



The dark side of Bitcoin: Do Emerging Asian Islamic markets help subdue the ethical risk?

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ABSTRACT

Continuous financing of illicit activities (drug and human trafficking, child abuse, cybercrimes) through Bitcoin nurtures the ethical risk of investors. Building on this argument, the current study investigates the extreme tail dependence between Bitcoin and Emerging Asian Islamic (EAI) markets. We report multiple tail-dependent copulas differing across turmoil periods for the whole sample period. Under the ethical-risk hypothesis and modern portfolio theory, our findings demonstrated stronger safe-haven properties of EAI for Bitcoin to mitigate ethical risk, and higher diversification benefits are documented for both equally adjusted and optimal portfolios. We formulated useful implications for policymakers, governments, regulation authorities, ethical investors, and portfolio managers for policymaking and strategizing their investment portfolios.

1. Introduction

From the evolutionary perspective, with the first release of the Bitcoin whitepaper by Nakamoto (2008) to the recent developments of non-fungible tokens (NFTs), decentralized financial instruments (DeFi's), and metaverses, cryptocurrencies have reflected a tremendous growth over the last two decades. Based on January 24, 2022, the total market capitalization of cryptocurrencies is USD 1.541 trillion, whereas Bitcoin accounts for USD 637 billion. Multiple online cryptocurrency exchanges are transacting a daily dollar volume of approximately USD 32 billion.¹ Meanwhile, various crypto-funds soared from USD 24 billion to USD 63 billion from 2020 to 2021.² Even with this massive worldwide increase in growth, cryptocurrencies are not free from their share of controversies, for instance, environmental concerns, energy-intensive use of cryptocurrencies, and carbon footprints of cryptocurrency mining.

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¹ Please see: <https://coinmarketcap.com/currencies/bitcoin/>

² Please see: <https://www.govconwire.com/2021/12/assets-in-worldwide-crypto-funds-hit-63b/#:~:text=Assets%20in%20global%20cryptocurrency%20fundsfrom%2035%20the%20previous%20year.>

Apart from the concerns mentioned above, the flip side of the picture unveils another dark side of Bitcoin through its unethical use leading to the ethical risk for investors, which is not yet covered by the earlier studies. The dark side of Bitcoin expands through its illegal use in various dubious activities of money laundering, drug trafficking, human trafficking, child exploitation, dark marketplace trading, cybercrime, and terror funding.³ *Fortune* (2022) reports that the legitimate use of cryptocurrencies is far outpacing the growth of criminal usage, and the share in illicit activities of cryptocurrency transactions is increasing significantly.⁴ In terms of value, cryptocurrency-related crimes surged to a new peak last year, with illegal addresses receiving USD 14 billion in digital currencies, remarkably up (79%) from USD 7.8 billion in 2020. Considering only the start of 2022, Chainalysis reports that illicit redressals have already reached over USD 10 billion worth of cryptocurrencies, where most incidents are based on cryptocurrency theft.⁵

A greater doubt exists among practitioners that Bitcoin has facilitated the online “darknet marketplaces” for carrying out illegal activities. Subsequently, approximately USD 76 billion of illegal activities per year involves Bitcoin, which constitutes 46% of Bitcoin transactions scaling illegal drugs in the US and European markets.⁶ On the regulatory front, the rejection of an application worth USD 100 million in cryptocurrencies exchange-traded fund (ETF) by the US Securities and Exchange Commission (SEC) in March 2017⁷ and further follow-up rejection proposals in 2018 stimulated regulatory concerns about cryptocurrencies’ usage underlying its ethical perspectives. Ban on the cryptocurrencies trade by the Chinese government⁸ and the introduction of the initial coin offering (ICOs) was made illegal in September 2017 due to its involvement in illicit trading. The solemn concerns of Mark Carney from the Bank of England about cryptocurrencies’ illegal use in terrorism, human trafficking, and child abuse have further incited the regulatory issues of cryptocurrencies.⁹ Following the rising financial stability concerns, a ban from the Russian Central Bank has put another question mark on the ethicality and credibility of the cryptocurrencies,¹⁰ which sufficiently transformed the black markets into black e-commerce.

Building on these highly conflicted ethical concerns of Bitcoin, we define ethical risk as the risk that evolved out of Bitcoin investing through its immoral use in illegal activities raising critical questions about one’s moral standards and ethical values (Hazgui and Brivot, 2020; Alotaibi et al., 2020). Theoretically, the ethical-risk hypothesis contends that the unethical behavior of investors varies with the level of perceived risk (Rettig & Pasamanick, 1964). Meanwhile, Knoll (2002) states that ethical criteria in the financial markets involve exclusionary and inclusionary approaches where investors tend to avoid (exclusionary approach) those investment streams which do not comply with their ethical and moral standards and vice versa. The modern portfolio theory (MPT), on the other hand, sufficiently explains the investors’ choices to construct portfolios with minimum risk and to achieve higher diversification benefits (Markowitz, 1952).

As legitimate investors in the cryptocurrency space would be interested in diversifying the ethical risk, Shari’ah-compliant markets provide the best possible setting. Islamic stocks vary from the conventional stocks in terms of no interest rate, abolition of usury (Riba), avoiding extreme uncertainty (Gharar), and speculation (Maysir) by restricting the transactions which involve gambling, short-selling, and no asset-backed instruments for completing the transaction (Naeem et al., 2021a; Shahzad et al., 2017). Following these instances, it is central to the policymakers, governments, regulatory bodies, ethical investors, and portfolio managers to seek investment streams that hedge the dark side of Bitcoin.

Emerging Asian Islamic (EAI) markets, among other financial markets, possess resilient characteristics which make them better investment opportunities, specifically during the economic downturn¹¹ mitigating the ethical risk of Bitcoin. Amidst the rising conflicts between Bitcoin and EAI due to their varied ethical approach, the current study tends to answer the questions like: Is there extreme tail dependence between Bitcoin and EAI? What are the proposed benefits of investing in EAI to diversify the ethical risk associated with Bitcoin?

Given the above enlightenments, the contribution of the current study is multi-fold. First, this is the pioneer study to examine the extreme tail dependence between Bitcoin and Emerging Asian Islamic (EAI) markets. To the authors’ best knowledge, no such study has been presented to unveil the extreme tail dependence between Bitcoin and EAI to magnify the diversification benefits, safe-haven, and hedge features of EAI to mitigate the ethical risk of Bitcoin. Second, on the theoretical front, the current study frames moral standards and ethical values as building blocks of ethical risk for investors and financial market participants to choose between Bitcoin and EAI following the exclusionary and inclusionary approach (Knoll, 2002).

Third, the study adopts a multi-step analysis approach that includes the AGDCC-GARCH estimation, time-varying optimal copula (TVOC) approach, and conditional diversification benefits (CDB) to provide a comprehensive outlook between Bitcoin and EAI. The significance of asymmetric generalized dynamic conditional correlation analysis (AGDCC-GARCH) is its novel characteristic in stipulating the correlations of Bitcoin with EAI to uncover potential hedges, safe-havens, and diversifiers. The time-varying optimal

³ Please see: <https://www.cognyte.com/blog/5-reasons-why-criminals-are-turning-to-cryptocurrencies/#:~:text=Just%20as%20cryptocurrencies%20are%20gaining%20illicit%20activities%20in%202020,20>.

