OIL$$

These coefficients indicate that crude oil prices (OIL) have a significant negative long-run impact on both gold and cocoa prices in Ghana. A unit increase in crude oil prices leads to a 50.283-unit decline in gold prices and a 44.098-unit decline in cocoa prices, suggesting that rising oil prices increase production costs and reduce profitability in the gold and cocoa sectors.

In terms of short-run dynamics as in **Table 6**, gold prices significantly respond to past values of gold itself, cocoa prices, and oil price shocks. Cocoa prices respond mainly to their own past values and crude oil price fluctuations, confirming the energy cost impact on cocoa production. Oil prices show limited short-run adjustments but are influenced by past cocoa prices and their own past values.

The error correction term for gold ($EC1 = -0.0940, p = 0.0052$) is significant, indicating that gold prices adjust toward equilibrium following a deviation. The speed of adjustment is moderate, meaning gold prices gradually return to long-run equilibrium. Cocoa prices exhibit a relatively faster adjustment speed ($EC1 = 0.1200$), suggesting that cocoa markets correct deviations more rapidly than gold markets. Oil prices show the slowest adjustment ($EC1 = -0.0092$), implying that oil prices are more influenced by external market forces rather than by domestic commodity market conditions.

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Table 6: Short-Run Adjustment Equations

Variable	**Error Correction Term (EC1)**	**Error Correction Term (EC2)**	**Significant Lags of Gold (d_*GOLDd*\ *_GOLDd_GOLD*)**	**Significant Lags of Cocoa (*d_COCOd*\ *_COCOd_COCO*)**	**Significant Lags of Oil (*d_OILd**_OILd_OIL*)**
Gold (*d_GOLDd*\ *_GOLDd_GOL*)	-0.0940 (p = 0.0052)	0.0746 (p = 0.0213)	*d_GOLD*7*d*\ *_GOLD_*7*d_GOLD*7 (-0.3199, p = 0.0046), *d_GOLD*6*d*\ *_GOLD_*6*d_GOLD*6 (-0.2246, p = 0.0482)	*d_COCO*5*d*\ *_COCO_*5*d_COCO*5 (-0.1298, p = 0.0211)	*d_OIL*4*d*\ *_OIL_*4*d_OIL*4 (-2.9118, p = 0.0119), d_OIL5d_OIL_5d_OIL5 (-2.9260, p = 0.0138)
Cocoa (*d_COCOd*\ *_COCOd_COC*)	0.1200 (p = 0.1607)	-0.0805 (p = 0.3319)	None	*d_COCO*2*d*\ *_COCO_*2*d_COCO*2 (-0.2728, p = 0.0802)	d_*OIL*5*d**_OIL_*5*d_OIL*5 (6.2425, p = 0.0421)
Oil (*d_OILd*\ *_OILd_OIL*)	-0.0092 (p = 0.0283)	0.0122 (p = 0.0034)	None	*d_COCO*3*d*\ *_COCO_*3*d_COCO*3 (-0.0140, p = 0.0555), *d_COCO*5*d*\ *_COCO_*5*d_COCO*5 (-0.0132, p = 0.0634)	*d_OIL*10*d**_OIL_*10*d_OIL*10 (-0.3008, p = 0.0391)

VECM (1) Model Diagnostics

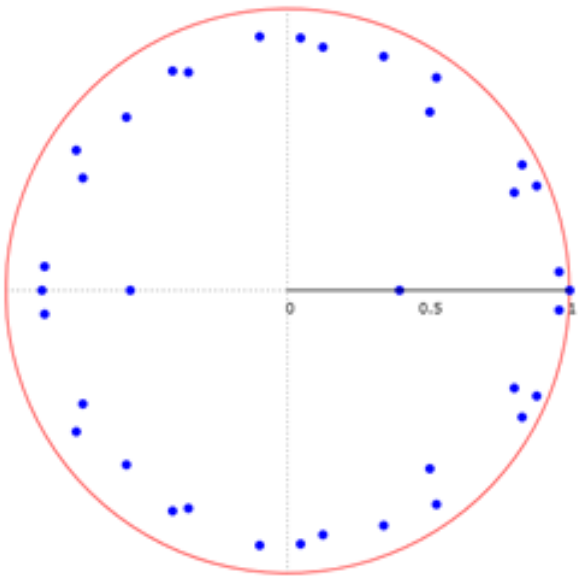

Figure 1: Unit circle plot

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The **Figure 1** below presents the inverse roots of the characteristic polynomial for the estimated Vector Error Correction Model (VECM), plotted against the unit circle to assess the model's stability. The key criterion for stability in a VECM (or its underlying VECM representation) is that all inverse roots should lie inside the unit circle. The plot indicates that all inverse roots are well within the unit circle, confirming that the estimated VECM (1) is stable.

