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Shock and Volatility Transmissions Across Global Commodity and Stock Markets Spillovers: Empirical Evidence from Africa

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Abstract: This paper investigates the link between commodity price volatility and stock market indices in Nigeria, Ghana, and Côte d'Ivoire, focusing on commodities such as oil, cocoa, and gold over a daily period spanning January 2, 2020, to December 31, 2021. In order to conduct this study, the BEKK-GARCH process developed by Kroner and Ng (1998) is applied to test the volatility transmission across commodity and stock markets, while focusing on the asymmetry in the conditional variances of these markets. The analysis reveals a 30% increase in volatility spillovers during the COVID-19 period, highlighting significant asymmetry in conditional variances between African stock markets and global commodity markets. Furthermore, the findings demonstrate that conditional variances in stock and commodity markets are asymmetrical. This study advances the literature on volatility transmission by providing novel evidence on asymmetric spillovers between African stock markets and global commodity prices, particularly during COVID-19. It offers insights into the unique role of emerging African markets in global financial interconnectedness.

Keywords: stock market; commodity market; BEKK-GARCH process; asymmetry; COVID-19

JEL Classification: C58; D53; F3; G15; Q43

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1. Introduction

With the growing trend of financial globalization, the interrelationships between dynamic returns and the transmission of volatility between capital markets and commodity markets have become more interesting and have generated increased interest in the financial community. The distribution of returns and volatility across markets causes a stock adjustment for policy makers. This adjustment aimes primarily at preventing the risk of contagion in the event of a crisis (Arouri et al., 2011). The interconnectedness of stock market returns and commodity price movements was strongly analysed, especially after the 2008 global financial crisis.

Volatility transmission is a concept that describes as the mechanism by which variation or shocks in one market make a particular impact on the volatility of another market (Yanet al., 2022). It is most applicable in the stock and commodity markets because these two are closely related. These commodities may become inflationary or deflationary, impact trade balances or even Gross Domestic Product hence, the stock returns.

Several econometric models have been employed in the analysis of volatility transmission in the literature among them the BEKK-GARCH (Baba-Engle-Kraft-Kroner) model (ÖzdemirandBilgiç, 2023). This model enables forecasting the time-varying conditional covariance and understanding how shocks pass through the markets. Thus, the BEKK-GARCH models are more appropriate for the cross-market analysis, as they are the multivariate models unlike univariate GARCH, which work with single time series.

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This line of research has developed in light of both large-scale financial crises, and changes in the world economy. Earlier research concentrated more on developed nations particularly USA and Europe in analysing volatility transmission. However, the rising importance of the emerging markets has led to a growing interest in knowledge of how in less developed financial systems volatility spreads (Spulbar et al., 2020). In particular, African markets are quite special due to the facts of their connection with commodity export and their sensitivity to world fluctuations. These markets are generally associated with lower levels of turnover, higher transaction costs and broader exposure to world prices for commodities, which are a preferred terrain for volatility transmission research.

In the context of Africa, the inter-channels of volatility between stock and commodity markets plays several roles. First, a considerable number of African countries are indebted due to exportation of narrowly based products for instance oil, cocoa, gold among others. Consequently, changes in global commodity prices impose direct effects on the revenue balances of these economies (Majumder et al., 2022). Second, the African stock markets tend to be less developed and, therefore, more illiquid and more susceptible to shocks than developed markets. Third, as witnessed by the integration of African markets with global financial markets, due to the opening up of cross-border flows, and increased flow of capital, the markets are more vulnerable and are more likely to transmit volatility from global markets (Logogye et al., 2024).

Over the last decade, the instabilities of financial markets have been manifested most evidently through global shocks like the COVID-19 pandemic, particularly in emerging and frontier markets (Canuto, 2023). COVID-19 made new records of unpredictability to the point that prices of commodities and the stock exchange. This context has led to renewed focus on analysis of the relationship between time varying volatility of global commodities prices and the African stock markets (Tiwari et al., 2022). To this end, learners have wondered how the pandemic affected volatility connections and whether earlier models can still serve as a means of identifying such changes.

This analysis focuses on the study of the returns volatility of three African stock markets, which correspond to most producer countries of the three commodities. It would be beneficial to expand this issue into the African context while adding other basic commodities other than oil, such as gold and cocoa, since the empirical results may provide information for the creation of precise models for asset valuation and volatility forecasts between these markets. The focus is also placed on the direction of volatility transmission studied.

To this end, the study seeks to answer key research questions including whether COVID-19 has impacted on volatility spillovers and whether the impact is symmetric or not across the African stock and global commodity markets. All these snippets are relevant in explaining the effects of volatility arising from the pandemic on African financial systems stability.

The rest of the paper is structured as follows to facilitate our investigation: The relevant literature is included in the next section. In Section 3, econometric methods are presented in order to describe the research plan. The data utilized for the preliminary study is presented in Section 4, and the findings are discussed in Section 5. The conclusion and policy implications are covered in Section 6.

2. Literature Review

The question of volatility transmission between two types of markets has been extensively studied in the literature, with reference only to oil to analyze co-movements between oil and stock markets. Malik and Ewing (2009) analyzed the transmission of volatility and shocks between oil and equity returns in five major market sectors using a bivariate GARCH. The results show evidence of a transmission of shocks and volatility between oil prices and certain market sectors. Choi and Hammoudeh, (2010) used data from the period between 1990 and 2006 to focus on the volatility behaviour of oil and industrial commodities markets with the stock market. Their results show high and low volatility patterns between the five commodity prices and the S&P 500. The GARCH-CCC model shows increasing correlations between all commodities since the 2003 Iraq war and decreasing correlations with the US stock index S&P 500.

