



# Dynamic connectedness between global commodity sectors, news sentiment, and sub-Saharan African equities

Samuel Kwaku Agyei<sup>a</sup>, Zaghum Umar<sup>b</sup>, Ahmed Bossman<sup>a,\*</sup>, Tamara Teplova<sup>c</sup>

<sup>a</sup> Department of Finance, School of Business, CC-191-7613, University of Cape Coast, Cape Coast, Ghana

<sup>b</sup> College of Business, Zayed University, P.O. Box 144534, Abu Dhabi, United Arab Emirates

<sup>c</sup> National Research University Higher School of Economics, Moscow, Russian Federation

## ARTICLE INFO

### JEL:

C22

C32

C58

G01

G11

G12

G15

N27

Q02

### Keywords:

Commodity sectors

Economic news sentiment

sub-Saharan Africa

Equities markets

Emerging markets

Spillover connectedness

## ABSTRACT

We examine the static and time-varying spillovers between global commodity sectors, economic news sentiment, and sub-Saharan African (SSA) equities. In a time-varying parameter vector autoregressions spillover connectedness approach, we find that: (i) there are significant spillovers between SSA equities, economic news sentiment, and global commodity sectors; (ii) the connectedness evolves across different times and is amplified by market crises; (iii) there are suitable market-specific SSA equities that bear safe-haven and hedge attributes for global commodity investors; (iv) agriculture is the main source of return and volatility spillovers; and (v) economic news sentiment index is a net transmitter of spillover during systemic crisis periods such as GFC and the COVID-19 pandemic. Our findings have notable implications for international investors, regulators, and practitioners.

## 1. Introduction

In recent decades, the attraction of significant private capital flows to the real sector of economies has been integrated into the development strategy of African economies (Bossman et al., 2022a). While sub-Saharan Africa (SSA) witnessed a rise in private capital flows in the early 21st Century, the sub-region experienced declines following the emergence of the 2008/09 global financial crisis (GFC), which was attributable to amplified levels of risk aversion among investors, stringent international credit conditions, and the bond markets' development (Boako et al., 2020).

The post-GFC capital flow losses and the uncertainty surrounding the generation of higher projected returns on African-based investments partly contribute to investors' indisposition to consider African investments as desirable diversification surrogates (Boako and Alagidede, 2016). However, the need for cross-asset, cross-market, and cross-regional, investment has been tagged critical for portfolio diversification (Umar and Gubareva, 2021b) subject to key events – such as the GFC, the European debt crisis, Brexit, the

\* Corresponding author.

E-mail addresses: [sagyei@ucc.edu.gh](mailto:sagyei@ucc.edu.gh) (S.K. Agyei), [zaghum.umar@gmail.com](mailto:zaghum.umar@gmail.com) (Z. Umar), [ahmed.bossman@outlook.com](mailto:ahmed.bossman@outlook.com) (A. Bossman), [tteplova@hse.ru](mailto:tteplova@hse.ru) (T. Teplova).

<https://doi.org/10.1016/j.ememar.2023.101049>

Received 31 March 2022; Received in revised form 22 June 2023; Accepted 5 July 2023

Available online 13 July 2023

1566-0141/© 2023 Elsevier B.V. All rights reserved.

trade tension between China and the US, the COVID-19 health crisis, and heightened geopolitical risks – in the 21st Century. This presents an opportunity for SSA economies to identify and benefit from the capital flows associated with cross-regional portfolios. Notwithstanding, the identification of potential channels for attracting international capital flows hinges on a comprehensive understanding of the dynamics of connectedness between financial markets from the sub-region and the global economy (Agyei and Bossman, 2023). Equally important is the transmission of economic conditions sentiment across these markets.

Motivated by the above, we examine the returns and volatility spillover connectedness between equities from SSA, economic news sentiment, and global commodities. In the global market arena, rampant commodity price volatility and hypothetical commodity financialization pose significant challenges to international investors in terms of asset allocation and risk management given the high integration between financial markets from developed economies. Several SSA markets presently fall in the emerging markets class, which is noted for its return predictability and the potential for offering high risk-adjusted returns (Buchanan et al., 2011; Mensi et al., 2017). Therefore, aside from substantiating our motivation to study the degree and nature of connectedness between SSA equities and global commodities, the reasons outlined above raise some interesting questioning themes whose responses need to be determined through empirical investigations. Furthermore, given the growing body of literature on the role of investor sentiment on asset performance, we incorporate the impact of economic news sentiment in the overall connectedness of commodity and SSA markets. Hence, in an attempt to examine the potential of SSA equities in attracting significant investment flows amid various forms of episodic financial market crises (including commodity markets shocks), we address the following questions:

- (i) What is the degree of connectedness between SSA equities, economic news sentiment, and global commodities and how does this connectedness evolve across different market events and periods?
- (ii) Do market crises affect the spillover patterns between SSA equities, economic news sentiment, and global commodities?
- (iii) Do SSA equities respond equally to shocks?
- (iv) Are there safe-haven and hedge equities from SSA?

By providing empirical answers to these questions, we contribute to several strands of literature. First, we add to the equities-commodities literature that has been well-articulated with much emphasis on commodity financialization (Adams et al., 2020; Adams and Glück, 2015; Antonakakis et al., 2017; Baldi et al., 2016; Gurdgiev and O’Riordan, 2021; Hu et al., 2020; Liu et al., 2021; Mayer, 2012; Sensoy et al., 2015; Yin et al., 2021; Zarembo et al., 2021b; Zhu et al., 2020) and herd behavior (Demirer et al., 2015). Although the conclusions from these works, particularly on the financialization hypothesis, have not been at par, the inclination of commodities markets toward high volatilities in recent periods has not been debated. In particular, we add a new dimension of investor sentiment by proxying the economic news sentiment index. Second, we add to the set of works that examine the susceptibility of commodity sectors to commodity market shocks. These works are driven by the increasing market volatilities in commodities markets, particularly in the 21st Century extending to the financial market stress during the apogee of the COVID-19 pandemic (Umar et al., 2019; Umar et al., 2022b; Umar et al., 2021c; Umar et al., 2021e; Zarembo et al., 2021a). Common documentation from these works suggests that during turbulent periods, shocks from leading commodities to other commodity sectors impact the price- and returns-generating dynamics in commodities markets.

Third, we contribute to the African market literature. Despite the relative underrepresentation, there has been a slight growth in the literature focused on financial markets from Africa against the backdrop of the 2020 global economic crisis of a pandemic origin (i.e., COVID-19). These works focus on the susceptibility of African markets to global uncertainties (Adam, 2020; Asafo-Adjei et al., 2020), the interplay between different assets from African markets (Bossman et al., 2022a), the link between African equities and digital currencies (Kumah and Odei-mensah, 2021), the interplay between African equities and oil price shocks (Asafo-Adjei et al., 2021; Assifuah-Nunoo et al., 2022; Boateng et al., 2021), the dynamics of connectedness between the US yield curve and African stocks (Bossman et al., 2023), or the causal links between selected commodities and African equities (Alagidede et al., 2021; Boako and Alagidede, 2016, 2017). It is worth noting that regardless of the approaches employed, these works fail to address important issues regarding total connectedness, the evolution of connectedness across different market events, and the impact of recent market crises on the patterns of connectedness between SSA equities and global commodities.

Lastly, we contribute to the growing strand of literature focused on the role of investor sentiment on various asset classes and markets by specifically looking at the interplay of economic news-based sentiment on the interlinkages of SSA equities and commodities. For instance, a large volume of literature looked at the impact of the recent pandemic on the commodity and equity markets. (Bossman et al., 2022d; Umar et al., 2021b; Umar and Gubareva, 2021a). However, to the best of our knowledge, the existing literature does not look at the impact of investor sentiment on SSA equities and commodity markets in a multivariate context.

Knowledge about the degree and sources of connectedness and the effect of recent market events on the connectedness patterns between SSA equities, economic news sentiment index, and global commodities is not only critical to portfolio management but also to inform SSA economies about the need to attractively regulate their equities markets to attract international capital flows through cross-regional portfolio diversification. Central to portfolio management are cross-asset/market returns and volatility connectedness (Diebold et al., 2017) and the portfolio selection theory emphasizes that, for diversification, an asset is fit for inclusion in a portfolio if its associated risks are outweighed by the returns it yields (Markowitz, 1952). Hence, in the absence of such evidence in the African equities-commodities literature, we add to the body of knowledge by examining the dynamic connectedness between SSA equities and global commodities in terms of both returns and volatilities. Our main contributions are threefold.

First, to the best of our knowledge, this is the first study to ascertain the returns and volatility spillover dynamics between SSA equities, economic news sentiment index, and global commodities in a period filled with notable market crises such as the 2011/12 European debt crisis, the 2016 Brexit, the 2019 trade tension between China and the US, the 2020 financial market meltdown

originated by the COVID-19 health crisis and heightened geopolitical risks amid the 2022 Russian-Ukrainian military actions. Most of these market events are post-GFC but dominate the 21st Century and given the systemic nature of the financial market crisis in the COVID-19 pandemic era, evidence from this study is pivotal for international investors and fund managers interested in diversifying their portfolios using cross-asset and cross-regional investments.

Second, by empirically determining whether SSA equities could offer reliable channels for cross-border portfolio investors and the influence of investor sentiment, we provide answers to questioning themes such as the potential of SSA equities to attract substantial portfolio investment flows amid harsh global commodities markets conditions and whether African equities are viable in providing hedging, safe-haven, and/or diversification benefits in times of global commodities price uncertainties and volatilities. Although a frontier sub-regional bloc like SSA has several member countries with equities markets mainly assumed to be safe-havens during crises due to their partial dissociation from global markets, there exist limited empirical answers to the aforementioned questioning themes. The prevalence of market crises in the last decade and concerns over commodity financialization highlight the need to provide empirical responses to such questioning themes and, hence, the timelines of this study cannot be overemphasized. Indicatively, our focus on SSA is not a misplaced priority given that the findings of this study would suggest some potential comparative advantages to which market regulators could pay attention.

Third, we use a wide-ranging commodities sample – including agriculture, energy, grains, industrial metals, livestock, precious metals, and softs – encompassing seven commodity sectors that are of importance to the African continent either by way of production or exports (Bossman and Agyei, 2022a, 2022b). We focus on commodity sectors rather than some selected commodities that may not be of interest to investors in terms of portfolio construction. We argue that international investors may be particular with sectoral investments rather than individual assets that may possess high risks. In terms of commodities, we could liken sectors to commodity sectors. Therefore, our analysis is sufficiently comprehensive as opposed to works that employ selected commodities from a particular commodity sector.