The ARCH effect test was conducted to check the presence of autoregressive conditional heteroskedasticity in the residuals and the results is in **Table 7.** From the table, the LM statistics and their p-values for all equations suggest that we fail to reject the null hypothesis of no ARCH effect at the 5% significance level. Hence, there is no significant ARCH effect in the model residuals.

Table 7: Results of ARCH Test for Order 12

Equation	**Coefficient (α_0)**	**Std. Error**	**t-ratio**	***p*-value**	***LM* Statistic**	***p*-value (Chi-square)**	**ARCH Effect?**
Eq. 1	4877.03	2368.8	2.059	0.043	3.96479	0.9841	No
Eq. 2	31534.1	15454	2.041	0.0448	6.75196	0.8736	No
Eq. 3	81.2508	42.5707	1.909	0.0601	1.43073	> 0.99	No

Impulse Response Function

The Impulse Response Function (IRF) analysis evaluates how shocks in one commodity price (gold, cocoa, or oil) affect the other markets over time. The responses are presented over a 12-period horizon following a one-standard-error shock.

Table 8 presents the results of the IRF for gold, cocoa and oil market from period 1 to period 12. For gold, a shock to gold prices has an immediate and strong positive impact on cocoa prices, peaking at period 3 before declining. Crude oil prices initially decline in response to a gold price shock, with the effect reaching its lowest point around period 6 before stabilizing. The impact on gold itself follows a dampening pattern, indicating that gold price shocks dissipate over time.

For the equation for cocoa, a shock to cocoa prices has a strong initial impact on cocoa itself, with the effect gradually diminishing over time. Gold prices respond positively but gradually, showing a delayed peak around period 11. Crude oil prices initially decline but stabilize after period 5, turning positive after period 9.

And for crude oil, a shock to oil prices has a strong and immediate effect on oil itself, peaking in period 1 and then declining gradually. Cocoa prices initially rise in response to oil price shocks but drop sharply after period 9, indicating potential cost-push effects. Gold prices react negatively at first, reaching the lowest point at period 6, before recovering after period 10, suggesting that oil price increases initially depress gold prices but have a stabilizing effect in the long run.

Table 8: IRF results for period 1 to 12.

Period	**Gold**	**Cocoa**	**Oil**
1. Response to a Shock in Gold Prices			
1	62.7070	29.0670	1.3344
2	45.3140	56.8750	0.1781
3	32.6070	68.1870	-1.2759
4	24.3430	42.7640	-1.6168
5	23.7680	38.6670	-1.7511
6	13.4520	35.0310	-1.9099
7	7.2919	31.3480	-1.5953

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8	1.7965	35.7320	-0.7568
9	8.5523	24.5710	0.0665
10	12.7340	27.0920	0.4359
11	21.2500	18.9880	-0.0791
12	21.8360	30.4050	-0.2133
2. Response to a Shock in Cocoa Prices			
1	0.0000	160.7500	-2.8367
2	11.7720	130.2900	-1.9478
3	10.9960	89.5730	-0.6959
4	13.6960	92.9160	-1.2610
5	7.8686	88.7840	0.1215
6	-0.6728	96.1890	-0.0206
7	9.2602	83.3210	0.1781
8	11.8060	66.6380	0.6149
9	12.2760	53.5820	1.1633
10	13.3900	41.0890	1.6023
11	19.4590	57.1180	1.4429
12	13.7060	36.1230	2.7201
3. Response to a Shock in Oil Prices			
1	0.0000	0.0000	7.3161
2	3.0883	12.8450	7.0714
3	2.0877	1.4163	6.3259
4	0.1854	15.8350	4.5372
5	-9.7280	12.8210	4.3135
6	-17.1600	30.3230	2.7220
7	-15.6330	13.9190	1.7193
8	-11.9260	10.3700	0.9514
9	-12.279	-13.3060	1.1243
10	-7.5622	-30.0770	0.3411
11	6.4795	-20.4590	-1.1416
12	13.8990	-12.6730	-1.3849

Forecast Error Variance Decomposition

The Forecast Error Variance Decomposition (FEVD) assesses the proportion of variation in each commodity price (gold, cocoa, and oil) that is attributable to shocks in itself and the other markets over time. The results is presented in **Table 9** below.

