

Hedging market risk using gold: A wavelet quintile correlation approach

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Abstract

This research assesses gold's hedging and haven qualities against stock market fluctuations. This study uses the daily returns of three exchange-traded funds that best reflect the gold market and the stock markets of developed and emerging economies: iShares MSCI World (URTH), SPDR Gold (GLD), and SPDR S&P Emerging Markets (EDIV). The data set spans January 13, 2012, to December 29, 2023. For analytical purposes, this study estimates the dynamic correlation from the DCC-GARCH model and the newly constructed wavelet quantile correlations (WQC). According to WQC, gold has consistently been a short- and long-term haven for emerging markets during the COVID-19 pandemic and the Russia-Ukraine conflict. However, gold only shows the long-term safe-haven status for the developed markets. Further, this study shows that gold and stock correlations, both short- and long-term, do change with time. Lastly, this research suggests trading strategies based on a constant proportion approach.

Public interest statements

This study is useful for people to understand hedging methods and trading strategies for gold products.

Keywords: Gold, Hedging, Quintile, Wavelet.

Paper type: Research paper

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Abstrak

Penelitian ini menilai kualitas lindung nilai emas terhadap fluktuasi pasar saham. Penelitian ini menggunakan return harian dari tiga reksa dana yang diperdagangkan di bursa yang paling mencerminkan pasar emas dan pasar saham negara maju dan negara berkembang: iShares MSCI World (URTH), SPDR Gold (GLD), dan SPDR S&P Emerging Markets (EDIV). Data yang digunakan mencakup periode 13 Januari 2012 hingga 29 Desember 2023. Untuk tujuan analisis, penelitian ini mengestimasi korelasi dinamis dari model DCC-GARCH dan korelasi kuantil wavelet (WQC) yang baru dibangun. Menurut WQC, emas secara konsisten menjadi aset safe haven jangka pendek dan jangka panjang untuk pasar negara berkembang selama pandemi COVID-19 dan konflik Rusia-Ukraina. Namun, emas hanya menunjukkan status safe haven jangka panjang untuk pasar negara maju. Lebih lanjut, penelitian ini menunjukkan bahwa korelasi emas dan saham, baik jangka pendek maupun jangka panjang, berubah seiring waktu. Terakhir, penelitian ini menyarankan strategi trading berdasarkan pendekatan proporsi konstan.

Pernyataan kepentingan publik

Studi ini berguna bagi masyarakat agar dapat memahami metode lindung nilai dan strategi trading untuk produk emas.

Kata Kunci: Emas, Lindung Nilai, Kuintil, Wavelet.

1. Introduction

Gold is commonly used as a hedge against volatility in the stock market during market turmoil (Nugroho, 2022). When expecting volatility in the stock market, investors may decrease their stock asset allocation and increase their holdings of low-risk assets such as gold (Ma et al., 2021). During market downturns, this act generates a negative relationship between stocks and gold (Lin et al., 2018). In risk management, hedges and haven assets have historically been considered practical tools (Hussain Shahzad et al., 2020). An asset that, on average, has no correlation or a negative correlation with a different asset or portfolio is considered a hedge, as stated by Baur and Lucey (2010). In addition, strict hedges have a (strongly) negative correlation with other assets or portfolios. On the other hand, an asset that is not correlated or inversely correlated with a different asset or a portfolio in a volatile market is referred to as a "haven." Due to its stable value, gold has long been regarded as a haven and a hedge. The academic literature provides ample documentation of the gold's hedge and safe-haven properties (Disli et al., 2021; Hamma et al., 2021; Izadi & Hassan, 2018; Kinatader et al., 2021).

Furthermore, the COVID-19 pandemic is connected to financial volatility, which can alter the characteristics of different financial assets (Bahloul et al., 2023). The COVID-19 pandemic has rocked the world monetary system, which motivates investors to look for a haven for their money and to reconsider the hedging and safe-haven qualities of several asset classes. For example, a previous study reassesses the safe-haven role of gold, digital currencies, foreign exchange, and commodities assets (Ji et al., 2020). The findings indicate that most assets are not safe havens, although gold and soybean futures can be used as haven assets during a COVID-19 pandemic.

