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Quantitative Easing: Money Supply and Commodity Prices of Oil, Gold, and Cocoa in Ghana

Samuel Kwaku Obeng[1*], Samuel Bassah Kofi Quansah[2], Theresa Dowetin[3], Ampem Darko Nsiah[4], Ezekiel Nii Noye Nortey[5], Ebenezer Okyere[6]

[1]Research and Statistics Unit, Minerals Commission of Ghana, Accra, Ghana
[2]SPARKX Ghana Ltd., Accra, Ghana
[3]Datus International School, Tema, Ghana
[4]Statistics Unit, CID Headquarters, Accra, Ghana
[5]Department of Statistics and Actuarial Science, University of Ghana, Accra, Ghana
[6]Research and Policy Unit, Bank of Ghana, Accra, Ghana
Email: *Samobeng2002@yahoo.com, *samobeng2002@gmail.com, kofi.quansah4@gmail.com, ablavi8001@yahoo.com, ampemn97@gmail.com, ennnortey@ug.edu.gh, ebenezer.okyere@bog.gov.gh

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Abstract

This study investigates the dynamic relationships between the money supply (M2) and key commodity prices (Cocoa, Gold, and Crude) in the context of Ghana. Utilizing Vector Error Correction Model (VECM) analysis, we analyze the short-term and long-term Granger causality relationships among these variables, aiming to shed light on the potential linkages between monetary policy and commodity markets. The analysis covers the period from December 1999 to April 2023, using lag structures of 1 and 8 to capture both short-term and more enduring effects. Our findings reveal significant Granger causality relationships between the money supply and various commodities, with nuanced patterns emerging across different lags. In the short-run, our results suggest bidirectional causal relationships between COCOA and M2, CRUDE and M2, and GOLD and M2. Additionally, M2 Granger causes changes in COCOA, CRUDE, and GOLD. However, the causal relationship between COCOA and GOLD appears to be unidirectional, with COCOA not significantly Granger causing changes in GOLD. The short-term findings highlight the intricate interplay between monetary policy and commodity markets. In the long-run (lag 8), our analysis unveils robust Granger causality relationships between the variables. Past values of COCOA, CRUDE, and GOLD Granger cause changes in M2, indicating a notable influence of commodity markets on the money supply. Similarly, M2 Granger causes changes in CRUDE and GOLD. Notably, the findings underscore a more comprehensive and in-

tertwined relationship between monetary policy and commodity prices in the long-run. Based on these results, we derive several policy implications. Policymakers should carefully consider the potential impact of monetary policy decisions, such as quantitative easing, on commodity markets and price dynamics. Measures to stabilize commodity prices, promote export diversification, manage inflation expectations, and enhance economic resilience are recommended. Additionally, effective data monitoring, international collaboration, and proactive risk management strategies are essential components for navigating the complex interactions between monetary policy and commodity markets. This study contributes to a deeper understanding of the intricate connections between monetary policy and commodity prices in Ghana, offering insights for policymakers, researchers, and stakeholders seeking to promote sustainable economic growth and stability. Further research can delve into the mechanisms underlying these relationships and explore their broader implications for trade balances, economic performance, and policy formulation.

Keywords

Quantitative Easing, Money Supply, Cocoa, Gold, Crude, VECM

1. Introduction

Ghana, formerly the Gold Coast, is a small country in West Africa with a land area of about 238,537 sq. tan. and a population of about 30.8 million [1]. According to the Central Intelligence Agency (CIA) report (February 8, 2019), Ghana has a market-based economy with relatively few policy barriers to trade and investment in comparison with other countries in the region and is endowed with natural resources. Ghana's economy was strengthened by a quarter century of relatively sound management, a competitive business environment, and sustained reductions in poverty levels, but in recent years has suffered the consequences of loose fiscal policy, high budget and current account deficits, and a depreciating currency [2].

Agriculture contributes about 20% of GDP and employs more than half of the labour force. Gold, oil, and cocoa exports, and individual remittances, are major sources of foreign exchange. Expansion of Ghana's nascent oil industry has boosted economic growth, but the fall in oil prices since 2015 reduced by half Ghana's oil revenue [2].

In 1957 Ghana became the first sub-Saharan African country to gain independence. It was hailed as the "black star" of Africa with a hopeful economic future to be based upon development of its natural and human resource endowments. However, after over fifty-seven years of independence Ghana has retrogressed from being classified in international circles as a middle-income nation to a low-income nation, with constant price per capita GDP in 2017 (that is 5044.05) just 40% above that in 1960 (that is 3026.19) [2] [3].

Among Ghana's woes have been high rates of inflation, a grossly over-valued exchange rate, persistent balance of payments deficits and declining rate of per capita income growth. Some of these problems were brought about by external factors such as instability of the world price of cocoa, oil, gold, and internal factors such as early political instability between 1960s and 1990s and general economic mismanagement. Large budgetary deficits are usually the attributed cause of the internal problems since heavy government borrowing from the banking sector has expanded the money stock and been inflationary [3].

Consequently, since the 1970s, the country's money supply has been increasing at a rate of over 40% per annum and the monetary policies pursued up to 1983 were unable to check this trend. Since 1983, when the Economic Recovery Programme (ERP) was instituted with IMF financing, fiscal discipline has been restored; yet the country's money supply kept increasing at high rates and inflation remained above 9%. The increases in the money supply were no longer due to deficit financing, since the country has registered budget surpluses since 1985, but rather to the inflow of funds from foreign multilateral and bilateral donor agencies and governments [3].

From 1960, when the Bank of Ghana gained full central banking status, the Ghanaian authorities have had the chance to pursue an independent monetary policy. However, the effectiveness of central bank control of the money supply has been curtailed by factors such as undue interference by governments in the operations of the Bank of Ghana and a low degree of financial intermediation in the country [3]. The Bank of Ghana defines money supply as demand deposits at the banks (both primary and secondary) plus currency in the hands of the public [3]. The money supply is the entire stock of currency and other liquid instruments circulating in a country's economy as of a particular time. The money supply can include cash, coins, and balances held in checking and savings accounts, and other near money substitutes. Economists analyze the money supply as a key variable to understanding the macro-economy and guiding macroeconomic policy.

Monetary policy is how a country's central bank controls its money supply. The main way central banks control money supply is buying and selling government debt in the form of short-term government bonds. Economists call this "open market operations" because the central bank is selling bonds on the open market. Central banks have other tools to indirectly control the money supply, like requiring banks to keep more money on hand (called reserve requirements) or changing the interest rate which they lend to private banks. In recent years, central banks have also experienced a new policy called quantitative easing (basically a turbocharged version of buying bonds).

According to Investopedia [4], quantitative easing is a monetary policy used by central banks to increase the supply of money by increasing the excess reserves of the banking system, generally through the buying of the central government's own bonds to stabilize or raise their prices and thereby lower long-term

interest rates. Quantitative easing (QE) is an unconventional monetary policy tool implemented by central banks to stimulate economic growth and combat deflationary pressures. This policy involves the purchase of financial assets, such as government bonds, to inject money into the economy and increase the money supply. This is often considered as a last resort to increase the money supply. This is done by borrowing from member bank reserve accounts, creating a depository liability, and then using these funds to buy investments like government bonds from financial firms such as banks, insurance companies and pension funds, in a process known as "monetizing the debt" [4].

The immediate effect of quantitative easing is an increase in the liquidity of the overall financial system [4]. Institutional investors and banks may then re-direct these cash received into lending to private, individuals or governmental institutions to invest in the economy [4]. These actors may alternatively invest these funds in acquisition of assets in the emerging market. The profitability of these actors can be improved in two ways. Firstly, they can tap into revenue generated by fast growing industries in countries where both private and public consumption is expanding rapidly [4]. Secondly, they can benefit from the predictable appreciation of local currencies in emerging economies or rather the depreciation of the Ghana cedi compared to other currencies. However, the resulting increase in liquidity in oversea markets could cause significant distortions in recipient countries, for example, in the form of inflation [4].

Quantitative easing in most cases does send shockwaves through the global commodity market, with traders fearing scarcity of supply and resulting in an immediate escalation in commodity prices. For instance, cocoa prices have recently jumped on the global market to levels not seen since the year 1970, sending a shockwave throughout the cocoa processing industry. Prices for cocoa reached £2465 per tonne on 19th July 2010, the highest level for a second-month contract in 32 years [4]. The increase in cocoa bean prices is being fueled by prospective economic recovery in emerging markets and short-term speculative movements in the futures market. Unlike in other commodities, average monthly cocoa prices in October 2010 (US$2909 per tonne) are now at similar levels to the price of hikes reached in mid-2008, according to International Monetary Fund (IMF) statistics [4]. This, however, indicates that an unsound money supply leads to inflation and extreme business cycles of boom and bust that are manipulated further by the central bank's interventions. In order words, a sound money supply leads to a prosperous economy and a limited government.