Methodologically, we utilize (Antonakakis et al., 2020) time-varying parameter vector-autoregressions (TVP-VAR) overall spillover connectedness matrix and the rolling connectedness index to observe the total connectedness between the variables of interest and how their connectedness evolves across different periods and events.

Our main results are summarized as follows. First, the connectedness between SSA equities and global commodity sectors is time-varying such that, in terms of returns, the connectedness between SSA equities and global commodity sectors measures between 32% and 70% while in terms of volatility, the total connectedness index ranges between 32% and 65%. Second, notable market crises – like commodity price shocks, the European debt crisis, Brexit, the trade tension between China and the US, and the COVID-19 health crisis – consistently impact the connectedness between SSA equities and global commodities by amplifying the connectedness level. Third, SSA equities offer heterogeneous responses to market shocks and as a result, Cote D'Ivoire, Ghana, Kenya, Mauritius, Nigeria, and Zambia are safe-havens and hedges during normal and stressed conditions, respectively. Lastly, the economic news sentiment index is a net transmitter of spillover during systemic crisis periods such as GFC and the COVID-19 pandemic.

We organize the rest of the study as follows. Section 2 describes the data after which it outlines the estimation procedure. We discuss our findings in Section 3 and conclude in Section 4.

## 2. Data metrics and methodology

### 2.1. Data metrics and statistical properties

We retrieve daily data for all variables from Bloomberg covering the period from 2nd December 2010 to 22nd July 2022, denoting a little more than the second decade of the 21st Century. We employ stock market data (returns and 10-day historical volatility) on ten SSA countries (namely, Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe). All stock data were close prices – measured in US\$ – of the respective stock markets. The choice of SSA stock markets was based on the markets with the longest available data. The sampled stock markets are also the largest in SSA and their capitalization and trading volume make them representative of the sub-region. In addition to the SSA equities were data on seven commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs). The selected commodity sectors represent the S&P GSCI sectoral commodity indices, which are one of the commonly used benchmarks for commodities in extant literature (Spierdijk and Umar, 2012, 2014; Umar et al., 2023). All commodities were expressed in US\$ per their respective units of measurement. These commodities were selected because they are the commodity sectors that African countries mostly contribute to their production or exportation (Bossman and Agyei, 2022a, 2022b) and have a pivotal contribution to economic development. To avoid the problems associated with asynchronous trading, close prices were used for the available dates that are common to stock all markets and sampled commodity sectors. The economic news sentiment index constructs sentiment scores from economics-related news articles from 24 major U.S. newspapers compiled by the news aggregator service Factiva.<sup>1</sup>

We present the descriptive statistics of the returns and 10-day volatility series in Table 1 under Panels A and B, respectively while the unconditional correlation matrix between the variables is presented under Panel C. Trajectories of the returns series are displayed in Fig. 1.

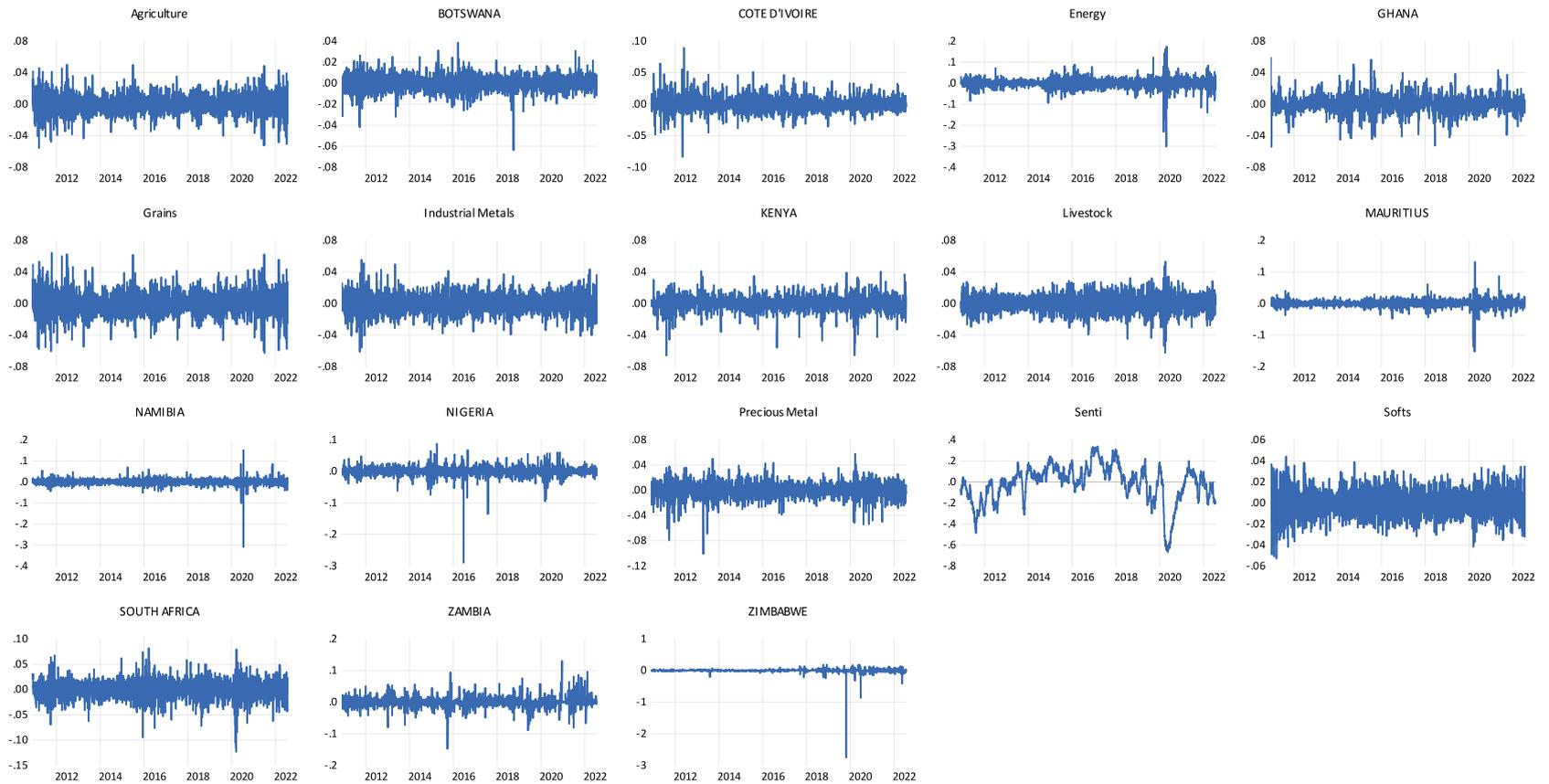
From Table 1-Panel A, all returns series show a positive mean over the sample period except for Ghana, Nigeria, and softs. Most

<sup>1</sup> Buckman et al. (2020) and Shapiro et al. (2017).

**Table 1**  
Summary statistics and correlation matrix.

Panel A: Summary statistics for returns																		
	Agriculture	Botswana	Cote D'Ivoire	Energy	Ghana	Grains	Industrial Metals	Kenya	Livestock	Mauritius	Namibia	Nigeria	Precious Metals	Sentiment	Softs	South Africa	Zambia	Zimbabwe
Mean	0.0000	0.0000	0.0004	0.0001	-0.0001	0.0000	0.0000	0.0002	0.0001	0.0000	0.0003	-0.0001	0.0001	-0.0192	-0.0001	0.0001	0.0001	0.0002
Median	0.0000	0.0000	0.0003	0.0005	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0005	0.0000	0.0000	0.0071	0.0000	0.0006	-0.0003	0.0000
Maximum	0.0503	0.0382	0.0889	0.1739	0.0587	0.0643	0.0554	0.0413	0.0530	0.1314	0.1500	0.0874	0.0572	0.3363	0.0440	0.0815	0.1298	0.1839
Minimum	-0.0558	-0.0638	-0.0836	-0.3018	-0.0544	-0.0630	-0.0609	-0.0659	-0.0623	-0.1530	-0.3097	-0.2896	-0.1011	-0.6694	-0.0528	-0.1227	-0.1482	-2.7449
Std. Dev.	0.0114	0.0065	0.0103	0.0215	0.0094	0.0135	0.0112	0.0088	0.0101	0.0108	0.0129	0.0143	0.0108	0.1774	0.0114	0.0171	0.0139	0.0603
Skewness	-0.0214	-0.4741	0.4046	-1.2609	-0.0249	0.0363	-0.0591	-0.7125	-0.2781	-1.4045	-4.0071	-3.2017	-0.7447	-0.9843	-0.0560	-0.5102	0.3173	-32.1134
Kurtosis	5.1368	8.9342	9.2171	27.4815	8.2099	5.3624	4.8076	9.3151	5.6052	44.5477	121.1048	64.7894	9.8266	4.6070	3.9365	7.0233	17.3259	1426.0520
Observations	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038	3038
Panel B: Summary statistics for volatility																		
Mean	0.1648	0.0001	0.0004	0.2752	0.0000	0.1962	0.1647	0.0002	0.1436	0.0001	0.0003	0.0000	0.1545	-0.0192	0.1686	0.0001	0.0001	0.0001
Median	0.1511	0.0000	0.0003	0.2284	0.0000	0.1805	0.1549	0.0002	0.1339	0.0000	0.0005	0.0000	0.1377	0.0071	0.1624	0.0006	-0.0003	0.0000
Maximum	0.4925	0.1138	0.1199	2.1408	0.2097	0.5949	0.5925	0.0836	0.6408	0.1397	0.1714	0.1238	0.6066	0.3363	0.4389	0.2244	0.1812	0.1839
Minimum	0.0394	-0.0638	-0.0836	0.0516	-0.0544	0.0408	0.0275	-0.0659	0.0383	-0.1530	-0.3097	-0.2896	0.0395	-0.6694	0.0430	-0.1227	-0.1482	-2.7449
Std. Dev.	0.0696	0.0068	0.0106	0.1981	0.0102	0.0826	0.0646	0.0090	0.0652	0.0111	0.0133	0.0145	0.0748	0.1774	0.0591	0.0176	0.0142	0.0604
Skewness	1.1936	1.0953	0.8463	3.7516	2.8636	1.1933	1.3578	-0.4255	2.8715	-0.6515	-2.9914	-2.8891	2.0656	-0.9853	1.0596	0.2021	0.9583	-32.1135
Kurtosis	4.9061	32.7050	13.8544	24.8973	65.9805	4.8200	7.1400	11.2763	18.9659	48.3054	117.3637	63.5056	9.8106	4.6095	4.9533	15.0169	24.1494	1425.9080
Panel C: Correlation matrix																		
	Agriculture	Botswana	Cote D'Ivoire	Energy	Ghana	Grains	Industrial Metals	Kenya	Livestock	Mauritius	Namibia	Nigeria	Precious Metals	Sentiment	Softs	South Africa	Zambia	Zimbabwe
Agriculture	1.0	0.1	0.1	0.3	0.0	1.0	0.3	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.5	0.2	0.0	0.01
Botswana		1.0	0.2	0.2	0.0	0.1	0.3	0.0	0.0	0.2	0.6	0.0	0.3	0.0	0.2	0.6	0.1	0.00
Cote D'Ivoire			1.0	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.2	0.0	0.2	0.0	0.1	0.2	0.0	0.02
Energy				1.0	0.0	0.2	0.3	0.1	0.1	0.1	0.2	0.1	0.2	0.0	0.3	0.3	0.0	0.06
Ghana					1.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.00
Grains						1.0	0.2	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.3	0.1	0.0	0.01
Industrial Metals							1.0	0.0	0.1	0.1	0.2	0.0	0.3	0.0	0.3	0.4	0.0	0.01
Kenya								1.0	0.0	0.1	0.0	0.2	0.0	0.0	0.0	0.1	0.0	-0.01
Livestock									1.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.01
Mauritius										1.0	0.2	0.1	0.0	0.0	0.1	0.2	0.0	0.02
Namibia											1.0	0.0	0.2	0.0	0.2	0.6	0.0	-0.01
Nigeria												1.0	0.0	0.0	0.0	0.1	0.0	0.01
Precious Metals													1.0	0.0	0.2	0.2	0.0	0.03
Sentiment														1.0	0.0	0.0	0.0	0.02
Softs															1.0	0.3	0.0	0.00
South Africa																1.0	0.0	0.00
Zambia																	1.0	0.02
Zimbabwe																		1