Moreover, the war between Russia and Ukraine immediately disrupted Europe's clean and dirty energy logistical supply chains, creating unforeseen challenges that raised global concerns about the financial markets, the recession, and high inflation rates (Mohammed et al., 2023). In this regard, the crisis over energy security has resurfaced as a result of Russia's invasion of Ukraine. Therefore, it becomes imperative to take precautions against the risk brought on by the

pandemic and the war between Russia and Ukraine. In light of this adversity, we believe that gold is a viable asset that can effectively protect stocks from the risk of a pandemic and war. This is the primary purpose of this paper.

Though there is a growing interest in elucidating the effects of COVID-19 and Russia's invasion of Ukraine on international financial markets, there are relatively few studies that reassess gold's hedge and safe-haven qualities in the context of the pandemic and the Russian invasion of Ukraine using a recently developed technique called the wavelet quintile correlation approach (after that, WQC). Hence, we contribute to the body of literature in the following manners: First, we re-examine how gold could have served as a "haven" and a "hedge" during the COVID-19 outbreak and the Russian invasion of Ukraine. Secondly, we employ the wavelet quintile correlation method, which enhances both wavelet analysis and quantile regression.

2. Theoretical Framework and Hypothesis

This paper is connected to the literature on gold, a distinct asset class and a haven asset. Due to its constant demand and capacity to act as a hedge, gold as a commodity can be seen as belonging to a distinct asset class (Robiyanto, 2018a). Gold is a valuable metal both a monetary asset and a commodity. Furthermore, as gold can be considered a reserve currency held by the major central banks as a constituent of their foreign exchange reserves, it can be seen as belonging to different kinds of assets (Baur & McDermott, 2010).

Similar to the definition of a haven from Baur and Lucey (2010), an asset with low volatility and strong liquidity used by investors afraid of market losses is referred to as a haven (Flavin et al., 2014). In essence, haven assets are risk diversifiers that are held to enhance asset portfolios' risk-return trade-off during volatile markets. Further, investors tend to flock to safe havens as a safeguard during uncertain times (Nugroho, 2021). The attractiveness of gold as a counter-cyclical investment vehicle and haven emerged globally during the 2008 global financial crisis (Robiyanto et al., 2017). While stock prices plummeted, gold prices withstood the downturn due to money fleeing for safety. Investors will try to move their money from a particular asset class to the more qualified and safe asset classes (flight for safety and flight for quality) during market turbulence when the rate of return of other instruments falls (Naeem et al., 2023). Investors must take this action to prevent the value of their investments from declining. Despite a persistent financial crisis, the gold market remains liquid, even when other financial markets are not (Robiyanto, 2018b). Additionally, gold is a very liquid valuable metal (Pal & Mitra, 2019).

Recently, scientists have created ground-breaking applications to satisfy some investors' religious requirements using the current blockchain. OneGram, an Islamic cryptocurrency, was created in May 2017 (Maierbrugger, 2017). The Dubai-based cryptocurrency OneGram was limited to speculation and was backed by real gold in a vault (Chowdhury & Razak, 2019). In contrast to Bitcoin and other well-known cryptocurrencies, digital currencies backed by commodities like gold should, in theory, be less volatile because their pricing is not set by the market (Jalan et al., 2021).

This paper is also closely associated with the literature on the methodologies used to measure the hedge effectiveness of gold against the risk of stock markets. The generalized autoregressive conditional heteroscedasticity (GARCH) models have been widely used in the literature. The models R. Engle (1982) and Bollerslev (1986) introduced are specifically created to get the volatility clustering of returns. Further, R. Engle (2002) extends the constant correlation model to the dynamic conditional correlation (DCC). Usually, practical factors like ease of estimation are used to construct multivariate GARCH requirements, which leads to a significant

loss of generality. Therefore, van der Weide (2002) created a multivariate generalized orthogonal (GO)-GARCH model.

