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# Bitcoin and Gold in Data-Driven Financial Risk Modelling: A Time-Varying Analytics Framework for Dual Financial Markets

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## Abstract

This study examines the time-varying relationships and hedging properties of Bitcoin and gold with respect to Pakistani Islamic and conventional equity markets, the exchange rate, and inflation under conditions of economic turbulence. Using daily data from August 1, 2010, to March 1, 2024, the study employs a data-driven Dynamic Conditional Correlation GARCH (DCC-GARCH) framework combined with an extreme quantile approach to conduct the empirical analysis. The results show that gold serves as a strong hedge against both conventional and Islamic stocks, as well as against exchange rate and inflation. Moreover, gold has strong protective ability against declines in conventional stocks, exchange rate risk, and high inflation risk. Further, Bitcoin is found to act not only as a hedge against conventional stocks but also as a diversifier for the Islamic stock index. However, it fails to play a safe-haven role against both stock markets and inflation risk in turbulent conditions.

These findings offer valuable insights for portfolio managers, policymakers, and investors seeking to enhance portfolio risk management during periods of economic uncertainty and market turbulence.

**Keywords:** Bitcoin Returns, Gold Returns, Data-Driven Approach, Islamic Stocks, Consumer Price Index

## Introduction

Due to globalization and the development of financial markets worldwide, on the one hand, investors can easily invest their surplus funds, but on the other hand, uncertainty exacerbates investors' fear of loss. Usually, investors incur losses when financial markets experience extreme and unfavorable movements. The Asian currency crises of 1997, the global financial crisis of 2008, and the recent COVID-19 pandemic left investors with huge losses (Tarchella et al., 2024). Due to the integrated financial market, some events create anxiety across countries, industries, and alternative asset classes, which motivate investors to search for assets that don't move in tandem with the shaking conditions of financial markets and sustain their value in times of extremely unfavorable conditions (Terraza et al., 2024). Historically, people have recognized gold as a currency and considered it a safe-haven asset in case of global uncertainty and bearish market conditions. Similarly, Bitcoin presents a unique alternative in the financial landscape. Its cryptographic foundation and decentralized nature suggest potential advantages in terms of independence from traditional financial systems. In the past few years, its value has massively increased and is considered digital gold (Popper, 2015). Therefore, it is crucial to examine the hedging and diversification properties of gold and Bitcoin. This study analyzes whether these two assets can be used as safe havens in case of bearish stock market conditions, currency depreciation, and high inflation rates in the context of Pakistan.

An asset is considered a hedging asset if it is negatively correlated or uncorrelated with other assets under normal market conditions, while it qualifies as a haven if this negative correlation or no correlation persists during periods of economic stress (Baur & Lucey, 2010; Kliber et al., 2019). Diversification is a strategy of investing in imperfectly correlated assets to reduce volatility without sacrificing expected returns (Reinholtz et al., 2021). Investors prefer hedging and safe-haven investments to manage risk and protect their investments against market volatility, inflation, and economic instability. Hedging strategies, such as using derivatives, are designed to offset risks, particularly those arising from market volatility, currency fluctuations, or commodity price changes. On the other hand, investors shift their investment to safe-haven assets such as gold, U.S. Treasury bonds, or the Swiss franc, which tend to retain or even increase in value during times of economic uncertainty, financial crises, or geopolitical tensions. Investors seek these assets to preserve capital and reduce exposure to

risk. During periods of high volatility, investors prefer hedging and safe havens as they offer protection against sudden market declines (Jana & Sahu, 2023a).

With the rising popularity of cryptocurrencies, investors tend to consider cryptocurrencies in their investment portfolios to effectively manage their risk. Therefore, numerous recent studies examined the role of cryptocurrencies in mitigating stock market risk and their empirical relationship with traditional assets (see, for example, Jana et al., 2024; Jiang et al., 2021; Kumah & Odei-Mensah, 2021; Uzonwanne, 2021). Some studies (see, for example, Bandhu Majumder, 2022; Wang et al., 2019) consider cryptocurrencies as safe-haven assets due to their potential negative or zero correlation with stock returns during economic uncertainty. Similarly, Gil-Alana et al. (2020) argued that cryptocurrencies can play a key role in diversifying investors' portfolios, as there is no cointegration between stock returns and cryptocurrency returns. On the other hand, Goodell and Goutte (2021) and Jiang et al. (2021) concluded that cryptocurrency has positive co-movements with the equity market; therefore, it cannot give any diversification benefit during normal or downturns.

Historically, gold and some other precious metals have been considered the most notable and effective investments against stock market returns in various emerging and developed markets (Ranaldo & Söderlind, 2010; Wen & Cheng, 2018). Evidence suggests that gold can shield an investor's wealth from extreme stock market falls during turbulent times (Baur & Lucey, 2010). Gold's ability as a haven is also examined by Baur and Glover (2012) and Bekiros et al. (2017) in the post-global financial crisis of 2007–2008. On the other hand, Bitcoin, a digital financial asset based on cryptography, is not only different from the rest of traditional currencies, but also unique in that it has no physical representation. Its value is based on a blockchain algorithm; therefore, it is independent of the control of any country or central authority. In fact, the design of Bitcoin as a medium of exchange draws its appeal from its independence from government control, its lowest transaction costs, and its highly secure peer-to-peer blockchain technology. Examining Bitcoin volatility reveals it to be more volatile than gold and other currencies. Researchers investigated the properties of Bitcoin as a hedge against the US dollar and the UK equity market, demonstrating its hedging ability (Dyhrberg, 2016). However, Shahzad et al. (2019) proposed that the role of Bitcoin is time-varying and differs across the different markets, and they also indicated that it has some safe-haven properties. Furthermore, gold's prominent role as one of the strongest safe-haven assets has been confirmed by numerous studies for developed stock markets (see Ali et al., 2020; Hussain Shahzad et al., 2017).

According to Markowitz's (1952) portfolio theory, investors can minimize overall risk by diversifying their investments across assets with uncorrelated returns. A key component of this diversification approach is to choose different stocks or physical assets for investment whose returns are not highly correlated. Therefore, argue that using safe-haven assets, like gold and potentially Bitcoin, can play a vital role in this strategy by providing stability and

protecting wealth in unfavorable market conditions. According to prospect theory, pioneered by Kahneman and Tversky (1979) investors behave risk-averse while their investments are doing well, but seek out opportunities when they are losing money. According to this hypothesis, investors would prefer to invest in safe-haven assets during market downturns to reduce their possible losses.

The primary rationale behind conducting this study stems from the increasing integration and volatility of global financial markets. Economic turbulence, triggered by events such as the Asian financial crisis of 1997, the global financial crisis of 2008, and the COVID-19 pandemic, has intensified investor fears of loss. In this volatile financial landscape, investors seek assets that can protect their wealth during downturns, referred to as safe-haven assets. Gold has historically been seen as a traditional safe-haven asset, while Bitcoin, as a digital currency, has emerged as a potential alternative due to its decentralized nature and independence from traditional financial systems. However, existing studies primarily focus on developed markets, with limited exploration of the roles of gold and Bitcoin as safe-haven assets in emerging markets such as Pakistan, especially with respect to both conventional and Islamic stock markets. This study aims to fill this gap by examining the effectiveness of gold and Bitcoin in hedging and protecting against stock market declines, exchange rate volatility, and inflation risks in the Pakistani context. The rationale also extends to addressing the lack of research comparing the performance of these assets during both normal and extreme market conditions.