In the short run (Period 1), gold price fluctuations are entirely self-driven (100%). Over time, the influence of cocoa and oil price shocks increases, with cocoa accounting for 13.08% and oil for 9.88% by Period 12. However, gold remains largely self-determined (77% even in the long run), suggesting that external shocks play a secondary role.

Cocoa prices are highly self-driven (96.83% in Period 1) but gradually influenced by gold price shocks (15.30%) over time. Oil price effects on cocoa are minimal, accounting for only 2.92% in the long run, indicating that cocoa prices are less exposed to crude oil market volatility than gold prices. Oil price fluctuations are primarily self-driven (84.49% in Period 1, remaining at 81.91% in Period 12).

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Cocoa prices have a growing influence on oil prices over time (11.44% in Period 12), suggesting potential cost-driven feedback loops. Gold price effects on oil remain low (6.65%), indicating limited direct interdependence between oil and gold price movements in Ghana.

Table 9: Forecast Error Variance Decomposition (FEVD) Results

Period	Std. Error	Gold (%)	Cocoa (%)	Oil (%)
1. Variance Decomposition of Gold Prices				
1	62.7070	100.0000	0.0000	0.0000
2	78.3180	97.5900	2.2600	0.1600
3	85.5700	96.2700	3.5400	0.1900
4	90.0130	94.3100	5.5200	0.1700
5	93.9350	93.0000	5.7700	1.2300
6	96.4350	90.1900	5.4800	4.3300
7	98.4020	87.1700	6.1500	6.6900
8	99.8390	84.7100	7.3700	7.9200
9	101.6980	82.3500	8.5600	9.0900
10	103.6390	80.8000	9.9100	9.2900
11	107.7650	78.6200	12.4300	8.9500
12	111.6740	77.0400	13.0800	9.8800
2. Variance Decomposition of Cocoa Prices				
1	163.3610	3.1700	96.8300	0.0000
2	216.9380	8.6700	90.9800	0.3500
3	244.4110	14.6100	85.1100	0.2800
4	265.4240	14.9900	84.4200	0.5900
5	282.8290	15.0700	84.2000	0.7300
6	302.3100	14.5300	83.8300	1.6400
7	315.4520	14.3300	83.9600	1.7000
8	324.5530	14.7500	83.5400	1.7100
9	330.1310	14.8100	83.3700	1.8200
10	335.1320	15.0300	82.4000	2.5700
11	341.1090	14.8100	82.3500	2.8400
12	344.5940	15.3000	81.7900	2.9200
3. Variance Decomposition of Oil Prices				
1	7.9590	2.8100	12.7000	84.4900
2	10.8250	1.5500	10.1000	88.3500
3	12.6220	2.1600	7.7400	90.1000
4	13.5690	3.2900	7.5600	89.1500
5	14.3450	4.4300	6.7700	88.8000
6	14.7260	5.8900	6.4200	87.6900
7	14.9120	6.8900	6.2800	86.8400
8	14.9750	7.0800	6.4000	86.5200
9	15.0620	7.0000	6.9200	86.0800

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10	15.1570	6.9900	7.9500	85.0500
11	15.2680	6.9000	8.7300	84.3700
12	15.5720	6.6500	11.4400	81.9100

DISCUSSIONS

The findings of this study align with some existing literature on Ghana's commodity price dynamics while offering new insights into the interrelationships among gold, cocoa, and crude oil prices.

