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Dynamic connectedness, hedge and safe-haven effects: cryptocurrencies, precious metals and African stock markets

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Abstract

Purpose – This study seeks to: (1) examine the extent of interconnectedness prevailing between the cryptocurrency market, the stock market and the precious metals market. (2) Conduct thorough assessment of hedge and safe-haven qualities of broad range of precious metals and cryptocurrencies against returns on the African stock market.

Design/methodology/approach – This study applied two novel approaches that is Cross-quantilogram, an advanced statistical technique used to examine the relationship between quantiles of response variable and the quantiles of predictor variables, and TVP-VAR, a technique that captures the dynamic connectedness of variables under consideration.

Findings – It was found that the three markets are highly interconnected, particularly among assets under the respective financial markets. It was further revealed that the Johannesburg Stock Exchange (JSE) was the most resilient stock market, whereas Bitcoin, BNB, Silver (XAG) and Platinum (XPT) also exhibited notable resistance to shocks. Finally, the study found that cryptocurrencies and precious metals portrayed varying hedge and safe haven qualities under the various stock markets.

Practical implications – The high interdependency between the African stock market, cryptocurrencies and precious metals suggests that none of the markets is immune to shocks form the other market. The finding that cryptocurrencies and precious metals exhibit some degree of safe-haven and hedge potentials, albeit limited in certain stock markets, provides investors with alternative investment options during market downturns. Since most African stock markets, except the JSE, are net receivers of shocks, investors in these markets should exercise caution during periods of global financial uncertainty.

Originality/value – To the best of our knowledge, this study is the first to explore the dynamic interconnectedness between seven carefully selected African stock markets, three distinct cryptocurrencies and four precious metals, while also assessing the hedge and safe-haven potential of the cryptocurrencies and precious metals against stock market returns. Additionally, the study stands out in recent literature by employing two novel approaches: the TVP-VAR model, which captures the dynamic connectedness among variables, and the Cross-Quantilogram, an advanced statistical method that analyzes the relationship between the quantiles of the response and predictor variables, all within a single study.

Keywords Hedge, Cryptocurrencies, Safe-haven, Precious metals, Dynamic connectedness, African stock market

Paper type Research paper

Data availability statement: Data on stock markets were gleaned from Bloomberg, whereas data on the cryptocurrencies and precious metals were sourced from https://www.investing.com. Dataset will be made available upon request.

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1. Introduction

The 2007 Global Financial Crisis (GFC), exacerbated by the failure of Lehman Brothers, among other factors, worsened uncertainty in financial markets, consequently leading to a sharp decline in investor confidence (Manohar and Raju, 2021). This episode was characterized by a dramatic rise in gold prices, a plunge in value of other assets, particularly stocks, and thus triggered calls for a review of risk management concepts and practices (Aftab *et al*., 2019). Accordingly, investors and researchers alike, over the years, continue to painstakingly examine alternative instruments that could provide a safe haven and hedge for investments.

Incontrovertibly, most investors are prone to fear and panic responses during times of economic and financial instability, and hence tend to "flee to safety" (Pistor, 2013). As the term implies, when faced with uncertainty, investors want a safe haven for their wealth, where it is safeguarded against losses. Kaul and Sapp (2006) loosely described safe haven as "an ideal venue to park money during periods of uncertainty." Baur and McDermott (2010) defined a hedge (safe haven) is an asset that is uncorrelated (negatively correlated) with another asset or portfolio on average (only during times of market stress or turmoil).

The cryptocurrency market, precious metals market and the stock market have been widely regarded as the most prominent investment destinations over the past decade (Van Hoang *et al*., 2016; Pieters and Vivanco, 2017; Hamdi *et al*., 2019). For instance, the precious metal market has increasingly become a crucial avenue for investment and wealth preservation, particularly during financial crises and market downturns due to their inherent value, universal acceptability, durability, storability and standardization (Baur and McDermott, 2010). Moreover, most precious metals exhibit insignificant to no correlation with other assets (Baur and McDermott, 2010), hence commonly referred to as zero-beta asset (McCown and Zimmerman, 2006, as referenced in Manohar and Raju, 2021). Indeed, these unique characteristics largely render precious metals suitable hedge or safe haven instruments. The cryptocurrency market, on the other hand, serves as a critical component of the international financial market through the provision of a new class of assets (Asafo-Adjei *et al*., 2021; Corbet *et al*., 2018). As of June 13 2023, the market capitalization of cryptocurrency was about US $1.1tn, with Bitcoin accounting for approximately 45.9%, followed by Ethereum (17.65%). It needs stating that the advent of cryptocurrencies has expanded the investment and diversification opportunities available to international investors (Asafo-Adjei *et al*., 2021).

Despite the radical difference between the aforementioned markets, Durcheva and Tsankov (2019) contend that the seeming seamless reallocation of funds from one market/investment instrument to the other connotes a certain level of interdependence among the three markets. A recent study by Korsah *et al*. (2024) reinforces this finding, suggesting that the African stock market exhibit interconnectedness with external markets, particularly in the long term. Evidence abound that connectedness and safe-haven/hedge properties tend to have a strong correlation, as greater interdependence underscores the investment potential of an alternative asset or market, especially amidst market turmoil (Mensi *et al*., 2022, 2023).

Regrettably, there is dearth of literature on the extent of interconnectedness between these critical markets under consideration – stock markets, cryptocurrency market and precious metals. Indeed, recent literature have focused primarily on the co-movement between cryptocurrencies and stock markets (Kumah and Odei-Mensah, 2021; Kumah *et al*., 2022) as well as precious metals and stock markets (Husain *et al*., 2019; Mensi *et al*., 2021). More worrying is the divergent findings, and the lack of more encompassing study on the hedge and safe haven qualities of precious metals and cryptocurrencies against uncertainty on the African stock market.

Evidently, while a strand of the literature alludes to the safe haven qualities of precious metals, specifically gold (Baur and McDermott, 2010; Gürgün and Ünalmış, 2014; Shahzad *et al*., 2020; Wen *et al*., 2022), a section of scholars holds contrary opinion, arguing it is time-varying (Shahzad *et al*., 2019) and mostly market-specific (Beckmann *et al*., 2015). Again, prior studies have mainly concentrated on advanced markets, with gold dominating research interest.

Similarly, previous studies have recorded conflicting findings on the effectiveness of cryptocurrencies, specifically Bitcoin, in providing safe-haven or hedge against stock market

returns. While notable studies such as Bouri *et al*. (2017a, b), Corbet *et al*. (2018) and Guesmi *et al*. (2019) maintain that bitcoin serves as a hedge (safe-haven) instrument, others have described the cryptocurrency market as a poor alternative, averring cryptocurrencies fail to provide a safe haven or (and) hedge (Conlon *et al*., 2020; Syuhada *et al*., 2022; Nkrumah-Boadu *et al*., 2022).

From the foregoing, it is abundantly clear that available literature is subject to two (2) major shortcomings: absence of empirical study on the interconnectedness among the aforementioned critical markets in the financial ecosystem, and the lack of comprehensive analysis of the hedge and safe-haven features of cryptocurrencies and precious metals in relation to returns on stock markets. The apparent lack of in-depth study on the extent of interdependence among the markets, coupled with the prevailing divergent findings on the safe haven and hedge potential of cryptocurrencies and precious metals against returns on the stock market, is particularly concerning in the African context. This stems from the fact that although the African stock market is still at the nascent stage (Mu *et al*., 2013), it is increasingly becoming a preferred destinations for international investors (Alagidede, 2008; Anyikwa and Le Roux, 2020), hence establishing its interdependence with the other markets under consideration, and whether cryptocurrencies and precious metals could provide a safe-haven/hedge for returns on the African stock market is critical to making informed investment decisions.

Against this backdrop, this study seeks to:

(1) Examine the extent of interconnectedness prevailing between the cryptocurrency market, the stock market and the precious metals market.

(2) Conduct thorough assessment of hedge and safe-haven qualities of broad range of precious metals and cryptocurrencies against returns on the African stock market.

To the best of our knowledge, this study is the first of its kind to examine the dynamic connectedness between the cryptocurrency market, precious metals market and seven (7) carefully selected stock markets in Africa, and assess the role of three (3) different cryptocurrencies and four (4) precious metals as hedge and safe haven for the stock markets. Further, this study stands out in recent literature as it applies two (2) novel approaches ie TVP-VAR, a technique that captures the dynamic connectedness of variables under consideration, and Cross-Quantilogram, an advanced statistical technique used to examine the relationship between quantiles of response variable and the quantiles of predictor variables, all within a single study.

It is particularly important to undertake such a study at this time in Africa due to the region's increased integration into the global financial system amidst growing vulnerabilities to external shocks, notably geopolitical risks, fluctuating commodity prices and global financial uncertainties. With cryptocurrencies gaining popularity and precious metals retaining their status as traditional safe assets, exploring their interactions with African markets is critical to informed investment decision and tailored policy formulation.

This study makes significant contribution to literature in diverse ways. Understanding the interdependency between the African stock market and the other markets – cryptocurrencies and precious metals – could reveal the extent of shock propagation (Baruník and Křehlík, 2018), providing early warning signals for both current and potential investors (Minoiu *et al*., 2015). Moreso, exploring the safe-haven and hedge potential of precious metals and cryptocurrencies against returns on the stock market provides valuable intuition into the diversification options (Mezghani and Boujelbène-Abbes, 2023), helping investors to mitigate potential losses and manage risk more effectively.

The study revealed three key findings: first, the three markets are highly interconnected, particularly among assets under the respective financial markets; second, the JSE emerged as the most resilient stock market, whereas Bitcoin, BNB, Silver (XAG) and Platinum (XPT) also exhibited notable resistance to shocks and third, cryptocurrencies and precious metals portrayed varying hedge and safe haven qualities under the various stock markets.