⁴ Please see: <https://fortune.com/2022/01/06/crypto-crime-all-time-high-2021/#:~:text=At%20the%20same%20time%2C%20howeverby%20blockchain%20research%20firm%20Chainalysis>.

⁵ Please see: <https://www.reuters.com/markets/us/cryptocurrency-crime-2021-hits-all-time-high-value-chainalysis-2022-01-06/>.

⁶ Please see: Foley et al. (2019)

⁷ Please see: <https://www.sec.gov/rules/sro/batsbzx/2017/34-80206.pdf>

⁸ Please see: <https://www.forbes.com/sites/kenrapoza/2017/10/18/chinas-blockchain-bitcoin-ban-no-match-for-stateless-cryptocurrency-market/?sh=4f30311c2de6>

⁹ Please see: <https://www.cNBC.com/2018/02/20/bitcoin-has-failed-as-a-currency-bank-of-england-governor-mark-carney.html>

¹⁰ Please see: <https://www.reuters.com/business/finance/russian-cbank-proposes-banning-cryptocurrencies-crypto-mining-2022-01-20/>

¹¹ Please see: <https://www.cNBC.com/2021/12/21/moodys-asia-better-poised-for-recovery-than-other-emerging-markets.html>

copula (TVOC) approach proposed by Liu et al. (2017) characterizes various tail dependence regimes which symbolize discrete copulas between Bitcoin and EAI for the period encompassing January 2, 2012 to December 23, 2021. In addition, this approach offers novel insights to the practitioners, policymakers, financial market participants, and investors to unlock the tail dependence among certain financial markets, Bitcoin and EAI in our case. TVOC approach is considered significant due to its multifarious benefits over other methodologies in terms of identifying extreme co-dependence under distressing circumstances, modeling the behavior of asymmetric negative dependence to portray the dynamic of dependence for a given direction, intensity, and simultaneity, and locating the copulas of Bitcoin and EAI under dynamic conditions. Meanwhile, the conditional diversification benefit (CDB) technique is novel in identifying the diversification potential of EAI against Bitcoin, covering the complete sample period designed for both equally weighted and optimally selected portfolios of Bitcoin and EAI.

Fourth, the current study provides fresh evidence on the safe-haven, hedge, and diversification avenues and spots the EAI with the maximum (minimum) tail-dependencies to hedge the dark side of Bitcoin in line with modern portfolio theory. Additionally, the study reports significant findings which highlight the low risk-bearing potential of EAI for shielding the investments from the ethical risk of Bitcoin. Finally, the study draws various theoretical, practical, and policymaking implications specifying guidelines for policymakers, governments, investors, and portfolio managers.

The findings of our multi-step analysis study through the AGDCC-GARCH approach indicate EAI provide stronger diversification avenues for Bitcoin in line with theoretical aspects. However, with their pronounced risk-mitigating features, EAI offers safe-haven benefits during uncertain times and hedge capacities when markets are experiencing normal circumstances. TVOC estimates for each pair of Bitcoin-EAI implied stronger safe-haven properties of EAI for Bitcoin during the distressing times of the European Debt Crisis, Shale Oil Crisis, Chinese stock market crash, cryptocurrencies' price bubble burst during 2017, US interest rate hike, COVID-19 pandemic, and cryptocurrencies price volatility in the first half of 2021. For instance, some EAI, such as Malaysia and Taiwan, demonstrated neutral dependence during normal circumstances, symbolizing their diversification potential against Bitcoin. The CDB analysis reiterated our findings of greater diversification benefits reported by EAI for Bitcoin for equally adjusted and optimal selection of portfolios. We proposed useful implications for policymakers, governments, regulatory bodies, ethical investors, and portfolio managers.

The remaining study is structured as follows: Section 2 presents a brief literature review of the earlier studies. Section 3 describes the methodology and data description. Section 4 elaborates on empirical results, and Section 5 concludes the study along with portfolio and policy implications.

2. Literature review

2.1. Theoretical framework

The connection of ethics in managing risk has not been widely researched. The fundamentals of ethical risk management are grounded in the compelling reasons to consider good ethical practices for portfolio creation and portfolio management. The two claims surrounded by the phrase "doing well by doing good" are vital to the modern finance theory as these claims offer simple yet powerful arguments that investors bear a moral obligation to guard their investments from any illicit use. Simultaneously, these two claims infer that investors can use their investments without generating ethical costs to promote their view of ethical corporates (Knoll, 2002; Francis and Armstrong, 2003; Karim, 2021a, 2021b). Despite yielding higher returns and risk premiums, we argue that some investments must be discouraged based on ethical grounds as they pose serious ethical risks to society. This ethical criterion can be used in multiple ways where investors screen their investments based on their moral values. In other words, investors tend to avoid investments that are inconsistent with their ethical standards through an exclusionary (negative) approach while embracing those investments by adopting an inclusionary (positive) approach complying with their moral norms (Knoll, 2002).

In terms of diversification benefits, modern portfolio theory (MPT), proposed by Markowitz (1952), offer strong theoretical underpinnings for constructing diversified portfolios to optimize their expected returns up to a certain level of market risk. At the same time, diversification cannot eliminate the risk of an investment. Rather diversification provides avenues for optimizing the investment streams and achieving higher expected returns. Structuring our arguments on these boulevards, the current study offers novel insights into framing the ethical risk of investments raised by investing in Bitcoin and optimizing the portfolios by including the EAI in the portfolio selection and risk minimization.

2.2. Relationship between Bitcoin and Emerging Asian Islamic markets

Prior literature examining the tail dependence between Bitcoin and Emerging Asian Islamic (EAI) markets is completely scarce despite bearing sufficient safe-haven/hedge and diversification potential. Few studies examined the risk transmission between Bitcoin and global, regional, and country-level Islamic stock indices (Rehman et al., 2020) and found asymmetric nexus of risk spillovers. Similarly, Ahmed (2021) investigated the differential sensitivity of Sharia-compliant stocks to Bitcoin's realized volatility and found an asymmetric trend in their dependence. Accordingly, Mensi et al. (2020) reported time- and frequency-dependent spillovers between Sukuk, major Islamic equities with Bitcoin price changes and found diversification potential of Islamic stocks and cryptocurrencies in the short-run than in the long-run. Finally, some studies considered hedging and diversification avenues of cryptocurrencies against Islamic and emerging markets stocks (Susilo et al., 2020; Demiralay and Bayraci, 2021).

Extant literature presents a few dimensions of cryptocurrencies and their dependence with conventional assets, for instance, dynamic connectedness between bitcoin and equity market (Dahir et al., 2019), implied volatility and cryptocurrency returns (Akyildirim

et al., 2020), returns, volatility, and trading volume of bitcoin (Aalborg et al., 2019), realized volatility of bitcoin (Urquhart, 2018), hedge and safe-haven properties of cryptocurrency (Naeem et al., 2020). These studies indicate a scarcity of literature examining the tail dependence between Bitcoin and Emerging Asian Islamic markets. Thus, the study's contribution is reiterated where EAI is employed in a portfolio to hedge the ethical risk, i.e., the dark side of Bitcoin through Islamic stocks.