Further, one drawback of the DCC-GARCH analysis method is that the conditional correlation does not consider the dynamics of the asymmetric effect. As such, it remains impossible to separate the positive and negative shocks' effects when analyzing past shocks' influence on volatility and future conditional correlation. The asymmetric DCC or ADCC-GARCH analysis technique can solve the issue and is more suited for measuring the correlation with various asset classes (Cappiello et al., 2006).

Applying the GARCH models, a study found that gold is a less expensive hedge than oil (Robiyanto et al., 2020). In addition, previous studies investigated the hedge effectiveness of gold and the dynamic correlations between digital currencies, oil, gold, credit default swap, and VIX using GO-GARCH, ADCC, and DCC models (Fakhfekh et al., 2023; Hachicha et al., 2022). The results show that gold and bitcoin are exceptional commodities for hedging, whereas the other assets seem to have a noticeable tendency to function as diversifiers.

Another frequently used method to measure the hedge effectiveness of gold against the stock market risk is the quantile regression of Koenker and Hallock (2001). Robiyanto (2018b) used the quantile regression and found that gold is a haven asset for Islamic stocks in Indonesia. In addition, the ability to hedge is limited if the gold market is bearish (Bouri et al., 2022).

Investors invest over varying time horizons in the financial markets. If investors want to view the monthly scale of expected market volatility, applying the GARCH models to monthly data is one approach to solve this issue. However, the data gets smoothed, and volatility gets less visible. A wavelet method addresses this issue (Kumar et al., 2017). Previous studies that used the wavelet analysis found that Bitcoin offers somewhat greater diversification prospects than gold in times of crisis (Bhuiyan et al., 2023; Bouri et al., 2020). In the near and medium term, gold and silver are excellent investments to hedge against geopolitical risk (Cheng et al., 2022). Ratner and Chiu (2013) proposed a multivariate GARCH-based quantile regression to evaluate the hedge property of credit default swaps. Unfortunately, this strategy does not allow us to gather information across different frequencies. Therefore, Kumar and Padakandla (2022) created a wavelet quintile correlation method (WQC) to solve the issue. Kumar and Padakandla (2022) tested the safe-haven status of gold and Bitcoin on six developed stock markets. They found that gold outperforms bitcoin as a haven asset over varying time horizons.

Based on the explanations above, we can infer that gold is a haven asset against the risk of developed stock markets over varying time horizons. However, the safe-haven status of gold against the risk of emerging stock markets over varying time horizons remains to be seen. Therefore, in this paper, we hypothesize:

H1: Gold is a haven asset over varying time horizons in the developed and emerging markets.

3. Methods

This study follows Nugroho and Kusumawardhani (2023) and uses exchange-traded funds (ETFs), namely SPDR S&P Emerging Markets (EDIV), SPDR Gold (GLD), and iShares MSCI World (URTH). ETFs are chosen because they allow investors to buy a diversified portfolio of equities and bonds at a lower cost (with lower fees). EDIV aims to offer a portfolio of 100 high-yielding common stocks from emerging markets, using a risk-adjusted yield ranking system and filtering for positive earnings-per-share and steady 3-year dividend growth. In addition, the URTH fund

consists of a broad range of stocks from developed markets worldwide. GLD provides investors with a cutting-edge, reasonably priced, and safe way to enter the gold market.

All prices were denominated in US dollars. We employ daily log returns. The daily data covers the sample from January 13, 2012, to December 29, 2023. The data are restricted by the availability of the aligned prices (the URTH ETF launch date was January 10, 2012). The data can be obtained from <https://www.tiingo.com/>. Moreover, we divide the data into two parts: the whole sample period and during COVID-19 and the Russian invasion of Ukraine.