Several works [3] [4] have been conducted but not in this area in Ghana. The one conducted by Kasteler [5] was for a developed country and used commodities like gold, oil and wheat but did not include cocoa. This study, however, bridges these gaps by researching into quantitative easing and the effects of money supply on commodity prices of gold, oil, and cocoa in Ghana. While QE has been widely discussed and studied in the context of developed economies, its effects on emerging markets, particularly on commodity

prices, remain relatively understudied. This research aims to explore the impact of QE on the money supply and commodity prices of oil, gold, and cocoa in Ghana, a prominent emerging market with a significant reliance on commodity exports. Also, the global financial crisis of 2008 prompted central banks worldwide to adopt unconventional monetary policies, including QE, to stabilize economies. Ghana, being a commodity-driven economy, faces potential implications from these global monetary measures. The link between QE, money supply, and commodity prices in the Ghanaian context requires closer examination to understand the possible effects on the country's economic stability and export revenues.

Rationale of the study

The rationale behind selecting Cocoa, Gold, and Crude as the key commodity prices for analysis in the context of Ghana can be attributed to their significant economic importance and their representation of diverse sectors within the country's economy.

1) **Cocoa**: Ghana is one of the world's largest producers of cocoa beans, which are the primary raw material for chocolate production. Cocoa exports contribute significantly to the country's foreign exchange earnings and employment. The cocoa sector supports the livelihoods of millions of Ghanaians, especially smallholder farmers. Fluctuations in cocoa prices can have a substantial impact on the country's trade balance and overall economic stability.

2) **Gold**: Gold has been a historically important commodity for Ghana's economy. The country is a major producer of gold and is ranked among the top gold-producing countries globally. Gold mining and related activities contribute to revenue generation, employment, and foreign exchange earnings. The price of gold often reflects global economic and geopolitical trends, making it an essential indicator for economic analysis and forecasting.

3) **Crude Oil**: While not as significant as cocoa and gold, crude oil is still an important commodity for Ghana. The discovery of oil in commercial quantities in the Jubilee Field off the coast of Ghana in 2007 marked a significant development for the country. Oil exports contribute to government revenues and foreign exchange earnings. Studying the relationship between money supply and crude oil prices helps understand how changes in oil prices impact the economy.

These three commodities, cocoa, gold, and crude oil, collectively represent diverse sectors of Ghana's economy:

- **Agriculture (Cocoa)**: Cocoa represents the agricultural sector, which is a vital component of Ghana's economy. Agriculture provides employment to a large portion of the population and contributes to both domestic consumption and export earnings.
- **Mining (Gold)**: The gold sector represents the mining industry, which plays a crucial role in Ghana's economy. It contributes to revenue, exports, and employment, while also influencing infrastructure and development projects.
- **Energy (Crude Oil)**: The crude oil sector represents the energy industry, a

newer and evolving sector in Ghana. Oil exports contribute to the country's revenue and foreign exchange earnings, with potential implications for infrastructure development and energy security.

By analyzing the dynamic relationships between these commodity prices and the money supply (M2), researchers aim to understand how changes in the money supply may impact these crucial sectors, as well as the broader economy. Fluctuations in commodity prices can have cascading effects on inflation, trade balances, investment, and overall economic stability. Therefore, studying these relationships provides valuable insights for policymakers, economists, and stakeholders seeking to make informed decisions about monetary policy and economic development in Ghana.

Objective of the Study

The main objective of this study is to examine the effects that changes to money supply have had on commodity prices using commodity prices for the past few decades. The specific objective is to examine how the changes that the central bank makes to the money supply affects the three major commodity sectors namely energy (oil), metal (gold) and cash crop (cocoa) in Ghana.

In order to achieve this objective, econometrics was used as a tool for analysis to aid in the accuracy of the relationship that may or may not exist between money supply and commodity prices. To be specific, Vector Autoregression (VAR) was employed to the selected data. In addition, a variety of data testing and estimation analysis were carried out to verify the efficacy of the VAR model.

Research Hypothesis

1) Quantitative easing has a significant effect on increasing the money supply in Ghana.

2) Quantitative easing has a significant impact on commodity prices, particularly oil, gold, and cocoa, in Ghana.

3) The increase in commodity prices due to QE leads to notable changes in Ghana's trade balance and economic performance.

1.1. Literature and Empirical Review

Ghana, located in West Africa, possesses a diverse and resource-rich economy that is intricately linked to global commodity markets. The country's commodity sectors, notably cocoa, gold, and crude oil, hold profound economic significance, shaping trade dynamics, government revenues, employment opportunities, and overall economic stability. At the heart of this economic tapestry lies the intricate interplay between these commodities and the nation's monetary policy. The efficacy of monetary policy, governed by the central bank, is instrumental in navigating the challenges and harnessing the opportunities presented by Ghana's commodity-driven economy.

Economic Significance of Commodity Markets:

Ghana's commodity markets are not mere sectors; they form the bedrock of the nation's economic fabric. Cocoa, an agricultural jewel, sustains millions of

smallholder farmers and contributes substantially to foreign exchange earnings. The gold industry, with its historical resonance, fuels revenue streams and employment avenues, while crude oil, a more recent entrant, holds the potential to transform the energy landscape and bolster government revenues. The prices of these commodities are inherently susceptible to global market fluctuations, geopolitical events, and supply-demand dynamics, rendering their impacts far-reaching and multifaceted.

Monetary Policy's Role:

In this intricate economic landscape, the role of monetary policy becomes paramount. The central bank's pursuit of stable prices, exchange rate stability, and sustainable economic growth acquires heightened significance due to the vulnerability of commodity markets to external shocks. The dynamics between the money supply (M2) and key commodity prices provide a lens through which the impacts of monetary policy ripple across sectors. Fluctuations in money supply can influence consumer spending, business investments, and borrowing costs, thus exerting indirect effects on commodity demand and prices. Moreover, the central bank's decisions on interest rates, currency interventions, and liquidity management have the potential to either mitigate or exacerbate the impacts of commodity price volatility.

In light of these complexities, understanding the intricate relationships between monetary policy and commodity markets is indispensable for effective policymaking. This study delves into the dynamic interplay between the money supply (M2) and the prices of cocoa, gold, and crude oil, unraveling insights that can guide policymakers in their quest for sustainable economic growth, price stability, and enhanced resilience against external shocks. By shedding light on these relationships, the study aims to empower Ghana's decision-makers with the knowledge needed to steer the nation's economy toward a path of prosperity in the face of the ever-evolving global commodity landscape.

Empirical Review

Kasteler [5] conducted a study to examine how the changes to the money supply (as measured by M2) impacted commodity prices of Gold, Oil and Wheat of the United States of America. Kasteler [5] used monthly data from January 1985 to December 2013 for the analysis. Kasteler [5] used vector autoregressive (VAR) model and vector error correction (VEC) model to analyze the data. After applying both the VAR and the VEC models to the data and using the SAS computational program, Kasteler [5] found a long-term relationship equilibrium between the prices of Gold, Oil, and Wheat commodities and the amount of M2.

The underlying impression here is that the Federal Reserve did anticipate correctly the potential short-term effects upon pricing with these several commodities. And given the potential serious economic repercussions that were being postulated at the time, the course of quantitative easing was potentially the least painful. So far, the economic recovery that is seen is borne out of the effectiveness of their policy.

Van Limbergen [6] also investigated the relationship between global liquidity and housing, equity, and commodity prices by means of Vector Autoregression analysis (VAR), be it in structural form (SVAR) or in cointegrated form (CVAR) approaches. Van Limbergen [6] constructed a global liquidity measure including data on both developed and emerging market countries, resulting in the coverage of 85 percent of world GDP. The findings of Van Limbergen [6] suggest that global monetary policy shocks have a significant impact on housing prices and, to a much lesser extent, commodity prices. Additional cross-country analysis reveals the existence of vast asymmetries in asset prices reactions between individual regions.

In a study conducted by Belke, Bordon and Hendricks [7], the interactions between money, interest rates, goods and commodity prices at a global level were examined. They aggregated data for major Organization for Economic Co-operation and Development (OECD) countries and followed the Johansen/Juselius cointegrated VAR approach. Their empirical model supported the view that, when controlling for interest rate changes and thus different monetary policy stances, money (defined as a global liquidity aggregate) is still a key factor to determine the long-run homogeneity of commodity prices and goods prices movements. The cointegrated VAR model fits with the data for the analyzed period from the 1970s until 2008 very well. The inclusion of commodity prices helped them to identify a significant monetary transmission process from global liquidity to other macro variables such as goods prices. They found further support of the conjecture that monetary aggregates convey useful information about variables such as commodity prices which matter for aggregate demand and thus inflation. Given this clear empirical pattern it appears justified to argue that global liquidity merits attention in the same way as the worldwide level of interest rates received in the recent debate about the world savings and liquidity glut as one of the main drivers of the current financial crisis, if not possibly more.

1.2. Significance of the Study

The findings of this study will unearth the hidden relationship between Ghana's money supply changes and commodity prices. These findings will assist the central bank, policy makers and economic think tanks to study the commodity prices before making or suggesting changes to money supply. Also, the findings will assist investors to monitor closely the changes in money supply before investing. Finally, the findings of this study will serve as additional literature to the existing ones for further research.

2. Materials and Methods

2.1. Research Design

The research design used was explanatory research design that falls under conclusive research designs. The explanatory research design was used since the study was to examine the effects that changes to money supply have had on

commodity prices using commodity prices for the past few decades. The study gave a concluding result on the effects that changes to money supply have had on commodity prices using commodity prices for the past few decades, hence conclusive research design.