Further, literature concerning Islamic stocks poses that they provide a greater investment shield against various volatile investments under normal and unstable economic parameters (Shahzad et al., 2017). In another study, Shahzad et al. (2019) employed the quantile generalized forecast error variance approach for various financial markets and found a system-wide connectedness of different asset classes. Alam and Ansari (2020) computed risk-adjusted measures for Islamic stocks and concluded that returns of Islamic markets are slightly higher than conventional markets. Usman et al. (2019), using the risk measures of CoVaR, claimed that religious stocks are upper tail dependent and conventional markets are lower tail dependent probably due to no involvement of usuary, interest rate, and presence of underlying assets for completing the transactions. Finally, Ahmad et al. (2018) highlights substantial interdependence between Islamic stocks and conventional financial markets using the traditional connectedness approach, where distressed periods displayed intense spillovers. The review of earlier literature further motivates the current study, where no existing studies investigated the tail dependence between Bitcoin and EAI to subdue the dark side of Bitcoin using ethical investments.

3. Methodology and data description¹²

3.1. Time-varying optimal copula (TVOC) approach

We assume that markets are experiencing severe economic conditions and are assembled asymmetrically. Thus, the dependence between Bitcoin and EAI is dynamic and time-varying. The copula approach, in this way, provides substantial information on markets' dynamics to restrict the dependence structure simultaneously. Generally, the dependence across markets is divided into positive and negative dependence with extreme events making the dependence structure nonlinear and complex. Therefore, Kendall's τ measures the dependence direction and intensity between Bitcoin and EAI. At first stance, the two tail dependence structures of Joe and Xu (1996) and Caillault and Guegan (2005) for the upper and lower tails are employed. However, additional functions of lower-upper tail and upper-lower tail explain the extreme dependencies between Bitcoin and EAI following the external shocks.

For two random constructs X and Y , along with their respective distribution functions F_X and F_Y for $\alpha = 0.05$,

$$\tau^{UU}(\alpha) = Pr(X > F_{X^{-1}}(1 - \alpha) | Y > F_{Y^{-1}}(1 - \alpha)) \quad (1)$$

$$\tau^{LL}(\alpha) = Pr(X < F_{X^{-1}}(\alpha) | Y < F_{Y^{-1}}(\alpha)) \quad (2)$$

$$\tau^{LU}(\alpha) = Pr(X < F_{X^{-1}}(\alpha) | Y > F_{Y^{-1}}(1 - \alpha)) \quad (3)$$

$$\tau^{UL}(\alpha) = Pr(X > F_{X^{-1}}(1 - \alpha) | Y < F_{Y^{-1}}(\alpha)) \quad (4)$$

Here $\tau^{UU}(\alpha)$ denotes upper-upper (upper) tail-dependence, $\tau^{LL}(\alpha)$ is indicative of lower-lower (lower) tail-dependence, $\tau^{LU}(\alpha)$ depicts lower-upper tail dependence, and $\tau^{UL}(\alpha)$ shows upper-lower tail-dependence. The additive lower-upper ($\tau^{LU}(\alpha)$) and upper-lower ($\tau^{UL}(\alpha)$) characterize complete dependence structures across markets specifying extreme co-movements. Therefore, $\tau^{LU}(\alpha)$ and $\tau^{UL}(\alpha)$ are more precise in terms of extreme dependence as compared to $\tau^{UU}(\alpha)$ and $\tau^{LL}(\alpha)$. Meanwhile, the asymmetric negative extreme dependence is expanded in the next sub-section through Clayton and Gumbel copulas.

A copula is a multivariate probability distribution with uniform marginal distributions on the intervals 0 and 1. In other words, if random constructs U and V are said to be uniform following 0 and 1 interval, respectively, then the copula function is denoted as the joint distribution of vectors U and V in terms of $(U, V) \sim C$. Following Sklar (1959), the bivariate random vector for X and Y constructs are obtained through joint distribution F as below:

$$F_{(x,y)} = C(F_X(x), F_Y(y)) \quad (5)$$

Here, marginal distributions are denoted by F_X and F_Y and C denotes copula function describing the dependence structure between X and Y . We assume that all functions can be varied; therefore, bivariate joint density is given as:

$$f(x, y) = c(u, v) f_X(x) f_Y(y) \quad (6)$$

In Eq. (6), $u = F_X(x)$ and $v = F_Y(y)$ along with the density function of copula $c(u, v) = \frac{\partial^2 C(u, v)}{\partial u \partial v}$.

¹² The time-evolution figures are drawn using the econometric software "E-VIEWS". All the estimations are done using R version 4.1.0. For the purpose of estimating descriptive statistics for the sampled markets we use the R-packages "psych" (<https://cran.r-project.org/package=psych>) and "summarytools" (<https://cran.r-project.org/package=summarytools>) versions 2.1.9 and 0.9.9, respectively. For the estimation of time-varying optimal copulas, we use the R-packages "copulas" (<https://cran.r-project.org/package=copula>) and "VineCopula" (<https://cran.r-project.org/package=VineCopula>), versions 1.0-1 and 2.4.3, respectively. Finally, for the estimation of conditional diversification benefits, we use the R-packages "rmgarch" (<https://cran.r-project.org/package=rmgarch>) and "cvar" (<https://cran.r-project.org/web/packages/cvar/cvar.pdf>), 1.3-9 and 0.4-1, respectively. All versions of R and related packages are available at <https://cran.r-project.org/>.

The most renowned copulas are Normal, t where both copulas define symmetric and positive/negative dependence. In return, Gumbel, rotated Gumbel, Clayton and rotated Clayton are representative of asymmetric positive dependence. It is important to note that a normal copula carries no tail dependence, whereas Student t copula possesses symmetric tail dependence. Meanwhile, Clayton and rotated Gumbel copulas symbolize lower tail dependence and Gumbel and rotated Clayton signify upper tail dependence. The upper and lower tail dependence are manifested as:

$$\lambda_U(v) = \lim_{v \rightarrow 1} P[X > F^{-1}(v) | Y > F^{-1}(v)] = \lim_{v \rightarrow 1} \frac{1 - 2v + C(v, v)}{1 - v} \quad (7)$$

$$\lambda_L(v) = \lim_{v \rightarrow 0} P[X < F^{-1}(v) | Y < F^{-1}(v)] = \lim_{v \rightarrow 0} \frac{C(v, v)}{v} \quad (8)$$

Here $0 \leq \lambda_U \leq 1$, $0 \leq \lambda_L \leq 1$.

For capturing extreme dependencies in counter directions, it is compulsory to construct fresh copulas by the rotation of 90 and 270 degrees. In this way, updated upper and lower tail dependencies of freshly created half-rotated copulas is written as:

$$\lambda_U'(v) = \lim_{v \rightarrow 1} P[X < F^{-1}(1-v) | Y > F^{-1}(v)] = \lim_{v \rightarrow 1} \frac{1 - 2v + C_{\frac{90}{270}}(v, v)}{1 - v}, \quad (9)$$

$$\lambda_L'(v) = \lim_{v \rightarrow 0} P[X > F^{-1}(1-v) | Y < F^{-1}(v)] = \lim_{v \rightarrow 0} \frac{C_{\frac{90}{270}}(v, v)}{v} \quad (10)$$

Here condition applies $0 \leq \lambda_U' \leq 1$ and $0 \leq \lambda_L' \leq 1$.

Given that Eq. (7) and Eq. (8) present positive tail dependence in the third and first quadrant, Eq. (9) and Eq. (10) reflect negative tail dependence in the fourth and second quadrant.¹³

Time-varying optimal copula (TVOC) joins all combinations of copulas¹⁴ and signposts potential dependencies in the tails in terms of switching from positive to negative dependence. Thus, there are two steps to model the TVOC approach 1) optimal copula and 2) time-varying modeling based on Liu et al. (2017).