This study follows Kumar and Padakandla (2022) and computes the WQC in the following manners. The Quantile Correlation (QC) between two variables \hat{X} and \hat{Y} is (Li et al., 2015): Suppose $\hat{Q}_{\tau, \hat{X}}$ be the τ^{th} quantile of \hat{X} and $\hat{Q}_{\tau, \hat{Y}}(\hat{X})$ be the τ^{th} quantile of \hat{Y} conditional upon \hat{X} . $\hat{Q}_{\tau, \hat{Y}}(\hat{X})$ is independent of \hat{X} if and only if the random variables $I(\hat{Y} - \hat{Q}_{\tau, \hat{Y}}) > 0$ and \hat{X} is independent. $I(\cdot)$ is the indicator function. For $0 < \tau < 1$, the quantile covariance is:

$$qcov_{\tau}(\hat{Y}, \hat{X}) = cov\{I(\hat{Y} - \hat{Q}_{\tau, \hat{Y}} > 0), x\} = E(\varphi_{\tau}(\hat{Y} - \hat{Q}_{\tau, \hat{Y}})(\hat{X} - E(\hat{X}))) \quad (1)$$

$\varphi_{\tau}(\hat{w}) = \tau - I(\hat{w} < 0)$. We calculate QC as:

$$qcor_{\tau}(\hat{X}, \hat{Y}) = \frac{qcov_{\tau}(\hat{Y}, \hat{X})}{\sqrt{(var(\theta_{\tau}(\hat{Y} - Q_{\tau, \hat{Y}}))var(\hat{X}))}} \quad (2)$$

Using the QC, we can obtain the correlation between asset pairs across various quantiles. In extreme circumstances, an asset with haven characteristics should negatively correlate with another asset, which QC will detect in the lower quantiles. But this addresses a portion of the issue. We assume that investors have varying preferences over various time horizons when choosing a safe-haven asset. We can determine these dynamics by examining the dependence structure across several timescales. For this reason, *wavelet quantile correlation* (WQC) is used.

First, we use a *maximum overlapping discrete wavelet transform* (MODWT), as suggested by Percival and Walden (2000), to decompose the asset pairs, \hat{X}_t and \hat{Y}_t . We go over MODWT in brief below.

Let $\hat{X}[i]$ be a signal of length T , such that $T=2^J$ for some integer J . Let an orthogonal wavelet define the low-pass and high-pass filters, $\hat{h}_1[i]$ and $\hat{g}_1[i]$, respectively. To produce the approximation coefficients $\hat{a}_1[i]$ and the detail coefficients $\hat{d}_1[i]$, $\hat{X}[i]$ is convolved with $\hat{h}_1[i]$ at the first level and with $\hat{g}_1[i]$ at the second. Here, the lengths of $\hat{a}_1[i]$ and $\hat{d}_1[i]$ are N .

$$\hat{a}_1[i] = \hat{h}_1[i] * s[i] = \sum_k \hat{h}_1[i - k]s[k]$$

$$\hat{d}_1[i] = \hat{g}_1[i] * s[i] = \sum_k \hat{g}_1[i - k]s[k]$$

After that, we apply the same strategy to filter $\hat{a}_1[i]$, but we use modified filters $\hat{h}_2[i]$ and $\hat{g}_2[i]$, which we got by dyadic up-sampling $\hat{h}_1[i]$ and $\hat{g}_1[i]$. We carry on recursively. For $J = 1, 2, \dots, J_0 - 1$, where $J_0 \leq J$, the approximation and comprehensive coefficients can be computed as follows:

$$\hat{a}_{j+1}[i] = \hat{h}_{j+1}[i] * \hat{a}_j[i] = \sum_k \hat{h}_{j+1}[i - k]\hat{a}_j[i]$$

$$\hat{d}_{j+1}[i] = \hat{g}_{j+1}[i] * \hat{a}_j[i] = \sum_k \hat{g}_{j+1}[i - k]\hat{a}_j[j]$$