2. Literature review

2.1 Empirical review

The relationship between precious metals and stock markets has received much attention among investors and researchers. A study by Baur and Lucey (2010) investigated the role of gold as a hedge or safe haven against stock markets in the US, UK and Germany, using a quantile regression model. The study found that gold serves as a hedge instrument against stock markets in the selected countries, and also acts as a safe haven asset during market stress periods. Fast-forward, Hood and Malik (2013) utilized a quantile framework with daily data to examine the role of commodities as hedge instruments or safe havens against US stock markets. Contrary to Baur and Lucey (2010)'s finding, it was observed that gold exhibits weak safe-haven properties against US stock markets. Similarly, Bredin *et al.* (2017) employed a wavelet technique to examine the hedge and safe haven characteristics of precious metals against stock and bond markets in the US, Germany and UK The research revealed that gold acts as a safe haven asset against stock markets. Reboredo (2013) explored the relationship between gold, oil prices and exchange rates, using a copula framework on a weekly data. The researcher concluded that gold can serve as a safe haven asset against both oil prices and exchange rates. Dar and Maitra (2017) utilized both DCC-GARCH and wavelet coherence models to examine the hedge and safe haven properties of gold against stock markets in US, China and India, using weekly data from November 1999 to October 2013. The authors found weak hedge and safe haven properties of gold against the said stock markets.

To shed light on the behavior of precious metals during crisis episodes, Mensi *et al*. (2017) examined the time-varying risk spillover between precious metals (gold, silver, platinum and palladium) and four major stock markets (the US, Europe, Asia and Japan), amidst the Global Financial Crisis (GFC) of 2008, using the Diebold and Yilmaz (2012) spillover index. The authors discovered significant volatility clustering for all return series in the heat of the crisis. Another notable financial crisis in recent times is the eurozone crisis. Uddin *et al*. (2019) carefully analyzed return and volatility spillovers among precious metals during the 2008 GFC and the 2010 Eurozone Crisis, and noticed that the trends in asymmetric spillover reached their highest point between 2010 and 2014, coinciding with growing uncertainty caused by the 2010 Crisis. The COVID-19 pandemic, like other crisis episodes, intensified calls for portfolio diversification. Lahiani *et al.* (2021) demonstrated that during the COVID crisis, precious metals and commodities had an unequal impact on the S&P 500 stock market index and they lost their status as safe haven assets relative to the S&P 500 index, similar to recent findings by Jana and Sahu (2024) in the context of India. On the contrary, Ji *et al*. (2020) conducted a study on safe-haven assets during the COVID-19 period, showing that commodities futures, particularly gold held up well as safe-haven investments.

Owing to the heightened desire by investors have a plethora of investment options and to enhance portfolio diversification, recent literature is replete with studies that seek to examine the safe-haven and hedge properties of alternative investment assets, particularly cryptocurrencies (Baur and Glover, 2012; Bekiros *et al*., 2017; Shahzad *et al*., 2019; Riahi *et al*., 2024). Similar to precious metals, research on the safe-haven and hedge properties of cryptocurrency have yielded varying findings, with extant literature focusing on bitcoin. Bouri *et al.* (2017a, b) explored various stock and cryptocurrency markets, and found that bitcoin only served as a strong safe haven during sharp weekly drops in Asian stocks. Shahzad *et al*. (2020) focused on the broad market indexes of G7 nations and discovered that while gold serves as a safe haven and hedge for multiple G7 economies, bitcoin only fulfils these roles for Canada. Jana and Sahu (2023) employed DCC-GARCH and found cryptocurrency have hedge properties. Conlon and McGee (2020) argue against bitcoin's ability to serve as a safe haven during the COVID-19 pandemic by showing that it moved in sync with the S&P 500 during the downturn. They also found that even a small exposure to bitcoin significantly increases the portfolio's negative risk. Będowska-Sójka and Kliber (2021) compared the performance of gold and two cryptocurrencies (Bitcoin and Ether) against major stock markets in the US and Europe. Their findings indicate that gold is the only true safe haven for all markets, particularly

in the lead-up to the COVID-19 pandemic. Chemkha *et al*. (2021) compared the safe-haven capacities of gold and bitcoin to major global stock markets and currencies. The study concluded that the volatile nature of bitcoin inhibits its safe-haven quality, whereas gold, at best, served as a weak safe haven for all but one market.

All in all, over concentration of study in advanced markets, the limitation of precious metals and cryptocurrencies to gold and bitcoin, respectively, coupled with the lack of convergence of findings in previous studies on both cryptocurrencies and precious metals against returns on the stock market, as established from the literature, make this pursuit highly expedient.

2.2 Theoretical review

This study is underpinned by two major theories, namely Safe Haven Theory and Inflationary Hedge Theory. The Safe Haven Theory, also known as the Flight-to-Quality or Flight-to-Safety theory, is a concept in finance that describes the behavior of investors during times of economic uncertainty or market volatility. It suggests that during periods of financial instability, investors tend to move their investments away from risky assets towards safer or less volatile assets, often considered as safe havens (Baur and Lucey, 2010). Safe haven assets are typically perceived as less risky and more stable compared to other investments. They are believed to offer protection against economic downturns (Ranaldo and Söderlind, 2010), geopolitical tensions (Selmi *et al*., 2022) or systemic risks in financial markets (Haq *et al*., 2021). The underlying principle of the Safe Haven Theory is the assumption that investors have a preference for preserving their capital and minimizing losses during turbulent times. Therefore, they seek refuge in assets that are expected to retain or increase their value while other investments experience significant declines.

The inflation hedge theory, on the other hand, posits that precious metals such as gold and silver, and other related financial instruments serve as hedge against inflation, as their values are inclined to rise during periods of high inflation. This idea has been explored in the context of African stock markets, where rising inflation is prevalent. According to Agyei-Mensah and Oppong (2014), African stock markets are particularly vulnerable to inflation and other macroeconomic factors that can affect investor behavior; hence the inflation hedge theory provides a compelling rationale for considering precious metals and other related assets as a potential hedge instrument due to their perceived intrinsic value.

3. Methodology

3.1 Data overview

We daily data on historical stock prices of seven (7) stock markets, spanning from 10th July, 2007 to 13th April, 2023; four (4) different precious metals, namely Palladium, Platinum, Silver and Gold and three (3) cryptocurrencies, namely Bitcoin, Ethereum and BNB. The timeframe for the study is primarily hinged on data availability. Database on stock market in Africa is largely riddled with data paucity. In most cases, data on the stock market, especially Rwandan Stock Market, span from early 2007 to December 2023.

Data on stock markets, gleaned from Bloomberg, were carefully selected from four (4) geographical zones in Africa. The Bourse de Casablanca (Morocco) and Egyptian Exchange (EGX) represent the North African region; Johannesburg Stock Exchange (South Africa) represent the southern part of Africa. In East Africa, Nairobi Securities Exchange (Kenya) and Dar es Salaam Stock Exchange (DSE) were used as a proxy, while the Ghana Stock Exchange (Ghana) and the Nigeria Stock Exchange represent the West of Africa.

The choice of these markets is underpinned by two critical considerations; the need to get a fair representation of the various regions across the continent and the fact that the selected markets constitute over 70% of the combined market capitalization of US$1.6tn in Africa, signifying their relevance in the market. The region (the African stock market) was carefully selected for the study given that it largely underexplored although it has become one of the preferred investment destinations for international investors, with foreign investment contributing, on average, twenty percent (20%) of total investment (World Bank, 2022).

Data on the cryptocurrencies and precious metals were sourced from https://www.investing.com. The choice of the three cryptocurrencies was influenced by their respective performance over the years (Matkovskyy *et al*., 2021). Platinum, Silver and Gold, on the other hand, have become the most sort after precious metals in recent times (Lei *et al.*, 2023), prompting their selection for this study.

3.2 TVP-VAR connectedness

In line with the first objective, this study employs the TVP-VAR model, built upon the Diebold and Yilmaz (2012), to capture the connectedness between the assets under the respective financial markets (cryptocurrency markets, precious metals and the stock markets), and the attendant spillovers. Unlike the standard VAR, this technique possesses unique features that helps to simultaneously identify the time-varying effects of different financial factors or variables, captures non-linearity more effectively and handles structural breaks (Wen *et al.*, 2019), thus making it more preferable to other techniques in the context of this study.

The following equations illustrate this model mathematically:

$$\lambda_t = B_t\lambda_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0, S_t) \tag{1}$$

$$\overrightarrow{(B||t)} = \overrightarrow{(B||t-1)} + u_t, u_t \sim N(0, R_t) \tag{2}$$

Where: λ_t, λ_{t-1} and the error term ε_t are specified as $k \times 1$ dimensional vectors. $\overrightarrow{(B||t)}$ denotes the vectorized form of B_t, and S_t whereas R_t represents the variance-covariance matrices. It is noteworthy that B_t, and S_t are $k \times k$ dimensional matrices. u_t, on the otherhand, is a $k^2 \times 1$ dimensional vector, and R_t is specified by $k^2 \times k^2$ dimensional matrix.

Further, the model leverages the generalized forecast error variance decomposition (GEFVD) to integrate the H-step forecast (Diebold and Yilmaz, 2012) to estimate the directional and net connectedness of asset returns. The n-variable procedure $\lambda_t = \lambda_{t,1}, \ldots \lambda_{t,n}$ is given by a multidimensional covariance stationary $VAR(p)$ proces:

$$\lambda_t = \sum_{s=1}^{p} \vartheta_h \lambda_{t-s} + \varepsilon_t \tag{3}$$

Where ϑ_h is an $n \times n$ p-order lag polynomial, and ε_t represents white noise with a non-diagonal error term matrix. It is instructive to state that the $VAR(p)$ procedure adheres to the moving average specification. Additionally, the TVP-VAR procedure must be transformed into time-varying coefficients of the vector moving average (VMA) as defined in Eq. (4):

$$z_t = B_t z_{t-1} + \varepsilon_t = \sum_{z=0}^{\infty} A_{jt}\varepsilon_{t-j} \tag{4}$$

Where A_{jt} denotes the square matrix of the coefficients.

The GEFVD of the H-step forecast of the jth asset return in response to shocks from the ith asset return is expressed as:

$$\Phi_{ij}^{g}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} \left(e_i' A_t \sum e_j\right)^2}{\sum_{h=0}^{H-1} \left(e_i' A_t \sum e_j\right)} \tag{5}$$

When $\theta_{ij}^{g}(H)$ is normalized, the spillover index can be represented as follows:

$$\widetilde{\theta}_{ij,t}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1,i=1}^{N} \theta_{ij}^{g}(H)} \tag{6}$$

where e_j denotes a vector with one on the position of the jth asset return, and $\sum_{j=1}^{N} \theta_{ij}^{g}(H) = 1$ and $\sum_{ij=1}^{N} \theta_{ij}^{g}(H) = N.\sigma_{jj}^{-1}$ represents the standard deviation of the error term.