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Arouri et al. (2011) examined, using the generalized VAR-GARCH approach, the transmission of yield and volatility between world oil prices and stock markets in the Gulf Cooperation Council (GCC) member countries during 2005-2010. Their results indicate that significant volatility spillovers between oil and stock markets in three GCC countries (Bahrain, Oman and Qatar). The effect of oil was positive on the stock markets of Qatar and Oman but negative on the Bahrain stock market. As for the transmission of volatility, it is more apparent from oil to stock markets. Modelling of dynamic conditional correlations (DCC-GARCH) on a set of 25 commodities from different sectors over a period spanning from 3 January 2001 to 28 November 2011 enabled Creti et al. (2013) demonstrate that the correlations between stock markets and commodity markets are highly volatile.

Mensi et al. (2013) using a VAR-GARCH model applied to daily data from 3 January 2000 to 31 January 2011 down on some commodity markets and some stock markets. They demonstrated significant correlation and transmission of volatility between commodity and equity markets. Ghorbel et al. (2013) applied the multivariate GARCH models (BEKK and DCC) to monthly data between May 2005 and December 2011 for oil prices and stock indices of the US, GCC countries and Brazil, Russia, India and China (BRIC). Their results showed a persistent level of volatility in the relevant crude oil and stock markets.

Using a tri-varied GARCH model (BEKK), Lajili (2013) showed that the US financial market has an impact on the oil market and other financial markets in oil producing countries (Russia, Kuwait, Indonesia and Venezuela). He also found a transmission of oil market volatility to all financial markets in producer countries. It also showed the existence of a strict relationship between physical markets and financial markets. What he says can be interesting to build a pricing model of financial assets in producer countries and allows for the prediction of oil price and volatility. In the same context, by applying a GARCH-VAR model to the data of the Kingdom of Saudi Arabia and Egypt from 1 January 2007 to 31 December 2011, Suliman and Idris (2013) was able to show that changes in the price of oil lead to an increase in volatility of stock market returns.

Cheng and Xiong (2013) argued that the massive abundance of investment capital in commodity futures markets over the past decade has sparked a debate about whether financialization is distorting commodity prices. They critically examined academic studies from the perspective of how financial investors affect risk sharing and discovery of information on commodity markets, to conclude that through these mechanisms, financialization has significantly changed commodity markets. Bunnag (2015), using the three multivariate models in this case of the VECH, BEKK and CCC model applied to daily data during the period 2009-2014, he concluded that the volatility of oil futures affects the volatility of carbon emissions futures. It also showed that the BEKK model is more reliable for examining the volatility of oil futures and the volatility of carbon futures yields. Basak and Pavlova, (2016) analysed how financialization affects commodity futures prices, volatility and correlation. They demonstrated that financial markets pass on shocks not only to forward prices but also to spot commodity prices and stocks. Spot prices rise with financialization and shocks on any commodity index thus affecting all stockable commodity prices.

Ederer et al. (2016) estimated a multivariate autoregressive (VAR) vector model to assess the effect of different groups of investors (index investors and fund managers) as well as the fundamental and macroeconomic variables on coffee, cotton, wheat and oil prices. They found that unlike index investors, the net long positions of fund managers have a significant effect on commodity prices, which can lead to commodity derivatives markets ceasing to play their fundamental role in development. Tsuji (2018) analyzed the transmission of returns, volatility spillovers and optimal hedging between oil futures and oil stocks in oil-producing countries. Applying the DCC-MEGARCH model to the daily prices of oil and gas indices from January 2000 to 15 August 2017 for the United States, Russia, Australia and Canada, he found a unidirectional transmission of returns between oil futures to oil stocks. Its results also indicate double-sided asymmetric volatility spillovers between oil futures and oil stocks for Australia and Russian, and one-way spillovers for US and Canada.

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Youcef, (2019) used the Threshold QuantileAutoRegressive (TQAR) model, it has shown the existence of strengthening links between equity markets and the agricultural products market since 2004 corresponding to the increase in institutional investment flows on the commodity markets. These results suggest that agents have a profound effect on commodity prices when the value of the commodity index is high. Furthermore, the relationship between agricultural and stock market returns is always significant when the return of the commodity index is in the higher regime. This suggests that stock markets have a major impact on agricultural commodity price dynamics. Boachen and Yunpeng, (2020) examined the financialization of the Chinese market from a market integration perspective. Their analyses concerned the integration between commodity markets and financial capital markets (stock markets, bond markets and foreign exchange markets) using multivariate GARCH models. They have resulted in the fact that the Chinese commodity futures market, especially the energy futures market, has a financialization phenomenon.

Applying a tri-varied GARCH-BEKK to daily data from 2 July 2012 to 2017, Ahmed and Huo (2021) found a significant one-way effect of oil yield to Chinese stock market yield suggesting strong reliance on the Chinese stock market in the oil market. Hung and Vo (2021), examined the directional effects and time-frequency relationship between oil and gold markets and equity markets at over the period before and during the COVID-19 pandemic. They concluded that before the COVID period, the S&P 500 and oil series are the net risk receivers, while gold is a net shock emitter. On the contrary, during the pandemic, crude oil and S&P 500 markets are the transmitters of yield fallout up to a maximum level of about 32%, so the gold market is a destination of the fallout. Although research on the aforementioned links is well established, it has not demonstrated how the pandemic influenced the financial and commodity markets of African nations to become more interconnected with the global financial market. Furthermore, it is still unknown how the global pandemic influences the dependency and connectivity between the global commodity markets and the African financial market (Urom et al., 2023). The COVID-19 pandemic, which began in December 2019, is still regarded as one of the most significant natural disasters to hit the world in recent memory. In addition to the direct impact of the pandemic on these markets, the existing degree of global financial linkages provides evidence that the COVID-19 pandemic may be increasing the degree of interdependence and connectivity between these markets.