$\hat{h}_{j+1}[i] = \hat{U}(\hat{h}_j[i])$ and $\hat{g}_{j+1}[i] = \hat{U}(\hat{g}_j[i])$. \hat{U} is the up-sampling operator. After applying a J -level decomposition to \hat{X}_t and \hat{Y}_t and getting the coefficients, we define the WQC as follows:

$$WQC_{\tau}(\hat{a}_j|\hat{X}|, \hat{a}_j|\hat{Y}|) = \frac{qcov_{\tau}(\hat{a}_j|\hat{X}|, \hat{a}_j|\hat{Y}|)}{\sqrt{\text{var}\left(\theta_{\tau}(\hat{a}_j|\hat{Y}| - Q_{\tau, \hat{a}_j|\hat{Y}|})\right)\text{var}(\hat{a}_j|\hat{X}|)}}$$

4. Results and Discussion

Descriptive Statistics

Table 1 reveals the basic statistics of the sample. Kurtosis values are more significant than 3, showing a leptokurtic distribution. As expected, the daily returns of stock markets are more volatile than gold, according to the Standard Deviation. In addition, gold has a lower correlation with developed stock markets.

Table 1.

Descriptive Statistics

	Mean (%)	Kurtosis	Standard Deviation (%)	Max (%)	Min (%)	Skewness
Gold	0.005	5.969	0.943	4.795	-9.190	-0.491
Developed markets	0.040	14.271	1.100	8.706	-12.078	-0.838
Emerging markets	0.003	10.944	1.177	7.668	-12.362	-1.015

source: data has processed (2024)

Wavelet Quintile Correlation

When there is market instability, an asset with safe-haven characteristics should negatively correlate with other assets, which is evident at lower quantiles. For Gold/Developed markets using whole sample **Fig. 1**, the correlation is negative in the lower quantiles (4-8, 128-256, and 256-512 days), showing haven status. Moreover, the correlation is negative in the median quantile for 128-256 days, reporting hedge status, and the correlation is positive and minimal in trading days below 128 days, showing diversifier status. For Gold/Developed markets during COVID-19 **Fig. 2**, the correlation is negative in the lower quantiles (256-512 days), showing haven status. Moreover, the correlation is positive in the median quantiles across all the timescales, showing diversifier status.

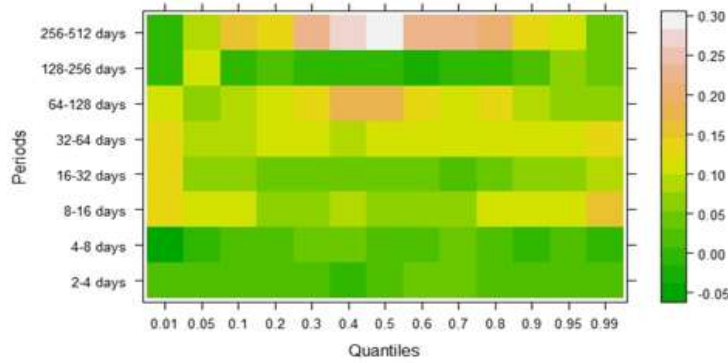


Figure 1.
Wavelet Quartile Correlation. Gold/Developed Stock Markets (whole-sample)

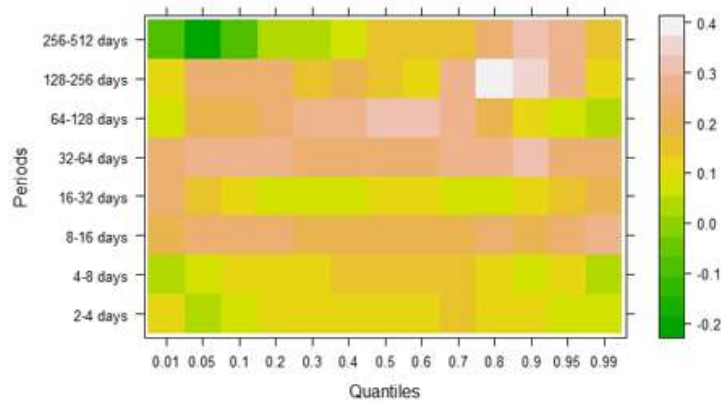


Figure 2
Wavelet Quartile Correlation. Gold/Developed Stock Markets (COVID-19-Russia/Ukraina Conflict)