The summary statistics reveal that gold prices are generally higher and more stable than cocoa and crude oil, while oil exhibits the highest volatility. This is consistent with Nunoo (2016), who highlighted that gold prices tend to be less volatile due to their function as a global store of value. Similarly, Barson et al. (2023) found that oil prices are prone to extreme fluctuations due to geopolitical tensions and supply chain disruptions, which align with the high standard deviation observed for oil in this study. The finding that cocoa prices display moderate variability supports Kyei et al. (2023), who noted that while cocoa is subject to seasonal fluctuations, price movements tend to be smoother than those of oil due to stable global demand. The skewness and kurtosis measures in this study indicate that gold and cocoa prices exhibit positive skewness, suggesting a tendency toward price spikes, while oil has the highest kurtosis, reflecting extreme price movements. These results support Oteng et al. (2024), who identified frequent extreme price changes in oil markets due to supply shocks. However, this study diverges from Antwi et al. (2020), who suggested that gold prices exhibit near-normal distribution characteristics, whereas the findings here indicate a longer right tail, suggesting sporadic sharp increases in gold prices.

The ADF and KPSS tests confirm that all three commodities are non-stationary at original levels but become stationary after first differencing, indicating that they share similar integration properties. This is in line with Obeng et al. (2023), who found that commodity prices in Ghana follow an integrated process and require differencing for stationarity. Additionally, Barson et al. (2023) highlighted the importance of first differencing in analyzing commodity prices, noting that ignoring non-stationarity could lead to misleading inferences. The near-borderline stationarity of cocoa prices in this study contradicts Antwi et al. (2020), who suggested that cocoa prices might be stationary due to government interventions in the Ghanaian cocoa market. However, the results here indicate that despite regulatory efforts, cocoa prices still follow a non-stationary process, likely due to international market influences.

The Johansen co-integration test confirms the presence of two significant co-integrating relationships, meaning that gold, cocoa, and oil prices maintain a long-run equilibrium. This finding aligns with Barson et al. (2023), who emphasized that global macroeconomic conditions create lasting linkages between commodity prices. Furthermore, the strong influence of crude oil prices on both gold and cocoa markets supports Oteng et al. (2024), who found that energy price shocks have far-reaching effects on Ghana's commodity sector. However, while this study finds that cocoa prices adjust the fastest to deviations from equilibrium, Nunoo (2016) suggested that gold prices tend to adjust more rapidly due to investor speculation. The slower adjustment of oil prices observed in this study contradicts Onomah (2019), who argued that oil prices respond dynamically to external market shocks. The difference may stem from Ghana's unique position as both an oil producer and importer, creating mixed adjustment behaviors.

The selection of Lag 1 as the optimal lag order suggests that Ghana's commodity prices exhibit strong short-term dependencies, meaning that past price movements influence current adjustments within a short period. This aligns with Obeng et al. (2023), who found that commodity prices in Ghana react quickly to global shocks. However, this study contradicts Barson et al. (2023), who argued that longer lags (up to 3–5 periods) capture more complex interdependencies. The divergence may be due to differences in data periods and methodological approaches, as longer lags may capture delayed policy interventions rather than immediate market reactions.

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The VECM results confirm that crude oil prices significantly impact both gold and cocoa markets, highlighting Ghana's dependence on global energy markets. This supports Antwi et al. (2020), who found that energy costs influence commodity prices by affecting production and transportation costs. The strong self-dependence of commodity prices in the short run aligns with Obeng et al. (2023), who emphasized that internal market dynamics play a dominant role in shaping short-term price movements. However, this study diverges from Onomah (2019), who found stronger bidirectional effects between gold and cocoa prices. Here, the interaction between gold and cocoa is weaker in the short run but strengthens over time, suggesting that external factors initially dominate, while internal market adjustments become more significant in the long run.

The IRF results confirm significant interdependencies between Ghana's gold, cocoa, and crude oil markets. Gold and cocoa prices are most sensitive to their own shocks, while crude oil price shocks have long-lasting effects on cocoa prices. These results are consistent with Kyei et al. (2023), who emphasized the strong link between energy costs and agricultural exports. Notably, crude oil shocks initially depress gold prices, but the impact fades over time, a result that aligns with Barson et al. (2023), who found that oil shocks create initial financial market uncertainty, leading to short-term declines in gold prices before recovery. However, this study contradicts Obeng et al. (2023), who suggested that oil shocks have a negligible effect on gold. The difference may be due to the time period studied or the specific global oil market conditions during the data sample used.

The FEVD results highlight the dominant role of self-dependence in gold and cocoa price dynamics, with over 77% of gold price fluctuations and 81% of oil price fluctuations being internally driven even in the long run. This supports Obeng et al. (2023), who found that commodity prices in Ghana are largely shaped by sector-specific factors rather than external influences. However, this study finds that gold price shocks explain 15.30% of cocoa price fluctuations in the long run, a result that differs from Antwi et al. (2020), who reported a weaker link between gold and cocoa prices. The stronger connection observed here may reflect more recent macroeconomic trends, such as global financial crises and shifts in investor sentiment, which simultaneously affect both commodities.