*Notes:* This table shows the summary statistics and correlation matrix of returns and 10-day historical volatility of commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). Panels A and B show the statistical properties and distribution of the data in terms of returns and volatility, respectively. Panel C shows the unconditional correlation matrix. The sample period spans from 2nd December 2010 to 22nd July 2022.



**Fig. 1.** Time series plots of returns on commodities and stocks from sub-Saharan Africa and news-based economic sentiment.

*Notes:* This figure shows plots of returns of commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). The sample period spans from 2nd December 2010 to 22nd July 2022.

series have negative skewness statistics, implying that negative returns dominated the sample period. This is not surprising given that the sample period is full of notable events that occasioned historical financial market meltdowns. All returns series show a leptokurtic behavior, as indicated by the kurtosis statistics. From Table 1-Panel B, the mean volatility shows that commodity sectors are highly volatile. The correlation matrix (Table 1-Panel C) shows a mix of negative and positive mild correlations between the sampled commodity sectors and SSA equities. The trajectories of returns over the sample period are representative of several volatility clusters and make it necessary to ascertain the static and dynamic connectedness between the variables.

2.2. Methodology: the TVP-VAR connectedness model

This estimation technique was purposely for the second research objective, which investigated the dynamic return spillover connectedness of various assets and financial markets. (Antonakakis et al., 2020) proposed a TVP-VAR model that extends the connectedness approach of (Diebold and Yilmaz, 2014) by allowing the variance-covariance matrix to vary via a Kalman filter estimation with forgetting factors in the view of (Koop and Korobilis, 2014).

The TVP – VAR(*p*) model is introduced as follows:

$$y_t = B_t z_{t-1} + \varepsilon_t \quad \varepsilon_t | \Omega_{t-1} \sim N(0, \Sigma_t) \tag{1}$$

$$vec(B_t) = vec(B_{t-1}) + \xi_t \quad \xi_t | \Omega_{t-1} \sim N(0, \Xi_t) \tag{2}$$

with

$$z_{t-1} = \begin{pmatrix} y_{t-1} \\ y_{t-2} \\ \vdots \\ y_{t-p} \end{pmatrix} \quad B'_t = \begin{pmatrix} B_{1t} \\ B_{2t} \\ \vdots \\ B_{pt} \end{pmatrix}$$

where  $\Omega_{t-1}$  expressed all available information until  $t - 1$ ,  $y_t$  and  $z_t$  correspond to  $m \times 1$  and  $mp \times 1$  vectors, respectively.  $B_t$  and  $B_{it}$  are  $m \times mp$  and  $mp \times 1$  dimensional matrices, respectively.  $\varepsilon_t$  is an  $m \times 1$  vector, and  $\xi_t$  is  $m^2p \times 1$  dimensional vector, with  $\Sigma_t$ , and  $\Xi_t$  being  $m \times m$  and  $m^2p \times m^2p$  dimensional matrices, respectively.  $vec(B_t)$  is the vectorization of  $B_t$  and is an  $m^2p \times 1$  dimensional vector.

A transformation of the TVP-VAR is made to its vector moving average (VMA) form based on the ‘‘Wold’’ representation theorem. In doing so, the generalized impulse response functions (GIRF) and generalized forecast error variance decompositions (GFEVD) are estimated. Resultantly, the retrieval of the VMA representation  $y_t$  takes its depicted form as  $\sum_{j=0}^{\infty} A_{jt} \mu_{t-j}$ , where  $A_{jt}$  is  $m \times m$  dimensional matrix.

The  $GIRF(\Psi_{ij,t}(H))$  represents the responses of all variables  $j$ , following a shock in  $i$  computed with an  $H - step$  ahead forecast.  $GIRF(\Psi_{ij,t}(H))$  has the following form:

$$GIRF(H, \sigma_{j,t}, \Omega_{t-1}) = E(y_t + H | e_j = \sigma_{j,t}, \Omega_{t-1}) - E(y_{t+H} | \Omega_{t-1}), \tag{3}$$

$$\Psi_{j,t}(H) = \frac{A_{H,t} \Sigma_t e_j}{\sqrt{\Sigma_{j,t}}} \frac{\sigma_{j,t}}{\sqrt{\Sigma_{j,t}}} \quad \sigma_{j,t} = \sqrt{\Sigma_{j,t}}, \tag{4}$$

$$\Psi_{j,t}(H) = \Sigma_{j,t}^{-1/2} A_{H,t} \Sigma_t e_j, \tag{5}$$

where  $e_j$  is an  $m \times 1$  selection vector which takes 1 with the selection of  $j$ th element, and 0 otherwise. Thence, the  $GFEVD(\tilde{\Phi}_{ij,t}(H))$  is computed based on  $\tilde{\Phi}_{ij,t}(H)$ , which has the following representation:

$$\tilde{\Phi}_{ij,t}(H) = \frac{\sum_{t=1}^{H-1} \Psi_t^2}{\sum_{j=1}^m \sum_{t=1}^{H-1} \Psi_t^2}, \tag{6}$$

with  $\sum_{j=1}^m \tilde{\Phi}_{ij,t}(H) = 1$ , and  $\sum_{i,j=1}^m \tilde{\Phi}_{ij,t}(H) = m$ .

Hinged on the above data, the total connectedness index (TCI) takes the expression:

$$C_t(H) = \frac{\sum_{i,j=1,t \neq j}^m \tilde{\Phi}_{ij,t}(H)}{\sum_{i,j=1}^m \tilde{\Phi}_{ij,t}(H)} * 100 = \frac{\sum_{i,j=1,t \neq j}^m \tilde{\Phi}_{ij,t}(H)}{m} * 100. \tag{7}$$

Total directional connectedness (TDC) to others, i.e.,  $i$  transmits its shock to all other variables  $j$  is introduced as:

$$C_{i \rightarrow j,t}(H) = \frac{\sum_{j=1, j \neq i}^m \tilde{\Phi}_{j,i,t}(H)}{\sum_{j=1}^m \tilde{\Phi}_{j,i,t}(H)} * 100. \quad (8)$$

TDC from others, i.e.,  $i$  receives from all other variables  $j$  takes the specification:

$$C_{i \leftarrow j,t}(H) = \frac{\sum_{j=1, j \neq i}^m \tilde{\Phi}_{j,i,t}(H)}{\sum_{j=1}^m \tilde{\Phi}_{j,i,t}(H)} * 100. \quad (9)$$

Net total directional connectedness is defined as:

$$C_{i,t}(H) = C_{i \rightarrow j,t}(H) - C_{i \leftarrow j,t}(H). \quad (10)$$

### 3. Results

The main results from our empirical analysis are presented in this section. We analyze the returns and volatility connectedness in static and dynamic frameworks. Under the static analysis, we present a spillover matrix that captures the overall index within the system of intended variables. This is supplemented by network analysis of the twosome-wise connectedness between the sampled SSA equities, news-based economic sentiment, and global commodity sectors. The dynamic connectedness is analyzed by expressing the total connectedness index as a function of time. Under this, we analyze the time-varying total, directional, and net spillover connectedness between SSA equities, news-based economic sentiment, and global commodity sectors.

#### 3.1. Analysis of static connectedness

The overall connectedness matrix between the variables in the system comprising the sampled SSA equities (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), the news-based economic sentiment and global commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs) are presented in [Table 2](#) under panels A and B for returns and volatility, respectively.

The total connectedness index (TCI), in the right bottom corner of [Table 2](#)-Panel A, expresses the overall level of returns connectedness of the system. The TCI between the sampled SSA equities, news-based economic sentiment, and global commodity sectors is 44.28%, suggesting that the combined dynamics of the system variables may explain approximately 44% of the returns variations in any of the variables from the system. We turn to the penultimate row "TO others" to gain more insights into each variable's contribution to the overall system connectedness in terms of returns. Among the SSA equities, South Africa (79.49%), Namibia (75.11%), and Botswana (66.92%) transmit returns spillovers in larger magnitudes to the system while among the commodity sectors, agriculture (83.37%) and grains (66.74%), are the largest transmitters of returns spillovers TO the system. The news-based economic sentiment transmits a 23.63% spillover TO the system of returns of commodities and SSA equities. The last column "FROM" contains the returns spillovers received by each variable from the system. Again, we can see that from the SSA equities, South Africa (62.95%), Namibia (61.33%), and Botswana (59.92%) receive returns spillovers in larger magnitudes from the system while among the commodity sectors, agriculture (64.33%), grains (51.43%), and industrial (50.29%) are the largest recipients of returns spillovers FROM the system. The corresponding value for the news-based economic sentiment is 33.70%.