2.2. Source of Data and Data Description

A secondary data on money supply (M2) and commodity (Gold, Crude and Cocoa) prices were requested from the Bank of Ghana. It is a monthly data between the periods of December 1999 and April 2023 (that is 281 data points). To request for this data, a letter was first sent to the Actuarial and Statistics Department, University of Ghana, Legon. The department then wrote a letter on behalf of the researcher to the Secretary of Bank of Ghana, who then sent the data to the school's secretary to be given to the researcher. The data reached the researcher finally through the Head of Actuarial and Statistics Department.

2.2.1. Money Supply

The Bank of Ghana uses three principal monetary aggregates as policy indicators for money supply. These are M1 (currency and checkable deposits), M2 (broad money supply which includes M1), M2+ (total liquidity which includes M2). M1 is also called transactions aggregates while M2 comprises M1 and Savings balances. This study used average monthly measure of M2 from December 1999 to April 2023 for its analysis. This was the most consistent and current data available across all the study variables. M2 was measured in million Ghana Cedis (GH¢M).

2.2.2. Gold

Gold was chosen because it is the measure of the commodities that fall within the metals category. Gold is a key exported metal commodity in Ghana. Notwithstanding the role that metal played as actual money in the olden days, the price of Gold is needed since it plays a very crucial role in the industrial sector as well as its popularity among customers. This data was as well compiled by the Bank of Ghana. This data was also measured in US$ per ounce. To get same currency unit for the data, this figure was converted into Ghana Cedis (GH¢) with the average monthly interbank exchange rates from December 1999 to April 2023.

2.2.3. Crude

It is mostly argued that the industrial revolution and our way of life depends on oil. Oil is very important in the markets and a primary source of energy in the world. Therefore, a study of the effects from money supply handling will never be complete if oil prices are not involved. What is included in this study is the actual crude price in United States Dollars (US$) per barrel. This figure was also converted into Ghana Cedis (GH¢) with the average monthly interbank exchange rates from December 1999 to April 2023.

2.2.4. Cocoa

Cocoa has been chosen because it is one of the worlds most accepted primarily foodstuff. Cocoa is the key cash crop that provides about one third of Ghana's export revenue. Being the major cash crop in Ghana, it is prudent to include it in this model. This data was compiled by the Bank of Ghana and was measured in US$ per tonne. For this study, it was also converted with the average monthly interbank exchange rate from December 1999 to April 2023 to Ghana Cedis since M2 is in Ghana Cedis.

2.3. Data Analysis

Vector Auto Regression (VAR) is the main method used in the analysis. VAR is an econometric method that reveals the interdependencies among multiple time series data. This study is to unearth the potential relationship between money supply (M2 and M2+), Gold, Oil and Cocoa with the average monthly money supply and commodity pricing data.

In normal linear regression or correlation models, the term causality is being looked at in one direction. That is, either Y causes X or X causes Y. For instance, in this study, we can say that M2 causes changes in gold prices. However, it can also happen that gold prices cause changes in M2. Therefore, one cannot from the onset determine which variable is causing the other. The causality may happen on both sides. That is, gold prices cause changes in M2 and M2 also causes changes in gold prices. Therefore, since causality may come from both variables to one another, we call this Granger Causality. That is X Granger causes Y if past values of X can be used to explain Y. If Granger causality holds, it does not guarantee that X Causes Y. This is why it is stated as Granger causality and not just causality. This only suggests that X might be causing Y. To go ahead with this analysis, both X and Y should be either stationary or non-stationary. None should be non-stationary whiles the other is stationary. Both should either be stationary or non-stationary (have a unit root) since it is hard for a stationary series to explain a stochastic trend variation in a unit root series. Therefore, to proceed with the analysis, unit root test is carried out for all the variables. When the X and Y are both stationary, we use the normal Ordinary Least Square (OLS) estimation for Autoregressive Distributed lag (ADL) regression model. However, since we may not know the direction of causality, we would rather perform the OLS on the VAR model. This VAR model for X and Y is given as.

$$Y_t = \alpha_1 + \delta_{1t} + \phi_{11}Y_{t-1} + \cdots + \phi_{1p}Y_{t-p} + \beta_{11}X_{t-1} + \cdots + \beta_{1q}X_{t-q} + \varepsilon_{1t} \quad (1)$$

$$X_t = \alpha_2 + \delta_{2t} + \phi_{21}Y_{t-1} + \cdots + \phi_{2p}Y_{t-p} + \beta_{21}X_{t-1} + \cdots + \beta_{2q}X_{t-q} + \varepsilon_{2t} \quad (2)$$

where α_1 and α_2 are the intercepts for Equations (1) and (2) respectively, δ_t is the deterministic trend, ϕ_{1p} and ϕ_{2p} are the coefficients or slopes of lags of Y in Equations (1) and (2) respectively, β_{1q} and β_{2q} are the slopes of lags of X in Equations (1) and (2) respectively, and ε_{1t} and ε_{2t} are the errors for Equations (1) and (2) respectively. The ε_{1t} and ε_{2t} are the vectors of unobservable terms which are assumed to have a zero mean and a constant variance. In other words, ε_t is an in-

dependent stochastic vector that follows a normal distribution ($\varepsilon_t \sim (0, \sigma)$).

The t-test under this is being used to select the number of lags of the dependent and the independent variables respectively.

However, when both variables are unit root series, the normal regression analysis (OLS) is spurious. Therefore, to resolve this problem, both variables are co-integrated. This does not only resolve the spurious problem, but also provides some nice financial intuition. Statistically, it is the unit root in the error term of the model that causes the spurious regression problem. When the variables are co-integrated, it cancels out the unit roots in the variables which makes the resulting error to be stationary. That is, the unit root vanishes when the co-integration is performed. Note that, if the variables are unit roots or are non-stationary, then they have stochastic trends. Therefore, when they are co-integrated, the relationship among them is expressed as Error Correction Model (ECM). However, since the direction of the causality is not known, we use Vector Error Correction Model (VECM). The VECM for X and Y is also given as.

$$\Delta Y_t = \alpha_1 + \delta_{1t} + \gamma_1 e_{t-1} + \phi_{11}\Delta Y_{t-1} + \cdots + \phi_{1p}\Delta Y_{t-p} + \beta_{11}\Delta X_{t-1} + \cdots + \beta_{1q}\Delta X_{t-q} + \varepsilon_{1t} \quad (3)$$

$$\Delta X_t = \alpha_2 + \delta_{2t} + \gamma_2 e_{t-1} + \phi_{21}\Delta Y_{t-1} + \cdots + \phi_{2p}\Delta Y_{t-p} + \beta_{21}\Delta X_{t-1} + \cdots + \beta_{2q}\Delta X_{t-q} + \varepsilon_{2t} \quad (4)$$

where e_{t-1} is the error correction variable. Note that the VECM is same as the VAR with differenced variables, except for the term e_{t-1}. Again, when the variables are non-stationary but are not co-integrated, then other explanatory variables must be added or the variables in the model must be transformed. This can also be done by differentiating the data by the second order or appropriate orders that meet the assumptions. Johansen test is mostly used to test for co-integration. Eviews and R software were used to facilitate the analysis.

2.4. Limitations

There was no specific limitation for this study since the data used was rightly available even on the website of the Bank of Ghana. However, this study is limited to the outcomes between December 1999 and April 2023. Primary data could be collected to buttress the results in future studies.

3. Analysis of Results and Discussions

Stationarity test on the data

Stationarity testing is an essential step in time series analysis. Stationarity refers to the statistical properties of a time series that do not change over time. In simpler terms, it means that the mean, variance, and autocorrelation structure of the data do not exhibit any systematic trend or pattern.

Stationarity is important because many time series analysis techniques, like Vector Autoregression (VAR) models, assume that the data is stationary. If the data violates the stationarity assumption, the analysis results may be unreliable or misleading. Therefore, before applying any time series analysis methods, it is

crucial to ensure that the data is stationary.

Figure 1 and Figure 2 represent the pictorial view of the four data sets between December 1999 and April 2023. The figures indicate that the M2 and the commodity prices are not stationary. However, all the four datasets were stationary at a maximum lag of four and a difference of 1 using Akaike Information Criterion (Refer to Table 1).

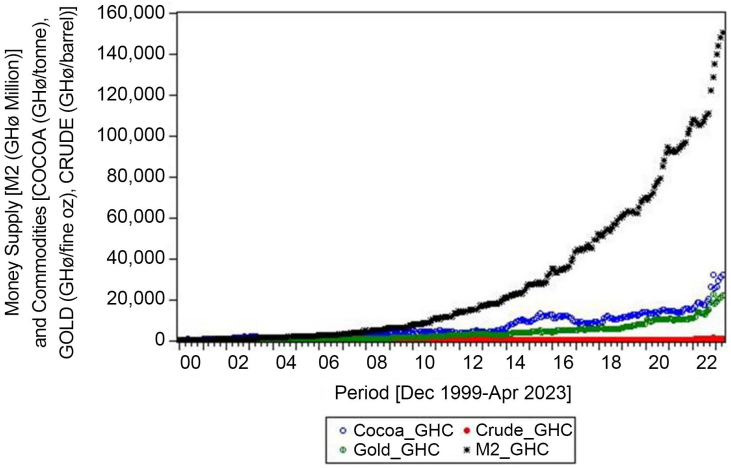

Figure 1. Scatter plot of M2 and the Commodities (1999-2023).