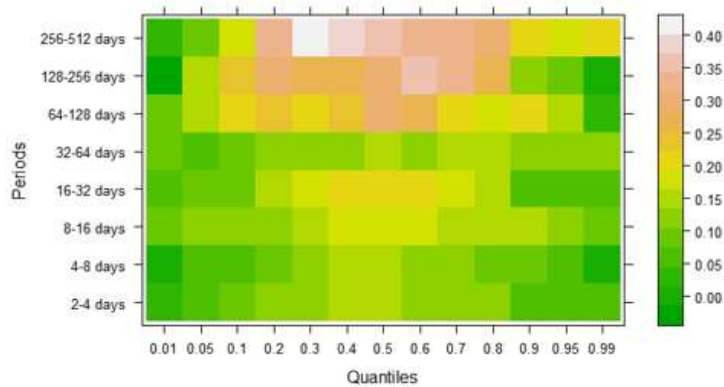


Figure 3
Wavelet Quartile Correlation. Gold/Emerging Stock-Market (whole-sample)

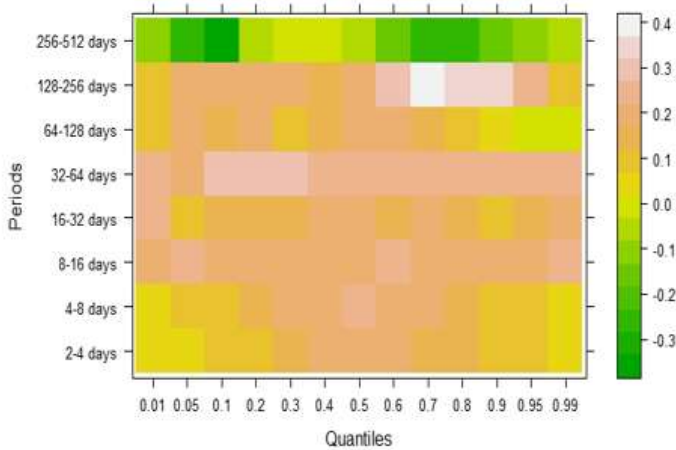


Figure 4.
Wavelet Quartile Correlation. Gold/Emerging Stock-Market (COVID-19-Russia/Ukraina Conflict)

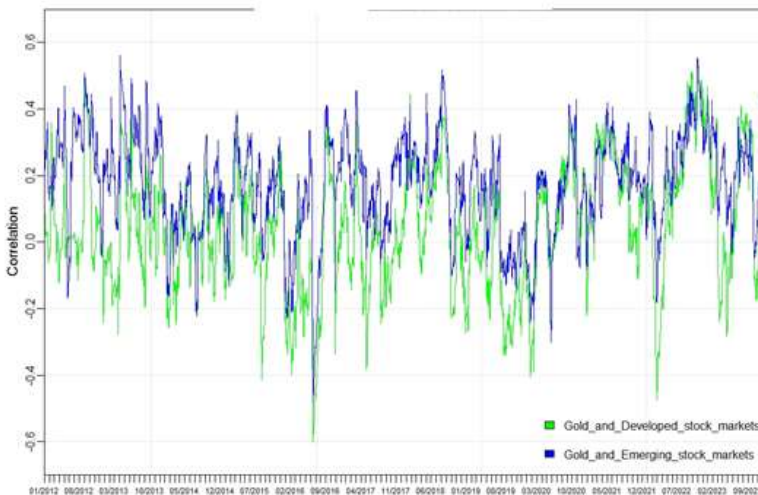


Figure 5.
Dynamic correlation -Gold/Stock Markets

For Gold/Emerging Markets using whole sample Fig. 3, the correlation is negative in the lower quantile (256-512 days), showing haven status. Moreover, the correlation is positive in the median quantiles across all the timescales, showing diversifier status. For Gold/Emerging markets during COVID-19 Fig. 4, the correlation is negative in the lower and median quantiles (256-512 days), showing haven and hedge status. This study hypothesizes that gold is a haven asset in developed and emerging markets over varying time horizons. The findings from Figures 1 to 4 indicate that our hypothesis is not rejected.