The total connectedness index (TCI), FROM, TO connectedness, net directional connectedness and net pairwise directional connectedness indices were obtained from Eqs. (7) and (11), respectively:

Total connectedness index (TCI):

$$TCI_{t}^{g}(H) = \frac{\sum_{i,j=1,i\neq j}^{N} \widetilde{\theta}_{ij,t}^{g}(H)}{\sum_{i,j=1,i}^{N} \widetilde{\theta}_{ij,t}^{g}(H)} = \frac{\sum_{i,j=1,i\neq j}^{N} \widetilde{\theta}_{ij,t}^{g}(H)}{N} \times 100 \tag{7}$$

FROM and TO connectedness index (NDC)

$$TD_{i-j}(H) = \frac{\sum_{i=1,i\neq j}^{N} \widetilde{\theta}_{ji,t}^{g}(H)}{\sum_{j=1,i\neq j}^{N} \widetilde{\theta}_{ji,t}^{g}(H)} \times 100 \tag{8}$$

$$TD_{j-i}(H) = \frac{\sum_{i=1,i\neq j}^{N} \widetilde{\theta}_{ij,t}^{g}(H)}{\sum_{j=1,i\neq j}^{N} \widetilde{\theta}_{ij,t}^{g}(H)} \times 100 \tag{9}$$

Net directional connectedness index (NDC):

$$CI_{i,t}^{g}(H) = TD_{i-j}(H) - TD_{I-J}(H) \tag{10}$$

Net pairwise directional connectedness index (NPDC):

$$NPDC_{ij}(H) = \left(\widetilde{\theta}_{ji,t}^{g}(H) - \widetilde{\theta}_{ij,t}^{g}(H)\right) \times 100 \tag{11}$$

3.3 The cross-quantilogram

To examine the hedge and safe haven potential of cryptocurrencies and precious metals, we employ the cross-quantilogram (CQG) method developed by Han *et al.* (2016) to explore the quantile interdependence between two series ($y_{1,t}$ and $y_{2,t}$). The cross-quantilogram provides a more detailed picture of the risk and dependency structure between variables, especially in extreme scenarios (Razzaq *et al.*, 2022), making it invaluable for assessing the hedge and safe-haven properties of financial instruments.

Generally, a quantile hit event can be expressed as $1\,[y_{i,t} < q_{i,t}(\alpha_i)]$ for $i = 1, 2$, where $q_{i,t}(\alpha_i)$ is the $\alpha_i \in (0, 1)$ quantile of $y_{i,t}$ and $1[\cdot]$ is the indicator function.

In other words, a quantile hit process reports observations below the range of a given quantile, possibly signaling outliers with suitable choices of α_i. The cross-correlation between two quantiles hits, one for $y_{1,t}$ and the other for $y_{2,t-k}$, for an arbitrary couple (α_1, α_2) with $k = 0, 1, \ldots,$ is defined as:

$$\text{CQG} : \rho_{(\alpha_1,\alpha_2)}(k) = E \tag{12}$$

where $E[\cdot]$ is the expected value operator and $\Psi_\alpha(x) = 1[x < 0] - \alpha$ is the quantile hit function.

The sample counterpart of Eq. (12) is given by:

$$\widehat{\rho}_{(\alpha_1,\alpha_2)}(k) = \sum_{t=k+1}^{T} \Psi_{\alpha_1}\left(y_{1,t} - \widehat{q}_{1,t}(\alpha_1)\right)\Psi_{\alpha_2} \tag{13}$$

where:

$\widehat{q}_{i,t}(\alpha_i)$ can be computed either through quantile regression on a set of covariates or via sample quantiles.

$\widehat{\rho}_{(\alpha_1,\alpha_2)}(k) \in [-1, 1]$ with the limiting values, meaning perfect negative and perfective positive correlation, respectively. Additionally, positive values of $\widehat{\rho}_{(\alpha_1,\alpha_2)}(k)$ connote a co-movement in the same direction for the quantile hit processes; whereas negative values denote a co-movement in opposite directions. This implies that observations falling inside a given α_1 quantile for $y_{1,t}$ will correspond to observations of $y_{2,t-k}$ outside its α_2 quantile. For $k > 0$, the information relating to $y_{2,t-k}$ unarguably precedes $y_{1,t}$, thus the directional predictability: a quantile hit $\mathbf{1}\,[y_{2,t-k} < q_{2,t-k}(\alpha_2)]$ is likely to be followed after k periods by a quantile hit $\mathbf{1}]$ if $\widehat{\rho}_{(\alpha_1,\alpha_2)}(k) > 0$ or $[y_{1,t} < q_{1,t}(\alpha_1)] < 0$.

Finally, the asymptotic distribution for $\widehat{\rho}_{(\alpha_1,\alpha_2)}(k)$ is derived following the stationary bootstrap method advanced by Politis and Romano (1994). For instance, the $(1-\gamma)$ confidence interval for $\rho_{(\alpha_1,\alpha_2)}(k)$ is defined as $\left[\widehat{\rho}_{(\alpha_1,\alpha_2)}(k) + T^{\frac{-1}{2}}C_{1,k,\gamma};\ \widehat{\rho}_{(\alpha_1,\alpha_2)}(k) + T^{\frac{-1}{2}}C_{1,k,\gamma}\right]$,where $C_{1,k,\gamma}$ and $C_{2,k,\gamma}$ are the critical values obtained as percentiles of the bootstrapped distributions.

4. Empirical finding

4.1 Results and discussion

The descriptive statistics reported in Table 1 shows that the daily average returns for the cryptocurrencies and precious metals in the period under consideration are negative. In respect to the stock market, it can be observed that Bourse de Casablanca (CSE), Nigeria Stock Exchange (NGX), Ghana Stock Exchange (GSE), Dar es Salaam Stock Exchange (DSE) and Egyptian Exchange (EGX) recorded negative average returns of −0.004, −0.002, −0.001, −0.002 and −0.002, respectively while the remaining markets, namely Johannesburg Stock Exchange (JSE) and Nairobi Securities Exchange (NSE) recorded positive returns of 0.0019 and 0.0071, respectively. This implies that, on the average, investing in stock market yields higher returns than cryptocurrencies and precious metals.

Again, from Table 1, it can be observed that the standard deviation is highest for cryptocurrencies, particularly BNB, followed by precious metals. The fact that cryptocurrencies have the highest standard deviation suggests that their prices or returns exhibit a greater degree of volatility and fluctuation compared to the other asset classes. High volatility can be both an opportunity and a risk. On the positive side, it presents the potential for substantial gains over a short period.

Table 1. Descriptive statistics of daily returns

Variable	Obs	Mean	Min	Max	Std. Dev	Skewness	Kurtosis	ADF
Panel A: Precious Metals Returns								
XPD	1931	−0.007	−2.332	3.044	0.0281	0.867	13.875	−23.388***
XPT	1931	−0.008	−2.341	3.058	0.299	0.872	13.888	−23.479***
XAG	1931	−0.002	−1.479	2.136	0.231	0.624	10.261	−21.345***
XAU	1931	−0.004	−0.653	0.781	0.119	0.195	6.396	−24.232***
Panel B: Cryptocurrencies Returns								
ETH	1931	−0.001	−4.508	12.664	0.842	1.948	32.118	−21.758***
BTC	1931	−0.004	−1.887	5.651	0.407	1.466	24.289	−22.189***
BNB	1931	−0.027	−10.109	26.124	1.735	2.099	36.667	−21.571***
Panel C: Stock Market Returns								
CSE	1931	−0.004	−0.568	1.007	0.079	1.717	7.293	−17.364***
JSE	1931	0.002	−0.7191	1.058	0.181	0.268	5.606	−22.418**
NSE	1931	0.007	−0.425	0.671	0.087	0.784	8.718	−19.666***
NGX	1931	−0.002	−0.577	0.498	0.092	0.204	7.542	−19.362***
GSE	1931	−0.001	−2.047	2.110	0.123	0.078	9.025	−21.322***
DSE	1931	−0.002	−1.002	1.221	0.013	0.040	6.432	−22.142***
EGX	1931	−0.002	−1.000	0.2413	0.071	0.022	5.331	−21.173***

Note(s): ***, ** and * indicate significance at 1%, 5% and 10% level, respectively. XPD, XPT, XAG, XAU, represent Palladium, Platinum, Silver and Gold, respectively. ETH, BTC and BNB are cryptocurrency returns in respect to Ethereum, Bitcoin and BNB. CSE, JSE, NSE, NGX, GSE, DSE and EGX are the respective stock markets, namely Casablanca Stock Exchange, Johannesburg Stock Exchange, Nairobi Stock Exchange, Nigeria Stock Exchange, Ghana Stock Exchange, Dar es Salaam Exchange and Egyptian Exchange
Source(s): Authors' own work

Further, the all assets under the respective panels exerted positively skewed distributions. The positive skewness suggests that there are relatively few extreme positive returns or price increases compared to the number of moderate or negative returns or price decreases. Meanwhile, the kurtosis indicate that the returns series are not normally distributed, whereas the ADF test statistics confirm the stationarity properties of the return series, at the first difference.

4.2 Dynamic total connectedness

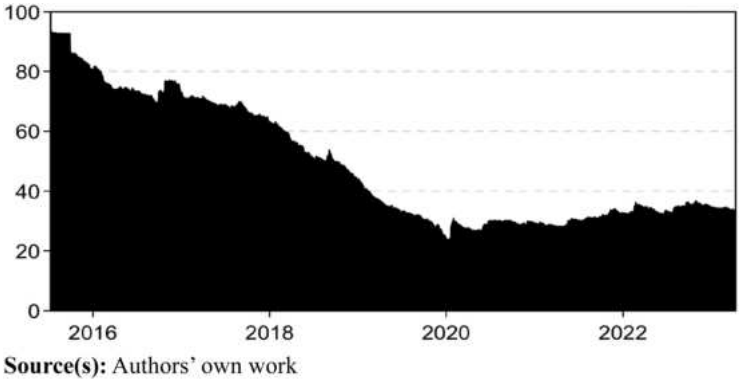
Table 2 shows the dynamic connectedness of the variables under consideration. From Table 2 it can be observed that the total connectedness index (TCI) for the period is 42.8%. This implies that 42.8% of shocks in the respect markets could be attributed to the spillovers between the seven stock markets under consideration, the various cryptocurrencies and precious metals. The dynamics of the TCI is clearly shown in Figure 1. As can be observed from Figure 1, TCI peaked at 90% in mid-2015, declined to 70% by 2017, briefly rose to nearly 80% in 2018 and subsequently exhibited a consistent decline to as low as 30% by 2020. Thereafter, TCI fluctuated between 30% and 39%, indicating varying degrees of interconnectedness between cryptocurrencies, precious metals and stock markets.