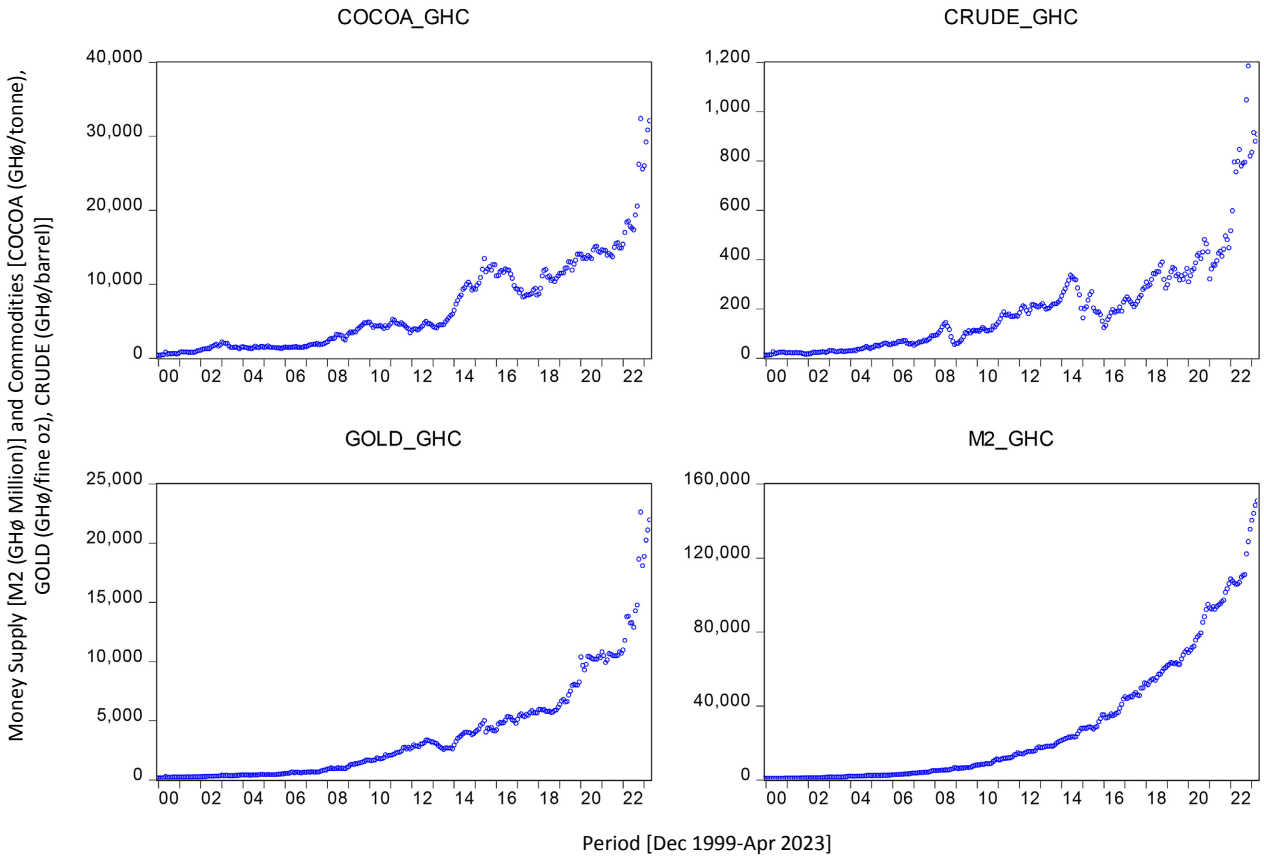

Figure 2. Categorical Scatter plot of M2 and the Commodities (1999-2023).

Table 1. Stationarity test (Augmented Dickey-Fuller test statistic).

Variable	Max Lags	Diff	t-Statistic	Prob.*	AIC
M2_GHC	4	1	−4.120781	0.0011	16.83092
Cocoa_GHC	4	1	−6.354149	0.0000	16.16099
Gold_GHC	4	1	−6.202446	0.0000	15.25414
Crude_GHC	4	1	−6.805638	0.0000	9.900551

Source: Authors own estimation, 2023.

As stated earlier, the p-values for M2, Cocoa, Gold and Crude after the Augmented Dicky-Fuller test at maximum lag of four and a difference of 1 was less than 0.05. In this case, the null hypothesis of the ADF test is that the time series has a unit root, indicating non-stationarity. A p-value less than 0.05 suggests that there is strong evidence to reject the null hypothesis. Therefore, when the p-values are less than 0.05 for these variables, it implies that there is statistical evidence that the variables are stationary after differencing.

In simpler terms, the ADF test results indicate that after applying a first-order difference and considering up to four lags, the variables M2, Cocoa, Gold, and Crude are likely to be stationary. Stationarity is an important concept in time series analysis as it suggests that the statistical properties of the data do not change over time, making it more amenable to various modeling techniques and analyses. However, to proceed, we need to determine the optimal lag of the data.

In the context of time series analysis, the optimal lag analysis is used to determine the appropriate number of lag terms to include in a model. The Akaike Information Criterion (AIC) is a widely used criterion for model selection. A lower AIC value indicates a better fit of the model to the data. The optimal lag analysis in **Table 2** shows that the data will be perfectly fit at lag 8 with AIC. This means that the lagged values of the variable(s) at a lag of 8 time periods back have a significant influence on the current value of the variable being analyzed. In practical terms, this could indicate that there is a pattern or relationship in the data that spans across an 8-time period lag. Including this lag in the model captures this pattern and improves the model's ability to explain and predict the variations in the data.

However, it's important to note that while an AIC value indicates a better fit relative to other models with different lag structures, it does not necessarily imply a "perfect" fit in an absolute sense. It means that among the lag options considered, lag 8 provides the best balance between model complexity and goodness of fit.

Now, to proceed with the Vector Error Correction Model (VECM), we need to check for cointegration. Cointegration is a statistical concept that assesses whether a linear combination of variables forms a stationary time series, indicating a long-term equilibrium relationship. The test helps determine whether variables are moving together over time, which is crucial in understanding their relationships and potential for modeling.

Table 2. Optimal lag determination.

Lag	LogL	LR	FPE	AIC	SC	HQ
0	−9347.007	NA	6.63e+24	68.50555	68.55844	68.52678
1	−7638.517	3354.400	2.73e+19	56.10635	56.37078*	56.21250
2	−7608.738	57.59453	2.47e+19	56.00540	56.48138	56.19647
3	−7553.242	105.7067	1.85e+19	55.71606	56.40357	55.99204
4	−7521.437	59.64767	1.65e+19	55.60027	56.49934	55.96117
5	−7491.538	55.19890	1.49e+19	55.49845	56.60905	55.94427
6	−7458.323	60.34717	1.31e+19	55.37233	56.69448	55.90306
7	−7427.061	55.88196	1.18e+19	55.26052	56.79421	55.87617
8	−7373.203	94.69584*	8.93e+18*	**54.98317***	56.72841	55.68374*

Source: Authors own estimation, 2023.

Johansen Cointegration Test

The p-values being less than 0.05 for all the specified cointegration rank cases as in Table 3 and Table 4 (none, at most 1, at most 2, and at most 3) imply that there are long-term equilibrium relationships among the variables M2, Cocoa, Gold, and Crude. These variables are likely moving together over time, indicating the presence of shared underlying relationships that may persist over the long run. The cointegration suggests that there could be common factors or economic forces influencing the variables M2, Cocoa, Gold, and Crude. These factors might be driving their long-term movements and dynamics. The cointegration could also imply intermarket relationships where changes in one variable might lead to changes in another variable over time. For example, changes in commodity prices (such as Cocoa and Crude) might be influenced by changes in monetary aggregates (such as M2) and geopolitical factors that affect the price of Gold. Again, investors and analysts may find insights into portfolio diversification strategies based on the cointegration relationships. If the variables are cointegrated, it might suggest that there are potential opportunities for diversification or hedging strategies. The cointegration relationships could provide insights into the broader economic interactions between monetary aggregates, commodity prices, and other factors affecting these markets. It is important to note that while cointegration implies a long-term relationship, it does not necessarily indicate causality or directionality between the variables. Further analysis in the subsequent section will unearth this to fully understand the nature and implications of these relationships and to determine how these variables interact with each other over time. Therefore, since there is cointegration we proceed to perform the VECM (Table 5).

Based on the VECM analysis results for Ghana on the monthly data of M2, Cocoa, Crude, and Gold from December 1999 to April 2023, we have the following equations:

Table 3. Unrestricted cointegration rank test (Trace).

Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.252748	134.6411	47.85613	0.0000
At most 1 *	0.108658	55.39320	29.79707	0.0000
At most 2 *	0.051865	24.10586	15.49471	0.0020
At most 3 *	0.034748	9.619578	3.841466	0.0019

Source: Authors own estimation, 2023.