This study contributes to the literature in several ways. First of all, this study sheds light on investment strategies and decisions in emerging markets, particularly in Pakistan, where both conventional and Islamic stock markets exist at the same time. The findings offer critical insights for investors looking to diversify their portfolios and protect against adverse market movements. It provides valuable information to policymakers and investors about the role of safe-haven assets in stabilizing financial systems during economic turmoil. Secondly, the existing literature has predominantly focused on developed economies, leaving a gap in understanding how gold and Bitcoin function as hedges and safe havens in emerging markets with unique financial dynamics. In particular, Pakistan, which faces distinct economic challenges such as currency depreciation and high inflation, demands tailored research to provide actionable insights for investors, policymakers, and portfolio managers. Moreover, Islamic finance has grown significantly in recent years, yet there is insufficient research on how digital assets like Bitcoin and traditional assets like gold perform in Islamic stock markets. As Islamic finance operates under different principles than conventional finance, it is crucial to understand the dynamics of asset performance in these two different markets. As a result, this study provides empirical evidence on the hedging and safe-haven roles of gold and Bitcoin in Pakistan's conventional and Islamic stock markets.

This study employs the DCC-GARCH model proposed by Engle (2002) and the extreme quantile approach developed by Baur and Lucey (2010) and Baur and McDermott (2010) to examine the hedging and safe-haven properties of Bitcoin and gold. The DCC-GARCH model is used to assess the presence of time-varying correlations among the variables. Following the methodology of Baur and McDermott (2010), the returns of Bitcoin and gold, along with those of the other variables under investigation, are analyzed to determine whether Bitcoin and gold serve as hedges and safe-haven assets against fluctuations in conventional and Islamic stock markets, the exchange rate, and inflation under both normal and extreme market conditions. An extreme quantile of the return distribution is created to assess the role of Bitcoin and gold as hedges or safe havens in average conditions and times of crisis.

The coming section of the paper is organized as follows: Section 2 shows a comprehensive review of past literature. Section 3 shows the methodology part, which consists of the data, its source, and the econometric model; Section 4 includes the application of the econometric model and its interpretation and explains the econometric results; and Section 5 ends with the conclusion and implications of this study.

## Literature Review

After the global financial crisis of 2007, the discussion of hedging and safe havens became an interesting topic for researchers, investors, and policymakers. The role of gold as a safe-haven asset was first investigated by Baur and Lucey (2010). They identified that gold is an asset that has protective properties against unfavorable movement in major US and European equity markets, but failed in the case of Australia, Canada, and BRIC markets. According to Baur and McDermott (2010), the asset may be considered a safe-haven asset if it has a negative or zero correlation to other assets in extreme market conditions. As explained by several studies (see Ciner et al., 2013; Flavin et al., 2014; Gürgün & Ünalmış, 2014), a safe-haven asset minimizes an investor's portfolio risk and offsets the risk of losses with the specific asset's returns in times of extreme market conditions. The condition of the market depends on various data-driven factors, such as information and changes in key economic factors.

Fama (1970) anticipated that the arrival of new information into the market would create movements in stock prices. According to Fraser and Power (1997), new information about any stock creates volatility in the equity market. They argued that good news is associated with favorable movements in stock prices, while bad news drags the stock market into a panic condition (Frank & Sanati, 2018). It is also observed that announcements can create a positive or adverse reaction in the equity market. Choi and Hammoudeh (2010) investigated the relationship between stock market volatility and the uncertain behavior of macroeconomic factors using data-driven econometric models such as GARCH and VAR models. They conclude that inflation and export volume have a significant relationship with stock return

volatility. As per the findings of (Bredin et al., 2015), gold has historically served as a refuge from the volatility of the US stock market in numerous financial crises. However, it did not exhibit this role during the economic downturns of the early 1980s. It is also observed that volatility spreads to the next period (Ahmad & Ramzan, 2016). Volatility is observed more in emerging economies than in developed markets, based on data-driven empirical evidence. In an examination of the capital market, Qadan and Yagil (2012) found that investor fear sentiments affect the gold volatility index. Gulko (2002) expressed the movement as a flight to quality when investors shift their capital from stock to bonds as the market faces extreme conditions in aggregate. Similarly, Beber et al., (2009) highlighted the "flight to quality and flight to liquidity concepts that investors search for liquid assets in times of stress. Baur and McDermott (2010) examined the properties of gold in the case of high volatility and adverse movement in the equity market. They observed that gold can protect the investor's wealth during the extreme movements in the equity market. They conclude that investors can include gold as a safe-haven in their portfolio to protect their investment in times of extreme equity market conditions.

Similarly, Hood and Malik (2013) examined the hedging and safe-haven attributes of gold, platinum, and silver with the volatility index for the period from November 1995 to November 2010 using data-driven econometric analysis of financial market volatility. Their result indicates that gold serves as a hedge for the U.S. stock market; however, its status as a safe-haven is relatively subdued compared to the volatility index. Iqbal (2017) adopted the data-driven EGARCH model to analyze the hedging potential of gold against the unfavorable movement of stock prices, the exchange rate, and the inflation rate for India, Pakistan, and the US. The finding indicated that gold acts as a safe-haven against extreme movements in the exchange rates of India and Pakistan, but failed to play this role for stock markets. It also found that gold only hedges the risk of inflation in the United States. Chang et al. (2020) examined the hedge and safe-haven potential of gold against the risk of falling stock returns, the exchange rate, and oil prices in Pakistan using the least squares approach during normal and stressful situations. They concluded that gold can be used as a hedging asset in normal and extreme conditions of the stock market.

In a similar vein, Ghazali et al. (2015) investigated the hedge and safe-haven characteristics of Sharia-compliant gold in Malaysia, analyzing both constant and time-varying relations between domestic stock and gold returns. Results indicate that the official gold standard of Malaysia serves as a strong hedge relative to Islamic gold accounts. Despite gold's potential for portfolio diversification, it remains a risky investment, with the official gold investment performing better due to its compensating properties of a strong hedge and safe-haven in extreme market conditions. Factors such as economies of scale and common currency denomination between gold and stock indices influence gold's performance as a safe-haven. In another study, Ghazali et al. (2022) explored gold's function as a hedge or safe-haven asset against inflation, employing quantile and TGARCH Specifications. The findings

suggest that gold serves as a strong hedge in the US and China, yet its efficacy varies across periods and countries. Notably, gold retains its safe-haven status in China but plays a lesser role in the UK and India. These insights emphasize the importance of considering country-specific factors in portfolio management strategies.

Although gold and Bitcoin have several common properties, they are still different from each other in various ways, such as tangibility, consumption, and use in various production processes. The Commodity Futures Trading Commission has recently classified and regulated Bitcoin as a commodity like gold. Baur et al. (2018) argued that Bitcoin has some unique properties like being independent of any government control, having no political affiliation, and using blockchain technology, which makes it similar to gold. Like gold, it does not generate cash flow and can be created through the process of "mining." The Bitcoin supply is limited to 21 million coins due to its dictated protocol. An inverted asymmetric reaction has been observed due to positive and negative news in both Bitcoin (Baur & Glover, 2012) and gold (Bouri et al., 2017).