As a robustness check, we re-test the findings using dynamic correlation from DCC-GARCH (Engle, 2002). Figure 5 shows that the correlations change with time. In addition, the average dynamic correlation between gold and stocks was negative during the COVID-19 period, suggesting that gold serves as a haven asset for stocks.

Table 2.*Simulation of Gold-Stock Proportions (%) in Developed Markets*

Rebalancing period = days																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.55	0.55	0.55	0.56	0.57	0.59	0.61	0.63	0.66	0.69	0.72	0.76	0.80	0.83
Sortino	0.86	1.14	1.45	1.78	2.12	2.47	2.82	3.16	3.48	3.77	4.02	4.22	4.39	4.51	4.60	4.65	4.68	4.69	4.69	4.67	4.65
Rebalancing period = weeks																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.55	0.55	0.55	0.56	0.57	0.58	0.61	0.63	0.66	0.69	0.72	0.76	0.80	0.83
Sortino	0.84	1.11	1.41	1.73	2.06	2.40	2.74	3.08	3.39	3.68	3.93	4.14	4.30	4.43	4.53	4.59	4.63	4.66	4.66	4.66	4.65
Rebalancing period = months																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.55	0.54	0.55	0.55	0.56	0.58	0.60	0.63	0.65	0.69	0.72	0.76	0.80	0.84
Sortino	0.91	1.17	1.46	1.76	2.09	2.42	2.75	3.08	3.39	3.66	3.91	4.11	4.27	4.39	4.48	4.54	4.58	4.59	4.59	4.58	4.57
Rebalancing period = quarters																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.55	0.54	0.55	0.55	0.56	0.58	0.60	0.63	0.65	0.69	0.72	0.76	0.80	0.84
Sortino	1.15	1.41	1.69	1.98	2.30	2.62	2.93	3.24	3.53	3.79	4.01	4.20	4.34	4.44	4.51	4.55	4.56	4.56	4.55	4.52	4.49
Rebalancing period = years																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.63	0.61	0.58	0.56	0.54	0.53	0.52	0.51	0.50	0.51	0.52	0.53	0.55	0.57	0.60	0.63	0.66	0.70	0.74	0.78	0.82
Sortino	3.18	3.39	3.60	3.82	4.05	4.26	4.45	4.62	4.76	4.85	4.90	4.91	4.88	4.82	4.74	4.64	4.53	4.43	4.32	4.21	4.12