3.1.1. Modeling optimal copula (OC)

As mentioned in the previous sub-section, various types of copulas describe positive and negative tail dependencies. Nevertheless, it is very difficult for them to fit the dependence types concurrently. Thus, the first step involves testing the direction of dependence between X and Y where corresponding copulas are selected based on their direction. For this purpose, the distribution-free test is applied proposed by Liu et al. (2017) to identify the underlying relationships. For variables X and Y having n length, it is measured whether Kendall's τ is positive provided that it measures the average market dependence and whether it is negative, where both null hypotheses set tau to be zero, that is, $\tau = 0$.

Results are interpreted following the conditions:

- i) OC fitting samples are selected from the set of copulas encompassing [normal, Student t , Clayton, rotated Clayton, Gumbel, and rotated Gumbel] if the value of Kendall's τ is positively significant.
- ii) OC fitting samples are selected from the set of copulas carrying [normal, Student t , Clayton-90 degree, rotated Clayton-270 degree, Gumbel-90 degree, and rotated Gumbel-270 degree] if the value of Kendall's τ is negatively significant.
- iii) OC fitting samples are selected from all set of copulas as mentioned in i) and ii) then the value of Kendall's τ is insignificant.

By employing this process of fitting OC samples, we can compare the log-likelihood values for each copula. Meanwhile, the changes in the market dependencies are tracked by repeating the two steps for each sub-sample as given below:

Step 1: We fit the sub-sample at time t where t is considered as the last point within the sub-sample, and then we compute the marginal distributions for constructs F_X and F_Y independently. Thus, we attain the uniform (0,1) series for u and v at each window;

Step 2: We calculate Kendall's τ for sub-sample at time t and perform the distribution-free tests as explained earlier. Given varying results in each copula, we select the OC from multiple sets of OC functions.

3.1.2. Modeling time-varying (TV) process

Based on Liu et al. (2017), a fixed window of 260 days and a rolling ahead process for each day is used following the sub-sample characteristics mentioned above. When OC modeling is combined with TV modeling process, the obtained copula reveals distinct dependence structures as obtained from TV process. In other words, as Patton (2006) and Creal et al. (2008) explained, the resultant copula only possesses the dynamic features which solely reflect positive or negative dependencies. In our study, the TV process is parallel to a regime-switching method, where one of the major benefits is that we do not have to compute a large number of parameters with the increase in the regimes. Apart from the Student t copula, the remaining copulas carry one respective parameter.

¹³ Please refer to Naem et al. (2021b) for copula specifications employed in the TVOC framework.

¹⁴ The list of copulas can be found in Liu et al. (2017).

3.2. Conditional diversification benefit

In order to determine the diversification benefits of Bitcoin and EAI, the study computed the conditional diversification benefit (CDB) technique of [Christoffersen et al. \(2018\)](#). The CDB is modeled by the probability q for the potential shortfall as:

$$CDB_i(\omega_i, q) = \frac{\omega_i ES_{i,t}(q) + (1 - \omega_i) ES_{g,t}(q) - ES_{p,t}(\omega_i, q)}{\omega_i ES_{i,t}(q) + (1 - \omega_i) ES_{g,t}(q) - VaR_t(q)}, \quad (11)$$

In Eq. (11), the EAI portfolio weight i is represented as ω_i at time t . Thus, we calculate the potential shortfall for probability (ES) as follows:

$$ES_{z,t}(q) = -E[r_{z,t} | r_{z,t} \leq F_{z,t}^{-1}(q)] \quad (12)$$

Here, the inverse distribution function of EAI z at time t is represented as $z = i, g$, and $F_{z,t}^{-1}(q)$. we segregate the upper bound of the potential shortfall $ES_{p,t}(\omega_i, q)$ as $\omega_i ES_{i,t}(q) + (1 - \omega_i) ES_{g,t}(q)$. However, the lower bound shortfall is determined as $VaR_t(q) = -F_{p,t}^{-1}(q)$ which is the value-at-risk (VaR) of the combined EAI's portfolio for q th quantile. Following this, the value of CDB varies between 0 and 1 where an increasing CDB value demonstrates higher diversification benefits and vice versa.

As mentioned earlier, for creating the combined portfolios, probability q is responsible for attaining diversification benefits measured for different EAI's portfolio weights given the probability figures of 5%. Thus, Eq. (12) can be re-stated as:

$$ES_{z,t}(q) = -\mu_{z,t} + \frac{\sigma_{z,t}}{q} d(D^{-1}(q)) \left[\frac{v + D^{-1}(q)^2}{v - 1} \right] \quad (13)$$

In Eq. (13), the cumulative distributive function is denoted as D and d describes the Student's t density function where v is degree of freedom. Thus, we represent VaR as $VaR_t(q) = -\mu_{p,t} + \sigma_{z,t} t D^{-1}(q)$.

3.3. Data and descriptive statistics

This study examines extreme tail dependence between Bitcoin¹⁵ and Emerging Asian Islamic (EAI) markets using the AGDCC-GARCH model, time-varying optimal copula approach, and conditional diversification benefit technique for the period spanning January 2, 2012 to December 23, 2021. For analysis purposes, we utilized the data of Bitcoin and constituents of MSCI Islamic Markets Indexes for the given Emerging Asian Islamic markets sourced from Datastream. The EAI's selected in the current study are MSCI Chinese Islamic stock index (CHN), MSCI Indian Islamic stock index (IND), MSCI Indonesian Islamic stock index (INS), MSCI Korean Islamic stock index (KOR), MSCI Malaysian Islamic stock index (MAL), MSCI Philippine Islamic stock index (PHL), MSCI Taiwan Islamic stock index (TAI), and MSCI Thailand Islamic stock index (THL). Morgan Stanley Capital Index is considered one of the most reliable sources for obtaining the data of various emerging markets, reflecting accurate information about the indices, as demonstrated by the former studies of [Foye \(2018\)](#) and [Cakici et al. \(2013\)](#).

[Table 1](#) illustrates the descriptive statistics of the variables included in the study, where BTC reveals the highest average returns among all other EAI's. While considering EAI's mean values, IND and TAI demonstrated comparable average returns, followed by KOR. Interestingly, closer to zero, zero, and negative average returns are reflected by CHN, THL, PHL, MAL, and INS. Variability of the average returns reiterates BTC as the riskiest investment with the highest standard deviation, while among EAI's, almost all markets exhibit comparable risk exposure for the given period. In addition, slightly negative values of skewness identify markets have suffered moderate losses given the uncertain distressed periods except for BTC, which display substantial exposure to losses for the whole sample period. The Jarque-Bera test of normality narrates remarkably higher values showcasing that the series is not normally distributed. The ARCH effect checks for the volatility in the time series, which validates sufficient ARCH effect among markets. The Ljung-Box test of autocorrelation indicated by Q(20) demonstrates that autocorrelation does not exist among markets. BTC correlation with all EAI's presents moderate and positive correlations with CHN, PHL, THL, INS, IND, and MAL, whereas KOR and TAI report negative correlations.