Limited studies have examined the relationship among Bitcoin, gold, and other commodities. A generalized variance model is applied to investigate the connectedness between the high volume of digital assets and other financial products such as developed commodity indexes, leading exchange rates like the USD, and developed equity markets such as the S&P 500 index. Limited literature has identified that cryptocurrencies provide diversification advantages to investors (see, for example, Al-Khazali et al., 2018; Bouoiyour & Selmi, 2015; Dyhrberg, 2016). Bouri et al. (2020) use a wavelet coherency approach to study the relationship of Bitcoin, gold, and commodity indices against the world's leading equity market indices for the period from July 20, 2010, to February 22, 2018. It is observed that Bitcoin has superiority over both commodities and gold. Similarly, Al Mamun et al. (2020) analyze the relationship between Bitcoin, the US dollar, US stocks, US bonds, and gold futures during geopolitical risk and market uncertainty. They found that gold serves as a hedge for Bitcoin, and interestingly, they show a positive relationship during rising economic unfavorable situations and uncertainty. Akhtaruzzaman et al. (2021) conducted an inquiry into the function of gold as a safe-haven amidst the COVID-19 crisis. The investigation reveals that gold exhibited a strong safe-haven role during Phase I (before March 16, 2020). However, gold lost its safe-haven attributes during Phase II, which started on March 17, 2020. Furthermore, a recent study investigates diversification opportunities for Australian investors, examining assets like Bitcoin, gold, and stock indices using MGARCH-DCC and wavelet analysis techniques. Findings indicate Bitcoin's low correlation but high volatility, contrasting with gold's potential for diversification within short holding periods. Cointegration tests reveal enduring associations among Australian stock indices and other variables, suggesting potential erosion of diversification benefits over time. Notably, gold emerges as a leader over Bitcoin at higher scales, echoing its traditional role as an economic hedge. Analysis of the AUD/USD exchange rate underscores its stability and minimal correlation with Bitcoin,

offering diversification potential. Employing advanced methodologies is crucial for discerning effective portfolio diversification strategies in dynamic investment landscapes (Abdullah et al., 2022).

Jana and Sahu (2023b) analyses six major cryptocurrencies and four global stock markets to explore the role of cryptocurrencies as a hedge, safe-haven, and diversifier by employing ADCC-GARCH and Wavelet Coherence Technique, using daily data. They found that stock returns and unstable cryptocurrency returns have high volatility persistence in the long run. Further, they concluded that unstable digital currencies serve as a hedge during stable economic periods, but not during economic turmoil in the stock markets. Similarly, Maouchi et al. (2024) investigated the financial properties (diversification, safe-haven, and hedging capabilities) of two gold-backed cryptocurrencies against the three main digital asset categories, i.e., traditional cryptocurrencies, Non-Fungible Tokens (NFTs), and Decentralized Finance (DeFi) tokens, considering major external and internal crises. They concluded that gold-backed cryptocurrencies are good diversifiers, with varying hedging and safe-haven properties depending on the nature of the crises, such as the COVID-19 pandemic and the Russia–Ukraine War.

The review of the literature indicates a complex discussion over the effectiveness of gold as a market risk hedge. Although some research suggests that gold is a reliable safe-haven asset, other research emphasizes the importance of contextual circumstances, especially in a variety of markets. The differing results are a result of methodological differences, market dynamics, and economic situations. On the other hand, limited perspectives on Bitcoin's function as a market risk hedge may be found in the literature. Some analysis indicates its potential as an asset for diversification, while other studies emphasize the importance of considering its special qualities and market dynamics. Despite differing viewpoints, there is agreement over the ability of gold to reduce risk in investment portfolios and the dearth of literature on bitcoin as a hedge, for further research to clarify the characteristics of gold and complex properties of bitcoin hedging qualities and changing market dynamics in various circumstances.

## Methodology

### Data Specification

The current study has used data-driven, market-based monthly data on Bitcoin prices, gold prices, equity indexes, the exchange rate, and the consumer price index (CPI) for inflation in the context of Pakistan. Our sample covers the period of the most recent fourteen years, from August 1st, 2010, to March 1st, 2024. The conventional stock market, Islamic stock market, exchange rate, and inflation rate are represented by the KSE100 index, KMI30 index, PKR/USD, and CPI, respectively. The data for gold, Bitcoin, the exchange rate, and both

stock indices are taken from investing.com, while data on the consumer price index is collected from FAO. The data is compiled from multiple data-driven financial market databases, including investing.com and FAO, ensuring high-frequency market consistency and reliability of empirical analysis. The gold and Bitcoin prices are multiplied by the respective monthly exchange rate of the Pakistani rupee per US dollar. After that, we have calculated the logarithmic return as:

$$R_{it} = Ln\left(\frac{P_t}{P_{t-1}}\right)$$

Where:

r = logarithmic return, $P_t$ = the price at time t, $P_{t-1}$ = the previous period's price, and ln = natural logarithm. Further detailed information is presented in Table 1.

**Table 1. Description of Variables, Measurement, and Data Sources**

| Var Name | Notation | Measurement | Source |
|---|---|---|---|
| Bitcoin | Btc | Price of 1 Bitcoin in PKR. | investing.com |
| Gold | Gold | Price of 1 Troy Ounce of gold in PKR. 1 Troy = 31.1 gm | investing.com |
| Conventional Stocks | KSE100 | Pakistan Stock Market | investing.com |
| Islamic Stocks | KMI30 | Karachi Meezan Stock Market | investing.com |
| Ex Rate | ExR | Ratio of USD to PKR | investing.com |
| CPI-Pak | CPI | Consumer Price Index | fao.org |

The price of Bitcoin and its volume have been increasing rapidly from zero since its inception. The price of Bitcoin was approximately 2,500 PKR at the midpoint of the year 2011 and rose to as high as 106,000 PKR at the end of the year 2016, and now, in the year 2024, the price of one Bitcoin reached an all-time high, i.e., 19935627 PKR.

In this study, two approaches have been applied to analyze the time-varying correlation and safe-haven properties of gold and Bitcoin. The first approach is DCC-GARCH, which examines the informational dependencies and time-varying correlations across financial assets that are important for developing a portfolio strategy. This approach examines the correlation between the prices of Bitcoin and gold and the indices under investigation over time. The second approach, the quantiles technique introduced by Baur and McDermott (2010) analyzed the adverse movements in the equity markets, exchange rate, and inflation rate.

## DCC-GARCH

Using the DCC-GARCH model introduced by Engle (2002), time-varying correlations are investigated throughout all return series with fewer computational complications. The DCC model is used to explicitly parameterize the conditional correlation and has the flexibility of a univariate GARCH model (Engle, 2002). Due to the obvious variety of return series, it is estimated for each pair of return series separately rather than all of them at once. Two steps

are involved in the estimation of the bivariate DCC model. A univariate GARCH (1, 1) model is estimated in the first stage. The standardized residuals from the first-stage estimation are used to calculate a time-varying correlation matrix in the second part. The DCC mean model is presented in Equation (1):

$$rt = \mu t + \omega rt\text{-}1 + \varepsilon t \quad (1)$$

where "rt" represents the vector of Bitcoin or gold return and the returns of other indices (conventional and Islamic stock indexes, exchange rate, and CPI); the conditional mean vector of "rt" is denoted with "μt," and εt is the residual term. The variance in GARCH (1,1) is specified as below in Equation (2):

$$ht = c + \alpha\, \varepsilon 2t\text{-}1 + bht\text{-}1 \quad (2)$$

The term ht represents the conditional variance; the term c denotes the constant of the equation, α ε2t-1 is an ARCH term that captures short-run and long-run persistence, while bht-1 represents the GARCH term. The DCC (1,1) equation is represented by the positive-definite matrix Qt, as specified in Equation (3):

$$Qt = (1 - \alpha - \beta)\, \bar{Q} + \beta Qt\text{-}1 + \alpha \varepsilon it\text{-}1 \varepsilon_{jt-1}' \quad (3)$$

In Equation (3), Qt is the N*N time-varying covariance matrix of $\varepsilon t\boldsymbol{\acute{\varepsilon}_t}$ represents a vector of standardized residuals obtained from the estimation of the GARCH (1, 1) process in the first step, where "$\bar{Q}$" is the unconditional correlation of "εiεj," and α and β are non-negative parameters. The purpose of the model is not only to generate the estimated values of DCC but also to generate the time-varying correlation points to plot and observe the correlation between the variables under investigation.