Table 4. Unrestricted cointegration rank test (Maximum Eigenvalue).

Hypothesized		Max-Eigen	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.252748	79.24791	27.58434	0.0000
At most 1 *	0.108658	31.28734	21.13162	0.0013
At most 2 *	0.051865	14.48628	14.26460	0.0461
At most 3 *	0.034748	9.619578	3.841466	0.0019

Source: Authors own estimation, 2023.

Table 5. Vector error correction estimates.

Cointegrating Eq:	CointEq1			
M2(−1)	1.000000			
COCOA(−1)	0.574882			
	(1.01312)			
	[0.56744]			
CRUDE(−1)	−10.39535			
	(28.4606)			
	[−0.36525]			
GOLD(−1)	−11.81135			
	(1.91877)			
	[−6.15570]			
C	14080.46			
Error Correction:	D(M2)	D(COCOA)	D(CRUDE)	D(GOLD)
CointEq1	−0.038958	−0.003653	−0.000141	−0.001368
	(0.00501)	(0.00402)	(0.00018)	(0.00254)
	[−7.77152]	[−0.90797]	[−0.77865]	[−0.53804]
D(M2(−1))	0.249914	0.080361	−0.001500	0.078183
	(0.05736)	(0.04604)	(0.00207)	(0.02909)
	[4.35662]	[1.74535]	[−0.72562]	[2.68724]

Continued

D(COCOA(−1))	0.136354	0.033708	−0.002994	−0.066563
	(0.14234)	(0.11425)	(0.00513)	(0.07219)
	[0.95795]	[0.29505]	[−0.58361]	[−0.92203]
D(CRUDE(−1))	−2.144315	2.607662	0.206720	2.829089
	(2.54291)	(2.04105)	(0.09164)	(1.28972)
	[−0.84325]	[1.27761]	[2.25588]	[2.19357]
D(GOLD(−1))	−0.184826	−0.199222	−0.016943	−0.125653
	(0.23172)	(0.18599)	(0.00835)	(0.11752)
	[−0.79763]	[−1.07116]	[−2.02907]	[−1.06918]
C	411.3472	74.25583	4.963978	44.62109
	(67.5471)	(54.2161)	(2.43412)	(34.2586)
	[6.08978]	[1.36963]	[2.03933]	[1.30248]
R−squared	0.438883	0.038976	0.036454	0.059681
Adj. R−squared	0.428607	0.021374	0.018806	0.042459
Sum sq. resids	2.66E+08	1.71E+08	345030.1	68346172
S.E. equation	986.5354	791.8344	35.55062	500.3522
F−statistic	42.70598	2.214376	2.065674	3.465409
Log likelihood	−2316.333	−2254.995	−1389.148	−2126.923
Akaike AIC	16.64755	16.20785	10.00106	15.28977
Schwarz SC	16.72564	16.28594	10.07915	15.36786
Mean dependent	537.9934	113.6340	3.213474	78.12186
S.D. dependent	1305.104	800.4350	35.88970	511.3251
Determinant resid covariance (dof adj.)		2.27E+19		
Determinant resid covariance		2.08E+19		
Log likelihood		−7788.861		
Akaike information criterion		56.03485		
Schwarz criterion		56.39927		
Number of coefficients		28		

Source: Authors own estimation, 2023.

1) Error Correction Term (ECT) equation: $ECT(t-1) = 1.000M2(t-1) + 0.575Cocoa(t-1) - 10.395Crude(t-1) - 11.811Gold(t-1) + 14080.46$

2) M2 equation (Money Supply): $D[M2(t)] = -0.038958ECT(t-1) + 0.249914D[M2(t-1)] + 0.136354D[Cocoa(t-1)] - 2.144315D[Crude(t-1)] - 0.184826 * D[Gold(t-1)] + 411.3472$

The results indicate the following:

1) Error Correction Term (ECT) equation: The error correction term (ECT) is

a crucial component of a Vector Error Correction Model (VECM). It measures the speed of adjustment back to the long-run equilibrium relationship when the variables deviate from that equilibrium. In this equation, we have four lagged variables: M2($t-1$), Cocoa($t-1$), Crude($t-1$), and Gold($t-1$).

The coefficients associated with each variable indicate the impact of the deviations from the long-run equilibrium on the ECT. For instance, a positive coefficient for Cocoa($t-1$) suggests that any deviation from the long-run equilibrium for cocoa prices will lead to a positive adjustment towards that equilibrium.

The constant term (14080.46) represents the intercept or the long-run equilibrium level of the ECT.

2) M2 equation (Money Supply): This equation models the behavior of M2 (money supply) in Ghana. The dependent variable is D[M2(t)], which represents the first difference of the money supply variable.

The coefficients in this equation indicate the short-run dynamic relationships between the variables. For example, the coefficient −0.038958 indicates that when the error correction term (ECT) increases by one unit, the money supply (M2) will decrease by approximately 0.039 units in the short run, all else being constant.

The lagged differences of the variables (D[M2($t-1$)], D[Cocoa($t-1$)], D[Crude($t-1$)], D[Gold($t-1$)]) show the lagged impact of changes in the variables on the current money supply.

The constant term (411.3472) represents the intercept or the constant component of the M2 equation.

The VECM analysis provides a dynamic model to understand the relationships between money supply (M2) and the commodity prices of Cocoa, Crude, and Gold in Ghana. The error correction term (ECT) equation helps to capture the long-run equilibrium relationships, while the M2 equation explains the short-run dynamics.

The coefficients in the equations are crucial in determining the direction and magnitude of the relationships between the variables. Additionally, the intercept terms provide information about the constant component of the model.

To draw meaningful conclusions from these results, further analysis and interpretation are required. Specifically, we focus on the significance of the coefficients, check for statistical assumptions, assess the overall model fit, and conduct hypothesis tests to validate the relationships between the variables (Table 6).

At the end of the VECM analysis for Ghana between December 1999 and April 2023, the following equations were obtained:

1) D(M2) = C(1) * (M2(−1) + 0.574881509507 * Cocoa(−1) − 10.3953452322 * Crude(−1) − 11.811354045 * Gold(−1) + 14080.4555981) + C(2) * D(M2(−1)) + C(3) * D(Cocoa(−1)) + C(4) * D(Crude(−1)) + C(5) * D(Gold(−1)) + C(6)

2) D(Cocoa) = C(7) * (M2(−1) + 0.574881509507 * Cocoa(−1) − 10.3953452322 * Crude(−1) − 11.811354045 * Gold(−1) + 14080.4555981) + C(8) * D(M2(−1)) + C(9) * D(Cocoa(−1)) + C(10) * D(Crude(−1)) + C(11) *

D(Gold(−1)) + C(12)

3) D(Crude) = C(13) * (M2(−1) + 0.574881509507 * Cocoa(−1) − 10.3953452322 * Crude(−1) −11.811354045 * Gold(−1) + 14080.4555981) + C(14) * D(M2(−1)) + C(15) * D(Cocoa(−1)) + C(16) * D(Crude(−1)) + C(17) * D(Gold(−1)) + C(18)

4) D(Gold) = C(19) * (M2(−1) + 0.574881509507 * Cocoa(−1) − 10.3953452322 * Crude(−1) − 11.811354045 * Gold(−1) + 14080.4555981) + C(20) * D(M2(−1)) + C(21) * D(Cocoa(−1)) + C(22) * D(Crude(−1)) + C(23) * D(Gold(−1)) + C(24)

Table 6. VECM.

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	−0.038958	0.005013	−7.771520	0.0000
C(2)	0.249914	0.057364	4.356625	0.0000
C(3)	0.136354	0.142339	0.957955	0.3383
C(4)	−2.144315	2.542913	−0.843251	0.3993
C(5)	−0.184826	0.231718	−0.797633	0.4253
C(6)	411.3472	67.54712	6.089782	0.0000
C(7)	−0.003653	0.004024	−0.907971	0.3641
C(8)	0.080361	0.046043	1.745347	0.0812
C(9)	0.033708	0.114247	0.295048	0.7680
C(10)	2.607662	2.041048	1.277609	0.2017
C(11)	−0.199222	0.185987	−1.071161	0.2843
C(12)	74.25583	54.21613	1.369626	0.1711
C(13)	−0.000141	0.000181	−0.778648	0.4364
C(14)	−0.001500	0.002067	−0.725619	0.4682
C(15)	−0.002994	0.005129	−0.583613	0.5596
C(16)	0.206720	0.091636	2.255882	0.0243
C(17)	−0.016943	0.008350	−2.029074	0.0427
C(18)	4.963978	2.434116	2.039335	0.0417
C(19)	−0.001368	0.002542	−0.538045	0.5907
C(20)	0.078183	0.029094	2.687239	0.0073
C(21)	−0.066563	0.072192	−0.922031	0.3567
C(22)	2.829089	1.289718	2.193572	0.0285
C(23)	−0.125653	0.117523	−1.069180	0.2852
C(24)	44.62109	34.25862	1.302478	0.1930
Determinant residual covariance		2.08E+19		