These findings reinforce the need for targeted policies to mitigate the risks of commodity price volatility in Ghana. Antwi et al. (2020) and Oteng et al. (2024) emphasized the importance of exchange rate stability and hedging mechanisms to protect against global price shocks. The results here support such recommendations, particularly for cocoa markets, which are highly sensitive to both internal and external shocks. Additionally, the findings suggest that global oil price shocks may have a smaller-than-expected impact on Ghana's cocoa and gold markets, which challenges Barson et al. (2023), who argued for a stronger pass-through effect. This calls for further research into the mechanisms that insulate Ghana's gold and cocoa prices from global oil price shocks, particularly regarding government policy and market structures.

Furthermore, the limited role of monetary policy interventions in stabilizing commodity prices, as implied by the FEVD results, contrasts with Obeng et al. (2023), who found significant monetary policy effects. Future research should explore which specific policy instruments are most effective in mitigating commodity price volatility, as existing studies provide mixed results on this issue.

CONCLUSION AND RECOMMENDATION

This study, through the VECM, confirms that the international prices of gold, cocoa, and crude oil in Ghana are integrated of order one (I(1)), and exhibit significant long-run equilibrium relationships. The Johansen co-integration test identifies two co-integrating vectors, indicating enduring economic linkages among the commodities. Crude oil exerts the greatest influence in the long run, supporting the theoretical proposition of price transmission in energy-dependent economies—where oil, as a production input and macroeconomic driver, shapes the pricing of related commodities (consistent with cost-push inflation and input-output price transmission theories). In the long-run, a 1-unit increase in crude oil prices is associated with a decline of 50.283 units in gold prices and 44.098 units in cocoa prices. This reflects the negative cost-push effect of oil

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on Ghana's export commodities. For short-run period, gold and cocoa prices show strong autoregressive behavior (e.g., gold lag coefficients:), while crude oil is weakly influenced by others, reaffirming the theory of oil price exogeneity in small open economies. In terms of speed of adjustment, cocoa prices adjust more rapidly to long-run disequilibria compared to gold and oil, suggesting higher price flexibility in agricultural commodities. IRF revealed that, oil price shocks have lasting positive effects on cocoa prices, but only transitory effects on gold, confirming asymmetric transmission mechanisms. And FEVD results shows gold and cocoa price movements are predominantly self-driven (77.04% and 81.79%, respectively), while crude oil price shocks account for only 9.88% of gold and 2.92% of cocoa price variation, contradicting expectations of higher oil price influence under the classical commodity comovement theory. These findings support a nuanced interpretation of commodity market interdependence. While long-run co-movement exists, short-run autonomy dominates, particularly in gold and cocoa markets. This suggests that while Ghana's commodity markets are susceptible to global oil dynamics in the long term, domestic supply-demand fundamentals and sector-specific rigidities mitigate short-run transmission effects. Theoretically, this reinforces the Partial Pass-Through Hypothesis in international price transmission literature and highlights the limited efficacy of the Law of One Price (LOOP) in Ghana's commodity trade structure. While the study thoroughly explores inter-commodity relationships using a robust VECM framework, it does not account for the potential mediating or confounding effects of domestic economic conditions.

Recommendations

To mitigate the adverse effects of oil price volatility on Ghana's key export commodities, particularly cocoa, the government and private sector actors should adopt targeted market stabilization policies such as commodity futures contracts and options trading. These financial instruments allow producers and exporters to lock in prices and reduce uncertainty associated with future price movements. For instance, cocoa producers could use cocoa futures on exchanges like ICE Futures U.S. to hedge against potential declines in prices triggered by rising crude oil costs. Similarly, energy-intensive exporters may consider crude oil options to hedge against fuel cost volatility, ensuring cost predictability in transportation and processing.

To reduce vulnerability to external price shocks, Ghana should invest in value-added processing for cocoa and gold, enabling the country to benefit from more stable export earnings rather than relying solely on raw commodity exports. Also, Ghana should implement macroprudential measures to limit volatility spillovers from global commodity markets to domestic inflation and exchange rates.

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