The peak TCI observed in mid-2015 could be attributed to global economic uncertainty, particularly concerns over China's economic slowdown and its ripple effects on emerging markets. During such periods, investors tend to seek safer assets, leading to increased demand for precious metals and cryptocurrencies as alternative stores of value. This flight to safety likely heightened correlations and interconnectedness among these asset classes as they responded similarly to external shocks. Similarly, the high level of TCI recorded in 2018 corresponds with heightened global trade tensions, primarily between the United States and China. Trade disputes and tariff escalations contributed to market volatility, prompting investors to diversify into safe

Table 2. Connectedness index

	XPD	XPT	XAG	XAU	ETH	BTC	BNB	CSE	EGX	JSE	NSE	NGX	DSE	GSE	FROM
XPD	*46.6*	11.99	11.9	5.23	1.88	5.26	5.93	0.6	1.87	3.92	1.91	0.65	0.67	1.53	53.41
XPT	7.38	*29.84*	29.8	4.81	2.13	6.1	8.78	0.55	1.27	4.95	1.78	0.58	0.53	1.47	70.16
XAG	7.38	29.84	*29.8*	4.81	2.13	6.11	8.78	0.55	1.27	4.95	1.78	0.58	0.53	1.47	70.17
XAU	7.38	12.35	12.3	*44.26*	3.16	4.53	6.43	0.84	1.13	3.22	1.56	0.92	0.71	1.16	55.74
ETH	3.16	6.52	6.52	0.79	*43.1*	14.42	13.9	0.57	1.06	4.31	2.13	1.2	0.74	1.59	56.94
BTC	2.23	6.73	6.72	1.01	11.6	*33.5*	25.6	0.67	1.9	5.39	2.1	0.79	0.42	1.36	66.49
BNB	2.29	6.92	6.92	0.95	9.27	23.4	*38.1*	0.63	1.98	5.23	1.88	0.67	0.49	1.32	61.92
CSE	1.84	2.81	2.81	2.27	1.17	2.84	3.7	*74.0*	1.99	2.88	1.13	1.33	0.65	0.51	25.93
EGX	3.61	5.06	5.05	1.69	1.44	6.36	7.68	0.96	*56.5*	5.63	2.3	0.99	0.85	1.78	43.42
JSE	2.44	7.64	7.63	0.7	2.52	7.61	11.4	0.9	2.09	*52.4*	1.99	0.73	0.49	1.43	47.59
NSE	2.6	4.87	4.86	1.18	2.44	4.93	4.81	0.92	2.29	4.48	*62.9*	1.17	0.56		37.1
NGX	3.61	2.62	2.61	2.91	1.58	3.18	3.26	1.24	2.3	2.43	1.46	*71.5*	0.47	0.76	28.43
DSE	1.88	3.03	3.02	1.36	0.71	3.39	3.88	0.79	1.48	2.55	1.34	0.58	*74.8*	1.13	25.15
GSE	2.1	4.51	4.5	0.85	1.39	4.22	5.18	0.46	1.82	3.71	2.1	0.52	0.72	*67.9*	32.05
TO	47.9	104.8	104.79	28.57	41.4	92.31	109.4	9.67	22.5	53.6	23.4	10.7	7.84	17.5	674.5
Inc Own	94.49	134.7	134.62	72.83	84.4	125.8	147.4	83.7	79.0	106.1	86.3	82.3	82.69	85.47	*TCI*
Net	−5.51	34.72	34.62	−27.2	−15	25.83	47.44	−16.2	−20.9	6.06	−13.7	−17.7	−17.31	−14.5	48.2%

Source(s): Authors' own work



Source(s): Authors' own work

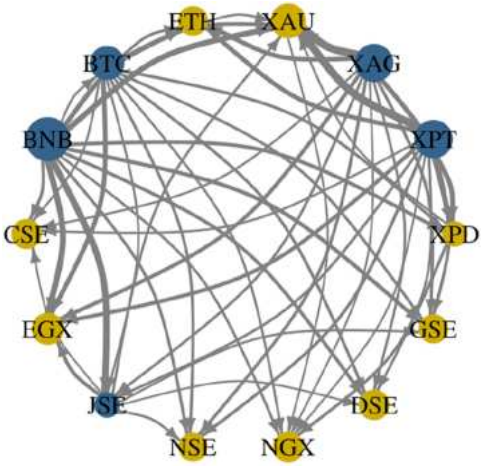
Figure 1. Total connectedness index

haven assets like gold and cryptocurrencies. These events underscore the role of geopolitical developments in influencing market interconnectedness, as uncertainties in global trade policies can disrupt commodity supply chains and impact asset correlations. One might intuitively expect an increased interconnectedness between cryptocurrencies, precious metals and stock markets in Africa due to heightened global uncertainty, economic disruptions and shifts in investor sentiment amidst the COVID-19 and in the heat of Russia–Ukraine war. The unexpected findings of low and fluctuating interconnectedness particularly between 2019 and 2023 demonstrates that while crises typically stimulate flight-to-safety behaviors and increased TCI, local and regional dynamics, including regulatory responses, market structure and economic policies, play crucial roles in shaping market outcomes.

4.3 Net connectedness and pairwise connectedness

Table 2 presents findings on interconnectedness and spillover of shocks among the various assets under consideration, and further brings to bear the net transmitters and net receivers of shocks. The findings in the table are corroborated by the network plot in Figure 2. It can be observed from Table 2 that among the precious metals under consideration, diamond (XPD) and gold (XAU) are net receivers of shocks, while platinum (XPT) and silver (XAG) are net transmitter of shocks. Table 2 further reveals that among the three precious metals, it is only ETH that turned out to be a net receiver of shocks while the remaining (BTC and BNB) proved to be somewhat immune to shocks. On the stock market front, JSE was the only net shock transmitters. The other markets considered in this study, namely CSE, EGX, DSE, NGX, NSE and GSE proved to be vulnerable to shocks, ie receive more shocks than it transmits.

The JSE exhibits greater resilience to shocks in comparison to other African stock markets due to several key factors. Diversification plays a crucial role as the JSE boasts a broad spectrum of listed companies across various sectors, which helps buffer the impact of economic shocks by spreading risk. Additionally, its substantial market size and liquidity as the largest exchange in Africa ensures there is ample liquidity, enabling smoother absorption of market shocks without significant price swings (Korsah and Mensah, 2023). Strong regulatory environment underpins market stability with transparent oversight, fostering investor confidence and mitigating extreme fluctuations. Moreover, the JSE's attractiveness to foreign investor participation brings in stable capital flows, which can stabilize the market during volatile periods. The relative economic stability of South Africa, where the JSE operates, further supports resilience by offering a more predictable economic environment compared to other African nations. Robust market infrastructure and the sophistication of investor participation also contribute to ensuring efficient market operations and risk management strategies that enhance overall market stability and resilience.



Source(s): Authors' own work

Figure 2. Network plot

Conversely, stock exchanges in emerging and frontier markets such as Egypt (EGX), Nigeria (NGX, NSE) and Ghana (GSE) exhibit higher vulnerability to external shocks. The poor resilience to shocks as demonstrated by these markets is consistent with findings by Korsah and Mensah (2023) who asserted that majority of stock markets in Africa are generally at the nascent stage, thus unable to withstand shocks from other markets.

The network plot presented in Figure 2 sheds more light on the extent of connectedness, the net receivers and transmitters of shocks, as well as the direction and intensity of the spillovers between the variables under consideration. To begin with, the size of the node represents the magnitude of shocks transmitted or received by a market, whereas the colur depicts whether a variable is a net receiver of shocks (yellow) or a net transmitter of shocks/spillovers (blue). The arrows signify the direction of the spillovers. The deeper the color of the arrow, the greater the magnitude of shock received or transmitted.

The results from Figure 2 confirm that XPT, XAG, BTC, BNB and JSE are net transmitters of shocks. Noticeably, BNB demonstrates significant resilience to shocks, transmitting substantial shocks to JSE and EGX. This resilience of BNB and BTC to shocks is supported by recent studies (Fernandes *et al.*, 2022; Tao and Qi, 2022). A careful observation of Table 2 and Figure 2 reveals that the level of interconnectedness is more pronounced among assets under the respective financial markets. However, in exceptional cases, some assets exhibited high inter-market connectedness. For instance, there is a strong interconnection between BNB (cryptocurrency market) on one hand, and JSE and EGX (stock market) on the other. This suggests that shocks in one market have a very high tendency to spill over to the other, regardless of the difference in the mode of operation.

4.4 Cross-quantilogram analysis

The results for the cross-quantilogram are presented in the form of heatmaps, with emphasis on the quantile-hits in all combinations of deciles for the two series. On the $y-axis$ are the quantiles for the respective stock markets, with a lag $k = 0, 1$ (representing the simultaneity and one-day lag effect, respectively). The $x-axis$, on the other hand, shows the individual cryptocurrencies and precious metals under consideration. Additionally, the colors, ranging from blue through white to red, portrays the level of spillover effect. Blue coloration suggests a negative correlation between two assets, while white and red depicts uncorrelation and positive correlation, respectively.

Prior to reporting on each cross-quantilogram, we deemed it expedient to undertake a preliminary significance test, through the stationary bootstrap procedure with 1,000 iterations and a size of 0.05. The correlation in Eq. (13) is tested for significance (null hypothesis $H0 : \widehat{\rho} = 0$), and in the event of no rejection, the value of the cross-quantilogram is set to zero.

It is noteworthy that a series on the $x-axis$ is regarded as a safe haven in relation to a series on the $y-axis$ when there exist null or negative correlation across the quantile combinations in the bottom left and the right corner of the heatmaps for different time lags. An asset is deemed as a hedge when mild red colour dominates in the heatmap whereas the dominance of blue shades on the heatmap reveals the diversifier characteristic of an asset. For clarity, the heatmaps are presented under the respective cryptocurrencies and stock markets nexus, as well as precious metals and stock markets. We begin with the safe haven and hedge qualities of BNB against returns volatilities on the selected stock markets.