Continued

Equation: D(M2) = C(1) * (M2(−1) + 0.574881509507 * COCOA(−1) − 10.3953452322 * CRUDE(−1) − 11.811354045 * GOLD(−1) + 14080.4555981) + C(2) * D(M2(−1)) + C(3) * D(COCOA(−1)) + C(4) * D(CRUDE(−1)) + C(5) * D(GOLD(−1)) + C(6)			
Observations: 279			
R-squared	0.438883	Mean dependent var	537.9935
Adjusted R-squared	0.428607	S.D. dependent var	1305.104
S.E. of regression	986.5354	Sum squared resid	2.66E+08
Durbin-Watson stat	1.973627		
Equation: D(COCOA) = C(7) * (M2(−1) + 0.574881509507 * COCOA(−1) − 10.3953452322 * CRUDE(−1) − 11.811354045 * GOLD(−1) + 14080.4555981) + C(8) * D(M2(−1)) + C(9) * D(COCOA(−1)) + C(10) * D(CRUDE(−1)) + C(11) * D(GOLD(−1)) + C(12)			
Observations: 279			
R-squared	0.038976	Mean dependent var	113.6340
Adjusted R-squared	0.021374	S.D. dependent var	800.4350
S.E. of regression	791.8344	Sum squared resid	1.71E+08
Durbin-Watson stat	1.908043		
Equation: D(CRUDE) = C(13)*(M2(−1) + 0.574881509507 * COCOA(−1) − 10.3953452322 * CRUDE(−1) − 11.811354045 * GOLD(−1) + 14080.4555981) + C(14) * D(M2(−1)) + C(15) * D(COCOA(−1)) + C(16) * D(CRUDE(−1)) + C(17) * D(GOLD(−1)) + C(18)			
Observations: 279			
R-squared	0.036454	Mean dependent var	3.213474
Adjusted R-squared	0.018806	S.D. dependent var	35.88970
S.E. of regression	35.55062	Sum squared resid	345030.1
Durbin-Watson stat	2.015359		
Equation: D(GOLD) = C(19)*(M2(−1) + 0.574881509507 * COCOA(−1) − 10.3953452322 * CRUDE(−1) − 11.811354045*GOLD(−1) + 14080.4555981) + C(20) * D(M2(−1)) + C(21) * D(COCOA(−1)) + C(22) * D(CRUDE(−1)) + C(23) * D(GOLD(−1)) + C(24)			
Observations: 279			
R-squared	0.059681	Mean dependent var	78.12186
Adjusted R-squared	0.042459	S.D. dependent var	511.3251
S.E. of regression	500.3521	Sum squared resid	68346176
Durbin-Watson stat	1.925121		

Source: Authors own estimation, 2023.

Equation (1) (D(M2)) describes the dynamics of the money supply (M2) in Ghana. The coefficients and their p-values suggest that:

• C(1): The coefficient is negative and highly significant (p-value = 0.0000). This indicates that changes in the lagged values of M2, Cocoa, Crude, and Gold

have a significant negative impact on the current change in M2.

• C(2): Positive and highly significant (p-value = 0.0000). It suggests that the lagged change in M2 itself positively influences the current change in M2.

• C(3), C(4), C(5): These coefficients are not statistically significant, suggesting that the lagged changes in Cocoa, Crude, and Gold do not have a significant impact on the current change in M2.

• C(6): Positive and highly significant (p-value = 0.0000). This is a constant term that affects the current change in M2.

Equation 2 (D(Cocoa)) represents the relationship involving Cocoa prices. Interpretations for the coefficients are similar to Equation (1). Notably:

• C(7): Not statistically significant, indicating that the lagged values of different variables do not significantly affect the current change in Cocoa prices.

• C(8): Positive and moderately significant (p-value = 0.0812), implying that the lagged change in M2 has a positive influence on the current change in Cocoa prices.

• C(9), C(10), C(11): Not statistically significant, suggesting that lagged changes in Cocoa, Crude, and Gold do not significantly impact the current change in Cocoa prices.

• C(12): Positive and moderately significant (p-value = 0.1711), representing a constant effect on Cocoa prices.

Equation 3 (D(Crude)) describes the dynamics of Crude oil prices. Key interpretations include:

• C(13): Not statistically significant, indicating that the lagged values of different variables do not significantly influence the current change in Crude oil prices.

• C(14) to C(17): None of these coefficients are statistically significant, suggesting that lagged changes in M2, Cocoa, Crude, and Gold do not have a significant impact on the current change in Crude oil prices.

• C(18): Positive and marginally significant (p-value = 0.0417), representing a constant effect on Crude oil prices.

Equation 4 (D(Gold)) represents the relationship involving Gold prices. Coefficient interpretations are similar to the previous equations:

• C(19) to C(23): These coefficients are not statistically significant, indicating that lagged changes in M2, Cocoa, Crude, and Gold do not significantly affect the current change in Gold prices.

• C(24): Positive and not statistically significant, suggesting a constant effect on Gold prices.

In summary, the VECM analysis provides insights into the relationships between the variables (M2, Cocoa, Crude, and Gold) for the specified period. The significance of coefficients varies across equations, with some variables having more impact on others in the system.

Table 7 show the results of VEC (Vector Error Correction) Granger Causality/Block Exogeneity Wald Tests for different dependent variables (D(M2),

D(Cocoa), D(Crude), and D(Gold)) in the context of a Vector Error Correction Model (VECM) analysis. These tests are used to assess the causal relationships between variables in a time series model. The "Excluded" variables are being tested for their ability to Granger-cause the "Dependent" variable.

Each row in the table corresponds to a different dependent variable. Interpreting the table for each dependent variable:

1) Dependent variable: D(M2)

• D(Cocoa): The chi-squared statistic is 0.917677 with 1 degree of freedom, resulting in a p-value of 0.3381. This suggests that the lagged changes in Cocoa do not significantly Granger-cause the current changes in M2.

Table 7. VEC granger Causality/Block exogeneity wald tests.

Dependent variable: D(M2)			
Excluded	Chi-sq	df	Prob.
D(COCOA)	0.917677	1	0.3381
D(CRUDE)	0.711073	1	0.3991
D(GOLD)	0.636218	1	0.4251
All	2.219480	3	0.5281
Dependent variable: D(COCOA)			
Excluded	Chi-sq	df	Prob.
D(M2)	3.046236	1	0.0809
D(CRUDE)	1.632285	1	0.2014
D(GOLD)	1.147386	1	0.2841
All	5.925048	3	0.1153
Dependent variable: D(CRUDE)			
Excluded	Chi-sq	df	Prob.
D(M2)	0.526523	1	0.4681
D(COCOA)	0.340604	1	0.5595
D(GOLD)	4.117142	1	0.0425
All	9.377184	3	0.0247
Dependent variable: D(GOLD)			
Excluded	Chi-sq	df	Prob.
D(M2)	7.221253	1	0.0072
D(COCOA)	0.850142	1	0.3565
D(CRUDE)	4.811758	1	0.0283
All	12.93593	3	0.0048

Source: Authors own estimation, 2023.

• D(Crude): The chi-squared statistic is 0.711073 with 1 degree of freedom, resulting in a p-value of 0.3991. This suggests that the lagged changes in Crude do not significantly Granger-cause the current changes in M2.

• D(Gold): The chi-squared statistic is 0.636218 with 1 degree of freedom, resulting in a p-value of 0.4251. This suggests that the lagged changes in Gold do not significantly Granger-cause the current changes in M2.

• Overall test (All): The chi-squared statistic is 2.219480 with 3 degrees of freedom, resulting in a p-value of 0.5281. This suggests that the combined effects of all excluded variables (D(Cocoa), D(Crude), and D(Gold)) do not significantly Granger-cause the current changes in M2.

2) Dependent variable: D(Cocoa)

• D(M2): The chi-squared statistic is 3.046236 with 1 degree of freedom, resulting in a p-value of 0.0809. This suggests that the lagged changes in M2 have a borderline significant Granger-causal relationship with the current changes in Cocoa.

• D(Crude): The chi-squared statistic is 1.632285 with 1 degree of freedom, resulting in a p-value of 0.2014. This suggests that the lagged changes in Crude do not significantly Granger-cause the current changes in Cocoa.

• D(Gold): The chi-squared statistic is 1.147386 with 1 degree of freedom, resulting in a p-value of 0.2841. This suggests that the lagged changes in Gold do not significantly Granger-cause the current changes in Cocoa.

• Overall test (All): The chi-squared statistic is 5.925048 with 3 degrees of freedom, resulting in a p-value of 0.1153. This suggests that the combined effects of all excluded variables (D(M2), D(Crude), and D(Gold)) do not significantly Granger-cause the current changes in Cocoa.

3) Dependent variable: D(Crude)

• D(M2): The chi-squared statistic is 0.526523 with 1 degree of freedom, resulting in a p-value of 0.4681. This suggests that the lagged changes in M2 do not significantly Granger-cause the current changes in Crude.

• D(Cocoa): The chi-squared statistic is 0.340604 with 1 degree of freedom, resulting in a p-value of 0.5595. This suggests that the lagged changes in Cocoa do not significantly Granger-cause the current changes in Crude.