## GARCH

Baur and McDermott (2010) provide the solution by incorporating the EGARCH (1, 1) model to deal with the heteroscedasticity problem in the data. The GARCH model can handle the heteroscedasticity problem and normalize the residuals, considering the conditional variance in the model.

Following the Baur and Lucey, (2010) econometric modeling technique, the current investigation developed a regression model on the same pattern to analyze the properties of gold and Bitcoin as diversifiers, hedges, and safe havens against other assets and indexes. Considering all discussions, the econometric Equation (4) is modeled to test the properties of gold and Bitcoin as hedges and safe havens. It represents the relationship between gold or Bitcoin and the rest of the variables under examination.

$$R_{it} = \alpha + \beta_t rKSE100._t + \gamma_t rKMI30_t + \rho_t rExR_t + \phi_t rCPI_t + \epsilon t_r \quad (4)$$

$$\beta_t = b_1 + b_2\text{DKSE100}_{q10\%} + b_3\text{DKSE100}_{q7.5\%} + b_4\text{DKSE100}_{q5\%} \quad (4a)$$

$$\gamma_t = \text{c}_1 + \text{c}_2 DKMI30_{q10\%} + \text{c}_3\text{DKMI30}_{q7.5\%} + c_4\text{DKMI30}_{q5\%} \quad (4b)$$

$$\rho_t = \text{f}_1 + \text{f}_2\text{DExR}_{q90\%} + \text{f}_3\text{DExR}_{q92.5\%} + \text{f}_4\text{DExR}_{q95\%} \quad (4c)$$

$$\phi_t = m_1 + \text{m}_2\text{DCPI}_{q90\%} + \text{m}_3\text{DCPI}_{q92.5\%} + \text{m}_4\text{DCPI}_{q95\%} \quad (4d)$$

$$\text{ht} = \text{c} + \alpha\ \varepsilon 2\text{t-1} + \text{bht-1} \quad (4f)$$

In equation 4, "Rit" symbolizes the returns of the assets "i" at a time "t." Whereas rKSE100, rKMI30, rExR, and rCPI represent the returns of the conventional stock index, the Islamic stock index, the exchange rate, and the inflation rate, respectively. To test the diversifier, hedging, and safe-haven, quantiles have been created to capture asymmetric shocks. A dummy has been created with a value of "1" for both the conventional stock and Islamic stock index if the return is below the specified quantiles of 10%, 7.5%, and 5%, otherwise zero. Similarly, the upper quantile is created to capture the adverse movement in the exchange rate and inflation rate. If the exchange rate and inflation rate exceed the specified upper quantiles, i.e., 90%, 92.5%, and 95%, it will have the value "1"; otherwise, zero. The parameters b1 and c1 represent the coefficients for conventional and Islamic stocks, respectively. The coefficient with zero (negative) projects a weak (strong) hedge or else a diversifier for dependent variables, i.e., gold and Bitcoin. The parameters b2, b3, b4 and c2, c3, and c4 examine the safe-haven dynamics of gold/Bitcoin at extreme conditions. If the said parameters become negative (zero) depicts strong (weak) safe-haven properties of the assets under investigation.

Similarly, $f^1$ and $m^1$ are the parameters to test the properties of the hedge for exchange rate and inflation; if the coefficient becomes zero, representing a strong (weak) hedge. The parameters $f^2$, $f^3$, $f^4$, and $m^2$, $m^3$, and $m^4$ test the safe-haven behavior of assets gold and Bitcoin for the specified quantiles. The coefficient value of the exchange rate or the inflation is significantly associated with positive (zero) attributes, such as safe-haven behavior. Investors may add safe-haven assets, i.e., gold or Bitcoin, or both, to the portfolio as risk mitigation instruments in times of adverse conditions in the market. The joint effect of quantiles is estimated using the Wald test to study the safe-haven property of each variable under study. The "ht" term refers to the variance that depends upon the residual square and the variance of the previous period.

## Results and Discussion

Fig. 1 represents the volatility in the returns of Bitcoin and the rest of the explanatory variables. If we see the history, Bitcoin shows two major spicks in the years 2011 and 2014. On the other hand, conventional and Islamic stock volatility is quite similar to each other.

They show several volatility spikes through the sample periods, but one major spike in the year 2020, probably contributed by the COVID-19 pandemic. Similarly, the exchange rate also represents major spicks in the year 2022. Notably, these patterns are extracted through a data-driven volatility analysis based on historical return distributions. These observations reflect data-driven market behavior across time-varying financial series.

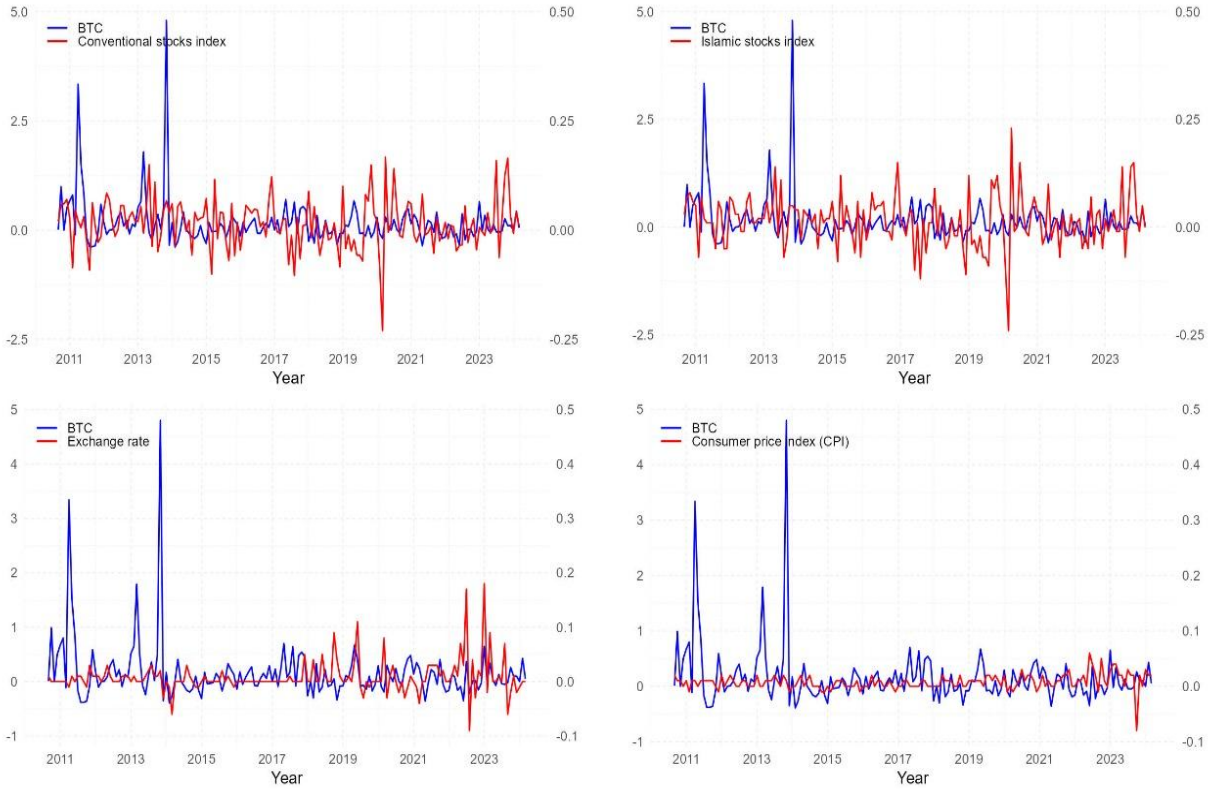


**Figure 1. Bitcoin Return Comparison with Other Indices**

On the other hand, Figure 2 represents an interesting movement of gold return volatility and other explanatory variables. If we see the overall volatility pattern, gold is more volatile in the year 2012 and at the end of 2022. These statistics are fully based on data-driven empirical estimation of market returns.