From Figure 3, it can be observed that blue shades (negative correlation) dominate the left bottom corner of the heatmap for CSE and JSE. On the contrary, there is evidence of strong positive correlation between BNB-DSE and BNB-GSE, depicted by the red shades at the lower quantiles. This implies that, during turbulent market regimes, BNB serve as a safe haven instrument for investors on the CSE and JSE. The predominantly red shades at the lower quantiles of BNB-DSE and BNB-GSE suggest the presence of strong co-movement in adverse market conditions, highlighting the absence of safe-haven potential for BNB in the said markets. In the case of BNB-EGX, BNB-NGX and BNB-NSE, there is negative correlations, evidenced by predominant mild blue shades across the respective heatmaps, suggesting the

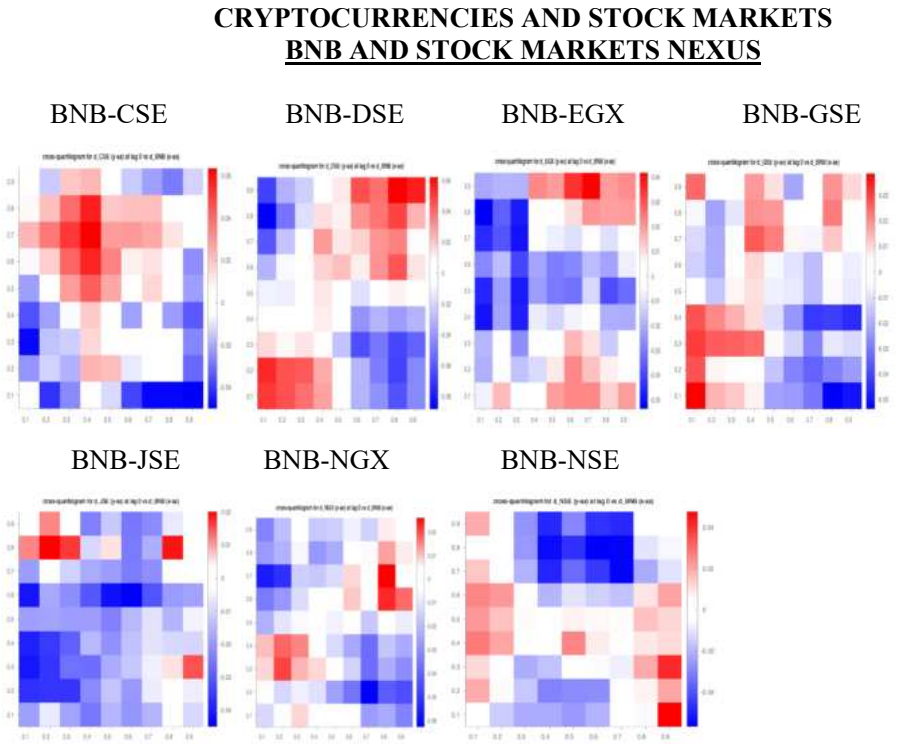


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Figure 3. BNB and stock market nexus

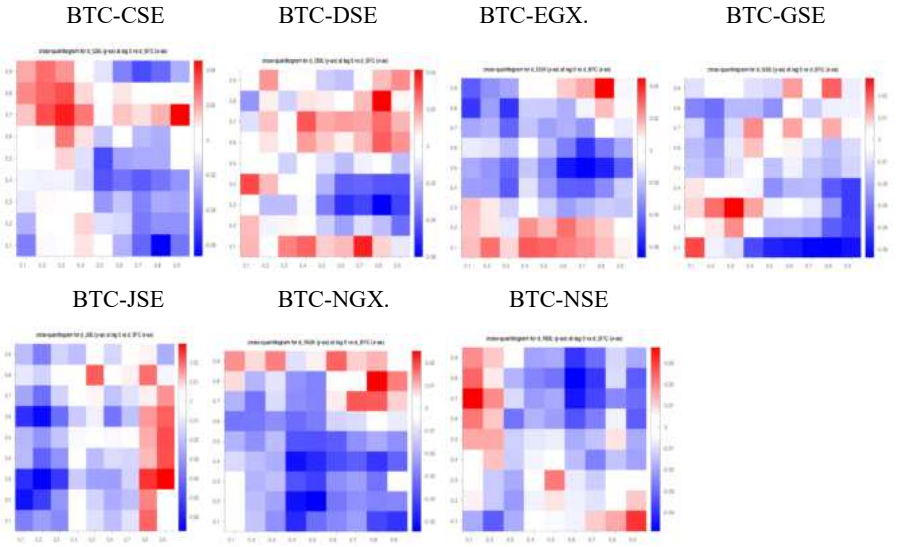

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Figure 4. BTC and stock market nexus

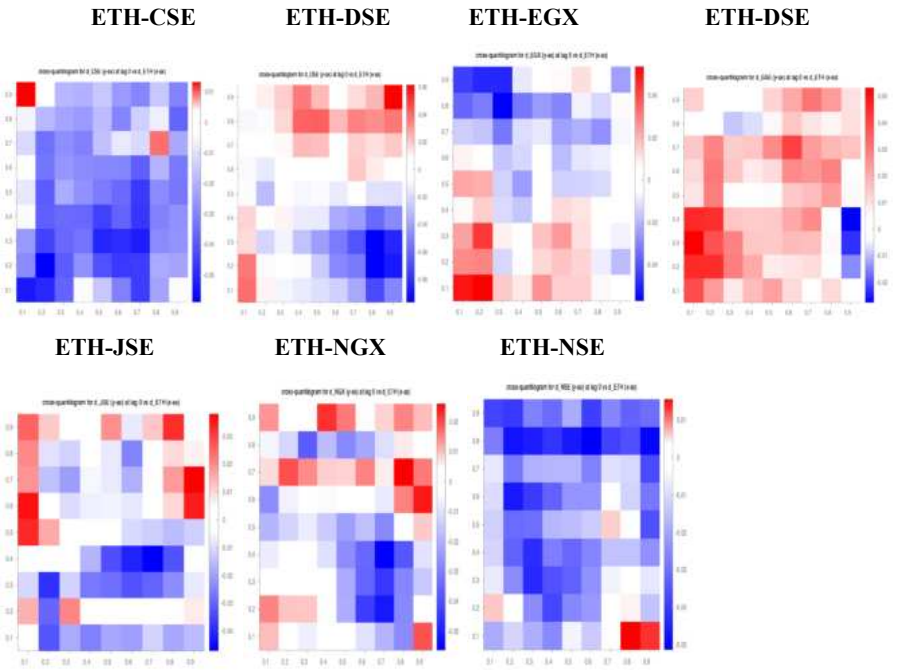

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Figure 5. ETH and stock market nexus

presence of hedge opportunity. It can be deduced that investors on the EGX, NGX and NSE can hedge against uncertainties in their stock returns by investing in BNB.

Focusing on BTC and Stock Market nexus in Figure 4, the plots reveal that there is no correlation between BTC and CSE in the lower quantiles. This implies that BTC can serve as a safe-haven for investment on CSE.A similar observation can be made of BTC-NSE, where there is an apparent zero correlation between the two assets. The widespread negative correlation between BT-NSE further portrays the hedge potential of BTC against returns on NSE. In relation to BTC-NGX and BTC-JSE, there is evidence of widespread blue shades at their respective lower quantiles, demonstrating that the BTC is a safe-haven asset. On the average, there exist positive correlation between BT and DSE, which supports the diversifier condition of an asset. It goes without saying that investors on the DSE can reduce the risk of losses by investing in BTC.

Further, we observe predominantly uncorrelation between ETH and DSE across almost all the quantiles. The implication is that investors can hold both ETH and DSE in a portfolio to minimize risk of losses.

In relation to ETH-Stock Market nexus, Figure 5 reveals a widespread weak negative correlation between ETH-CSE and ETH-NSE. This demonstrates the ETH provides hedge opportunity for investors on the CSE and NSE. A critical observation of the ETH-GSE bares widespread mild red shades across the heatmap. This is in conformity with the diversifier attribute of two assets.

Turning to the precious metals and stock market nexus, we observe from Figure 6 the presence of negative correlation between XAG and CSE, as well as XAG and EGX in the

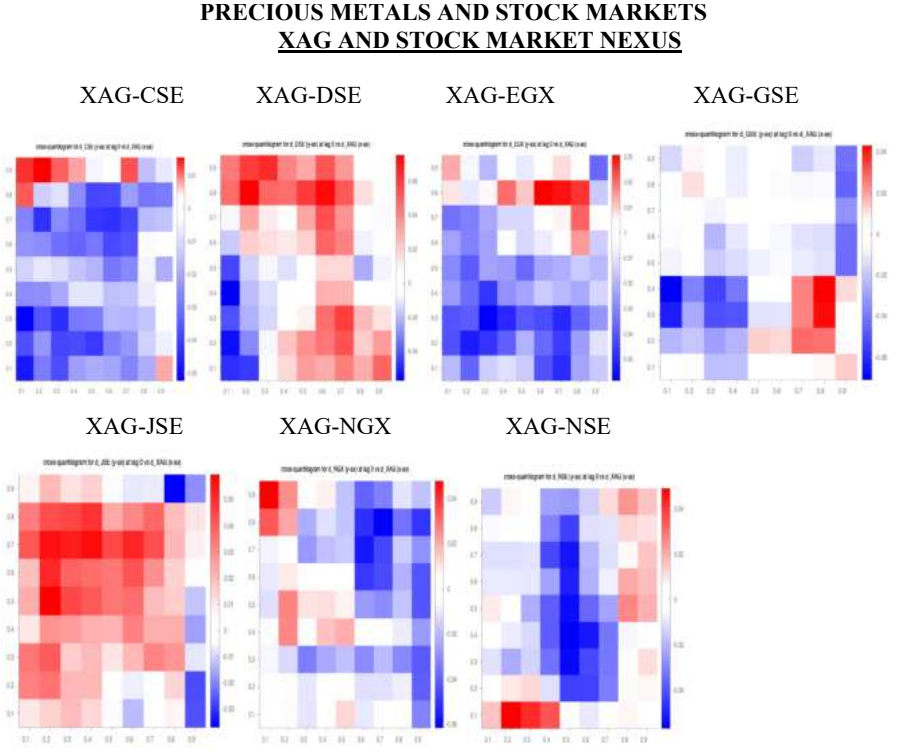

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Figure 6. XAG and stock market nexus

lower quantiles. This gives an indication that XAG could provide a safe haven for the CSE and EGX markets. The result for XAG-GSE in Figure 6 shows no-correlation to weak negative correlation across the heatmap, signifying the hedge potential of the XAG against possible losses on the GSE. A careful observation of XAG-NSE and XAG-NGX relationship reveals that XAG fails to provide safe-haven and hedge for the two markets. On the XAG-JSE front, the whole heatmap is dominated by faint red shading, suggesting that XAG possesses strong hedge potential.