Further, to observe the time-varying patterns of return series between BTC and EAI's, it is necessary to compute their evolution of return series to evaluate the significant periods where markets have undergone financial or economic distress situations. [Fig. 1](#) displays the evolution of the return series of selected markets over the period. Numerous spikes symbolize various economic, financial, or pandemic events, resulting in sharp spillovers during the sample period. BTC demonstrated enhanced spillovers during 2017, reflective of the cryptocurrencies bubble burst ([Karim et al., 2022a](#); [Lucey et al., 2021](#)) and during the global pandemic of COVID-19 ([Naeem et al., 2021c](#); [Naeem and Karim, 2021](#); [Yousaf and Ali, 2021](#)). However, an abnormal spike during the first half of 2021 denotes price anomalies of cryptocurrencies ([Karim et al., 2022b](#)) which spiked the return of BTC. Considering EAI's, all emerging Islamic markets indicated spikes in their returns during European Debt Crisis spanning 2010–2012 ([Iqbal et al., 2021](#)), Shale oil crisis (2014–2016), where variations in the oil prices intensified the return spillovers ([Balli et al., 2019](#)), Chinese stock market crash in a single day during 2016 ([Womack, 2017](#)), Brexit referendum during 2016 ([Mensi et al., 2021](#)), US interest rate hike for the period 2017–2018 ([Elsayed et al., 2020](#)), COVID-19 pandemic ([Yarovaya et al., 2020](#); [Yousaf and Yarovaya, 2022](#)), and threats to the new variant of coronavirus –

¹⁵ The data has been sourced from: www.coinmarketcap.com

Table 1
Descriptive statistics and correlation.

	CHN	IND	INS	KOR	MAL	PHL	TAI	THL	BTC
Mean	0.004	0.036	-0.003	0.020	-0.012	0.000	0.034	0.001	0.361
Maximum	6.001	9.941	15.165	10.701	6.061	7.028	8.426	10.091	48.478
Minimum	-8.915	-14.244	-11.362	-10.576	-5.825	-16.814	-8.362	-16.784	-66.395
Std. Dev.	1.373	1.284	1.564	1.398	0.904	1.453	1.196	1.500	5.351
Skewness	-0.169	-0.698	-0.088	0.010	0.077	-1.158	-0.065	-0.743	-1.000
Kurtosis	2.762	10.952	8.045	4.742	4.677	12.528	4.946	12.449	19.463
JB	842.768 ^a	13,250.939 ^a	7040.869 ^a	2445.717 ^a	2382.220 ^a	17,643.980 ^a	2662.327 ^a	842.768 ^a	13,250.939 ^a
ARCH	184.763 ^a	551.038 ^a	633.822 ^a	813.264 ^a	305.559 ^a	676.375 ^a	243.253 ^a	184.763 ^a	551.038 ^a
Q(20)	28.459 ^a	78.119 ^a	37.199 ^a	61.775 ^a	34.830 ^a	25.670 ^a	29.915 ^a	28.459 ^a	78.119 ^a
Corr_BTC	0.044	0.015	0.029	-0.017	0.007	0.034	-0.001	0.034	1.000

Note: CHN (China), IND (India), INS (Indonesia), KOR (Korea), MAL (Malaysia), PHL (Philippines), TAI (Taiwan), THL (Thailand), and BTC (Bitcoin). JB is the Jarque–Bera normality test. Q(20) refer to the Ljung-Box test for autocorrelation of the return series. The ARCH test checks the existence of the ARCH effect. Corr_BTC indicates correlation of Emerging Asian Islamic markets with Bitcoin.

"a" indicates 1% level of significance.

omicron during the end of 2021. Whether economic, financial, or pandemic-oriented, these incidents reflect the exposure of markets to extreme periods demonstrating tail characteristics among the markets. Thus, each event marks severe spillovers in the plots of the return series, as indicated in Fig. 1.

To determine the asymmetric volatility connectedness, we applied a dynamic conditional correlation (AGDCC-GARCH) model between BTC and EAIs to express whether the correlation of BTC with EAIs is time-varying and asymmetric. Fig. 2 indicates substantial time-varying patterns among EAIs with strong positive (negative) dependence. Importantly, it must be noted that positive territories signify good correlational spillovers while negative territories demonstrate bad correlational spillovers for the whole sample period (Iqbal et al., 2021). A keener look at the volatility spillovers manifests that INS market is most correlated with BTC shaping extreme positive spillovers during the sample period. Spillovers are spiked during several economic stressful periods and the highest volatility is expressed during COVID-19, in line with Abakah et al. (2021) and Arfaoui and Yousaf (2022). The IND market formed positive spillovers during the Shale oil crisis, indicating its hedging capacity, and switched to a negative position afterward during the cryptocurrency price bubble burst and COVID-19 confirming its strong safe-haven features of the BTC as explained by the dominance of negative asymmetries in IND market. Nevertheless, THL, CHN, PHL, KOR, TAI, and MAL revealed a consistent position in their spillovers where COVID-19 is marked as the most significant event determining positive (negative) asymmetries. The near to zero values of EAIs against BTC implies that the Islamic stocks of THL, CHN, PHL, KOR, TAI, and MAL can offer diversification benefits to investors for conquering the volatility of BTC during uncertain economic conditions in line with Naeem et al. (2021a) and Shahzad et al. (2019) who documented stronger diversification avenues of Islamic stocks against other financial markets.

The probable explanation of the highest volatility correlation of INS market to BTC is the substantial number of cryptocurrency investors than regular stock market investors, which form approximately 6.5 million people investing in cryptocurrencies.¹⁶ Despite Shari'a compliances and regulatory sanctions, the Indonesian market possesses larger investors in cryptocurrencies due to the greater influence of social media among youngsters. Concurrently, the Indian market exhibits 59% growth in cryptocurrencies, which grew 641% in 2021 than 2020.¹⁷ Due to the growing concentration of both of these markets in terms of cryptocurrencies investment, positive (negative) correlations are evident in Fig. 2, shadowing their hedge and safe-haven features for Bitcoin. The Malaysian market manifests a unique persistent correlation (near zero), which points toward its 3.1% population owning cryptocurrencies.¹⁸ Hence, an insignificant number of investors and a neutral position in Fig. 2 echo the greater diversification benefits of MAL against BTC. However, the rest of the EAIs depict varying asymmetries but remain closer to zero, substantiating their varying diversification potential for BTC.

4. Empirical results

4.1. Time-varying optimal copula (TVOC) estimates

For understanding the extreme tail dependence between Bitcoin and Emerging Asian Islamic (EAI) markets, we measured the pairwise dependence between BTC and EAIs to evaluate their extreme dependence following different time-varying optimal copulas. The detailed analysis of each pair is presented in Figs. 3–10, where tail dependence is demonstrated between Bitcoin and each EAI employed in the study. Fig. 3 illustrates the TVOC estimates for Bitcoin and Chinese Islamic stock market returns. The best-fitting copula (Panel b) between BTC and CHN are Student's *t* (symmetric and tail-dependent), rotated Gumbel (asymmetric positive dependence), R1 Clayton (asymmetric negative dependence), and Normal (symmetric without tail dependence). The time-varying

¹⁶ Please see: <https://www.abc.net.au/news/2021-11-21/cryptocurrency-is-considered-haram-in-indonesia/100630646>

¹⁷ Please see: https://www.business-standard.com/article/markets/india-s-cryptocurrency-market-grew-641-over-past-year-says-report-121100500104_1.html