The short-term effects of the coronavirus disease of 2019 (COVID-19) on stock market performance in thirteen (13) African nations were assessed and measured by Takyi and Bentum-Ennin (2021). Using a novel Bayesian structural time series approach (a state-space model) and daily time series stock market data from October 1, 2019, to June 30, 2020, estimates indicate that stock market performances in Africa have significantly decreased in relative terms during and after the COVID-19 pandemic for ten countries.

Aboluwodi et al. (2022) investigated the long-term relationships between the global asset markets—such as those for gold, platinum, oil, and cryptocurrencies—and the South African stock (JSE) and real estate markets. They demonstrate that the cointegration linkages between the JSE and Bitcoin, the JSE and Oil, and the JSE and Real Estate were considerable before to the Covid pandemic, but that these relationships diminished or vanished during the Covid pandemic. Conversely, there are cointegration relationships between the gold-real estate market and the oil-platinum market. It implies that JSE grew volatile during Covid time comparing to Oil, Platinum, Gold markets in South Africa.

Urom et al. (2023) investigated the connectivity between 12 African equity markets and the global commodity, developed equity markets. Although there is a modest connection between African equities markets and these markets, they discovered that during the pandemic, there was a notable improvement in the degree of connectivity between these markets. Furthermore, the energy market controls how shocks are transmitted in the commodity market system. With respect to the equity market system, the French and South African equity markets exhibit the highest levels of spillover during the entire sample and during the peak of the epidemic, respectively.

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Aaawaar et al. (2023) investigated the factors influencing the time-varying return volatility of Africa's equities markets in the study. Using monthly indices of the top eight African stock markets, the authors discover that history, domestic exchange rates, treasury bill rates, money supply, inflation rates, changes in global crude oil prices, US and UK stock market volatility, and COVID-19 shocks all contribute to the dynamic process of volatility in African stock markets. Furthermore, it seems that the only African markets that are not affected by advanced market volatility spillovers are those in North Africa. For portfolio managers, these markets may therefore offer chances for global diversification.

3. Econometric Methods

We describe the econometric methods applied to the asymmetric BEKK-GARCH process, the empirical problem addressed in the paper. Market volatility forecasting frequently uses General Autoregressive Conditional Heteroskedasticity (GARCH) models for conditional volatility. This is because they can display time series characteristics like volatility clustering and represent the time-varying conditional variances. Similarly, it has been demonstrated that multivariate GARCH models can forecast the dynamics of stock market volatility across various financial institutions. MGARCH models have been widely utilized to examine how the correlation and covariance between various series evolve over time by defining the conditional variance and covariance equations.

When examining volatility interdependence and transmission mechanisms among various financial time series, multivariate models such as BEKK (Baba-Engle-Kraft-Kroner), CCC (Constant Conditional Correlation), or DCC (Dynamic Conditional Correlation) specifications are more pertinent than univariate models (Arouri et al., 2011b). El Ghini and Saidi (2017), Anyikwa and Le Roux (2020), Ahmed and Rui (2021), Chang et al. (2011), Agnolucci (2009), Hammoudeh et al. (2009), Hassan and Malik (2007), and several more empirical investigations attest to the superiority of these models. However, only the bivariate relationship is examined in the current studies that use MGARCH to examine volatility transmissions.

The nature of the aforementioned market is examined in our paper. A GARCH model with BEKK specification has been successfully used to evaluate and capture the spillovers between equities and commodity markets (Jouini and Harrathi, 2014; Salisu and Oloko, 2015; Ahmed and Rui, 2021, Dehbashi et al., 2022). Here, we examine the return and volatility transmission in a few African countries using the multivariate BEKK-GARCH technique within simultaneous equation systems (Engle and Kroner, 1995). The conditional mean equation, which may be summarized as follows, allows us to define our model:

$$r_t = \mu + \varepsilon_t \qquad \varepsilon_t = \frac{D_t \phi_t}{I_{t-1}} \rightarrow N(0, H_t) \tag{1}$$

where r_t is a (6×1) vector of stock and comodity returns, μ is a (6×1) vector of constant terms, ε_t is a (6×1) vector of error terms whose (6×6) conditional variance-covariance matrix is H_t, $D_t = diag(h_{11,t}^{1/2}, \ldots, h_{66,t}^{1/2})$ with $h_{ii,t}$ as the conditional variance of the market *i*, ϕ_t is a sequence of independently and identically distributed random variables and I_{t-1} is the market information available at time *t-1*.

The multivariate BEKK-GARH parameterization proposed by Engle and Kroner (1995) guarantees the positive semi-defiteness of the matrix H_t that depends on the squares and cross products of the error terms ε_t and volatility. It then provides cross-market shock and volatility effects in the conditional variance equation. Kroner and Ng (1998) provide a BEKK specification in order to investigate the asymmetric responses of conditional volatility to negative shocks by considering the following form of the matrix H_t.

$$H_t = C'C + A'\varepsilon_{t-1}'\varepsilon_{t-1}A + B'H_{t-1}B + D'\xi_{t-1}'\xi_{t-1}D \tag{2}$$

where ξ_t is defined as ε_t if ε_t is negative and zero otherwise, C is a (6×6) lower triangular matrix of constants, A and B are (6×6) matrices whose diagonal parameters measure respectively the effects of own past shocks and past volatility of return series on its current conditional volatility. The off-diagonal elements of these matrices measure the shock and volatility spillovers between return series. The diagonal coefficients of the matrix *D* of order (6×6) measure the responses of awn negative shocks of return series on its current conditional volatility, whereas the off-diagonal parameters d_{ij} measure the response of market *i*to negative shock of market *j*[1].