• D(Gold): The chi-squared statistic is 4.117142 with 1 degree of freedom, resulting in a p-value of 0.0425. This suggests that the lagged changes in Gold have a significant Granger-causal relationship with the current changes in Crude.

• Overall test (All): The chi-squared statistic is 9.377184 with 3 degrees of freedom, resulting in a p-value of 0.0247. This suggests that the combined effects of all excluded variables (D(M2), D(Cocoa), and D(Gold)) significantly Granger-cause the current changes in Crude.

4) Dependent variable: D(Gold)

• D(M2): The chi-squared statistic is 7.221253 with 1 degree of freedom, resulting in a p-value of 0.0072. This suggests that the lagged changes in M2 have a significant Granger-causal relationship with the current changes in Gold.

• D(Cocoa): The chi-squared statistic is 0.850142 with 1 degree of freedom,

resulting in a p-value of 0.3565. This suggests that the lagged changes in Cocoa do not significantly Granger-cause the current changes in Gold.

• D(Crude): The chi-squared statistic is 4.811758 with 1 degree of freedom, resulting in a p-value of 0.0283. This suggests that the lagged changes in Crude have a significant Granger-causal relationship with the current changes in Gold.

• Overall test (All): The chi-squared statistic is 12.93593 with 3 degrees of freedom, resulting in a p-value of 0.0048. This suggests that the combined effects of all excluded variables (D(M2), D(Cocoa), and D(Crude)) significantly Granger-cause the current changes in Gold.

In summary, the Granger Causality/Block Exogeneity Wald Tests are used to determine whether the lagged changes in certain variables Granger-cause the current changes in the dependent variables. The p-values indicate the significance of these relationships. The overall tests for all excluded variables suggest that the combined effects of those variables may or may not be significant in Granger-causing the dependent variables, depending on the case.

Short Run Causal Relationship or Pairwise Granger Causality

The "Pairwise Granger Causality Tests" in Table 8 are used to assess whether one variable's past values (lagged values) can predict or "Granger cause" changes in another variable. Granger causality helps determine whether past values of one variable provide useful information in predicting the future values of another variable. The null hypothesis for each test is that the specified variable does not Granger causes the other variable. The p-values associated with each test indicate the significance of the Granger causality relationship. From Table 8, the p-value is very low (less than 0.05), indicating strong evidence to reject the null hypothesis. This suggests that past values of COCOA do Granger cause changes in M2 (money supply). Similarly, the p-value being less than 0.05 suggests that past values of M2 (money supply) do Granger cause changes in COCOA. There was also strong evidence that past values of CRUDE do Granger cause changes in M2. Strong evidence that past values of M2 do Granger cause changes in CRUDE. Strong evidence that past values of GOLD do Granger cause changes in M2. Strong evidence that past values of M2 do Granger cause changes in GOLD. Evidence that past values of CRUDE do Granger cause changes in COCOA. Meanwhile, there was lack of evidence that past values of COCOA Granger cause changes in CRUDE. Additionally, there was evidence that past values of GOLD do Granger cause changes in COCOA. Also, there was lack of evidence that past values of COCOA Granger cause changes in GOLD. Additionally, there was weak evidence that past values of GOLD do Granger cause changes in CRUDE. There was also lack of evidence that past values of CRUDE Granger cause changes in GOLD. In summary, the results suggest that there are Granger causality relationships between these variables, but the strength and direction of the relationships can vary. Keep in mind that the significance levels (p-values) indicate the strength of evidence against the null hypothesis of no Granger causality. The lower the p-value, the stronger the evidence against the null hypothesis.

Table 8. Short run causal relationship or pairwise granger causality (at lag 1).

Null Hypothesis:	Obs	F-Statistic	Prob.
COCOA does not Granger Cause M2	280	14.8609	0.0001
M2 does not Granger Cause COCOA		8.77275	0.0033
CRUDE does not Granger Cause M2	280	21.7955	5.E-06
M2 does not Granger Cause CRUDE		14.2910	0.0002
GOLD does not Granger Cause M2	280	47.8282	3.E-11
M2 does not Granger Cause GOLD		10.8162	0.0011
CRUDE does not Granger Cause COCOA	280	8.00615	0.0050
COCOA does not Granger Cause CRUDE		0.08142	0.7756
GOLD does not Granger Cause COCOA	280	5.50849	0.0196
COCOA does not Granger Cause GOLD		0.03643	0.8488
GOLD does not Granger Cause CRUDE	280	3.38438	0.0669
CRUDE does not Granger Cause GOLD		2.18043	0.1409

Source: Authors own estimation, 2023

The presence of Granger causality relationships between the money supply (M2) and key commodity prices (Cocoa, Gold, and Crude) in Ghana, with varying strengths and directions, signifies important interactions within the economy. The differentiation between short-run and long-run Granger causality relationships adds further nuance to the understanding of how changes in the money supply and commodity prices impact each other.

Bidirectional Causality in the Short-Run:

When bidirectional Granger causality is observed in the short-run, it implies that changes in the money supply can influence commodity prices, and vice versa, over relatively shorter time horizons. In this context, an increase in the money supply might lead to increased consumer spending, potentially driving up demand for commodities such as cocoa, gold, and crude oil. On the other hand, an increase in commodity prices could affect inflation expectations, prompting central banks to adjust the money supply through monetary policy measures like interest rate changes.

Conversely, decreases in commodity prices could impact the income of commodity producers, potentially influencing their purchasing power and overall economic activity. These bidirectional short-run causal relationships can result from various factors, including supply shocks, market sentiment, and speculative behavior.

Unidirectional Causality in the Short-Run:

Unidirectional Granger causality in the short-run suggests a one-way influence between the money supply and commodity prices within a relatively limited timeframe. For instance, if the money supply Granger-causes cocoa prices, it could mean that changes in the money supply lead to changes in consumer demand, which, in turn, affect cocoa prices. This could be due to factors such as seasonal variations in cocoa consumption or immediate reactions to changes in consumer sentiment.

Similarly, if commodity prices Granger-cause the money supply, it implies that fluctuations in commodity prices impact economic activity, which may prompt changes in monetary policy to address inflationary or deflationary pressures.

Long Run Causal Relationship or Pairwise Granger Causality

The "Pairwise Granger Causality Tests" in Table 9 show the results of Granger causality tests between different pairs of variables with a lag of 8. This provided the long run Granger causality among the variables. The result suggests that past values of COCOA Granger cause changes in M2 (money supply). It also suggests that past values of M2 (money supply) Granger cause changes in COCOA. The paper additionally suggests that past values of CRUDE Granger cause changes in M2. Similarly, the paper suggests that past values of M2 Granger cause changes in CRUDE. The paper suggests that past values of GOLD Granger cause changes in M2. The paper suggests that past values of M2 Granger cause changes in GOLD. It also suggests that past values of CRUDE Granger cause changes in COCOA. The result again suggests that past values of COCOA Granger cause changes in CRUDE. Also, the paper suggests that past values of GOLD Granger cause changes in COCOA. However, the paper suggests that past values of COCOA do not significantly Granger cause changes in GOLD. Meanwhile, it suggests that past values of GOLD Granger cause changes in CRUDE. It additionally suggests that past values of CRUDE Granger cause changes in GOLD. In summary, the results indicate Granger causality relationships between these variables, with the strength and direction of the relationships varying based on the p-values. Strong evidence to reject the null hypothesis suggests that past values of one variable provide useful information in predicting the future values of another variable.

Table 9. Long run causal relationship or pairwise granger causality (at lag 8).

Null Hypothesis:	Obs	F-Statistic	Prob.
COCOA does not Granger Cause M2	273	2.46760	0.0136
M2 does not Granger Cause COCOA		13.4519	3.E-16
CRUDE does not Granger Cause M2	273	6.66578	6.E-08
M2 does not Granger Cause CRUDE		7.32371	9.E-09
GOLD does not Granger Cause M2	273	7.69450	3.E-09
M2 does not Granger Cause GOLD		5.38840	3.E-06
CRUDE does not Granger Cause COCOA	273	9.82071	7.E-12
COCOA does not Granger Cause CRUDE		5.18408	5.E-06
GOLD does not Granger Cause COCOA	273	6.94529	3.E-08
COCOA does not Granger Cause GOLD		1.39736	0.1978
GOLD does not Granger Cause CRUDE	273	4.75360	2.E-05
CRUDE does not Granger Cause GOLD		7.25292	1.E-08

Source: Authors own estimation, 2023.

Long-Run Causality Relationships:

The finding that p-values are lower for long-run Granger causality relationships indicates stronger and more persistent interactions between the money supply and commodity prices. This suggests that over extended periods, changes in the money supply and commodity prices have a more profound and sustained impact on each other. Long-run causality could reflect structural shifts in the economy, such as changes in production capabilities, technological advancements, or shifts in global demand and supply dynamics.

Implications:

The bidirectional and unidirectional causal relationships found in the short-run analysis highlight the intricate feedback mechanisms between the money supply and commodity prices. These relationships underscore the interconnectedness of the financial and real sectors of the economy. Policymakers should consider these interactions when formulating monetary policy and assessing the potential effects of changes in the money supply on commodity markets and vice versa.