¹⁸ Please see: <https://triple-a.io/crypto-ownership-malaysia/>

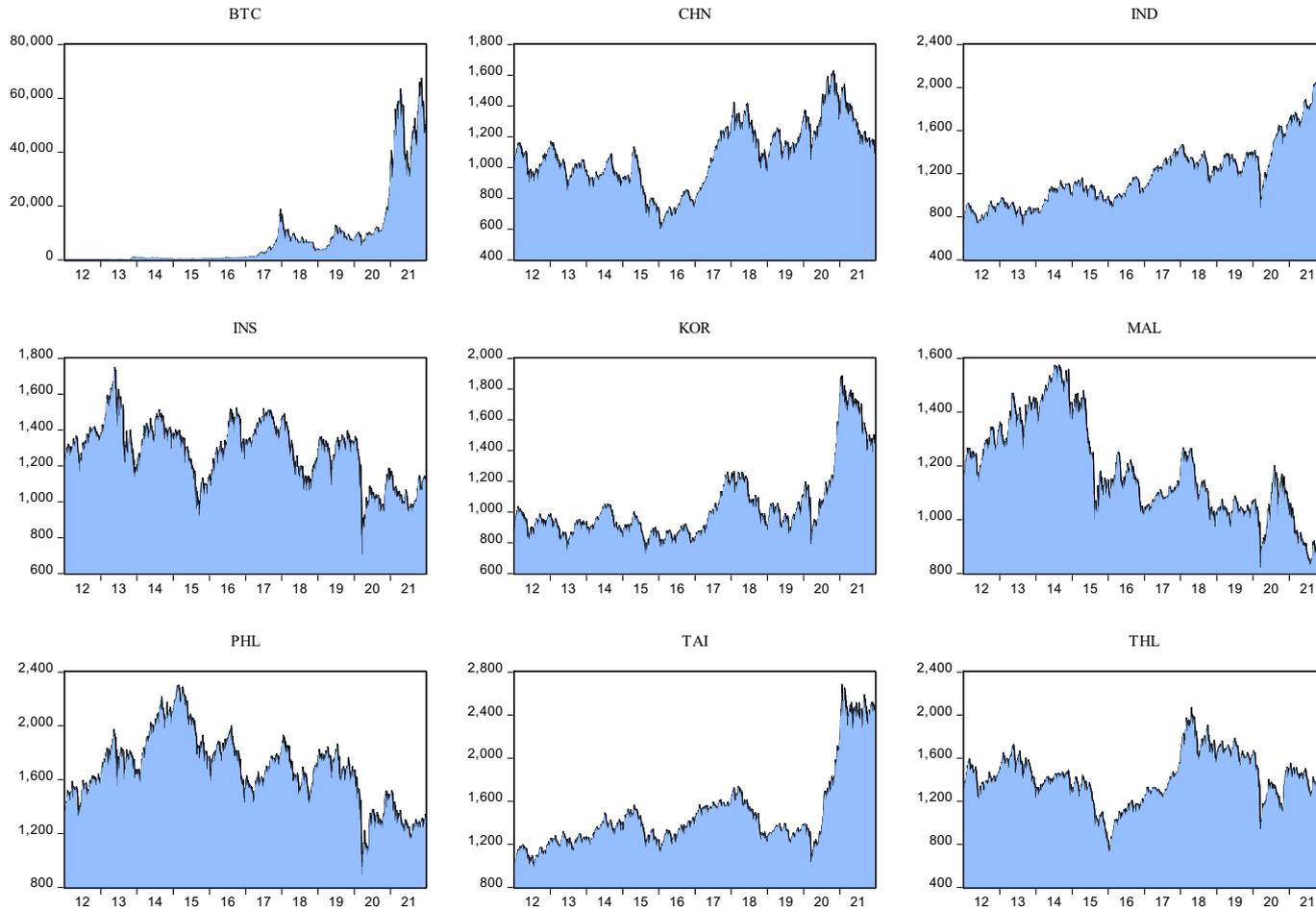


Fig. 1. Time evolution of Bitcoin and Emerging Asian Islamic markets.

Note: This figure indicates the evolution of Bitcoin and Emerging Asian Islamic markets from 2/01/2012 to 23/12/2021.

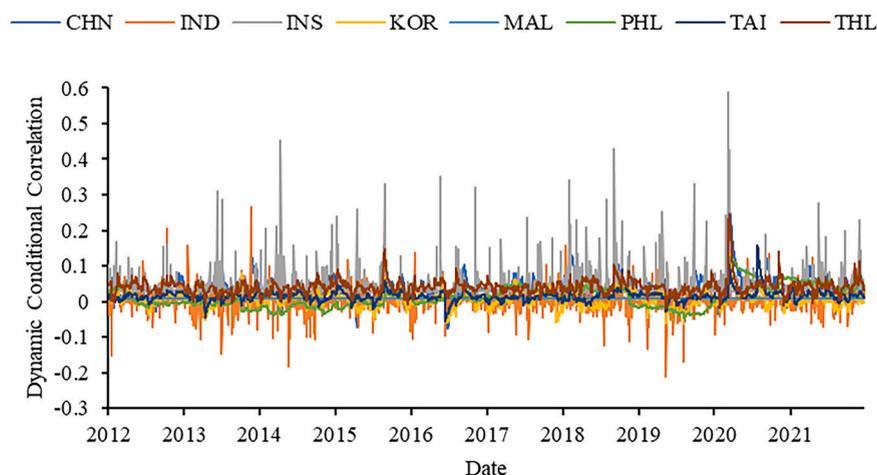


Fig. 2. Dynamic conditional correlation between Bitcoin and Emerging Asian Islamic returns.

Note: This figure indicates the dynamic conditional correlation between Bitcoin and Emerging Asian Islamic markets using AGDCC-GARCH model.

characteristics of TVOC estimates manifested by Kendall's Tau (Panel a) indicate various regimes where dependence structure varied between the copulas, as explained in panel (b). Predominantly, the rotated Gumbel arrangement during European Debt Crisis (2010–2012) necessitates the safe-haven feature of CHN for BTC.

During Shale oil crisis (2014–2015), the copula arrangement switched between Student's t copula to rotated Gumbel reiterating its strong safe-haven characteristics for BTC. Meanwhile, the Chinese market crash in 2016 indicates the dominance of Student's t copula, indicating symmetric tail-dependence between the markets. During COVID-19, the dependence between CHN-BTC is asymmetric negative, but they maintain their position near zero, emphasizing greater diversification avenues offered by the CHN market against BTC. It is also highlighted that dependence remained positive during stable market turns, supporting hedging capabilities of CHN Islamic stock market against BTC. Our findings corroborate Usman et al. (2019), who inferred that dependence mechanisms between Islamic stocks and financial stocks are time-varying, offering greater hedge, safe-haven, and diversification potential for conventional stocks. In line with Ahmad et al. (2018) and Naeem et al. (2021a), a greater safe-haven and diversification avenue persists in the Islamic markets for investors, portfolio managers, and policymakers to mitigate their risk during unstable economic conditions. Fig. 3c–f demonstrate time-varying optimal copulas in the lower-upper, upper-upper, lower-lower, and upper-lower dependence arrangements, which reverberate the existence of various tail-dependent copulas given various tail-dependencies between CHN and BTC. Tail-dependent structures in all panels recall strong safe-haven avenues following distressing periods, while hedge characteristics are dominant during stable periods. Concurrently, diversification benefits exist for the CHN Islamic stock market investors for the copulas maintaining their position near zero.