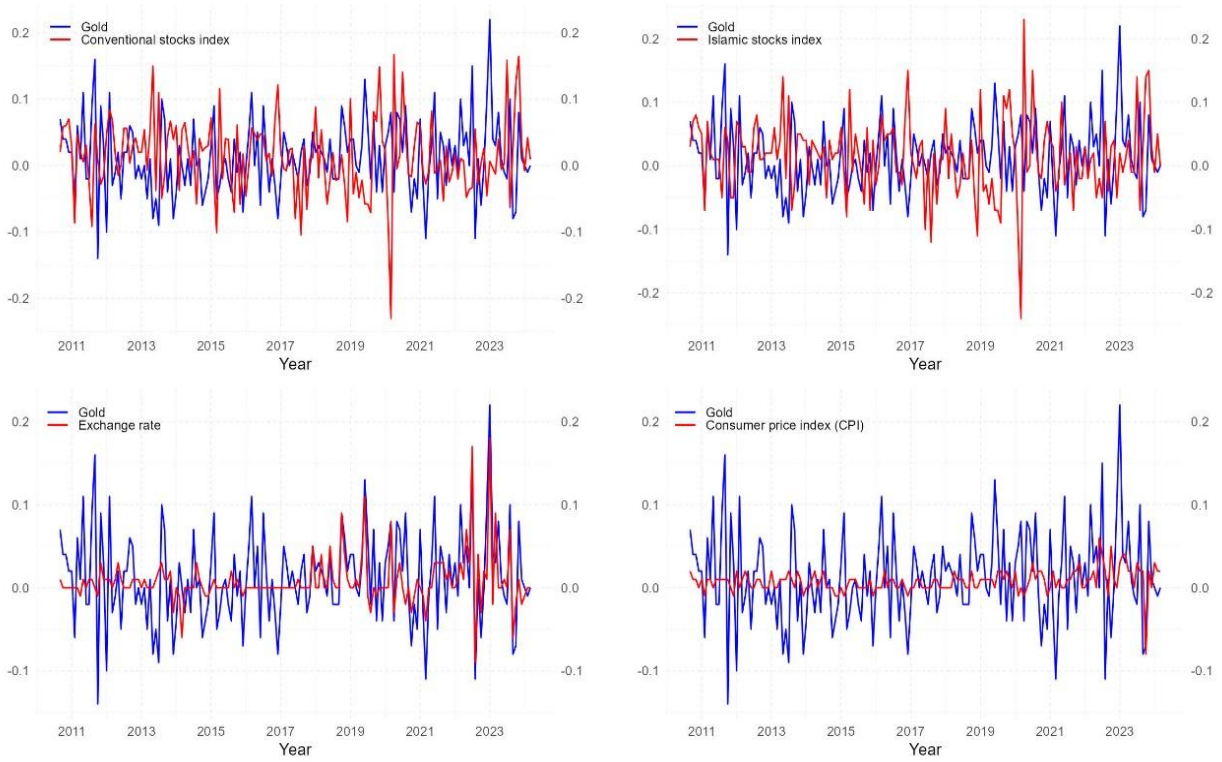


**Figure 2. Gold Returns Comparison with Other Indices**

## Descriptive Statistics

The descriptive analysis of the dataset is shown in Table 2. The mean values are the average returns of all observations for each of the assets and indices. From August 1st, 2010, to March 1st, 2024, the average monthly returns of Bitcoin, Gold, Conventional Stock, Islamic Stock, and Exchange Rate are 15.9 percent, 1.2 percent, 1.3 percent, 1.3 percent, and 0.8 percent, respectively. The standard deviation of Bitcoin, Gold, Conventional Stock, Islamic Stock, Exchange Rate, and Consumer Price Index is 0.54, 0.055, 0.056, 0.060, 0.030, and 0.013, respectively, which shows that returns of all variables are slightly deviated from their respective average returns except Bitcoin. Bitcoin shows more deviation from its mean value. The skewness values of the data indicate that the left tails of the distributions of Bitcoin, conventional stocks, and Islamic stocks are larger than the right tails, while gold, exchange rate, and consumer price index slightly deviate toward the right side. The kurtosis values show that Bitcoin has a long tail compared to other variables. Similarly, the p-value of the Jarque-Bera test for all variables is significant except for gold, meaning that the data is not normally distributed. These statistics are fully based on data-driven empirical estimation of market returns.

**Table 2. Descriptive Statistics**

| Descriptive Statistics | Bitcoin | Gold | Conventional Stocks | Islamic Stocks | Exchange Rate | CPI |
|---|---|---|---|---|---|---|
| Mean | 0.159 | 0.012 | 0.013 | 0.013 | 0.008 | 0.006 |
| Median | 0.050 | 0.009 | 0.014 | 0.015 | 0.001 | 0.006 |
| Maximum | 4.79 | 0.215 | 0.166 | 0.232 | 0.182 | 0.063 |
| Minimum | -0.39 | -0.143 | -0.23 | -0.24 | -0.08 | -0.080 |
| Std. Dev. | 0.54 | 0.055 | 0.056 | 0.060 | 0.030 | 0.013 |
| Skewness | -5.28 | 0.337 | -0.092 | -0.046 | 2.496 | -0.817 |
| Kurtosis | 40.50 | 3.741 | 4.917 | 5.133 | 15.64 | 15.174 |
| Jarque-Bera | 10314 | 6.825 | 25.21 | 30.98 | 1256 | 1024.8 |
| Probability | 0.000 | 0.032 | 0.000 | 0.000 | 0.000 | 0.000 |
| Observation | 163 | 163 | 163 | 163 | 163 | 163 |

## Unit Root and Heteroscedasticity Test

The series had been tested for the problems of unit root and heteroscedasticity before proceeding to estimate the DCC-GARCH and quantile regression models. Every individual series is tested for unit root by using the Augmented Dickey-Fuller test, whether the series is stationary or not. The results of the ADF for all series are presented in Table 3. The result shows that all the variables are stationary at level, and there is no issue with unit roots in the data.

**Table 3. Unit root Test (Augmented Dickey-Fuller test statistic)**

| Variable(s) | Difference Level | T-statistic | Prob. value |
|---|---|---|---|
| Bitcoin | I(0) | -11.17 | 0.0001 |
| Gold | I(0) | -13.01 | 0.0001 |
| Conventional Stocks | I(0) | -12.64 | 0.0001 |
| Islamic stocks | I(0) | -13.29 | 0.0001 |
| Exchange Rate | I(0) | -7.915 | 0.0000 |
| Consumer Price Index | I(0) | -11.88 | 0.0000 |

After that, it is also important to perform the heteroscedasticity test before performing the multivariate GARCH model to determine whether heteroscedasticity exists between gold/Bitcoin and the rest of the indices (stock markets, exchange rate, and consumer price index) because the ARCH effect is necessary to run the GARCH models. The heteroscedasticity test has been performed for Bitcoin and the independent variables in Table 4, and the same test is performed for gold with the rest of the indices. The estimation in Table 4 confirmed that heteroscedasticity exists between the dependent and independent variables, which means that residuals are not constant over time. This confirms that a data-driven ARCH-type volatility framework is appropriate for modelling the series.