Understanding these causal relationships is essential for ensuring macroeconomic stability, managing inflation, and promoting sustainable economic growth. The findings can guide policymakers in making informed decisions to mitigate potential negative impacts and harness positive synergies between changes in the money supply and fluctuations in commodity prices within Ghana's economic landscape.

The finding that there are Granger causality relationships between the money supply (M2) and key commodity prices (Cocoa, Gold, and Crude) in the long-run analysis, with lower p-values compared to the short-run, has significant implications for understanding the influence of commodity markets on the broader economy of Ghana.

Implications of Past Values of Commodities Granger Causing Changes in the Money Supply:

When past values of commodities Granger cause changes in the money supply in the long-run, it suggests a more enduring and fundamental linkage between commodity markets and the broader economy. This implies that historical fluctuations in commodity prices have exerted a lasting impact on monetary policy decisions and the money supply. In other words, changes in commodity prices over time have led to adjustments in the money supply by the central bank.

This phenomenon reflects the following implications:

1) **Supply-Demand Dynamics**: Past movements in commodity prices can reflect shifts in supply and demand conditions within the economy. Persistent increases or decreases in commodity prices may signal changes in production capacities, consumer behavior, or global market trends. The central bank might respond by adjusting the money supply to manage inflationary pressures or stimulate economic activity.

2) **Terms of Trade and Export Revenues**: Commodity prices, especially for key exports like cocoa, gold, and crude oil, are closely tied to the country's terms of trade and export revenues. Fluctuations in commodity prices can impact

Ghana's trade balance, foreign exchange reserves, and overall economic performance. The central bank might adjust the money supply to stabilize the exchange rate and manage external imbalances.

3) **Inflationary Pressures**: Changes in commodity prices can influence inflation expectations. Higher commodity prices can contribute to overall inflation, affecting consumer purchasing power and production costs. The central bank's response through monetary policy could impact money supply growth to manage inflation and maintain price stability.

4) **Economic Confidence and Investment**: Fluctuations in commodity prices can affect investor sentiment and economic confidence. A decline in commodity prices might lead to reduced revenues and investment in related sectors, influencing overall economic activity. The central bank's management of the money supply can influence borrowing costs and investment decisions.

Influence of Commodity Markets on the Broader Economy:

The finding that past values of commodities Granger cause changes in the money supply underscores the integral role of commodity markets in shaping Ghana's broader economic landscape. Commodity markets serve as a conduit through which external forces, such as global demand, geopolitical events, and supply shocks, influence domestic economic conditions. The central bank's responses to these externalities, as reflected in adjustments to the money supply, demonstrate the interconnectedness between monetary policy and the performance of key commodity sectors.

This interplay highlights the need for policymakers to carefully consider the dynamics of commodity markets when formulating monetary policy. The findings emphasize that changes in commodity prices can have far-reaching consequences, influencing inflation, investment, trade, and overall macroeconomic stability. By recognizing the influence of commodity markets on the broader economy, policymakers can adopt a more holistic approach to managing economic challenges and capitalizing on opportunities within Ghana's unique economic context.

4. Conclusions

In conclusion, the findings from the "Pairwise Granger Causality Tests" indicate that there are Granger causality relationships among the variables M2 (money supply), Cocoa, Gold, and Crude in Ghana, both in the short-run and in the long-run (lag 8). These relationships suggest that the past values of certain variables provide useful information for predicting the future values of other variables. Specifically, the results suggest that there are significant Granger causality relationships between COCOA and M2, M2 and COCOA, CRUDE and M2, M2 and CRUDE, GOLD and M2, GOLD and CRUDE, COCOA and CRUDE, and CRUDE and GOLD. Additionally, while there is evidence of some Granger causality relationships between COCOA and GOLD, COCOA and CRUDE, and GOLD and CRUDE, there is no significant evidence that past values of COCOA

Granger cause changes in GOLD.

Considering the set hypotheses, the findings have implications for each hypothesis:

1) Quantitative easing has a significant effect on increasing the money supply in Ghana:

• The Granger causality relationship between CRUDE and M2 suggests that changes in crude oil prices may affect the money supply, possibly through economic mechanisms influenced by quantitative easing policies.

2) Quantitative easing has a significant impact on commodity prices, particularly oil, gold, and cocoa, in Ghana:

• The observed Granger causality relationships between various commodity prices and M2 indicate that quantitative easing may influence the prices of these commodities in Ghana. The findings suggest that past changes in M2 could impact the prices of these commodities, implying a potential link between monetary policy and commodity markets.

3) The increase in commodity prices due to QE leads to notable changes in Ghana's trade balance and economic performance:

• The Granger causality relationships between different commodities and M2 could imply that changes in commodity prices driven by quantitative easing might affect Ghana's trade balance and economic performance. However, further analysis is needed to establish the exact channels through which these relationships operate and their broader economic implications.

Recommendations

Based on the analysis and findings, the following recommendations can be considered:

1) Monetary Policy Analysis: Given the observed Granger causality relationships between the money supply (M2) and various commodities, policymakers should carefully monitor the potential impact of monetary policies, such as quantitative easing, on commodity prices. Understanding these dynamics can help anticipate and manage potential price fluctuations.

2) Trade Policy and Economic Performance: Policymakers should pay attention to the potential implications of changes in commodity prices on Ghana's trade balance and overall economic performance. This might involve considering strategies to mitigate any adverse effects on trade and economic stability that could arise from fluctuations in commodity prices.

3) Economic Diversification: Given the influence of commodity prices on Ghana's economy, efforts to diversify the economy and reduce dependency on specific commodities could enhance resilience against external shocks. Diversification strategies can help mitigate the potential risks associated with commodity price volatility.

4) Further Research: While the Granger causality relationships provide valuable insights, further research is needed to explore the underlying mechanisms and dynamics driving these relationships. A more comprehensive analysis could

involve incorporating additional variables and employing advanced econometric techniques to better understand the causal linkages.

Policy Implications

The findings from the analysis of Granger causality relationships between the variables (M2, Cocoa, Gold, and Crude) in the context of Ghana have several important policy implications. These implications are based on the observed relationships and can guide policymakers in making informed decisions to enhance economic stability and promote sustainable growth:

1) Monetary Policy and Quantitative Easing (QE):

• The identified Granger causality relationships between the money supply (M2) and various commodities suggest that monetary policy decisions, including quantitative easing, can have ripple effects on commodity markets. Policymakers need to consider these relationships when implementing and communicating monetary policy changes to ensure that they are well-aligned with broader economic goals.

• When implementing QE or adjusting money supply, policymakers should carefully assess potential impacts on commodity prices. While QE can stimulate economic activity, its effects on different commodities may vary. Balancing the potential benefits of QE with its impact on commodity prices is essential to achieve desired macroeconomic outcomes.

2) Commodity Price Management:

• The Granger causality relationships highlight the interdependence between commodity prices and the money supply. Policymakers can consider measures to manage and stabilize commodity prices, especially for critical commodities like cocoa, gold, and crude oil. Market interventions, price stabilization mechanisms, and strategic reserves could be explored to mitigate extreme price fluctuations that might result from monetary policy actions.

3) Trade Balance and Export Diversification:

• Changes in commodity prices, influenced by monetary policy, can impact Ghana's trade balance. Policymakers should design trade policies that respond effectively to fluctuations in commodity prices, ensuring that exports remain competitive and imports remain manageable.

• To reduce vulnerability to commodity price shocks, the government could focus on promoting export diversification and value-added processing of commodities. Encouraging industries beyond commodities could help buffer against external shocks and improve overall economic resilience.

4) Inflation Management and Expectation Management:

• The Granger causality relationships between commodity prices and the money supply have implications for inflation dynamics. Policymakers need to manage inflation expectations and communicate clearly with the public about the potential effects of monetary policy on various commodity prices.

• When implementing monetary policy measures to control inflation, policymakers should consider how these measures might affect commodity markets

and adjust policy accordingly to avoid unintended consequences.

5) Risk Management and Economic Resilience:

• The findings underscore the importance of effective risk management strategies at both the macroeconomic and sectoral levels. Policymakers should develop contingency plans and policies to address the potential economic impact of commodity price volatility, especially during periods of significant monetary policy shifts.

• Strengthening economic resilience through prudent fiscal management, diversification of revenue sources, and investment in infrastructure and technology can help mitigate the adverse effects of fluctuations in commodity prices.

6) Data Monitoring and Analysis:

• Given the dynamic relationships revealed by the analysis, policymakers should establish robust data monitoring and analysis systems to continuously track the interactions between the money supply and commodity prices. Timely data collection and analysis can facilitate informed decision-making and help policymakers respond effectively to changing economic conditions.

7) International Collaboration and Research:

• Given the interconnectedness of commodity markets and monetary policy, policymakers could engage in international collaboration and research to better understand global factors influencing commodity prices and their implications for domestic economic stability.

It is important for policymakers to consider these implications within the broader context of Ghana's economic priorities, objectives, and challenges. A comprehensive approach that integrates monetary policy, trade policy, fiscal management, and economic diversification strategies will be crucial for promoting sustainable growth and stability in the face of changing commodity prices influenced by monetary policy actions.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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