Table 3.
Simulation of Gold-Stock Proportions (%) in Emerging Markets

Rebalancing period = days																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.89	0.85	0.81	0.78	0.74	0.71	0.68	0.66	0.63	0.62	0.60	0.59	0.58	0.58	0.58	0.59	0.60	0.62	0.64	0.66	0.69
Sortino	0.34	0.37	0.40	0.44	0.48	0.52	0.56	0.61	0.65	0.70	0.74	0.78	0.81	0.84	0.86	0.87	0.88	0.88	0.88	0.87	0.86
Rebalancing period = weeks																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.89	0.85	0.81	0.78	0.74	0.71	0.68	0.66	0.63	0.61	0.60	0.59	0.58	0.58	0.58	0.59	0.60	0.62	0.64	0.66	0.69
Sortino	0.31	0.34	0.36	0.39	0.42	0.45	0.49	0.53	0.57	0.61	0.65	0.69	0.72	0.76	0.78	0.80	0.82	0.83	0.84	0.84	0.84
Rebalancing period = months																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.89	0.85	0.81	0.77	0.74	0.71	0.68	0.65	0.63	0.61	0.60	0.59	0.58	0.58	0.58	0.59	0.60	0.62	0.64	0.66	0.69
Sortino	0.39	0.41	0.44	0.46	0.49	0.53	0.56	0.60	0.64	0.68	0.72	0.76	0.79	0.82	0.85	0.87	0.89	0.90	0.90	0.91	0.91
Rebalancing period = quarters																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.89	0.85	0.81	0.77	0.74	0.70	0.67	0.65	0.62	0.61	0.59	0.58	0.58	0.58	0.58	0.59	0.60	0.62	0.64	0.67	0.69
Sortino	0.55	0.58	0.61	0.65	0.69	0.73	0.78	0.82	0.87	0.92	0.97	1.02	1.05	1.09	1.11	1.13	1.15	1.15	1.15	1.15	1.15
Rebalancing period = years																					
Stocks	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0
Gold	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Volatility	0.90	0.85	0.81	0.77	0.73	0.69	0.66	0.63	0.61	0.59	0.57	0.56	0.54	0.55	0.55	0.55	0.56	0.57	0.59	0.61	0.63
Sortino	1.01	1.10	1.20	1.31	1.44	1.58	1.73	1.88	2.05	2.22	2.38	2.55	2.69	2.83	2.94	3.03	3.09	3.14	3.17	3.18	3.18

Gold demonstrates haven characteristics in both the short and long term. However, gold only shows haven attributes over the long term during the COVID-19 and the Russian invasion of Ukraine. These findings indicate that the haven attribute of gold is dynamic. Gold and stock correlations, both short- and long-term, change with time. These results support the findings from previous studies (Akhtaruzzaman et al., 2021; Syuhada et al., 2022).

Another intriguing discovery indicates that the pandemic negatively impacts both the long-term and short-term stock-gold relationship. One of the possible reasons is that the citizens of emerging countries are experiencing a health crisis due to COVID-19, and these developing nations' rates of COVID-19 vaccination are lower than those of the developed nations (Chu et al., 2022).

Practical Implications

The next discussion is about the determination of gold-stock weights for a practical purpose. **Table 2** shows the simulation of gold-stock weights for developed markets. Constant weight strategy is used to create a portfolio consisting of gold and stocks. The graph shows that the yearly rebalancing period is the optimal one since the Sortino ratio is higher. A higher Sortino ratio means higher portfolio performance. The graph also indicates that there is an inverse relationship between the Sortino ratio and downside volatility. In other words, the diversification is not a free lunch. The risk reduction is accompanied by a reduction in returns. Focusing on yearly rebalancing and downside volatility, the optimal gold-stock proportion for risk reduction is 40% gold and 60% stocks in developed markets. Similarly, Table 3 shows the simulation of gold-stock weights for emerging markets. The graph shows that the yearly rebalancing period is the optimal one since the Sortino ratio is higher. The graph also illustrates that there is an inverse relationship between the Sortino ratio and downside volatility. Focusing on yearly rebalancing and down-side volatility, the optimal gold-stock proportion for risk reduction is 60% gold and 40% stocks in emerging markets.

5. Conclusion

Using the recently created Wavelet Quantile Correlation, this study evaluates gold's attractiveness as a safe-haven asset. Our findings demonstrate that during the epidemic, gold continuously demonstrates both short- and long-term haven status for emerging markets. However, gold only showed long-term safe-haven status during the outbreak for the developed markets. One of the potential causes could be the COVID-19 health crisis emerging nations' citizens are going through, as well as the fact that immunization rates for the virus are lower in these countries than in developed ones.

Investors can use the rich economic implications of this paper's results to guide their portfolio allocation decisions. For instance, investors with different time horizons typically worry about the features of asset returns in their respective periods. Quantifying the time-frequency linkages of stock and gold returns becomes increasingly important for asset allocation. The limitation of this study is that the Wavelet Quantile Correlation does not take into account regime changes in the economy. Hence, future studies will focus on building a gold-stock portfolio considering transaction costs and regime changes.

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Availability of data and materials

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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