While the "TO" and "FROM" analysis emphasizes the contribution of each variable to the system, it does not show which variables are net spillover transmitters or recipients. Therefore, we turn to the last row ("NET") of [Table 2](#)-Panel A, where the net spillover position for each variable is shown. A positive (negative) value indicates a net transmitter (receiver) of returns spillovers. South Africa, Namibia, Zimbabwe, and Botswana are the net transmitters among the SSA equities, rendering Ghana, Cote D'Ivoire, Kenya, Nigeria, Zambia, and Mauritius net recipients of returns spillovers. The news-based economic sentiment is a net recipient of spillover. Among the commodity sectors, agriculture, grains, industrial metals, and energy are net transmitters whereas softs, precious metals, and livestock are the net recipients of returns spillovers.

We repeat the above analysis for volatility spillovers in [Table 2](#)-Panel B. While the observations concerning the volatility spillovers are generally similar to those on the returns spillovers, they differ in magnitudes. The TCI, in the right bottom corner of [Table 2](#)-Panel B, expresses the overall level of volatility connectedness of the system. The TCI between the sampled SSA equities, news-based economic sentiment, and global commodity sectors is 42.12%, suggesting that the combined dynamics of the system variables may explain approximately 42% of the volatility variations in any of the variables from the system. Turning to the penultimate row "TO others", we gain more insights into each variable's contribution to the overall system connectedness in terms of volatility. Among the SSA equities, Namibia (70.06%), South Africa (69.02%), and Botswana (63.2%) transmit volatility spillovers in larger magnitudes to the system while among the commodity sectors, agriculture (74.72%) and grains (68.21%), are the largest transmitters of volatility spillovers TO the system. Lastly, news-based economic sentiment transmits a spillover of 27.1% to the system of volatilities. The last column "FROM" contains the volatility spillovers received by each variable from the system. Again, we can see that from the SSA equities, Namibia (58.15%), South Africa (57.61%), and Botswana (56.93%) receive volatility spillovers in larger magnitudes from the system while among the commodity sectors, agriculture (59.72%) and grains (59.23%), are the largest recipients of volatility spillovers FROM the

**Table 2**  
Static connectedness.

	Ghana	Cote D'Ivoire	Kenya	Namibia	Nigeria	South Africa	Zambia	Zimbabwe	Mauritius	Botswana	Agriculture	Energy	Industrial Metals	Precious Metals	Livestock	Softs	Grains	Sentiment	FROM
Panel A: returns																			
Ghana	69.65	2.03	1.78	1.52	1.38	1.74	1.97	1.99	1.55	1.77	1.73	1.79	2.35	1.34	1.89	1.8	1.73	1.98	30.35
Cote D'Ivoire	1.88	61.6	1.78	3.84	1.55	3.59	1.37	1.65	1.63	4.54	1.73	2.14	2.99	3.46	1.27	1.95	1.71	1.32	38.4
Kenya	1.72	1.84	68.25	1.94	3.86	1.98	1.58	1.54	2.48	1.67	1.74	1.7	1.66	1.52	1.79	1.67	1.75	1.3	31.75
Namibia	0.76	2.56	1.08	38.67	0.85	18.25	0.87	0.68	3.04	15.96	1.88	2.46	3.46	3.38	1	2.61	1.41	1.09	61.33
Nigeria	1.33	1.67	2.66	1.79	68.96	2.31	1.15	1.83	2.05	1.49	1.54	2.52	1.79	1.58	1.75	1.75	1.6	2.23	31.04
South Africa	0.99	2.17	1	17.92	1	37.05	0.88	0.8	2.93	12.69	2.08	4.02	6.06	3.5	1.29	3.14	1.5	0.98	62.95
Zambia	2.23	1.35	1.63	1.97	1.36	1.99	70.17	1.63	1.57	2.16	1.83	1.34	1.97	1.66	1.99	1.61	1.87	1.68	29.83
Zimbabwe	2.25	1.52	1.41	1.25	1.81	1.52	1.24	73.76	1.68	1.37	1.57	1.56	1.39	1.46	1.6	1.55	1.7	1.34	26.24
Mauritius	1.39	2.03	2.01	5.09	2.08	4.93	1.36	1.5	59.52	4.43	2.29	2.26	1.98	1.73	1.64	2.08	2.18	1.49	40.48
Botswana	1.11	3.2	1.05	17.48	0.88	13.96	1.06	0.91	2.76	40.08	1.68	2.23	3.37	4.35	1.27	2.19	1.3	1.13	59.92
Agriculture	0.85	0.99	0.89	1.82	0.82	1.91	0.68	0.64	1.24	1.42	35.67	2.96	2.44	1.78	1.24	10.7	32.93	1.02	64.33
Energy	1.18	1.83	1.06	3.18	1.48	5.06	1	1.23	1.78	2.51	4.08	54.29	6.58	3.54	1.79	4.9	3.14	1.35	45.71
Industrial Metals	1.58	2.2	1.18	4.18	1.14	7.52	1.3	1.13	1.62	3.7	3.17	6.37	49.71	5.47	1.66	4.21	2.4	1.47	50.29
Precious Metals	1.16	2.82	1.22	4.65	1.26	4.85	1.36	1.12	1.71	5.37	2.65	3.63	6.02	54.05	1.75	2.82	2.24	1.32	45.95
Livestock	1.86	1.42	1.65	1.96	1.5	2.07	1.81	1.65	1.76	2.05	2.44	2.29	2.36	2.13	66.78	2.47	2.25	1.55	33.22
Softs	0.96	1.57	1.19	3.22	1.19	3.78	1.07	0.99	1.4	2.48	14.03	4.42	4.34	2.5	1.67	48.57	5.15	1.47	51.43
Grains	0.97	1	0.93	1.47	0.92	1.49	0.73	0.78	1.26	1.17	36.74	2.51	1.95	1.62	1.2	4.5	39.85	0.9	60.15
Sentiment	1.68	1.54	1.84	1.82	1.97	2.51	1.32	1.72	2.02	2.12	2.2	2.41	2.45	2.02	1.92	2.28	1.86	66.3	33.7
TO others	23.9	31.73	24.34	75.11	25.05	79.49	20.76	21.77	32.49	66.92	83.37	46.61	53.15	43.05	26.73	52.23	66.74	23.63	797.06
NET	-6.45	-6.66	-7.41	13.78	-5.99	16.54	-9.07	-4.47	-7.99	7	19.04	0.9	2.86	-2.9	-6.49	0.8	6.59	-10.07	<b>TCI = 44.28</b>
Panel B: volatility																			
Ghana	69.41	1.87	1.69	1.37	1.3	1.82	1.72	2	1.29	1.6	1.71	2.22	2.26	2	1.74	1.79	1.6	2.6	30.59
Cote D'Ivoire	1.84	64.11	1.63	4.27	1.31	3.82	1.33	1.47	1.69	4.74	1.61	1.89	1.67	1.8	1.75	2.1	1.56	1.42	35.89
Kenya	1.66	1.7	67.23	1.91	3.35	2.22	1.59	1.51	2.53	1.88	1.63	1.9	2.29	2.1	1.61	1.58	1.69	1.63	32.77
Namibia	0.84	2.96	1.16	41.85	0.96	20.19	1.15	0.83	3.3	17.97	1.01	1.11	1.09	1.14	1.3	1.15	0.96	1.02	58.15
Nigeria	1.3	1.51	2.72	1.88	69.7	2.55	1.29	1.72	2.07	1.4	1.85	1.67	2.11	1.82	1.49	1.31	1.7	1.9	30.3
South Africa	1.14	2.71	1.13	20.77	1.2	42.39	1.25	0.98	3.3	15.16	1.21	1.36	1.16	1.59	1.27	1.14	1.09	1.16	57.61
Zambia	2	1.37	1.63	2.08	1.39	2.07	71.18	1.64	1.64	2.33	1.37	1.47	1.44	2.35	1.74	1.49	1.32	1.48	28.82
Zimbabwe	1.97	1.48	1.3	1.22	1.63	1.68	1.29	73.14	1.67	1.36	1.8	1.78	1.77	1.86	1.61	1.5	1.73	1.21	26.86
Mauritius	1.26	1.87	2.07	5.16	2.16	5.02	1.49	1.41	61.99	4.45	1.66	1.78	1.38	1.59	1.58	1.7	1.76	1.65	38.01
Botswana	1.11	3.36	1.13	19.42	0.82	15.69	1.38	1.01	2.98	43.07	1.07	1.33	1.11	1.47	1.53	1.16	1.03	1.33	56.93
Agriculture	0.93	0.82	1.15	0.98	1.25	1.12	0.72	1.13	0.93	0.95	40.28	2.02	1.66	2.14	1.75	6.05	35.01	1.08	59.72
Energy	1.96	1.5	1.57	1.35	1.5	1.59	1	1.54	1.79	1.46	3.27	60.85	4.97	4.22	2.98	3.86	2.8	1.79	39.15
Industrial Metals	2.02	1.41	1.78	1.29	1.98	1.35	1.36	1.57	1.34	1.26	4.41	4.5	56.82	5.98	2.24	4.5	4.27	1.92	43.18
Precious Metals	1.56	1.61	1.66	1.87	1.97	2.44	1.79	1.54	1.74	2.02	2.82	4	4.67	60.26	2.74	2.39	2.84	2.08	39.74
Livestock	1.52	1.56	1.64	2.11	1.66	2.02	1.4	1.74	1.67	1.87	2.58	5.42	3.13	3.04	59.42	4.44	2.63	2.17	40.58
Softs	1.51	1.56	1.54	1.53	1.44	1.77	1.1	1.47	1.79	1.64	6.95	5.2	3.96	3.85	2.77	56.65	3.77	1.49	43.35
Grains	0.88	0.81	1.23	1	1.19	1.08	0.74	1.12	1.03	1.05	37.3	1.9	1.52	2.05	1.74	3.42	40.77	1.17	59.23
Sentiment	1.77	1.5	1.76	1.87	1.9	2.59	1.48	1.48	1.92	2.05	2.45	2.93	3.03	2.6	2.77	2.97	2.46	62.47	37.53
TO others	25.27	29.62	26.79	70.06	27.03	69.02	22.08	24.17	32.67	63.2	74.72	42.47	39.25	41.61	32.6	42.53	68.21	27.1	758.4
NET	-5.32	-6.27	-5.98	11.92	-3.27	11.41	-6.75	-2.69	-5.33	6.27	15	3.31	-3.93	1.86	-7.98	-0.82	8.98	-10.44	<b>TCI = 42.12</b>

Notes: This table shows the static connectedness matrix between returns and 10-day historical volatility of commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). Panels A and B show the static spillover connectedness matrix in terms of returns and volatility, respectively. The sample period spans from 2nd December 2010 to 22nd July 2022.