The model given by Eqs. (1) and (2) is the most appropriate specification we have obtained based on the AIC and SIC criteria. In the literature, it is shown that such model allows well capturing of the shock and volatility spillovers between markets. The considered model is estimated using the maximum likelihood method based on the Broyden-Fletcher-Goldfarb-Shanno (BFGS) optimization algorithm.

4. Data and Preliminary Analysis

We investigate the transmissions of volatility among global comodity (roil, rcocoa and rgold) and equity markets (rnse, rbrvm and rgse) in African selected countries. To avoid aggregation biais of global comodity prices, we use individual comodity futures including oil, cocoa and gold.

Data used are from 2 January 2018 to 31 December 2021, which covers COVID-19 episode of wide instabilities for both stock and comodity markets. To identify a more effective hedging tool for the COVID-19 period, we divide the study into the following two distinct periods: Period 1, which was not under the influence of the COVID-19 and period 2 under the influence of COVID-19. All daily series are converted to log returns by taking the log-difference of index values $R_t=\ln(X_t/X_{t-1})$ where X_t is the futures price at time t. Figure 1 demonstrates the price trend for the markets under review.

[1] The significance of the coefficient d_{ij} indicates the presence of asymmetric volatility transmission between markets *i* and *j*.

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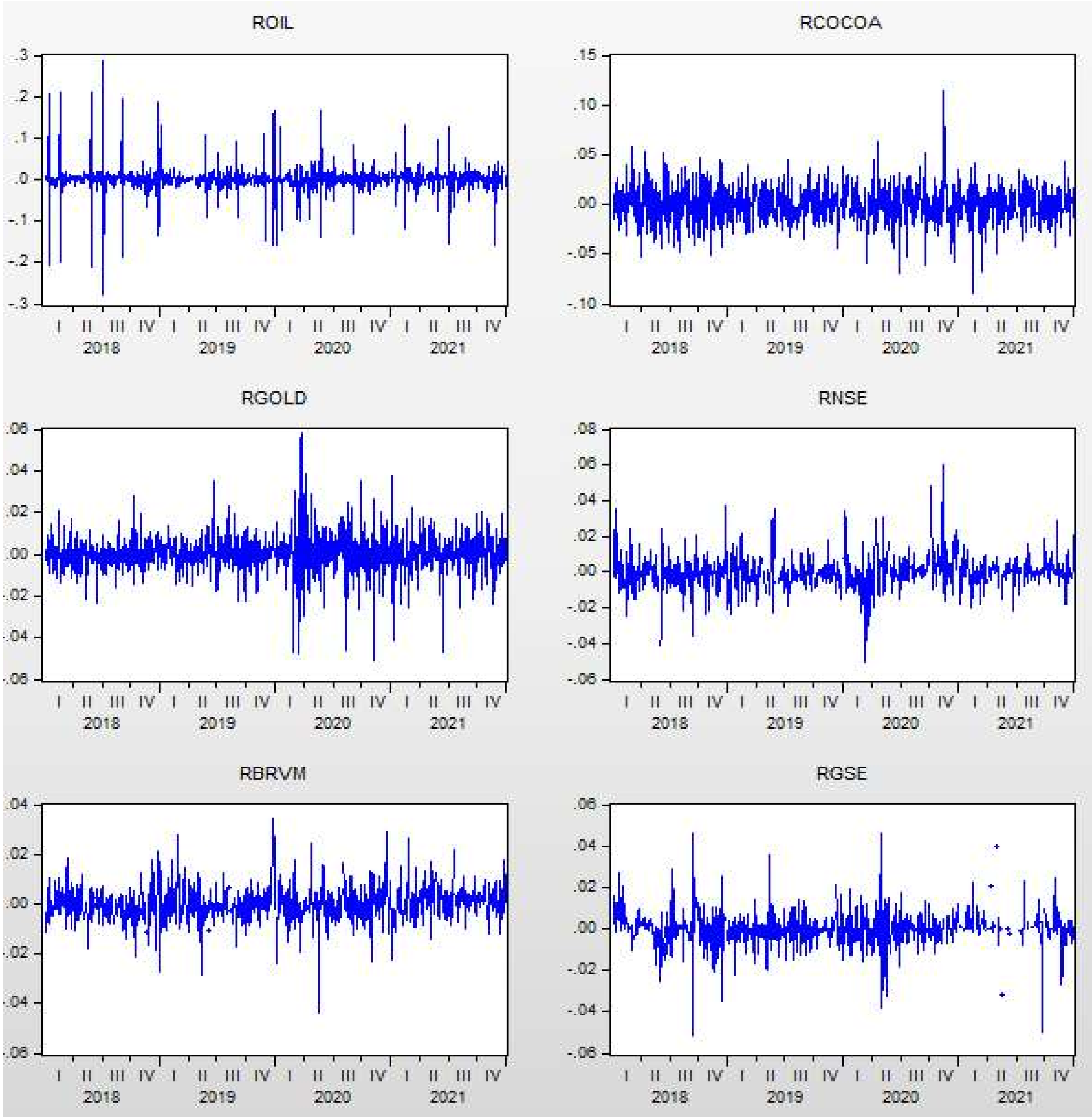

Figure 1. Plots of comodities and equity reteurns.

We observe that there are significant occurrences of elevated return volatility in each case during the COVID-19 pandemic period. This is why we are motivated to look at the interconnectedness of these markets within this particular time frame in order to determine whether there is a chance of an increase or decrease in shock transmission given the unstable state of the global financial and commodity markets as a result of the epidemic. Market return descriptive statistics are shown in Table 1.