Fig. 4 illustrates TVOC estimates between Bitcoin and Indian Islamic stocks where copulas are largely divided into Student's t (symmetric and tail-dependent), Normal (symmetric and no tail-dependence), R1 Clayton (asymmetric negative dependence), and R2 Gumbel (asymmetric negative dependence). The time-varying attributes of these copulas in panel (a) demonstrate that copulas mainly remained in the negative region for the overall sample period, with the dominance of Student's t copula during Shale oil crisis and Chinese market crash. The copula is organized symmetrically but with the dominance of tail-dependence features. Further, during the US interest rate hike and the cryptocurrency price bubble burst, the copulas switched to R1 Clayton, reflecting asymmetric negative dependencies. Particularly, during COVID-19, the copulas mainly resided in the negative territories with the dominance of R1 Clayton and R2 Gumbel arrangement validating the safe-haven features of IND Islamic stock market for BTC following the distressed periods of cryptocurrencies bubble burst and COVID-19. Soon after the markets started returning to normal circumstances, the copulas resumed their position to the Student's t , denoting symmetric tail-dependencies.

Empirically, our findings are in line with Arif et al. (2021), who reported strong safe-haven features of Islamic stocks during the distressed periods for various financial stocks. Accordingly, Ebrahim et al. (2016) argue that Islamic stocks outperform conventional investment streams when a financial contagion hits the economy. This is intuitive due to their inherent low-risk bearing potential and lower leverage involvement while making investments following the Shari'a guidelines. Thus, IND Islamic market stocks provide greater safe-haven potential against BTC following the volatile economic conditions. Fig. 4c–f disintegrates the copulas into lower-upper, upper-upper, lower-lower, and upper-lower tails, which sufficiently reiterates our findings as presented in panel (a) of Fig. 4. Overall, it is stressed that IND Islamic stock market possesses greater safe-haven potential against BTC when markets are experiencing economic, financial, and pandemic-related turmoil.

Fig. 5 exhibits extreme tail dependence between BTC and INS Islamic stock market where predominant copulas correspond to Student's t (symmetric tail dependent), Clayton and rotated Gumbel (asymmetric positive dependence), Normal (symmetric without tail-dependence), and R1 Gumbel and R2 Gumbel (asymmetric negative dependence). Panel (a) manifests various tail-dependent copulas for the sample period where initially copulas resided in the positive territories indicating co-movement between BTC and INS market. During the cryptocurrency's price bubble burst in 2017, the copulas switched to R1 Gumbel and R2 Gumbel, showcasing

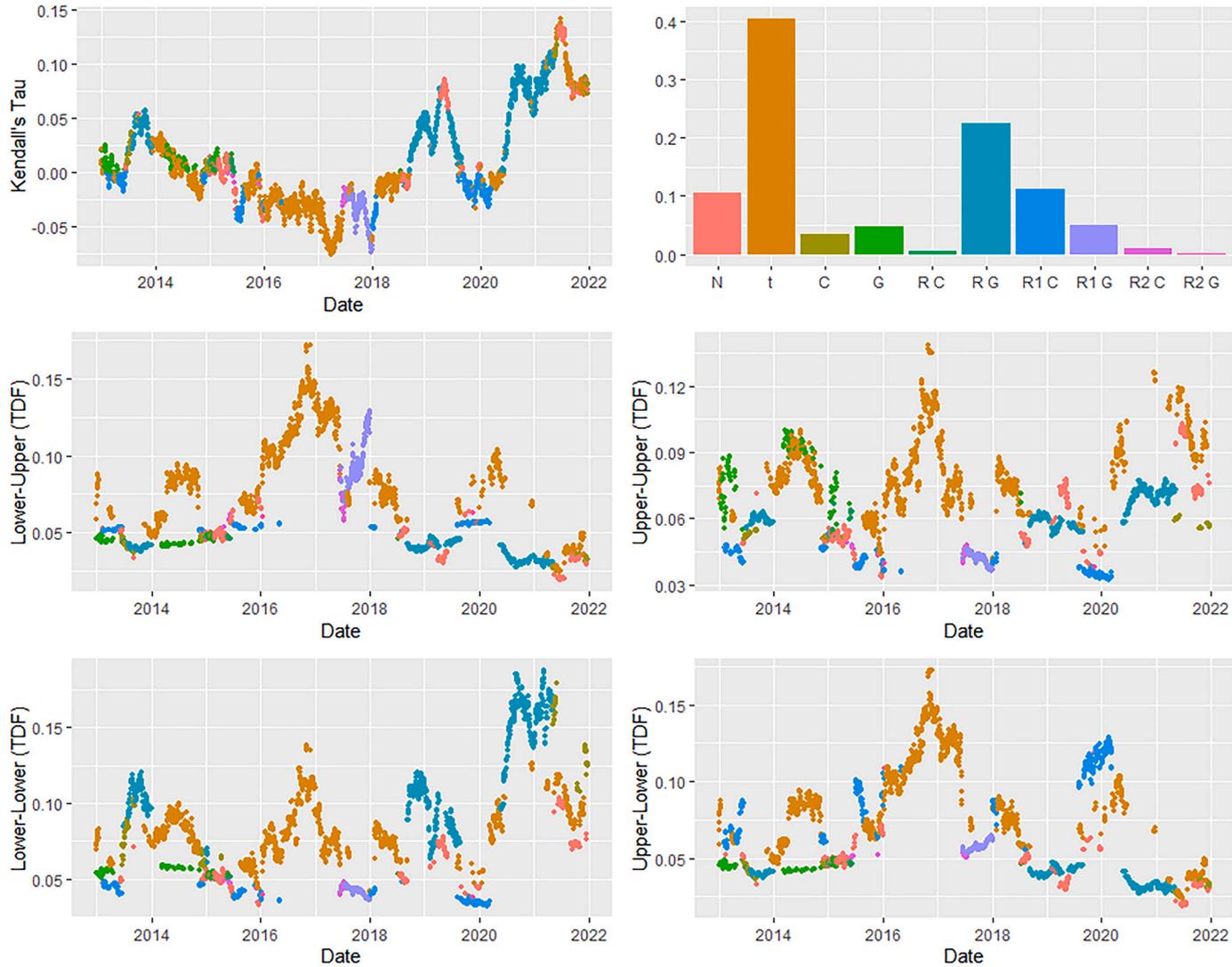


Fig. 3. Time-varying optimal copula estimates for Bitcoin returns and Chinese Islamic returns.

Note: Panel (a) shows the Kendall's τ derived from the tail dependence parameters and panel (b) shows the percentages of best-fitted copula. The histogram (panel b) shows the proportion of the total number of best-fitting copulas for every copula. The horizontal axis of panel b represents the various types of copula model considered in this paper such as N: normal; t: Student's-t; C: Clayton; G: Gumbel; RC: 180° rotated Clayton; RG: 180° rotated Gumbel; R1C: 90° rotated Clayton; R1G: 90° rotated Gumbel; R2C: 270° rotated Clayton; R2G: 270° rotated Gumbel.