**Table 4. Heteroscedasticity Test**

| | | | |
|---|---|---|---|
| Breusch-Pagan-Godfrey Test For Bitcoin | | | |
| F-statistic | 8.673 | Prob. F(3,2606) | 0.000 |
| Obs*R-squared | 25.80 | Prob. Chi-Square(3) | 0.000 |
| Breusch-Pagan-Godfrey Test For Gold | | | |
| F-statistic | 17.119 | Prob. F(3,2606) | 0.000 |
| Obs*R-squared | 50.443 | Prob. Chi-Square(3) | 0.000 |

## Autocorrelation

This study also checks the autocorrelation for the data used in the analysis. Results of autocorrelation presented in Table 5 below. Here, our null hypothesis is that "there is no serial correlation". So, in our case, the p-value of the LM test is insignificant at the 5% level of confidence, meaning that our sample data is free from autocorrelation issues. This supports the reliability of the data-driven time series specification.

**Table 5. Autocorrelation Test**

| | | | |
|---|---|---|---|
| Breusch-Godfrey Serial Correlation LM Test for Bitcoin | | | |
| F-statistic | 2.774 | Prob. F(3,2606) | 0.065 |
| Obs*R-squared | 5.634 | Prob. Chi-Square(2) | 0.059 |
| Breusch-Godfrey Serial Correlation LM Test for Gold | | | |
| F-statistic | 272.67 | Prob. F(3,2606) | 0.070 |
| Obs*R-squared | 158.47 | Prob. Chi-Square(2) | 0.068 |

## Dynamic Conditional Correlation (DCC-GARCH) Estimation

The time-varying correlation is generated between Bitcoin and other explanatory variables (conventional stock, Islamic stock, exchange rate, and inflation rate) to understand the dynamic relationship of a portfolio over a period of time. The time-varying correlation values are generated, and the correlation points are graphically plotted in Figure 2 and Figure 3. The estimation is fully data-driven using multivariate time-varying econometric modeling.

Table 6 presents the results of the DDC-GARCH model. The upper three rows of the table contain the GARCH (1, 1) estimation for the variance equation, while the lower two rows show the DCC results. The upper part shows the volatility effect, while the lower part, i.e., alpha (DCC) and beta (DCC), shows the dynamic conditional correlation, which is our main objective of the study. The primary concern of applying the DCC model is to test whether there is a time-varying correlation between Bitcoin and the rest of the variables under examination. If the sum of alpha (DCC) and beta (DCC) is greater than zero but less than one, it means that a time-varying correlation exists between the variables. The result of alpha DCC shows the short-run conditional correlation persistence, which is insignificant for all variables in this study. The beta DCC represents the persistence of the long-run correlation of Bitcoin with conventional stock, Islamic stock, exchange rate, and consumer price index. The estimation output of Beta DCC is significantly persistent for long-run correlation for all variables except the conventional stocks. The condition that the sum of alpha (dcc) and beta

(dcc) is greater than zero and less than 1 is fulfilled, which means that the relationship between Bitcoin and the rest of the variables changes over a period of time. All estimates are derived from data-driven financial time series modeling.

**Table 6. DCC-GARCH Estimation for Bitcoin**

| Coeff. | Conventional Stocks | Islamic stock | Exchange Rate | Consumer Price Index | Bitcoin |
|---|---|---|---|---|---|
| γ0 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 1.636 |
| γ1 (ARCH) | 0.777 | 0.777 | 0.777 | 0.777 | 0.176 |
| γ2 (GARCH) | 0.677 | 0.677 | 0.677 | 0.677 | 0.788 |
| Alpha (DCC) | 0.139 (0.100) | 0.000 (0.0005) | 0.078 (0.130) | 0.000 (0.0003) | |
| Beta DCC | 0.412 (0.350) | 0.80*** (0.103) | 0.667*** (0.118) | 0.830** (0.414) | |
| The value inside the parenthesis shows Std. Error and without parenthesis show coefficient, while * , **, ***, represent statistical significance at the 10%, 5% and 1% level respectively | | | | | |

Figure 3 graphically presents the dynamic conditional correlation of Bitcoin returns with conventional stocks, Islamic stocks, exchange rate returns, and the consumer price index. The figure indicates that the correlation between Bitcoin and conventional stocks is around 0.005, which is near zero. The DCC graph shows that the correlation between Bitcoin and Islamic stocks, on average, moves very near to zero; this graphical association between Bitcoin and Islamic stocks indicates that the dynamic correlation, on average, is very low. Similarly, the dynamic correlation graph between Bitcoin and the exchange rate shows a zero correlation, which clearly suggests that there is weak hedging potential for the exchange rate. On the other hand, the correlation between Bitcoin and inflation on average is positive, suggesting the potential for hedging. These results are entirely data-driven and derived from time-varying correlation estimates.

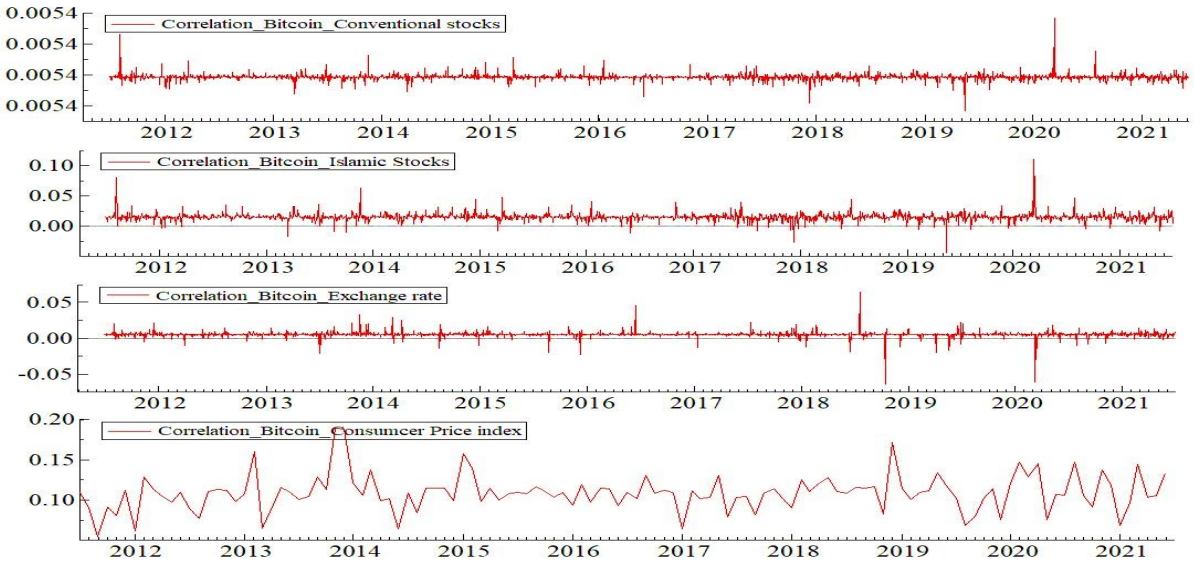


**Figure 3. Dynamic Conditional Correlation Plot of BTC with other variables**

Similarly, the results of Table 6 show the DDC-GARCH estimation of gold. The sum of alpha and beta DCC values for all variables is larger than 0 but less than one, which means that there is a dynamic conditional correlation among the variables. The p-value of alpha DCC is significant at 5% for all variables except Islamic stock, meaning that gold has a persistent correlation with conventional stock, Islamic stock, and the exchange rate. This confirms a data-driven dependency structure between gold and financial markets.