Table 1. Descriptive statistics and stochastic propretis of return series.

	roil	rcocoa	rgold	rnse	rbrvm	rgse
Mean	*0.000352*	*0.000382*	*0.000308*	*0.000089*	*-0.00011*	*-0.00021*
Median	*0.001507*	*0.001150*	*0.000504*	*-0.00027*	*-0.00037*	*0.0000*
Maximum	*0.287098*	*0.114913*	*0.057754*	*0.060478*	*0.034804*	*0.046232*
Minimum	*-0.27851*	*-0.08902*	*-0.05055*	*-0.05033*	*-0.04405*	*-0.05127*
Std. Dev	*0.034435*	*0.018902*	*0.009497*	*0.00962*	*0.006909*	*0.008042*

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Skewness	*-0.03103*	*-0.03579*	*-0.21704*	*0.417345*	*0.152220*	*-0.20895*
Kurtosis	*25.65900*	*5.041799*	*9.277966*	*9.193079*	*7.221705*	*11.93962*
Jarque-Bera	*22013.5*	*169.2235*	*1711.105*	*1553.902*	*712.1402*	*2956.706*
ARCH Effect test						
F-Statistics	*276.215*	*4.907*	*35.768*	*68.709*	*14.311*	*110.831*
N^*R^2	*217.736*	*4.892*	*34.636*	*64.055*	*14.120*	*98.051*
Unit root tests						
ADF^L	*-22.173*	*-31.275*	*-32.515*	*-17.496*	*-16.063*	*-32.826*
PP^L	*-61.297*	*-31.295*	*-33.299*	*-24.043*	*-27.168*	*-33.447*
KPSS	*0.2072*	*0.0258*	*0.1414*	*0.3392*	*0.2859*	*0.2298*

Note: rnse, rbrvm[2] and rgse stands respectively for Nigerian, Côte d'Ivoirian and Ghanaian stock markets. ARCH are all significant at 1% level. When conducting ADF and PP tests, we include intercept in the test equation. ADF^L, PP^L and $KPSS^L$ are for level data, which are return series. ADF^L and PP^L are significant at 1% level. For KPSS test, since its null hypothesis is that the time series is stationary, $KPSS^L$ are all not significant. .

Informations from this Table 1 suggest that all the chosen commodity indexes exhibit a positive mean return for the sample period and this is highest for uranium. Regarding African equity markets, there are positive mean returns for Nigeria but negative mean returns for the remaining markets.

Additionally, the global commodity market for cocoa has the greatest mean returns. Furthermore, all return series seem to be negatively skewed, with the exception of the Côte d'Ivoire and Nigerian equity markets, which show positive skewness. In contrast to a normal distribution, the return is strongly leptokurtic with fat tails, as indicated by the big value of kurtosis, which ranges from the lowest of 5.04 for the cocoa return to the greatest of 25.66 for the oil return. Significant asymmetry and excess kurtosis are seen in these early descriptive statistics. The Jarque-Bera test statistics, which reject the null hypothesis of normality for all of the market returns under investigation at a 1% significance level, further support the non-normality.

The findings of the ARCH test demonstrate the existence of the ARCH effect at a 5% significance level inside all returns, in accordance with the F and N*R2 statistics, which reject the null hypothesis that a set of residuals shows no conditional heteroscedasticity. Therefore, it is appropriate and justified for us to measure return volatility using GARCH family models. To investigate trend stationarity, we combine the Phillips-Perron (PP) and Augmented Dickey-Fuller (ADF) tests with KPSS tests. All test results show that price level data demonstrate a stationary feature, as shown in Table 1.

The unconditional correlation matrix between market returns is shown in Table 2. The potential advantages of portfolio diversification and assistance opportunities are implied by the low correlation between the indicators. Butwhen compared to other commodity and equity combinations, the connections between the Johannesburg stock exchange and oil and cocoa are stronger.

Table 2. Correlations matrix.

	roil	**rcocoa**	**rgold**	**rnse**	**rbrvm**	**rgse**
roil	1.000					

[2]brvm: Bourse Régionale des ValeursMobilières represents the regional stock exchange of the member states of the West African Economic and Monetary Union (WAEMU), namely, Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal, and Togo.

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rcocoa	0.122	1.000				
rgold	0.042	0.082	1.000			
rnse	-0.078	0.024	-0.009	1.000		
rbrvm	-0.061	-0.028	0.018	-0.006	1.000	
rgse	-0.002	0.027	-0.040	0.046	-0.016	1.000

5. Results and Discussion

To better understand the links among African equity and global comodity markets in terms of shocks and volatility, we have estimated[3] the BEKK-GARCH (1,1) process given by Eqs. (1) and (2). Tables 3–5 below report the results of estimates respectively for total period, Covid period and before covid period with diagnostic tests.

Table 3. Estimate results (Total period).