From Figure 6, the result shows that XAU provided a safe haven for NGX, GSE and JSE markets, marked by the negative correlation between XAU and returns on the said markets in times of economic turbulence. On the contrary, XAU failed to serve as safe-haven for CSE, DSE and NSE.

A closer examination of the relationship between XPD and returns on the respective stock markets from Figure 7 reveals that the precious metal can serve as a safe haven for investments on the DSE, GSE and JSE. In the case of XPD-EGX, it can be observed that, averagely, there is a weak positive dependence between the two instruments, demonstrating that XPD can be classified as a diversifier.

Finally, Figures 8 and 9 reveals that XPT could serve as a potential safe haven for GSE and NSE. The widespread faint red color, representing positive correlation between XPT and JSE conforms to the diversification effect of XPT on the JSE.

From the foregoing, it is clear that cryptocurrencies generally exhibit hedging or safe-haven properties in most African markets. This result is a sharp contradiction to prior research that highlights the volatile and speculative nature of cryptocurrencies, and concludes that cryptocurrencies are unreliable safe-haven and hedge instrument (Almeida and Gonçalves,

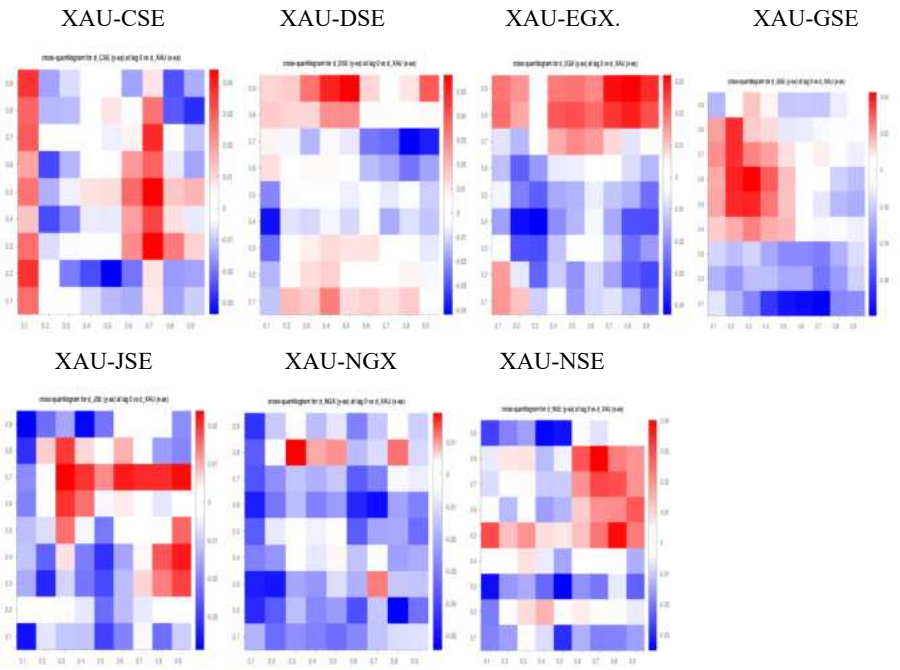

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Figure 7. XAU and stock market nexus

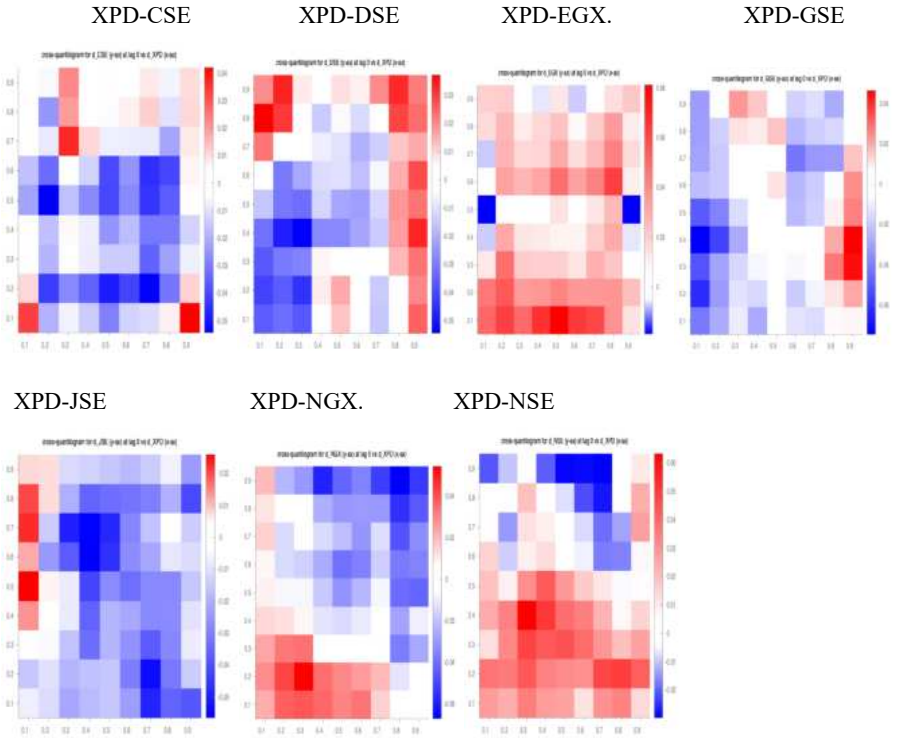

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Figure 8. XPD and stock market nexus

2022; Jana *et al.*, 2023; Abdul-Rahim *et al.*, 2022; Omri, 2023; Diniz-Maganini and Rasheed, 2022).

Similarly, precious metals demonstrated hedging and safe-haven effects in African markets within the study period. This finding was quite expected given the historical reputation of precious metals as safe havens, contrary to the seminal work by Baur and McDermott (2010) which found the absence of safe-haven and hedge qualities of precious metals for stock markets in Africa. The findings buttress the postulation that the financial market in Africa is one of the most preferred investment destinations for international investors (Alagidede, 2008; Anyikwa and Le Roux, 2020).

5. Conclusion

This study sought to achieve two objectives: first, examine the extent of interconnectedness prevailing between the cryptocurrency market, the stock market and the precious metals market; and second, conduct thorough assessment of hedge and safe-haven qualities of broad range of precious metals and cryptocurrencies against returns on the African stock market.

Applying the TVP-VAR model, we established the presence of high interconnectedness between the cryptocurrency market, precious metals and African stock market. This signals the high potential for volatility in one market to spillover to the other. The study further revealed, in relation to the precious metals under consideration, that XPT and XAG were net transmitters of shocks whereas XPD and XAU were net receivers of shocks. This renders XPT and XAG more susceptible to shocks than XPD and XAU. Relatedly, BTC and BNB received

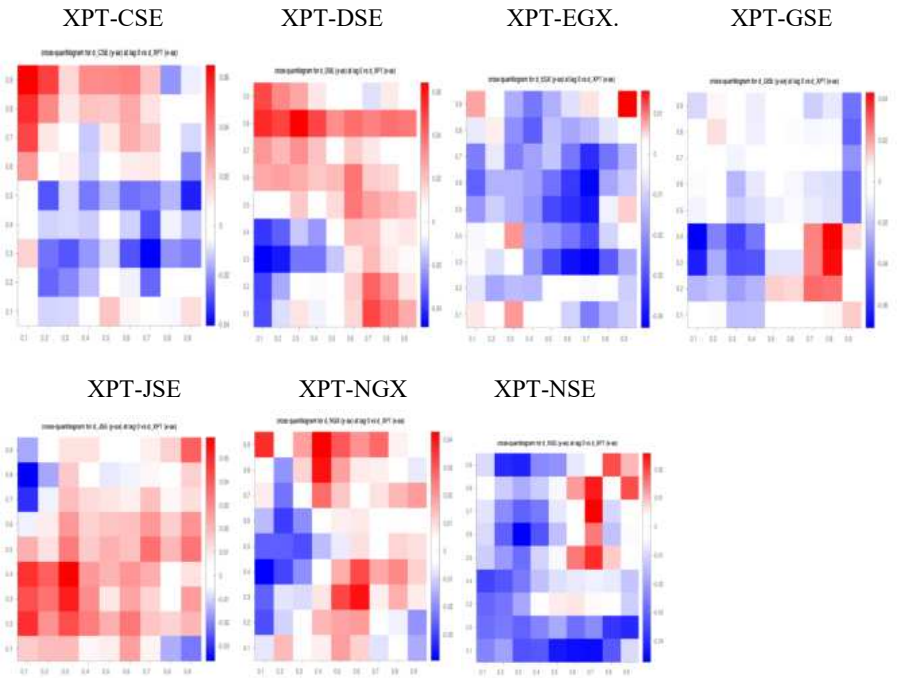

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Figure 9. XPT and stock market nexus

more shocks than they could transmit while ETH proved to be immune to shocks, recording a positive net transmission of shocks. Among the stock markets, the JSE proved to be the only shock transmitter. Surprisingly, the remaining six markets received more shocks than they could emit, an indication that, save the JSE, all the stock markets under consideration are unable to withstand shocks.

Finally, we found that cryptocurrencies and precious metals exhibited safe-haven and hedge qualities, albeit limited potential in some stock markets, after employing Cross-Quantilogram technique. This reinforces the need for investors to carefully and continuously examine the various precious metals and cryptocurrencies prior to investing in same.

6. Key practical implications

The high potential for volatility spillover between the African stock market, cryptocurrencies and precious metals suggests that investors should be cautious when constructing portfolios involving these markets. A negative shock in one market (e.g. cryptocurrency) could quickly propagate to others (e.g. precious metals or stock markets), increasing overall portfolio risk.

Additionally, given that the interconnectedness of these markets can change over time, investors must continuously monitor market dynamics and adjust their portfolios accordingly. A one-size-fits-all diversification strategy may not work, and active management will be crucial to minimize risk.