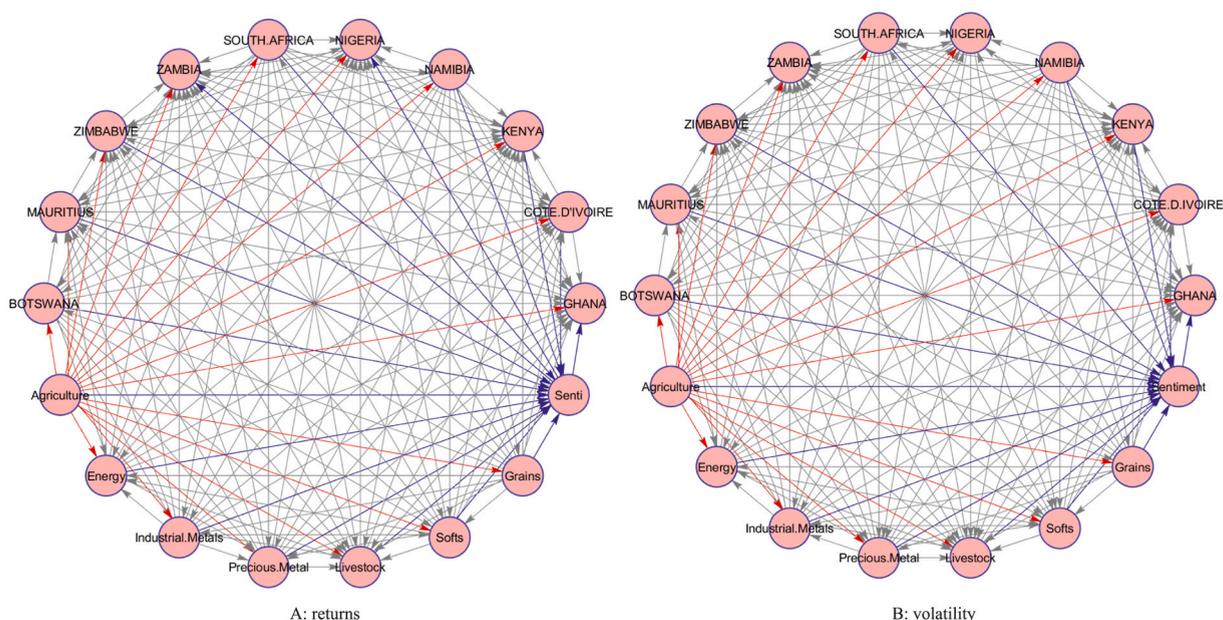
system. The news-based sentiment index receives a spillover of 37.53% from the system of the volatility of commodities and SSA equities.

We turn to the last row (“NET”) of Table 2-Panel B where the net spillover position for each variable is shown. While all SSA equities and the news-based economic sentiment retain their position as either net transmitters or recipients of volatility spillovers as in the case of returns spillovers, the net volatility spillover position of commodity sectors differs from that of returns. Thus, in terms of volatility spillovers, in addition to agriculture and grains, precious metals and grains are net transmitters of volatility spillovers while in addition to livestock, energy and industrial metals are net recipients of volatility spillovers.

To proceed, we turn to the pairwise spillovers between the SSA equities, news-based economic sentiment, and global commodity sectors. We use network analysis to carefully evaluate the pairwise connectedness of net transmitters and receivers of returns and volatility spillovers in the system. This network analysis enables us to identify the net transmitters and net receivers of returns and volatility spillovers on a pairwise basis. Fig. 2 shows the SSA equities' net pairwise connectedness with news-based economic sentiment and global commodity sectors. For any given pair, the arrow's source (edge) denotes the spillover transmitter (recipient). Fig. 2-Panel A shows the network plot in terms of returns spillovers while Fig. 2-Panel B is for volatility spillovers.

Several observations could be made from the network plots. First, South Africa and agriculture are the largest net transmitters of spillovers in terms of returns and volatility, respectively. Second, Mauritius (among SSA equities), economic news-based sentiment, and livestock (among commodities) are the largest net recipients of returns and volatility spillovers, respectively. In all, it is worth noting that the findings reported from the spillover matrix for returns and volatility are confirmed by the network plots.

We document important findings from the static spillover analysis. First, from the static domain, we observe that the returns and volatility spillover dynamics for SSA equities are more comparable than for commodity sectors as well as that of news-based economic sentiment. This observation highlights the predictability of equities from emerging markets (Agyei et al., 2022c; Buchanan et al., 2011; Mensi et al., 2017). Second, returns and volatility spillovers are mainly internal to the respective markets. For instance, approximately 95% of the total spillovers attributable to equities from Zimbabwe are a result of internal market shocks. Among several other SSA equities, a substantial proportion (mostly greater than 80%) of the overall spillovers are contributed internally. While this calls for the attention of regulators, it confirms the partial dissociation of SSA markets from the global economy (Anyikwa and Le Roux, 2020). The high internal market shocks confirm the results reported by (Bossman and Agyei, 2022a) that returns from African equities are highly uncertain given the history of returns from other African equities and commodity sectors based on effective transfer entropies. The results also corroborate those of (Bossman et al., 2022c) and (Mensi et al., 2021) who report high idiosyncratic spillovers between equities markets from different regions. In terms of commodity sectors, we also observe moderate-to-high idiosyncratic spillovers, indicating a considerable level of uncertainties even when combined with some equities. This is consistent with the observation of (Agyei et al., 2022b) that based on the common information shared by commodities markets, market returns are highly uncertain given the history of shocks in one market. The importance of news-based economic sentiment underscores the findings of various studies that



**Fig. 2.** Network plots of the static connectedness between returns and volatility of commodity sectors and stocks from sub-Saharan Africa amid news-based economic sentiment.

*Notes:* This figure shows network plots of returns (Panel A) and volatility (Panel B) connectedness between commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). The sample period spans from 2nd December 2010 to 22nd July 2022.

have underscored the importance of investor sentiment for equities and commodities (Bossman et al., 2022d; Esparcia et al., 2022; Umar et al., 2021a; Umar et al., 2021b; Umar et al., 2021d).

The above discussion highlights the possibility of some hidden dynamics when the connectedness of the system is observed from an aggregate level only. The reason for the potential hidden dynamics is because the key events that accompany the evolution of markets differ across time and these events have unique characteristics, causing varying impacts on financial markets across time. Hence, the need for a dynamics assessment is emphasized. We achieve this in the next subsection.

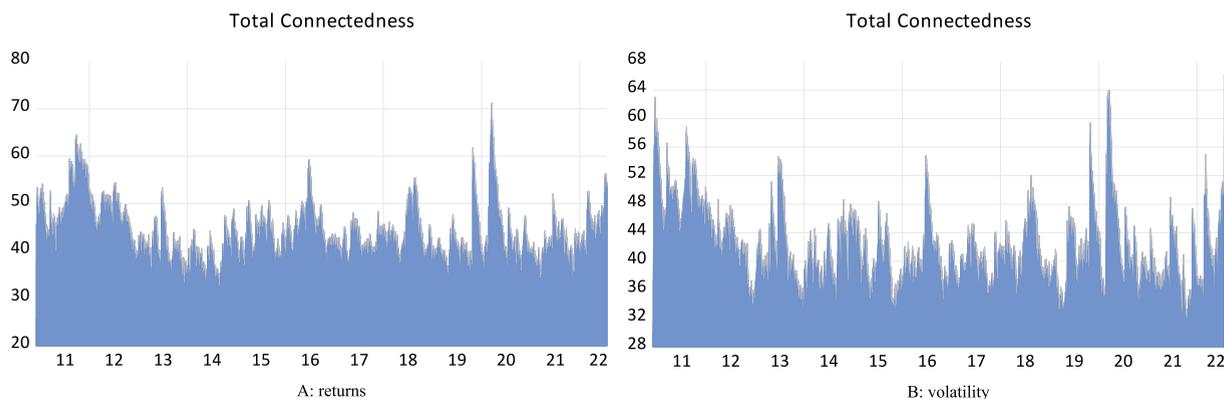
### 3.2. Analysis of dynamic connectedness

In this sub-section, the system's overall connectedness is modeled in a time-varying framework to express the connectedness measures across time. The time-varying TCI between SSA equities, news-based economic sentiment, and global commodity sectors is shown in Fig. 3. Panels A and B express the system's total connectedness as a function of time in terms of returns and volatility, respectively. From Fig. 3, both the returns and volatility spillovers vary in magnitudes across time, albeit with lower magnitudes in terms of volatility spillovers. For instance, in terms of returns spillovers, the TCI ranges between 32% and 70% while in terms of volatility, the TCI ranges between 32% and 65%. In both cases, the time-varying spillovers show spontaneous hikes that mainly coincide with some market events. The rocketed TCI in late 2010 has two attributions. First, we attribute this hike to the pronounced dependency of emerging markets on prime commodities for export and revenue generation in the period 2001–2010, leading to the quadrupling of gold prices and persistent increases in the prices for crude oil and gold (Narayan et al., 2013). Second, the hike could result from a delayed impact of the 2008/09 GFC. The intense impacts of these market events cause investors to behave in a similar fashion that corroborates herd behavior. This observation is consistent with (Demirer et al., 2015) conclusion that huge price movements in commodity sectors such as metals and energy significantly induce herd behavior in other sectors.

Other hikes in spillover connectedness are spotted in 2011/2012, 2016, 2018/19, 2020, and 2022, which we attribute to the European debt crisis, the Brexit dialogues, the trade tension between China and the US, the COVID-19 health crisis, and the military actions between Russia and Ukraine, respectively. Each of these market events had its distinct repercussions, influencing market participants to undertake actions to rebalance portfolios. In crisis periods, similarities in investor behavior – such as the rush for safe assets for diversification – across different markets and regions result in high cross-asset and cross-market connectedness (Agyei et al., 2022a). Hence, the rocketed connectedness index in the aforementioned event periods is not counterintuitive.

There are important observations from the time-varying TCI that need to be highlighted. First, in terms of returns spillovers, among the spotted hikes, the highest was recorded in early 2020, corroborating the financial market turbulence aroused by the COVID-19 health crisis and the adverse investor sentiment. This results from the policies that were rolled out at the apogee of the pandemic to curtail its spread and limit the consequence on major economic sectors and adverse investor sentiment spillover (Agyei et al., 2021; Umar and Gubareva, 2021b). The measures to curtail the effects of the pandemic caused share prices to plummet and had implications on financial markets globally (Arif et al., 2022; Bossman and Agyei, 2022a; Bossman et al., 2022b,e; Mensi et al., 2022; Naeem et al., 2022).