**Table 7. DCC-GARCH Estimation for Gold**

| | Convn Stock | Islamic stock | Exchange Rate | Consumer Price index | Gold |
|---|---|---|---|---|---|
| γ0 | 7.283 | 7.283 | 7.283 | 7.283 | 0.009 |
| γ1 (ARCH) | 0.156 | 0.156 | 0.156 | 0.156 | 0.048 |
| γ2 (GARCH) | 0.612 | 0.612 | 0.612 | 0.612 | 0.944 |
| Alph DCC | 0.0000<br>(0.0007) | 0.020<br>(0.059) | 0.045**<br>(0.020) | 0.000<br>(0.009) | |
| Beta DCC | 0.785<br>(1.165) | 0.69***<br>(0.185) | 0.942***<br>(0.019) | 0.843*<br>(0.430) | |

The value inside the parenthesis shows Std. Error and without parenthesis show coefficient, while * , **, ***, represent statistical significance at the 10%, 5% and 1% levels, respectively.

In the long run, as shown by beta DCC, the conditional correlation process between gold and stocks, Islamic stocks, the exchange rate, and CPI persists over time. The results indicate that there is a time-varying relationship between gold and the rest of the indices under investigation. Figure 3 presents the dynamic conditional correlation of gold returns with conventional stock, Islamic stock, exchange rate, and consumer price index. The figures represent the DCC output, indicating that there is a dynamic relationship between all variables because relationships vary over different time periods. The relationship is not static.

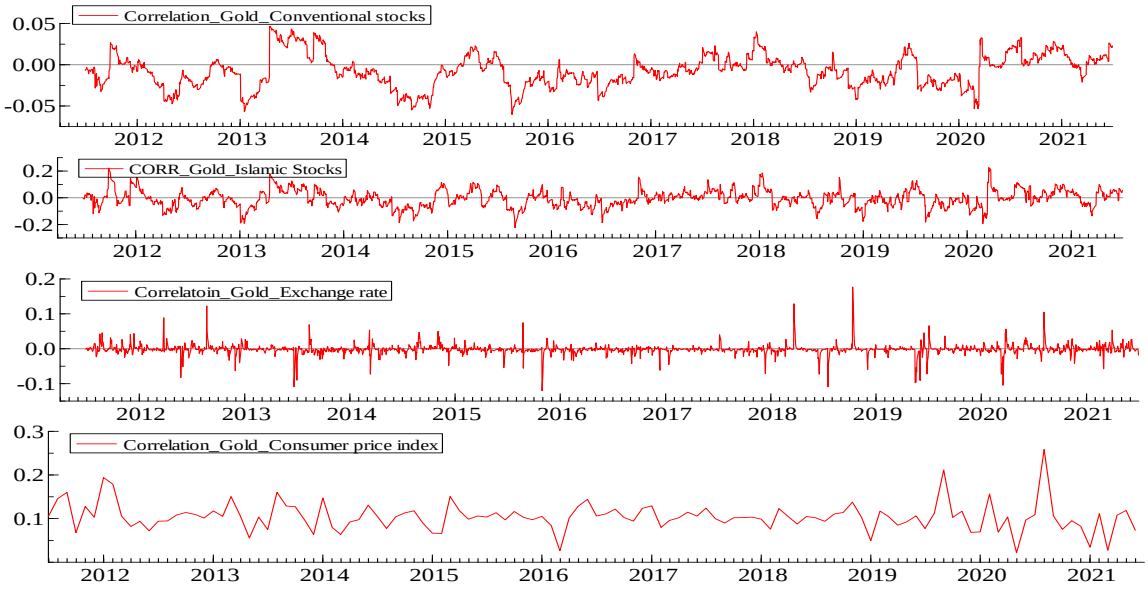


**Figure 4. Dynamic Conditional Correlation Plot of Gold with Other Variables**

The results indicate that the correlation between gold and conventional stocks is negative on average, and the gold correlation with the exchange rate on average stays at zero, with slight changes observed during higher volatility regimes. On the other hand, the correlation between gold and Islamic stock returns is nearly positive or zero on average, and the strength of the correlation seems extremely low, moving around 0 and 0.05.

The volatility periods indicate that the correlations are extremely sensitive to shocks and extreme changes. Finally, the correlation between gold and Islamic stock returns can be seen as positive on average. The graphical presentation of gold and consumer price index suggests a positive correlation on average.

The econometric analysis of gold with respect to the rest of the variables is shown in Table 8. The coefficient, -0.28, of a conventional stock is significantly negative, which means there is an inverse relationship between gold and the conventional stock market on average, which indicates a strong hedging characteristic on average. Technically, all coefficients are estimated using data-driven quantile regression techniques capturing market extremes.

The significance of gold as a safe-haven is evident in its ability to mitigate the impact of extreme market shocks experienced by conventional stock indexes, particularly when returns plummet to the lower quantile of 7.5%. Equally, there appears to be zero relationship between gold and market performance at the 10th and 5th quartiles. The substantial joint effect value of -0.28 underscores the concept that investors can effectively protect their investments by adding gold into their portfolios during periods of heightened uncertainty.

**Table 8. Estimation of quantile regression for Gold**

| Gold | KSE100 Index | | KMI 30 | | Ex. R | | | CPI | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef | Z-Stat | Coef | Z-Stat | | Coef | Z-Stat | Coef | Z-Stat |
| c(1)Hedge | -0.28** | 0.06 | -0.10* | 0.08 | c(1)Hedge | 0.99* | 0.24 | 0.54 | 0.50 |
| c(2)10% | 0.02 | 0.02 | -0.03 | 0.32 | $c(2)_{90\%}$ | 0.69 | 0.57 | 0.12 | 1.18 |
| c(3)7.5% | -0.04 | 0.03 | -0.81** | 0.45 | $c(3)_{92.5\%}$ | -0.89 | 0.81 | 1.51 | 1.89 |
| c(4)5% | 0.015 | 0.01 | 0.86* | 0.39 | $c(4)_{95\%}$ | 0.125 | 0.07 | -1.5 | 1.65 |
| Wald Test | | | | | | | | | |
| c(1)+c(2)+c(3)+c(4) | -0.288* | | -0.10 | | c(1)+c(2)+c(3)+c(4) | 0.922* | | 0.58* | |

Note: The table shows the role of gold as a diversifier, hedge, or safe-haven asset in time-average conditions and bearish market situations, respectively. C(1) depicts the gold relationship as a diversifier or hedge in time-average market conditions, while the sum of c(1),c(2), c(3), and C(4) shows the gold role as a safe-haven in turmoil conditions of the rest of the variables under study. *, **, ***, Statistical significance at the 1%, 5% and 10% level respectively.

The study findings are aligned with the results of previous studies (see Baur & McDermott, 2010; Ghazali et al., 2022; Gürgün & Ünalmış, 2014; Iqbal, 2017; Raza et al., 2016), which show that gold is an attractive investment to hedge the equity market in normal as well as extreme conditions. Similarly, the parameter for gold and Islamic stocks is -0.10,

which indicates that gold has a negative relationship on average to Islamic stocks throughout the sample period. This finding indicates that gold can be hedged in the case of the Islamic stocks index. The result is consistent with the findings of Aftab et al. (2019), Chang et al. (2020), and Raza et al. (2016). Similarly, the result for safe-haven dynamics is negative for the 10% and 7.5% quantiles, and the value of the joint effect is -0.1, which indicates an overall negative relationship. The finding suggests that gold plays the role of a safe-haven against the adverse shocks that happen in the Islamic stock market in Pakistan. The safe-haven result is aligned with the result of Aftab et al. (2019) and Chang et al. (2020).