The finding that cryptocurrencies and precious metals exhibit some degree of safe-haven and hedge potentials, albeit limited in certain stock markets, provides investors with alternative investment options during market downturns. For instance, XPT and XAG being

net shock transmitters suggest that they could be valuable hedging assets in times of market turbulence, whereas XPD and XAU, which receive more shocks, may offer less protection in volatile markets.

Since most African stock markets, except the JSE, are net receivers of shocks, investors in these markets should exercise caution during periods of global financial uncertainty. Investors may want to reduce their exposure to African stocks during such periods or implement hedging strategies, such as increasing allocations to cryptocurrencies like ETH or certain precious metals that show hedging potential.

7. Recommendations for future research

The current study focuses on African stock markets, but future research could compare the behavior of these markets with other emerging market stock exchanges (e.g. in Asia or Latin America) to assess whether the findings are region-specific or part of a broader global trend. Such comparisons could help identify unique characteristics of African markets.

With the rise of stablecoins (e.g. USDT, USDC) and central bank digital currencies (CBDCs), future studies could explore how these assets interact with traditional markets. Stablecoins, in particular, have a different volatility profile and could play a role in reducing shock transmission or acting as safe havens.

References

Abdul-Rahim, R., Khalid, A., Karim, Z.A. and Rashid, M. (2022), "Exploring the driving forces of stock-cryptocurrency comovements during COVID-19 pandemic: an analysis using wavelet coherence and seemingly unrelated regression", *Mathematics*, Vol. 10 No. 12, p. 2116, doi: 10.3390/math10122116.

Aftab, M., Shah, S.Z.A. and Ismail, I. (2019), "Does gold act as a hedge or a safe haven against equity and currency in Asia?", *Global Business Review*, Vol. 20 No. 1, pp. 105-118, doi: 10.1177/0972150918803993.

Agyei-Mensah, B.K. and Oppong, H. (2014), "Dynamic linkages between African stock markets and inflation rates", *Journal of African Business*, Vol. 15 No. 2, pp. 105-118.

Alagidede, P. (2008), "African stock market integration: implications for portfolio diversification and international risk sharing", *Proceedings of the African Economic Conferences*, pp. 1-31.

Almeida, J. and Gonçalves, T.C. (2022), "Portfolio diversification, hedge and safe-haven properties in cryptocurrency investments and financial economics: a systematic literature review", *Journal of Risk and Financial Management*, Vol. 16 No. 1, p. 3, doi: 10.3390/jrfm16010003.

Anyikwa, I. and Le Roux, P. (2020), "Integration of African stock markets with the developed stock markets: an analysis of co-movements, volatility and contagion", *International Economic Journal*, Vol. 34 No. 2, pp. 279-296, doi: 10.1080/10168737.2020.1755715.

Asafo-Adjei, E., Adam, A.M. and Darkwa, P. (2021), "Can crude oil price returns drive stock returns of oil producing countries in Africa? Evidence from bivariate and multiple wavelet", *Macroeconomics and Finance in Emerging Market Economies*, Vol. 17, pp. 1-19, doi: 10.1080/17520843.2021.1953864.

Baruník, J. and Křehlík, T. (2018), "Measuring the frequency dynamics of financial connectedness and systemic risk", *Journal of Financial Econometrics*, Vol. 16 No. 2, pp. 271-296, doi: 10.1093/jjfinec/nby001.

Baur, D.G. and Glover, K.J. (2012), "The destruction of a safe haven asset?", SSRN 2142283.

Baur, D.G. and Lucey, B.M. (2010), "Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold", *The Financial Review*, Vol. 45 No. 2, pp. 217-229, doi: 10.1111/j.1540-6288.2010.00244.x.

Baur, D.G. and McDermott, T.K. (2010), "Is gold a safe haven? International evidence", *Journal of Banking and Finance*, Vol. 34 No. 8, pp. 1886-1898, doi: 10.1016/j.jbankfin.2009.12.008.

Beckmann, J., Berger, T. and Czudaj, R. (2015), "Does gold act as a hedge or a safe haven for stocks? A smooth transition approach", *Economic Modelling*, Vol. 48, pp. 16-24, doi: 10.1016/j.econmod.2014.10.044.

Będowska-Sójka, B. and Kliber, A. (2021), "Is there one safe-haven for various turbulences? The evidence from gold, Bitcoin and Ether", *The North American Journal of Economics and Finance*, Vol. 56, 101390, doi: 10.1016/j.najef.2021.101390.

Bekiros, S., Boubaker, S., Nguyen, D.K. and Uddin, G.S. (2017), "Black swan events and safe havens: the role of gold in globally integrated emerging markets", *Journal of International Money and Finance*, Vol. 73, pp. 317-334, doi: 10.1016/j.jimonfin.2017.02.010.

Bouri, E., Jalkh, N., Molnár, P. and Roubaud, D. (2017a), "Bitcoin for energy commodities before and after the December 2013 crash: diversifier, hedge or safe haven?", *Applied Economics*, Vol. 49 No. 50, pp. 5063-5073.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D. and Hagfors, L.I. (2017b), "On the hedge and safe haven properties of Bitcoin: is it really more than a diversifier?", *Finance Research Letters*, Vol. 20, pp. 192-198, doi: 10.1016/j.frl.2016.09.025.

Bredin, D., Conlon, T. and Potì, V. (2017), "The price of shelter-Downside risk reduction with precious metals", *International Review of Financial Analysis*, Vol. 49, pp. 48-58.

Chemkha, R., BenSaïda, A., Ghorbel, A. and Tayachi, T. (2021), "Hedge and safe haven properties during COVID-19: evidence from Bitcoin and gold", *The Quarterly Review of Economics and Finance*, Vol. 82, pp. 71-85, doi: 10.1016/j.qref.2021.07.006.

Conlon, T. and McGee, R. (2020), "Safe haven or risky hazard? Bitcoin during the COVID-19 bear market", *Finance Research Letters*, Vol. 35, 101607, doi: 10.1016/j.frl.2020.101607.

Conlon, T., Corbet, S. and McGee, R.J. (2020), "Are cryptocurrencies a safe haven for equity markets? An international perspective from the COVID-19 pandemic", *Research in International Business and Finance*, Vol. 54, 101248, doi: 10.1016/j.ribaf.2020.101248.

Corbet, S., Meegan, A., Larkin, C., Lucey, B. and Yarovaya, L. (2018), "Exploring the dynamic relationships between cryptocurrencies and other financial assets", *Economics Letters*, Vol. 165, pp. 28-34, doi: 10.1016/j.econlet.2018.01.004.

Dar, A.B. and Maitra, D. (2017), "Is gold a weak or strong hedge and safe haven against stocks? Robust evidences from three major gold-consuming countries", *Applied Economics*, Vol. 49 No. 53, pp. 5491-5503, doi: 10.1080/00036846.2017.1310998.

Diebold, F.X. and Yilmaz, K. (2012), "Better to give than to receive: predictive directional measurement of volatility spillovers", *International Journal of Forecasting*, Vol. 28 No. 1, pp. 57-66, doi: 10.1016/j.ijforecast.2011.02.006.

Diniz-Maganini, N. and Rasheed, A.A. (2022), "Price efficiency and safe-haven property of Bitcoin in relation to stocks in the pandemic era", *Studies in Economics and Finance*, Vol. 39 No. 3, pp. 403-418, doi: 10.1108/sef-06-2021-0235.

Durcheva, M. and Tsankov, P. (2019), "Analysis of similarities between stock and cryptocurrency series by using graphs and spanning trees", *AIP Conference Proceedings*, Vol. 2172 No. 1, doi: 10.1063/1.5133581.

Fernandes, L.H., Bouri, E., Silva, J.W., Bejan, L. and de Araujo, F.H. (2022), "The resilience of cryptocurrency market efficiency to COVID-19 shock", *Physica A: Statistical Mechanics and Its Applications*, Vol. 607, 128218, doi: 10.1016/j.physa.2022.128218.

Guesmi, K., Saadi, S., Abid, I. and Ftiti, Z. (2019), "Portfolio diversification with virtual currency: evidence from bitcoin", *International Review of Financial Analysis*, Vol. 63, pp. 431-437, doi: 10.1016/j.irfa.2018.03.004.

Gürgün, G. and Ünalmış, İ. (2014), "Is gold a safe haven against equity market investment in emerging and developing countries?", *Finance Research Letters*, Vol. 11 No. 4, pp. 341-348, doi: 10.1016/j.frl.2014.07.003.

Hamdi, B., Aloui, M., Alqahtani, F. and Tiwari, A. (2019), "Relationship between the oil price volatility and sectoral stock markets in oil-exporting economies: evidence from wavelet

nonlinear denoised based quantile and Granger-causality analysis", *Energy Economics*, Vol. 80, pp. 536-552, doi: 10.1016/j.eneco.2018.12.021.

Han, H., Linton, O., Oka, T. and Whang, Y.J. (2016), "The cross-quantilogram: measuring quantile dependence and testing directional predictability between time series", *Journal of Econometrics*, Vol. 193 No. 1, pp. 251-270, doi: 10.1016/j.jeconom.2016.03.001.

Haq, I.U., Chupradit, S. and Huo, C. (2021), "Do green bonds act as a hedge or a safe haven against economic policy uncertainty? Evidence from the USA and China", *International Journal of Financial Studies*, Vol. 9 No. 3, p. 40, doi: 10.3390/ijfs9030040.

Hood, M. and Malik, F. (2013), "Is gold the best hedge and a safe haven under changing stock market volatility?", *Review of Financial Economics*, Vol. 22 No. 2, pp. 47-52, doi: 10.1016/j.rfe.2013.03.001.

Husain, S., Tiwari, A.K., Sohag, K. and Shahbaz, M. (2019), "Connectedness among crude oil prices, stock index and metal prices: an application of network approach in the USA", *Resources Policy*, Vol. 62, pp. 57-65, doi: 10.1016/j.resourpol.2019.03.011.

Jana, S. and Sahu, T.N. (2023), "Can diversification be improved by using cryptocurrencies? Evidence from Indian equity market", *Journal of Financial Economic Policy*, Vol. 15 No. 6, pp. 551-573, doi: 10.1108/jfep-02-2023-0047.

Jana, S. and Sahu, T.N. (2024), "A wavelet analysis of investing in cryptocurrencies in the Indian stock market", *International Journal of Emerging Markets*. doi: 10.1108/ijoem-05-2023-0698.