Second, in terms of volatility spillovers, the highest peaked connectedness is found in late 2010 corresponding to the persistent increases in the prices for crude oil and gold, as earlier mentioned. Again, this highlights the conclusion that intense volatility in commodity prices for energy (e.g., crude oil) and metal (e.g., gold) sectors causes huge spillovers in other sectors (Narayan et al., 2013). These observations are consistent with the strand of literature that document that during turbulent periods, shocks from leading commodities to other commodity sectors impact the price- and returns-generating dynamics in commodities markets along with an



**Fig. 3.** Total time-varying connectedness between returns and volatility of commodity sectors and stocks from sub-Saharan Africa amid news-based economic sentiment.

*Notes:* This figure shows the plots of the time-varying returns (Panel A) and volatility (Panel B) connectedness between commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). The sample period spans from 2nd December 2010 to 22nd July 2022.

adverse effect on investor sentiment (Umar et al., 2019; Umar et al., 2022b; Umar et al., 2021c; Umar et al., 2021e; Zaremba et al., 2021a).

Third, while the connectedness index was getting restored to average levels after the apogee of COVID-19, the commencement of the military actions between Russia and Ukraine in late February 2022, which has aroused geopolitical tensions, has amplified further the connectedness index, although not to the level triggered by the COVID-19 pandemic. Our findings are consistent with the conclusions of (Bedowska-Sojka et al., 2022; Boungou and Yatié, 2022), (Umar et al., 2022a; Umar et al., 2022c) that the Russian-Ukrainian military conflict has affected cross-asset/market linkages<sup>2</sup> as well as the significant impact of investor sentiment during such periods of heightened uncertainty.

To supplement the time-varying analysis, we need to understand the risk-reduction attributes of each variable in the system. This is necessary to inform portfolio management decisions in different market conditions. To achieve this, we present the net spillover position of each variable in Fig. 4 under panels A and B for returns and volatility spillovers, respectively. The following observations are made from the net dynamic connectedness between SSA equities, news-based economic sentiment, and global commodity sectors. First, among the SSA equities, Cote D'Ivoire, Ghana, Kenya, Mauritius, Nigeria, and Zambia are net receivers of returns and volatility spillovers across most of the sample period while Botswana, Namibia, South Africa, and Zimbabwe are net transmitters. Second, among the commodity sectors, Agriculture, grains, industrial metals, and energy are net transmitters of returns and volatility spillovers across most of the sample period while livestock, precious metals, and softs are mainly net recipients. Interestingly, we notice that for both the return and volatility systems, news-based economic sentiment emerges as a transmitter of spillover during the two main global crises marked by the GFC and the COVID-19 period. These results are consistent with existing literature on the critical role of investor sentiment in the propagation of spillover across various markets during such global crisis periods.

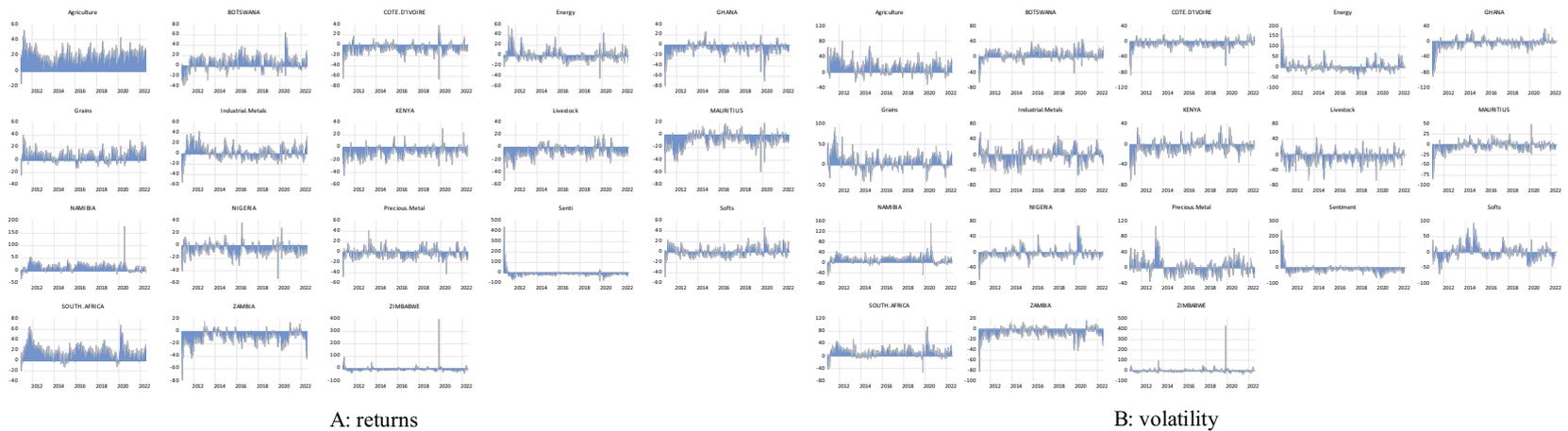
Third, it is important to note that while the net position of SSA equities and news-based economic sentiment is much more consistent for either returns or volatility spillovers, the net position of commodity sectors is less consistent. For instance, while energy and industrial metals are mostly transmitters of returns spillovers, they are mainly recipients of volatility spillovers. Again, these results highlight the predictability of equities from emerging markets (Buchanan et al., 2011; Mensi et al., 2017). As mentioned above, the news-based economic sentiment becomes a prominent source of spillover during the GFC and the coronavirus pandemic-induced crisis. Fourth, the changing roles of commodity sectors and the mix of net transmitters and recipients of returns and volatility spillovers among SSA equities signal the usability of SSA equities for diversification. The net recipient role of equities from Cote D'Ivoire, Ghana, Kenya, Mauritius, Nigeria, and Zambia makes them safe-havens and hedges during normal and stressed conditions, respectively (Baur and Lucey, 2010). Similarly, among the commodity sectors, livestock, precious metals, and softs are safe-havens and hedges based on prevailing market conditions. This calls for further investigations of the conditional interdependence between various commodity sectors and African equities. Similarly, we notice that during extreme market conditions, news-based investor sentiment is an important parameter to gauge the dynamics of interlinkages across various asset and financial markets.

#### 4. Conclusions

This study examines the static and dynamic connectedness between SSA equities, news-based economic sentiment, and global commodity sectors. The study aims to empirically respond to questioning themes such as: (i) the degree of connectedness between SSA equities, news-based economic sentiment, and global commodities and how the connectedness evolves across different market events and periods; (ii) whether market crises affect the spillover patterns between SSA equities, news based economic sentiment, and global commodities; (iii) whether SSA equities respond equally to shocks; and (iv) whether there are safe-haven and hedge equities from SSA. Accordingly, the SSA stock markets (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe) with available data over the period 2nd December 2010 to 22nd July 2022 are sampled together with seven commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs) that are pivotal to SSA economies in terms of production, export, and income generation. The economic news sentiment index constructs sentiment scores from economics-related news articles from 24 major U.S. newspapers compiled by the news aggregator service Factiva. The TVP-VAR total spillover connectedness matrix and the rolling connectedness index are used to examine the static and dynamic connectedness between the sampled SSA equities, news-based economic sentiment, and commodity sectors.

The static analysis reveals moderate but significant spillover connectedness between SSA equities, news-based economic sentiment, and global commodities. The results divulge that the main transmitters of system spillovers among SSA equities markets are South Africa, Namibia, and Botswana, while among commodities, agriculture, and grains. The main net recipients of system spillovers are Mauritian equities and livestock along with the news-based economic sentiment. In response to the main questioning themes, our dynamic analysis reveals the following: (i) the connectedness between SSA equities, news-based economic sentiment, and global commodity sectors is time-varying such that, for returns, the connectedness between SSA equities, news-based economic sentiment, and global commodity sectors measure between 32% and 70% while in terms of volatility, the total connectedness index ranges between 32% and 65%; (ii) notable market crises – e.g., commodity price shocks, the European debt crisis, Brexit, the trade tension between China and the US, the COVID-19 health crisis – in the second decade of the 21st Century consistently impact the connectedness between SSA equities, news-based economic sentiment, and global commodities by amplifying the connectedness level; (iii) SSA equities offer heterogeneous responses to market shocks, whereas, the news-based economic sentiment is a net transmitter of

<sup>2</sup> See also, Adekoya et al. (2023), Agyei (2023), Bossman and Gubareva (2023), Bossman et al. (2023a, 2023b), and Khalfaoui et al. (2022).



**Fig. 4.** Net time-varying connectedness between returns and volatility of commodities and stocks from sub-Saharan Africa amid news-based economic sentiment.

*Notes:* This figure shows the plots of net time-varying returns (Panel A) and volatility (Panel B) connectedness between commodity sectors (agriculture, energy, grains, industrial metals, livestock, precious metals, and softs), SSA stocks (Botswana, Cote D'Ivoire, Ghana, Kenya, Mauritius, Namibia, Nigeria, South Africa, Zambia, and Zimbabwe), and the news-based economic sentiment (sentiment). The sample period spans from 2nd December 2010 to 22nd July 2022.

spillover during GFC and COVID-19 pandemic-induced crisis; and (iv) equities from Cote D'Ivoire, Ghana, Kenya, Mauritius, Nigeria, and Zambia potentially serve as safe-havens and hedges during stressed and normal conditions, respectively.

Our findings have several implications for portfolio and policy management. First, from the dynamic analysis, we observe that hiked spillover connectedness restores to average levels after a while following event periods, suggesting that there is a form of saturation that occurs with information spillovers when events befall markets for a long period. Impliedly, herd behavior may be seen as a transitory factor that accompanies stressed periods. In particular, during the GFC and the COVID-19-induced crisis, the news-based economic sentiment is a transmitter of spillover. Hence, investors should carefully observe the net spillover position of various assets before embarking on portfolio rebalancing. Second, we find that huge price volatilities in leading commodity sectors such as energy and metals influence herd behavior in commodities markets. As a result, the portfolio implication suggests that cross-commodity sector investments may not necessarily improve portfolio returns due to the presence of herd behavior and adverse economic sentiment. Hence, investors should instead focus on cross-asset and cross-regional investments by including some equities from developing countries like SSA. Equally important is the finding that during extreme market conditions, news-based investor sentiment is an important parameter to gauge the dynamics of interlinkages across various asset and financial markets.