	roil (i=1)	rcocoa (i=2)	rgold (i=3)	rnse (i=4)	rbrvm (i=5)	rgse (i=6)
μ	0.00041*	0.00025	-0.00007	-0.00017	-0.00009	0.00007
a_{i1}	-0.072*	0.137*	-0.283***	-0.172**	-0.144*	-0.124**
a_{i2}	-0.028***	0.147***	-0.137***	0.068**	0.007	0.008
a_{i3}	-0.025	0.080	-0.097***	0.122**	-0.061**	-0.082***
a_{i4}	-0.042***	-0.106***	0.069***	0.325***	0.029	-0.029*
a_{i5}	0.028	0.031	-0.079***	0.238***	0.221***	0.060***
a_{i6}	-0.033*	-0.125***	0.103***	0.082*	-0.00005	-0.075**
b_{i1}	0.504***	-0.1333**	0.124***	0.304***	0.348***	0.123***
b_{i2}	-0.052***	1.081***	-0.243***	-0.012	0.077***	0.097***
b_{i3}	-0.026	0.818***	0.693***	-0.225***	0.122**	-0.005
b_{i4}	0.047**	-0.029	-0.021**	0.586***	0.260***	0.041***
b_{i5}	-0.197***	-0.130***	0.037**	-0.556***	0.518***	0.048**
b_{i6}	0.081***	0.078***	0.008	-0.282***	-0.055	0.906***
d_{i1}	-0.110**	0.169	-0.062	0.210	-0.033	0.329***
d_{i2}	0.022	-0.096***	-0.012	-0.010	-0.075**	0.115***
d_{i3}	0.053	-0.153**	-0.053	0.115	0.032	0.072*
d_{i4}	0.023	0.194***	-0.019	-0.169**	-0.346***	-0.015
d_{i5}	-0.392***	-0.209***	0.139***	0.148*	0.313***	-0.027
d_{i6}	-0.075**	-0.049	0.014	0.054	-0.032	0.264***
JB	46212.40***	194.485***	869.456***	791.616***	991.136***	22210.47***
LB	86.042***	38.825	27.848	102.44***	89.477***	73.819***
LB^2	46.848	39.257	22.951	19.702	40465	84.623***
ARCH	1.179	0.129	0.436	0.048	0.013	0.163

JB is the Jarque–Bera normality test of the standardized residuals; LB is the Ljung-Box test for autocorrelation of order 36 of the standardized residuals; LB2 is the Ljung-Box test for autocorrelation of order 36 of the squared standardized residuals; and ARCH refers to the test for conditional

[3] The indirect links between African and comodity markets in terms of shocks and volatility are not reported in the paper due to the large number of estimated coefficients.

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heteroscedasticity of the standardized residuals. *, ** and *** indicate significance level of 10%, 5% and 1%, respectively.

Table 4. Estimate results (Covid period).

	roil (i=1)	rcocoa (i=2)	rgold (i=3)	rnse (i=4)	rbrvm (i=5)	rgse (i=6)
μ	0.00028	0.00045	0.00024	0.00076***	0.00037	0.00074
a_{i1}	-0.077**	-0.073	-0.107***	-0.288***	-0.082	-0.014
a_{i2}	0.006	-0.113***	-0.053***	-0.028	-0.093**	-0.120***
a_{i3}	-0.054	-0.459***	-0.47	-0.259*	-0.137	0.024
a_{i4}	0.009	-0.034	0.012	0.122***	0.059	-0.005
a_{i5}	-0.449***	-0.082*	-0.038*	0.713***	-0.234***	-0.156***
a_{i6}	0.023	-0.066	0.088***	-0.034	0.017	0.0003
b_{i1}	0.906***	-0.296***	0.158***	-0.316***	-0.119*	-0.023
b_{i2}	-0.044***	0.787***	0.039***	-0.294***	-0.023	0.031*
b_{i3}	0.010	0.274***	0.648***	0.303***	-0.099	0.112***
b_{i4}	0.052***	-0.158***	-0.078***	0.696***	0.151***	0.027**
b_{i5}	-0.095***	-0.236***	0.134***	-0.341***	0.190***	-0.002
b_{i6}	0.017	0.085**	-0.065***	-0.032	0.151***	0.938***
d_{i1}	-0.035	0.227**	0.026	0.131	-0.394***	0.121
d_{i2}	0.128***	-0.144*	0.136***	0.421***	-0.432***	0.005
d_{i3}	0.144*	0.376**	-0.169***	0.910***	0.513***	0.172***
d_{i4}	0.097***	-0.013**	0.053*	0.121	-0.468***	-0.038
d_{i5}	-0.053	-0.111	0.064	0.125	0.006	-0.065
d_{i6}	-0.038	0.979	-0.137***	0.171*	0.112	0.478***
JB	2993.99***	306.84***	142.94***	693.46***	941.46	14541.96***
LB	31.005	29.550	40.369	71.371***	36.883	37.941
LB^2	17.931	24.396	19.910	41.859	28.073	56.675**
ARCH	0.286	0.000000001	0.075	2.594	0.188	0.081

JB is the Jarque–Bera normality test of the standardized residuals; LB is the Ljung-Box test for autocorrelation of order 36 of the standardized residuals; LB2 is the Ljung-Box test for autocorrelation of order 36 of the squared standardized residuals; and ARCH refers to the test for conditional heteroscedasticity of the standardized residuals. *, ** and *** indicate significance level of 10%, 5% and 1%, respectively.

Table 5. Estimate results (Before Covid period).

	roil (i=1)	rcocoa (i=2)	rgold (i=3)	rnse (i=4)	rbrvm (i=5)	rgse (i=6)
μ	0.00127*	0.00026	0.000006	-0.00095***	-0.00041	0.00009
a_{i1}	-0.066	-0.251**	0.0309	0.025	0.152*	0.160*
a_{i2}	-0.044***	0.176***	-0.168***	0.253***	-0.028	0.116***
a_{i3}	-0.019	-0.282***	0.151***	0.200***	-0.084	0.238***
a_{i4}	-0.025	-0.194***	0.121***	0.263***	0.070**	0.032
a_{i5}	0.103***	-0.110**	0.012	0.045	-0.306***	-0.006
a_{i6}	-0.028	-0.273***	0.006	0.079	-0.044	-0.046
b_{i1}	0.929***	0.299***	-0.153**	-0.007	0.706***	-0.063
b_{i2}	0.014	0.662***	-0.428***	-0.007	-0.098***	0.155***