The value of the exchange rate with respect to gold is positive. The positive relationship between the two variables suggests strong hedging potential on average. On the other hand, the positive value of gold indicates a relationship with the exchange rate during extreme movements in the currency market. Gold protects the investment as the percentage change in the rate exceeds the upper quantile of 95%. Their joint effect value is significantly 0.92, which indicates a strong relationship. Therefore, gold can act as a strong safe-haven in times of extreme depreciation in exchange rates. A similar result was reported by Aftab et al. (2019), Chang et al. (2020), and Iqbal (2017), who found that gold serves as a safe-haven asset during periods of currency depreciation. The empirical findings regarding gold's role as a hedge against the Consumer Price Index (CPI) yield positive results, suggesting its potential hedging effectiveness against inflation under normal economic conditions. The value of joint testing is significantly higher than 0.58, which indicates that gold can be proven to be a good safe-haven to protect portfolios in times of extreme general price hikes that happen in Pakistan.

The findings in Table 9 show the relationship between Bitcoin as a protective asset and the rest of the indices. The coefficient -0.31 of hedge shows a significant negative relationship, representing strong hedging potential of Bitcoin for conventional stocks on average time period; but, conversely, the significant positive value 0.84 of hedge for Islamic stocks indicates the characteristic of a diversifier asset. The outcome of our study is consistent with the findings of Bouri et al. (2020) and Dyhrberg (2016) that Bitcoin acts like virtual gold as it has the properties to hedge for the conventional equity market but is not aligned with the Islamic equity index.

The investigation of the hedging property of Bitcoin with respect to exchange rate risk evidenced that it has failed to hedge the exchange rate risk under average conditions in Pakistan, as the coefficient is -1.18, and the coefficient -1.97 indicates Bitcoin's failure to hedge the inflation risk on average during the sample period.

The results of safe-haven dynamics of a specific quantile show that Bitcoin's relationship to conventional stocks is positive during periods of extreme stock returns below 10%, 7.5%,

and 5% of the threshold. The coefficient of joint effect is 1.84, which indicates that Bitcoin fails to possess a safe-haven role for conventional stocks.

**Table 9. Estimation of quantile regression for Bitcoin**

| BTC | KSE100 Index | | KMI 30 | | Ex.R | | | CPI | |
|---|---|---|---|---|---|---|---|---|---|
| | Coef | Z-Stat | Coef | Z-Stat | | Coef | Z-Stat | Coef | Z-Stat |
| c(1)Hedge | -0.31*** | -0.4 | 0.84* | 0.328 | c(1)Hedge | -1.18 | 0.97 | -1.97 | 2.23 |
| c(2)10% | 0.59 | 4.31 | 1.01 | 1.01 | $c(2)_{90\%}$ | 0.34 | 2.73 | -7.21 | 7.46 |
| c(3)7.5% | 0.40 | 9.02 | -7.07 | 2.17 | $c(3)_{92.5\%}$ | -1.52 | 2.47 | 5.12 | 8.28 |
| c(4)5% | 1.15 | 8.23 | 5.3 | 2.71 | $c(4)_{95\%}$ | 3.86 | 2.29 | 3.51 | 5.04 |
| Wald Test | | | | | | | | | |
| c(1)+c(2)+c(3)+c(4) | 1.84 | | 1.07 | | c(1)+c(2)+c(3)+c(4) | 1.5* | | 0.54 | |

Note: The table shows the role of Bitcoin as a diversifier, hedge, or safe-haven asset in time-average conditions and extreme situations, respectively. C(1) depicts the Bitcoin relationship as a diversifier or hedge in times of average market conditions, while the sum of c(1),c(2), c(3), and C(4) shows the Bitcoin role as a safe-haven in turmoil conditions of the rest of the variables under study. *, **, ***, Statistical significance at the 1%, 5% and 10% level respectively.

On the other hand, the relationship between Bitcoin and the Islamic Stock Index is only negative in an extremely low quantile of 7.5%, i.e., -7.07, but positive for the rest of the quantiles. The positive value of the joint effect is 1.07, which negates the ability to protect against the risk of Islamic stock during the turmoil condition. Interestingly, the investigation provides evidence that the relationship between Bitcoin and the exchange rate is positive during the adverse movement that happens in the currency market of Pakistan, as the value of joint testing is significantly positive, i.e 1.5, which shows that Bitcoin has a strong ability to mitigate the risk of exchange rate volatility in a turmoil condition. Conversely, the results for Bitcoin and the consumer price index for the extreme upper quantile of 92.5% and 95% are positive but negative when they exceed the upper quantile of 90%. The value of joint testing of quantiles is negative, which indicates that Bitcoin cannot protect from extreme price hikes. The result for Bitcoin is aligned with the findings of Al Mamun et al. (2020) and Bouri et al. (2020), who suggested that other factors determine Bitcoin price and is increasing exponentially. Likewise, Ciaian et al. (2016) stated that Bitcoin's acceptability, trust, and attractiveness can be seen in its rapidly growing prices and market capitalization. Overall, Bitcoin has the ability to hedge conventional stock but acts as a diversifier for Islamic stock. It acts only as a safe-haven for the exchange rate during periods of turmoil in PKR.

## Conclusion

The findings of the study indicate that gold can effectively serve as a hedge against movements in equity indices, exchange rates, and inflation. The strong relationships observed among these assets suggest that gold possesses significant hedging potential. Additionally, the findings demonstrate that gold acts as a robust safe-haven during market turmoil, mitigating extreme shocks in conventional stocks, exchange rates, and inflation. However, its

effectiveness as a safe-haven against adverse movements in the Islamic stock index of Pakistan appears to be comparatively weaker. In contrast, Bitcoin demonstrates hedging potential only against conventional stocks, serving as a diversifier for Islamic stock indices on average. However, it fails to exhibit hedging properties against exchange rate and inflation risks on average. Furthermore, the joint estimation of Bitcoin coefficients reveals that Bitcoin may serve as a safe-haven during extreme exchange rate fluctuations. However, it fails to protect investors' wealth during extreme conditions in both equity indices and periods of high inflation.

Overall, while Bitcoin may offer some protection against extreme exchange rate depreciation, it does not consistently hedge against other market risks. Comparatively, the study suggests that gold is a more reliable asset for investors due to its stability and ability to mitigate downside risk despite its relatively low volatility. Although Bitcoin may assist investors in hedging exchange rate risk, its extreme volatility requires careful risk management. The findings indicate that gold is comparatively more stable and reliable than Bitcoin. This study presents several important managerial implications for portfolio managers, investors, and policymakers navigating economic instability. The findings underscore gold's strong role as a hedge against stock market declines, exchange rate fluctuations, and inflation, suggesting that it should be a key component in risk mitigation strategies. This study emphasizes the need to include gold as a safe-haven for investors engaged in both conventional and Islamic stock markets, particularly when protecting against severe financial shocks.

Moreover, the study highlights that Bitcoin can still act as a hedge against exchange rate movements and as a diversifier for Islamic stocks. Investors interested in cryptocurrencies and seeking portfolio diversification through digital assets may find these findings useful. Further, the study emphasizes the need to develop regulatory frameworks that recognize the growing role of cryptocurrencies like Bitcoin as alternative financial assets. Future research could investigate the role of other cryptocurrencies in hedging and diversification, extending beyond Bitcoin to include assets such as stablecoins or Ethereum. These assets may exhibit different dynamics compared to Bitcoin, particularly in the context of Islamic finance, where Shariah-compliant investment instruments are becoming increasingly relevant. Overall, the conclusions are based on a data-driven empirical framework using multivariate volatility and quantile econometric models.

## Authors' Contribution

All the authors contributed equally to the final manuscript.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Ethical Approval

All ethical practices and standards have been observed during the writing of this study.

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