Third, for policymakers and regulators, the need for revamping the various emerging equities markets arises since it is through a resilient stock market that they could reliably attract international investors aimed at reducing downside risks. Furthermore, due to the high chance of herding in commodity sectors, a rise in commodity-based investment will be accompanied by a rise in safe assets like equities from emerging markets such as SSA. There is the incentive, therefore, for commodity producers in SSA to continue production to contribute to improving exports and commodity-based investments whilst strengthening equities markets and increasing their capitalization and openness to international investors. Ensuring these would not only improve their foreign capital accumulation but would also facilitate a continuous demand for equity investments from SSA and this, in turn, would multiply their wealth accumulation.

### CRedit authorship contribution statement

**Samuel Kwaku Agyei:** Conceptualization, Validation, Formal analysis, Writing – original draft, Writing – review & editing, Supervision. **Zaghum Umar:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Supervision, Investigation, Project administration, Resources, Software, Visualization, Writing - original draft, Writing - review & editing. **Ahmed Bossman:** Conceptualization, Methodology, Validation, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Tamara Teplova:** Conceptualization, Validation, Formal analysis, Writing – original draft, Writing – review & editing.

### Declaration of Competing Interest

The authors have declared that there are no conflicts of interest.

### Data availability

Data will be made available on request.

### Acknowledgement

This article was supported by the Russian Science Foundation, under grant 22-18-00276, <https://rscf.ru/project/22-18-00276/>.

### References

- Adam, A.M., 2020. Susceptibility of stock market returns to international economic policy: evidence from effective transfer entropy of Africa with the implication for open innovation. *J. Open Innov.* 6 (3), 71.
- Adams, Z., Glück, T., 2015. Financialization in commodity markets: a passing trend or the new normal? *J. Bank. Financ.* 60, 93–111. <https://doi.org/10.1016/j.jbankfin.2015.07.008>.
- Adams, Z., Collot, S., Kartsakli, M., 2020. Have commodities become a financial asset? Evidence from ten years of financialization. *Energy Econ.* 89, 104769 <https://doi.org/10.1016/j.eneco.2020.104769>.
- Adekoya, O.B., Asl, M.G., Oliyide, J.A., Izadi, P., 2023. Multifractality and cross-correlation between the crude oil and the European and non-European stock markets during the Russia-Ukraine war. *Res. Policy* 80, 103134. <https://doi.org/10.1016/j.resourpol.2022.103134>.
- Agyei, S.K., 2023. Emerging markets equities' response to geopolitical risk: time-frequency evidence from the Russian-Ukrainian conflict era. *Heliyon* 9 (2), e13319. <https://doi.org/10.1016/j.heliyon.2023.e13319>.
- Agyei, S.K., Bossman, A., 2023. Exploring the dynamic connectedness between commodities and African equities. *Cogent Econ. Financ.* 11 (1), 2186035. <https://doi.org/10.1080/23322039.2023.2186035>.
- Agyei, S.K., Isshaq, Z., Frimpong, S., Adam, A.M., Bossman, A., Asiamah, O., 2021. COVID-19 and food prices in sub-Saharan Africa. *Afr. Dev. Rev.* 1–12 <https://doi.org/10.1111/1467-8268.12525>.
- Agyei, S.K., Adam, A.M., Bossman, A., Asiamah, O., Owusu Junior, P., Asafo-Adjei, R., Asafo-Adjei, E., 2022a. Does volatility in cryptocurrencies drive the interconnectedness between the cryptocurrencies market? Insights from wavelets. *Cogent Econ. Financ.* 10 (1) <https://doi.org/10.1080/23322039.2022.2061682>.
- Agyei, S.K., Owusu Junior, P., Bossman, A., Arhin, E.Y., 2022b. Situated information flow between food commodity and regional equity markets: an EEMD-based transfer entropy analysis. *Discret. Dyn. Nat. Soc.* 2022 <https://doi.org/10.1155/2022/3938331>.
- Agyei, S.K., Owusu Junior, P., Bossman, A., Asafo-Adjei, E., Asiamah, O., Adam, A.M., 2022c. Spillovers and contagion between BRIC and G7 markets: new evidence from time-frequency analysis. *PLoS One* 17 (7), e0271088. <https://doi.org/10.1371/journal.pone.0271088>.

- Alagidede, I.P., Boako, G., Sjo, B., 2021. African equity markets' exposure to oil and other commodities - implications for global portfolio diversification. *J. Econ. Financ.* 45, 288–315. <https://doi.org/10.1007/s12197-020-09527-3>.
- Antonakakis, N., Chatziantoniou, I., Filis, G., 2017. Oil shocks and stock markets: dynamic connectedness under the prism of recent geopolitical and economic unrest. *Int. Rev. Financ. Anal.* 50, 1–26. <https://doi.org/10.1016/j.irfa.2017.01.004>.
- Antonakakis, N., Chatziantoniou, I., Gabauer, D., 2020. Refined measures of dynamic connectedness based on time-varying parameter vector autoregressions. *J. Risk Financ. Manage.* 13 (4), 84. <https://doi.org/10.3390/jrfm13040084>.
- Anyikwa, I., Le Roux, P., 2020. Integration of African stock markets with the developed stock markets: an analysis of co-movements, volatility and contagion. *Int. Econ. J.* 34 (2), 279–296. <https://doi.org/10.1080/10168737.2020.1755715>.
- Arif, M., Naeem, M.A., Farid, S., Nepal, R., Jamasb, T., 2022. Diversifier or more? Hedge and safe haven properties of green bonds during. *Energy Policy* 168, 113102. <https://doi.org/10.1016/j.enpol.2022.113102>.
- Asafo-Adjei, E., Agyapong, D., Agyei, S.K., Frimpong, S., Djimatey, R., Adam, A.M., 2020. Economic policy uncertainty and stock returns of Africa: a wavelet coherence analysis. *Discret. Dyn. Nat. Soc.* 2020, 1–8. <https://doi.org/10.1155/2020/8846507>.
- Asafo-Adjei, E., Adam, A.M., Darkwa, P., 2021. Can crude oil price returns drive stock returns of oil producing countries in Africa? Evidence from bivariate and multiple wavelet. *Macroecon. Financ. Emerg. Market Econ.* 1–19. <https://doi.org/10.1080/17520843.2021.1953864>.
- Assifuah-Nunoo, E., Owusu Junior, P., Adam, A.M., Bossman, A., 2022. Assessing the safe haven properties of oil in African stock markets amid the COVID-19 pandemic: a quantile regression analysis. *Quant. Financ. Econ.* 6 (2), 244–269. <https://doi.org/10.3934/QFE.2022011>.
- Baldi, L., Peri, M., Vandone, D., 2016. Stock markets' bubbles burst and volatility spillovers in agricultural commodity markets. *Res. Int. Bus. Financ.* 38, 277–285. <https://doi.org/10.1016/j.rifaf.2016.04.020>.
- Baur, D.G., Lucey, B.M., 2010. Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. *Financ. Rev.* 45 (2), 217–229. <https://doi.org/10.1111/j.1540-6288.2010.00244.x>.
- Bedowska-Sojka, B., Demir, E., Zaremba, A., 2022. Hedging geopolitical risks with different asset classes: a focus on the Russian invasion of Ukraine. *Financ. Res. Lett.* 103192. <https://doi.org/10.1016/j.frl.2022.103192>.
- Boako, G., Alagidede, P., 2016. Global commodities and African stocks: a 'market of one?'. *Int. Rev. Financ. Anal.* 44, 226–237. <https://doi.org/10.1016/j.irfa.2016.02.009>.
- Boako, G., Alagidede, P., 2017. Co-movement of Africa's equity markets: regional and global analysis in the frequency-time domains. *Physica A* 468, 359–380. <https://doi.org/10.1016/j.physa.2016.10.088>.
- Boako, G., Alagidede, I.P., Sjo, B., Uddin, G.S., 2020. Commodities price cycles and their interdependence with equity markets. *Energy Econ.* 91, 104884. <https://doi.org/10.1016/j.eneco.2020.104884>.
- Boateng, E., Adam, A.M., Owusu Junior, P., 2021. Modelling the heterogeneous relationship between the crude oil implied volatility index and African stocks in the coronavirus pandemic. *Res. Policy* 102389.
- Bossman, A., Agyei, S.K., 2022a. ICEEMDAN-based transfer entropy between global commodity classes and African equities. *Math. Probl. Eng.* 2022, 1–28. <https://doi.org/10.1155/2022/8964989>.
- Bossman, A., Agyei, S.K., 2022b. Interdependence structure of global commodity classes and African equity markets: a vector wavelet coherence analysis. *Res. Policy* 79, 103039. <https://doi.org/10.1016/j.resourpol.2022.103039>.
- Bossman, A., Gubareva, M., 2023. Asymmetric impacts of geopolitical risk on stock markets: a comparative analysis of the E7 and G7 equities during the Russian-Ukrainian conflict. *Heliyon* 9 (2), e13626. <https://doi.org/10.1016/j.heliyon.2023.e13626>.
- Bossman, A., Adam, A.M., Owusu Junior, P., Agyei, S.K., 2022a. Assessing interdependence and contagion effects on the bond yield and stock returns nexus in sub-Saharan Africa: evidence from wavelet analysis. *Sci. Afr.* 16, e01232. <https://doi.org/10.1016/j.sciaf.2022.e01232>.
- Bossman, A., Agyei, S.K., Owusu Junior, P., Agyei, E.A., Akorsu, P.K., Marfo-Yiadom, E., Amfo-Antiri, G., 2022b. Flights-to-and-from-quality with Islamic and conventional bonds in the COVID-19 pandemic era: ICEEMDAN-based transfer entropy. *Complexity* 2022, 1–25. <https://doi.org/10.1155/2022/1027495>.
- Bossman, A., Owusu Junior, P., Tiwari, A.K., 2022c. Dynamic connectedness and spillovers between Islamic and conventional stock markets: time- and frequency-domain approach in COVID-19 era. *Heliyon*. <https://doi.org/10.1016/j.heliyon.2022.e09215>.
- Bossman, A., Teplova, T., Umar, Z., 2022d. Do local and world COVID-19 media coverage drive stock markets? Time-frequency analysis of BRICS. *Complexity* 2022, 2249581. <https://doi.org/10.1155/2022/2249581>.
- Bossman, A., Umar, Z., Teplova, T., 2022e. Modelling the asymmetric effect of COVID-19 on REIT returns: a quantile-on-quantile regression analysis. *J. Econ. Asymm.* 26, e00257. <https://doi.org/10.1016/j.jeca.2022.E00257>.
- Bossman, A., Umar, Z., Agyei, S.K., Teplova, T., 2023. The impact of the US yield curve on sub-Saharan African equities. *Financ. Res. Lett.* 103636. <https://doi.org/10.1016/j.frl.2023.103636>.
- Bossman, A., Gubareva, M., Teplova, T., 2023a. Asymmetric effects of geopolitical risk on major currencies: Russia-Ukraine tensions. *Financ. Res. Lett.* 51, 103440. <https://doi.org/10.1016/j.frl.2022.103440>.
- Bossman, A., Gubareva, M., Teplova, T., 2023b. EU sectoral stocks amid geopolitical risk, market sentiment, and crude oil implied volatility: an asymmetric analysis of the Russia-Ukraine tensions. *Res. Policy* 82, 103515. <https://doi.org/10.1016/j.resourpol.2023.103515>.
- Boungou, W., Yatié, A., 2022. The impact of the Ukraine–Russia war on world stock market returns. *Econ. Lett.* 215, 110516. <https://doi.org/10.1016/J.ECONLET.2022.110516>.
- Buchanan, B.G., English, P.C., Gordon, R., 2011. Emerging market benefits, instability and the rule of law. *Emerg. Mark. Rev.* 12 (1), 47–60. <https://doi.org/10.1016/j.ememar.2010.09.001>.
- Demir, R., Lee, H.T., Lien, D., 2015. Does the stock market drive herd behavior in commodity futures markets? *Int. Rev. Financ. Anal.* 39, 32–44. <https://doi.org/10.1016/j.irfa.2015.02.006>.
- Diebold, F.X., Yilmaz, K., 2014. On the network topology of variance decompositions: measuring the connectedness of financial firms. *J. Econ.* 182 (1), 119–134. <https://doi.org/10.1016/J.JECONOM.2014.04.012>.
- Diebold, F.X., Liu, L., Yilmaz, K., 2017. Commodity connectedness. In: *NBER Working Paper Series (No. 23685; Vol. 23685)*.
- Esparcia, C., Jareño, F., Umar, Z., 2022. Revisiting the safe haven role of gold across time and frequencies during the COVID-19 pandemic. *North Am. J. Econ. Financ.* 61. <https://doi.org/10.1016/j.najef.2022.101677>.
- Gurdgiev, C., O'Riordan, C., 2021. A wavelet perspective of crisis contagion between advanced economies and the BRIC markets. *J. Risk Financ. Manage.* 14 (10), 503. <https://doi.org/10.3390/jrfm14100503>.
- Hu, C., Li, Z., Liu, X., 2020. Liquidity shocks, commodity financialization, and market comovements. *J. Futur. Mark.* 40 (9), 1315–1336. <https://doi.org/10.1002/FUT.22127>.
- Khalfaoui, R., Gozgor, G., Goodell, J.W., 2022. Impact of Russia-Ukraine war attention on cryptocurrency: evidence from quantile dependence analysis. *Financ. Res. Lett.* 103365. <https://doi.org/10.1016/j.frl.2022.103365>.
- Koop, G., Korobilis, D., 2014. A new index of financial conditions. *Eur. Econ. Rev.* 71, 101–116. <https://doi.org/10.1016/J.EUROECOREV.2014.07.002>.
- Kumah, S.P., Odei-mensah, J., 2021. Are cryptocurrencies and African stock markets integrated? *Quart. Rev. Econ. Financ.* 81, 330–341. <https://doi.org/10.1016/j.qref.2021.06.022>.
- Liu, C., Sun, X., Wang, J., Li, J., Chen, J., 2021. Multiscale information transmission between commodity markets: an EMD-based transfer entropy network. *Res. Int. Bus. Financ.* 55, 101318. <https://doi.org/10.1016/J.RIBAF.2020.101318>.
- Markowitz, H., 1952. Portfolio selection. *The J. Financ.* 7 (11), 77–91.
- Mayer, J., 2012. The growing financialisation of commodity markets: divergences between index investors and money managers. *J. Dev. Stud.* 48 (6), 751–767. <https://doi.org/10.1080/00220388.2011.649261>.
- Mensi, W., Hammoudeh, S., Kang, S.H., 2017. Risk spillovers and portfolio management between developed and BRICS stock markets. *N. Am. J. Econ. Financ.* 41, 133–155. <https://doi.org/10.1016/j.najef.2017.03.006>.