Jana, S., Sahu, T.N. and Pandey, K.D. (2023), "Revisiting the cryptocurrencies role in stock markets: ADCC-GARCH and Wavelet Coherence", *Macroeconomics and Finance in Emerging Market Economies*, Vol. 17, pp. 1-26, doi: 10.1080/17520843.2023.2211380.

Ji, Q., Zhang, D. and Zhao, Y. (2020), "Searching for safe-haven assets during the COVID-19 pandemic", *International Review of Financial Analysis*, Vol. 71, 101526, doi: 10.1016/j.irfa.2020.101526.

Kaul, A. and Sapp, S. (2006), "Y2K fears and safe haven trading of the U.S. dollar", *Journal of InternationalMoneyandFinance*, Vol. 25 No. 5, pp. 760-779, doi: 10.1016/j.jimonfin.2006.04.003.

Korsah, D. and Mensah, L. (2023), "Geopolitical risk, economic policy uncertainty, financial stress and stock returns nexus: evidence from African stock markets", *Journal of Capital Markets Studies*, Vol. 8 No. 1, pp. 25-42, doi: 10.1108/jcms-08-2023-0031.

Korsah, D., Amewu, G. and Achampong, K.O. (2024), "The impact of geopolitical risks, financial stress, economic policy uncertainty on African stock markets returns and volatilities: wavelet coherence analysis", *Journal of Humanities and Applied Social Sciences*, Vol. 6 No. 5, pp. 450-470, doi: 10.1108/jhass-12-2023-0172.

Kumah, S.P. and Odei-Mensah, J. (2021), "Are Cryptocurrencies and African stock markets integrated?", *The Quarterly Review of Economics and Finance*, Vol. 81, pp. 330-341, doi: 10.1016/j.qref.2021.06.022.

Kumah, S.P., Odei-Mensah, J. and Baaba Amanamah, R. (2022), "Co-movement of cryptocurrencies and African stock returns: a multiresolution analysis", *Cogent Business and Management*, Vol. 9 No. 1, 2124595, doi: 10.1080/23311975.2022.2124595.

Lahiani, A., Mefteh-Wali, S. and Vasbieva, D.G. (2021), "The safe-haven property of precious metal commodities in the COVID-19 era", *Resources Policy*, Vol. 74, 102340, doi: 10.1016/j.resourpol.2021.102340.

Lei, H., Xue, M., Liu, H. and Ye, J. (2023), "Precious metal as a safe haven for global ESG stocks: portfolio implications for socially responsible investing", *Resources Policy*, Vol. 80, 103170, doi: 10.1016/j.resourpol.2022.103170.

Manohar, J.M. and Raju, G.A. (2021), "An assessment of gold as a hedge or safe haven: evidence from major gold producing countries", *Asian Economic and Financial Review*, Vol. 11 No. 7, pp. 524-533, doi: 10.18488/journal.aefr.2021.117.524.533.

Matkovskyy, R., Jalan, A., Dowling, M. and Bouraoui, T. (2021), "From bottom ten to top ten: the role of cryptocurrencies in enhancing portfolio return of poorly performing stocks", *Finance Research Letters*, Vol. 38, 101405, doi: 10.1016/j.frl.2019.101405.

McCown, J.J. and Zimmerman, J.R. (2006), "Is gold a zero-beta asset? Analysis of the investment potential of precious metals", *SSRN Electronic Journal*. doi: 10.2139/ssrn.920496.

Mensi, W., Al-Yahyaee, K.H. and Kang, S.H. (2017), "Time-varying volatility spillovers between stock and precious metal markets with portfolio implications", *Resources Policy*, Vol. 53, pp. 88-102, doi: 10.1016/j.resourpol.2017.06.001.

Mensi, W., Hernandez, J.A., Yoon, S.M., Vo, X.V. and Kang, S.H. (2021), "Spillovers and connectedness between major precious metals and major currency markets: the role of frequency factor", *International Review of Financial Analysis*, Vol. 74, 101672, doi: 10.1016/j.irfa.2021.101672.

Mensi, W., Ali, S.R.M., Vo, X.V. and Kang, S.H. (2022), "Multiscale dependence, spillovers, and connectedness between precious metals and currency markets: a hedge and safe- haven analysis", *Resources Policy*, Vol. 77, 102752, doi: 10.1016/j.resourpol.2022.102752.

Mensi, W., Aslan, A., Vo, X.V. and Kang, S.H. (2023), "Time-frequency spillovers and connectedness between precious metals, oil futures and financial markets: hedge and safe haven implications", *International Review of Economics and Finance*, Vol. 83, pp. 219-232, doi: 10.1016/j.iref.2022.08.015.

Mezghani, T. and Boujelbène-Abbes, M. (2023), "Financial stress effects on financial markets: dynamic connectedness and portfolio hedging", *International Journal of Emerging Markets*, Vol. 18 No. 10, pp. 4064-4087, doi: 10.1108/ijoem-06-2020-0619.

Minoiu, C., Kang, C., Subrahmanian, V.S. and Berea, A. (2015), "Does financial connectedness predict crises?", *Quantitative Finance*, Vol. 15 No. 4, pp. 607-624, doi: 10.1080/14697688.2014.968358.

Mu, Y., Stotsky, J.G. and Phelps, P. (2013), "Bond markets in Africa", *Review of Development Finance*, Vol. 3 No. 3, pp. 121-135, doi: 10.1016/j.rdf.2013.07.001.

Nkrumah-Boadu, B., Owusu Junior, P., Adam, A. and Asafo-Adjei, E. (2022), "Safe haven, hedge and diversification for African stocks: cryptocurrencies versus gold in time- frequency perspective", *Cogent Economics and Finance*, Vol. 10 No. 1, 2114171, doi: 10.1080/23322039.2022.2114171.

Omri, I. (2023), "Directional predictability and volatility spillover effect from stock market indexes to Bitcoin: evidence from developed and emerging markets", *The Journal of Risk Finance*, Vol. 24 No. 2, pp. 226-243, doi: 10.1108/jrf-06-2022-0130.

Pieters, G. and Vivanco, S. (2017), "Financial regulations and price inconsistencies across Bitcoin markets", *Information Economics and Policy*, Vol. 39, pp. 1-14, doi: 10.1016/j.infoecopol.2017.02.002.

Pistor, K. (2013), "A legal theory of finance", *Journal of Comparative Economics*, Vol. 41 No. 2, pp. 315-330, doi: 10.1016/j.jce.2013.03.003.

Politis, D.N. and Romano, J.P. (1994), "The stationary bootstrap", *Journal of the American Statistical Association*, Vol. 89 No. 428, pp. 1303-1313, doi: 10.2307/2290993.

Ranaldo, A. and Söderlind, P. (2010), "Safe haven currencies", *Review of Finance*, Vol. 14 No. 3, pp. 385-407, doi: 10.1093/rof/rfq007.

Razzaq, A., Sharif, A., An, H. and Aloui, C. (2022), "Testing the directional predictability between carbon trading and sectoral stocks in China: new insights using cross- quantilogram and rolling window causality approaches", *Technological Forecasting and Social Change*, Vol. 182, 121846, doi: 10.1016/j.techfore.2022.121846.

Reboredo, J.C. (2013), "Is gold a hedge or safe haven against oil price movements?", *Resources Policy*, Vol. 38 No. 2, pp. 130-137, doi: 10.1016/j.resourpol.2013.02.003.

Riahi, R., Bennajma, A., Jahmane, A. and Hammami, H. (2024), "Investing in cryptocurrency before and during the COVID-19 crisis: hedge, diversifier or safe haven?", *Research in International Business and Finance*, Vol. 67, 102102, doi: 10.1016/j.ribaf.2023.102102.

Selmi, R., Bouoiyour, J. and Wohar, M.E. (2022), "Digital gold and geopolitics", *Research in International Business and Finance*, Vol. 59, 101512, doi: 10.1016/j.ribaf.2021.101512.

Shahzad, S.J.H., Bouri, E., Roubaud, D., Kristoufek, L. and Lucey, B. (2019), "Is Bitcoin a better safe-haven investment than gold and commodities?", *International Review of Financial Analysis*, Vol. 63, pp. 322-330, doi: 10.1016/j.irfa.2019.01.002.

Shahzad, S.J.H., Bouri, E., Roubaud, D. and Kristoufek, L. (2020), "Safe haven, hedge and diversification for G7 stock markets: gold versus bitcoin", *Economic Modelling*, Vol. 87, pp. 212-224, doi: 10.1016/j.econmod.2019.07.023.

Syuhada, K., Hakim, A., Suprijanto, D., Muchtadi-Alamsyah, I. and Arbi, L. (2022), "Is Tether a safe haven of safe haven amid COVID-19? An assessment against Bitcoin and oil using improved measures of risk", *Resources Policy*, Vol. 79, 103111, doi: 10.1016/j.resourpol.2022.103111.

Tao, R. and Qi, S. (2022), "Dynamic connectedness of major digital currencies: a time- varying approach", *Discrete Dynamics in Nature and Society*, Vol. 2022 No. 1, 9768336, doi: 10.1155/2022/9768336.

Uddin, G.S., Shahzad, S.J.H., Boako, G., Hernandez, J.A. and Lucey, B.M. (2019), "Heterogeneous interconnections between precious metals: evidence from asymmetric and frequency-domain spillover analysis", *Resources Policy*, Vol. 64, 101509, doi: 10.1016/j.resourpol.2019.101509.

Van Hoang, T.H., Lahiani, A. and Heller, D. (2016), "Is gold a hedge against inflation? New evidence from a nonlinear ARDL approach", *Economic Modelling*, Vol. 54, pp. 54-66, doi: 10.1016/j.econmod.2015.12.013.

Wen, F., Zhang, M., Deng, M., Zhao, Y. and Ouyang, J. (2019), "Exploring the dynamic effects of financial factors on oil prices based on a TVP-VAR model", *Physica A: Statistical Mechanics and Its Applications*, Vol. 532, 121881, doi: 10.1016/j.physa.2019.121881.

Wen, F., Shui, A., Cheng, Y. and Gong, X. (2022), "Monetary policy uncertainty and stock returns in G7 and BRICS countries: a quantile-on-quantile approach", *International Review of Economics and Finance*, Vol. 78, pp. 457-482, doi: 10.1016/j.iref.2021.12.015.

World Bank Group (2022), *World Development Report 2016: Digital Dividends*, World Bank Publications.

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