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b_{i3}	-0.033	0.743***	0.071	-0.079	0.432***	0.156***
b_{i4}	-0.007	0.206***	0.052**	0.846***	0.0049	-0.077***
b_{i5}	0.011	-0.441***	-0.107***	0.103**	0.292***	-0.335***
b_{i6}	-0.102***	0.176***	-0.297***	0.016	1.024***	0.605***
d_{i1}	0.035	-0.514***	0.094	-0.170	0.241**	-0.061
d_{i2}	0.005	0.041	-0.175***	0.169**	-0.065	0.386***
d_{i3}	-0.033	-0.066	0.032	-0.079	-0.068	0.315***
d_{i4}	0.077***	0.116*	0.028	-0.283***	-0.136***	-0.116***
d_{i5}	-0.003	-0.141	0.139**	-0.093	0.044	-0.042
d_{i6}	-0.022	-0.186	0.348***	-0.251**	-0.133*	-0.062
JB	34126.78***	1.66	466.51***	328.91***	114.53***	2015.64***
LB	63.247***	34.651	39.211	58.192**	69.102***	72.339***
LB^2	30.598	55.897**	18.766	22.500	22.282	13.394
ARCH	0.415	1.153	1.261	0.023	0.817	0.988

JB is the Jarque–Bera normality test of the standardized residuals; LB is the Ljung-Box test for autocorrelation of order 36 of the standardized residuals; LB2 is the Ljung-Box test for autocorrelation of order 36 of the squared standardized residuals; and ARCH refers to the test for conditional heteroscedasticity of the standardized residuals. *, ** and *** indicate significance level of 10%, 5% and 1%, respectively.

While Table 3 shows the own effects and shocks and volatility spillovers effects between markets, Tables 4 and 5 provide an assessment of the role of COVID-19 on changing these effects.

5.1. Past Own Effects

The estimate results for total period reported in Tables 3 indicate that for all markets, the current values of conditional volatility are sensitive (positively for world cocoa price, Nigerian and rbrvm stock markets and negatively for world oil price, world gold price and Ghanaian stock market) to their past own shocks since the corresponding diagonal coefficients a_{ii} are statistically significant. Tables 4 and 5 show the same results for oil and Nigeria stock market in Covid and before Covid periods suggesting no impact of Covid for thse two markets. For the other markets, COVID-19 has mixed effects transforming the positive sensitivty of past awn shocks to negative for gold and and vice versa for rbrvm stock market. For cocoa and Ghanaian stock market, the sensitivity is the same in the total period compared to that of before the Covid period and contrary to the Covid period. For the past own volatility effect in case of total period, the results outline that for all markets, the current conditional volatility is positively influenced by its past value since the corresponding diagonal coefficients b_{ii} are positive and statistically significant. As noted in Table 3, the estimated coefficients for ARCH and GARCH models in our conditional variance equations for all the groups are statistically significant. This shows that the African stock market (Nigerian, rbrvm and Ghanaian) and global comodity market (oil, cocoa and gold) have strong ARCH and GARCH effects. Our results are in line with those of Beirne et al. (2009), who emphasize the suitability of the GARCH family models in these analyses and offer compelling evidence of ARCH and GARCH effects in emerging markets.

One noteworthy characteristic is that, for all markets, past own volatility is higher than past own shocks. This suggests that, for all markets, previous own volatility is more significant in forecasting current conditional volatility than past own shocks. With the exception of gold, which has higher past own shocks than past own volatility prior to the Covid period, these findings hold true for all markets during the Covid period and before to it.

5.2. Shocks and Volatility Spillovers Between Stock and Global Comodity Markets

Four bidirectional Shock and volatility transmissions are identified by the empirical results in Table 5. Unexpected news has a negative impact, but historical volatility between the price of oil and the stock markets in Nigeria, Ghana, and Brazil has a favorable impact. The spillovers from the most recent bidirectional transmissions between the Nigerian stock market and gold are negative for the previous volatility and favorable for the unexpected news. Additionally, we find evidence of bilateral shock transmission between the Nigerian stock market and the cocoa market (negative in the opposite direction and positive from the cocoa to the stock index) and between the Ghanaian stock market and the gold market, as well as negative shock spillover effects between the world oil price and the BRM stock market.

While the price of cocoa and the rbrvm stock index are correlated in terms of volatility, with the cocoa price having a positive impact on the stock index and the stock index having a negative influence on the cocoa, the Ghanaian stock and cocoa markets have bidirectional positive volatility linkages. There is only one negative unidirectional shock transmission from cocoa to the Ghanaian stock index, in contrast to these bidirectional transmissions. The historical volatility of the Nigerian and Ghanaian stock markets has a positive (negative) impact on the current conditional volatility of the price of oil (gold), and vice versa for rbrvm.

The Ghanaian stock market has a favorable impact on the cocoa price, while the BRM stock markets have a negative impact on the current value of conditional volatility. Conversely, the historical volatility of the oil price has a favorable impact on the conditional volatility of the Nigerian stock market, while the historical volatility of the gold price has a negative impact. The Ghanaian stock market, or Rbrvm, has a favorable impact on all commodity markets, including those for cocoa and oil.

Overall, the shock and volatility spillovers effect run at the same time from global comodity price to stock markets, such as from stock markets to comodity price. This conclusion contradicts that of Jouini and Harrathi (2014) who point out that, based on multivariate GARCH type models, in contrast to shock links, the volatility spillovers run more from GCC stock markets to world oil price rather than from oil to stock markets. These insights point to the importance of opting for an accurate methodology and employing a sufficiently sophisticated econometric approach to analyze empirically the links among African stock markets and comodity markets in terms of volatility. Another noticeable feature from the results is that shock links and volatility spillovers are mixed (positive and negative).