- Mensi, W., Al-Yahyaee, K.H., Vo, X.V., Kang, S.H., 2021. Modeling the frequency dynamics of spillovers and connectedness between crude oil and MENA stock markets with portfolio implications. *Econ. Anal. Policy* 71, 397–419. <https://doi.org/10.1016/j.eap.2021.06.001>.
- Mensi, W., Muhammad, S., Vo, X.V., Kang, S.H., 2022. Spillovers and connectedness between green bond and stock markets in bearish and bullish market scenarios. *Financ. Res. Lett.* 103120 <https://doi.org/10.1016/j.frl.2022.103120>.
- Naeem, M.A., Conlon, T., Cotter, J., 2022. Green bonds and other assets: evidence from extreme risk transmission. *J. Environ. Manag.* 305, 114358 <https://doi.org/10.1016/j.jenvman.2021.114358>.
- Narayan, P.K., Narayan, S., Sharma, S.S., 2013. An analysis of commodity markets: what gain for investors? *J. Bank. Financ.* 37 (10), 3878–3889. <https://doi.org/10.1016/j.jbankfin.2013.07.009>.
- Sensoy, A., Hacihasanoglu, E., Nguyen, D.K., 2015. Dynamic convergence of commodity futures: not all types of commodities are alike. *Res. Policy* 44, 150–160. <https://doi.org/10.1016/J.RESOURPOL.2015.03.001>.
- Spierdijk, L., Umar, Z., 2012. Are Commodities a good Hedge against inflation? A comparative approach. *SSRN Electron. J.* <https://doi.org/10.2139/ssrn.1730243>.
- Spierdijk, L., Umar, Z., 2014. Are commodity futures a good hedge against inflation? *J. Invest. Strat.* 3 (2) <https://doi.org/10.21314/jois.2014.048>.
- Umar, Z., Gubareva, M., 2021a. Faith-based investments and the Covid-19 pandemic: analyzing equity volatility and media coverage time-frequency relations. *Pac. Basin Financ. J.* 67 <https://doi.org/10.1016/j.pacfin.2021.101571>.
- Umar, Z., Gubareva, M., 2021b. The relationship between the COVID-19 media coverage and the environmental, social and governance leaders equity volatility: a time-frequency wavelet analysis. *Appl. Econ.* 53 (27), 3193–3206. <https://doi.org/10.1080/00036846.2021.1877252>.
- Umar, Z., Nasreen, S., Adebola, S., Kumar, A., 2019. Exploring the time and frequency domain connectedness of oil prices and metal prices. *Res. Policy* 64 (August 2018), 101516. <https://doi.org/10.1016/j.resourpol.2019.101516>.
- Umar, Z., Adekoya, O.B., Oliyide, J.A., Gubareva, M., 2021a. Media sentiment and short stocks performance during a systemic crisis. *Int. Rev. Financ. Anal.* 78 <https://doi.org/10.1016/j.irfa.2021.101896>.
- Umar, Z., Aziz, S., Tawil, D., 2021b. The impact of COVID-19 induced panic on the return and volatility of precious metals. *J. Behav. Exp. Financ.* 31 <https://doi.org/10.1016/j.jbef.2021.100525>.
- Umar, Z., Gubareva, M., Naeem, M., Akhter, A., 2021c. Return and volatility transmission between oil price shocks and agricultural commodities. *PLoS One* 16 (2), 1–18. <https://doi.org/10.1371/journal.pone.0246886>.
- Umar, Z., Gubareva, M., Yousaf, I., Ali, S., 2021d. A tale of company fundamentals vs sentiment driven pricing: the case of GameStop. *J. Behav. Exp. Financ.* 30 <https://doi.org/10.1016/j.jbef.2021.100501>.
- Umar, Z., Jareño, F., Escibano, A., 2021e. Oil price shocks and the return and volatility spillover between industrial and precious metals. *Energy Econ.* 99, 105291 <https://doi.org/10.1016/j.eneco.2021.105291>.
- Umar, Z., Bossman, A., Choi, S., Teplova, T., 2022a. Does geopolitical risk matter for global asset returns? Evidence from quantile-on-quantile regression. *Financ. Res. Lett.* 48 (May), 102991 <https://doi.org/10.1016/j.frl.2022.102991>.
- Umar, Z., Gubareva, M., Teplova, T., Alwahedi, W., 2022b. Oil price shocks and the term structure of the US yield curve: a time-frequency analysis of spillovers and risk transmission. *Ann. Oper. Res.* 1–25 <https://doi.org/10.1007/s10479-022-04786-1>.
- Umar, Z., Polat, O., Choi, S., Teplova, T., 2022c. The impact of the Russia-Ukraine conflict on the connectedness of financial markets. *Financ. Res. Lett.* 48 (May), 102976 <https://doi.org/10.1016/j.frl.2022.102976>.
- Umar, Z., Sayed, A., Gubareva, M., Vo, X.V., 2023. Influence of unconventional monetary policy on agricultural commodities futures: network connectedness and dynamic spillovers of returns and volatility. *Appl. Econ.* 55 (22), 2521–2535. <https://doi.org/10.1080/00036846.2022.2103084>.
- Yin, L., Nie, J., Han, L., 2021. Intermediary capital risk and commodity futures volatility. *J. Futur. Mark.* 41 (5), 577–640. <https://doi.org/10.1002/fut.22185>.
- Zaremba, A., Szczygielski, J.J., Umar, Z., Mikutowski, M., 2021a. Inflation hedging in the long run: practical perspectives from seven centuries of commodity prices. *J. Altern. Invest.* 24 (1), 119–134. <https://doi.org/10.3905/jai.2021.1.136>.
- Zaremba, A., Umar, Z., Mikutowski, M., 2021b. Commodity financialisation and price co-movement: lessons from two centuries of evidence. *Financ. Res. Lett.* 38 (January 2021), 101492 <https://doi.org/10.1016/j.frl.2020.101492>.
- Zhu, H., Huang, R., Wang, N., Hau, L., 2020. Does economic policy uncertainty matter for commodity market in China? Evidence from quantile regression. *Appl. Econ.* 52 (21), 2292–2308. [https://doi.org/10.1080/00036846.2019.1688243/SUPPL\\_FILE/RAEC\\_A\\_1688243\\_SM5371.RAR](https://doi.org/10.1080/00036846.2019.1688243/SUPPL_FILE/RAEC_A_1688243_SM5371.RAR).