The results presented in Tables 4 and 5 show that both shocks and volatility transmissions between markets are affected by COVID-19. New transmissions emerge while others disappear. For shocks from stock markets to commodity markets, transmissions appear between rbrvm and Ghanaian markets to gold, while those from Nigerian markets to cocoa and gold disappear. In the opposite direction, shocks are transmitted from oil price to both Nigerian and Ghanaian markets and from cocoa to rbrvm, with some transmissions disappearing (from oil price to rbrvm, from cocoa to Nigerian markets, and from gold to Ghanaian markets). Regarding volatility transmissions from stock to commodity markets, new transmissions are observed from Nigerian and rbrvm markets to oil, while transmissions from the Ghanaian market to oil disappear. In the reverse direction, volatility transmissions emerge from oil, cocoa, and gold to Nigerian markets and fromcocoa and gold to rbrvm market.

5.3. Shocks and Volatility Spillovers Among Comodity Markets

Table 5 shows bidirectionnal mixed transmissions of shock spillovers for oil/cocoa (which disappear in Covid period) and unidirectional negative from oil and cocoa to gold. There is strong evidence of volatility spillovers, which is bidirectional negative for oil/cocoa and mixed for cocoa/gold. Similarly, our results reveal no shock and volatility spillover effects from gold to oil. No Covid impact on volatility transmission is detected.

5.4. Shocks and Volatility Spillovers Among Stock Markets

From the perspective of shock and volatility transmissions among selected African stock markets, the results in Table 3 reveal interesting insights. For the Nigeria/Ghana country pair, the shock linkage from the first country to the second one is negative, and positive for the other direction. For the other country pairs, there are unidirectional positive shock spillovers from brvm to Ghananian to Nigeria and no evidence of shock interdependence from Nigerian and Ghananian stock markets to brvm. For the volatility spillover effects, the results display mixed bidirectional links (Nigeria/Ghana-brvm), and positive unidirectional relationships from brvm to Ghananian markets. In covid period, new shock transmissions mixed are observed, positive from brvm to Nigerian stock market and negative from Ghananian to Nigerian markets. Shock transmissions from the Nigerian market to brvm disappear and emerge as volatility transmissions.

Consistent with Ahmed and Rui's (2021) research, we discover that the conditional volatility of stock and commodity markets typically varies more quickly over time due to internal innovation impulsions and volatility than cross-market values. These findings imply that personal values are more capable than cross-market values of forecasting future conditional volatility. The fact that, aside from the own coefficients, the differences between the cross-market ARCH and GARCH coefficients are generally not very significant indicates that the sensitivity of the current conditional volatility to cross-market historical news and volatility is nearly equal.

These observations make the assumption that conditional volatilities are extremely unstable and fluctuate significantly over external shocks. These characteristics align with those inferred from the market return dynamics presented in Figure 1, where the returns' behavior vary significantly throughout the COVID-19 pandemic.

5.5. Asymmetric Effects

The results presented in Table 3 show evidence of asymmetric responses to negative own shocks except for gold market. The impacts are negative for oil, cocoa and Nigerian but positive for rbvm and Ghanian. Regarding the magnitude of the estimates, the observed impact on the stock markets is more important (double to triple) compared to comodity markets. For the cross-market asymmetric responses between comodity and stock prices, we find bidirectional asymmetric effects between oil/Ghana and cocoa/brvm with different signs. Among stock markets, there is evidence of bidirectional asymmetric responses between the Nigerian and brvm stock markets. The results also display positive (Nigeria/cocoa, cocoa-gold/Ghana) and negative (rbvm-gold/oil) unidirectional asymmetric responses from market one to market two, and no asymmetric spillovers for the oil/cocoa-gold comodity pairs, Nigerian-brvm/Ghananian country pairs and oil-gold/Nigeria comodity-stock pairs. Comapred to before Covid period (Table 5), results for Covid period (Table 4) indictes that the pandemic supports asymmetric responses to negative own shocks for cocoa, gold and Ghananian markets. Among comodity prices, Covid allow asymmetric responses from cocoa and gold to oil. Other new asymmetric responses due to Covid are detected from gold to cocoa, Nigeria and brvm; from Nigeria to gold and from cocoa to rbvm. Contrary, Covid support non-asymmetric responses from cocoa and Nigeria to Ghana; from brvm to gold and from Ghana to brvm.

6. Conclusion and Policy Implications

Using the asymmetric BEKK-GARCH process created by Kroner and Ng (1998), the study investigates the empirical problem of shock and volatility transmissions between African stock and international commodity markets. To the best of our knowledge, no multivariate models have been used to analyze the volatility transmissions of African countries in prior publications, which lends credence to the analysis. The findings are generally acceptable and show that, for patterns of volatility, the effects of shock spillovers on stock markets and commodity prices are comparable.

Additionally, the findings demonstrate both unidirectional and bidirectional volatility interdependencies inside and across a few chosen markets. With the exception of the Cocoa-Gold-Nigeria/oil, gold/Nigeria, and Nigeria-rbvm/Ghana pairs, where non-asymmetric responses are noted, the results are noteworthy from the standpoint of asymmetry in the conditional variances since there are asymmetric spillovers to negative shocks among and across selected markets. Return volatility in certain markets has been found to have increased as a result of the COVID-19 outbreak and the ensuing economic uncertainty.

The result might indicate that investors are confident in the actions taken by different African governments to address this issue. The findings indicate that shock and volatility transmissions between and across markets with varying signs and levels are both impacted by the pandemic. Asymmetric market reactions to adverse shocks are also impacted by pandemics, which encourage the formation of new asymmetric reactions while eradicating others.The relationship among selected African country stocks and comodity markets in terms of volatility transmissions is crucial for policy makers. The regulation of stock markets and comodity price policies can be done based on sound decisions. Globally, the volatility transmissions among and across markets tell us about the informations contained in each market that enable the prediction of future fluctuations in the other markets.

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