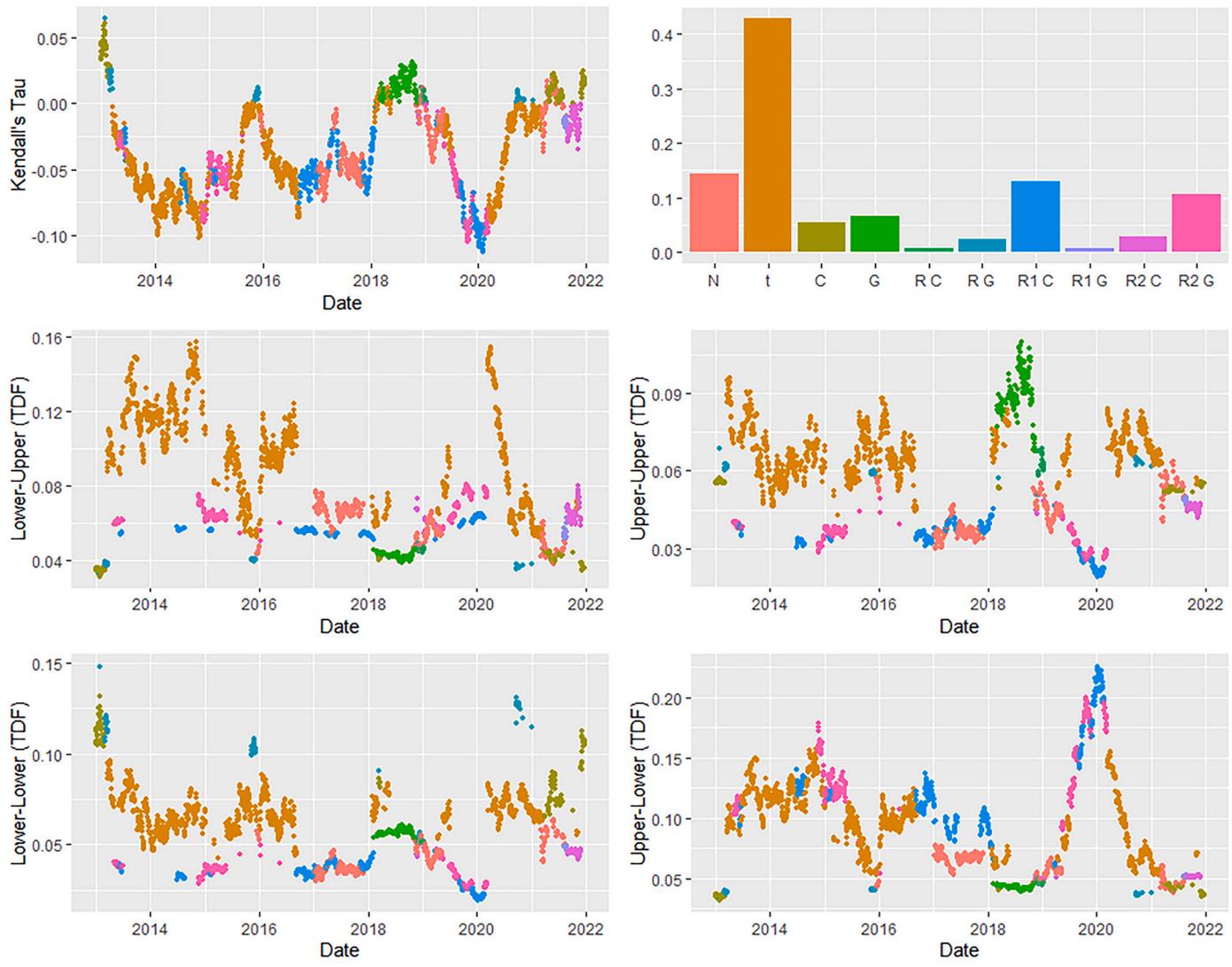


Fig. 4. Time-varying optimal copula estimates for Bitcoin returns and Indian Islamic returns.
 Note: Refer to note in Fig. 2.

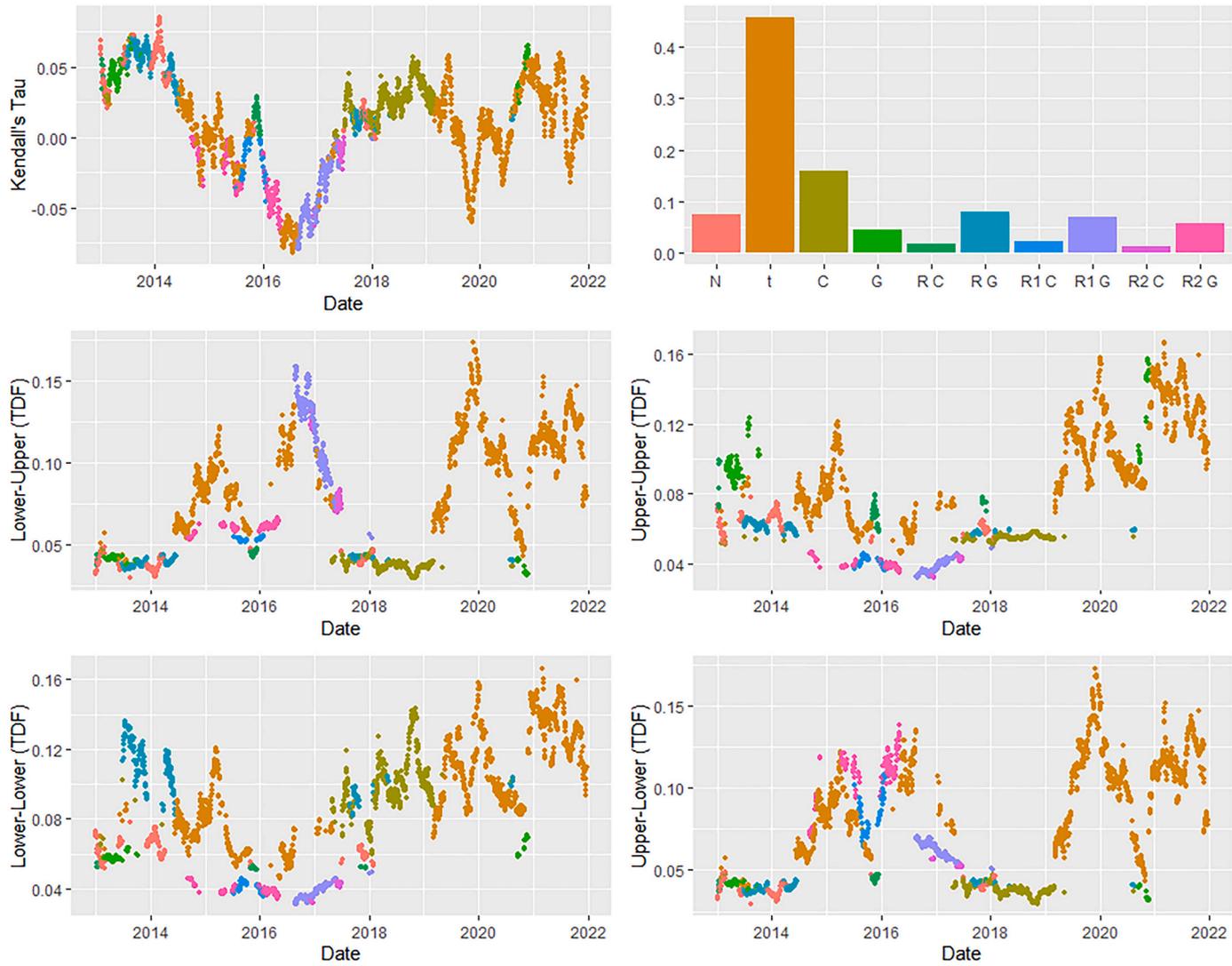


Fig. 5. Time-varying optimal copula estimates for Bitcoin returns and Indonesian Islamic returns. Note: Refer to note in Fig. 2.

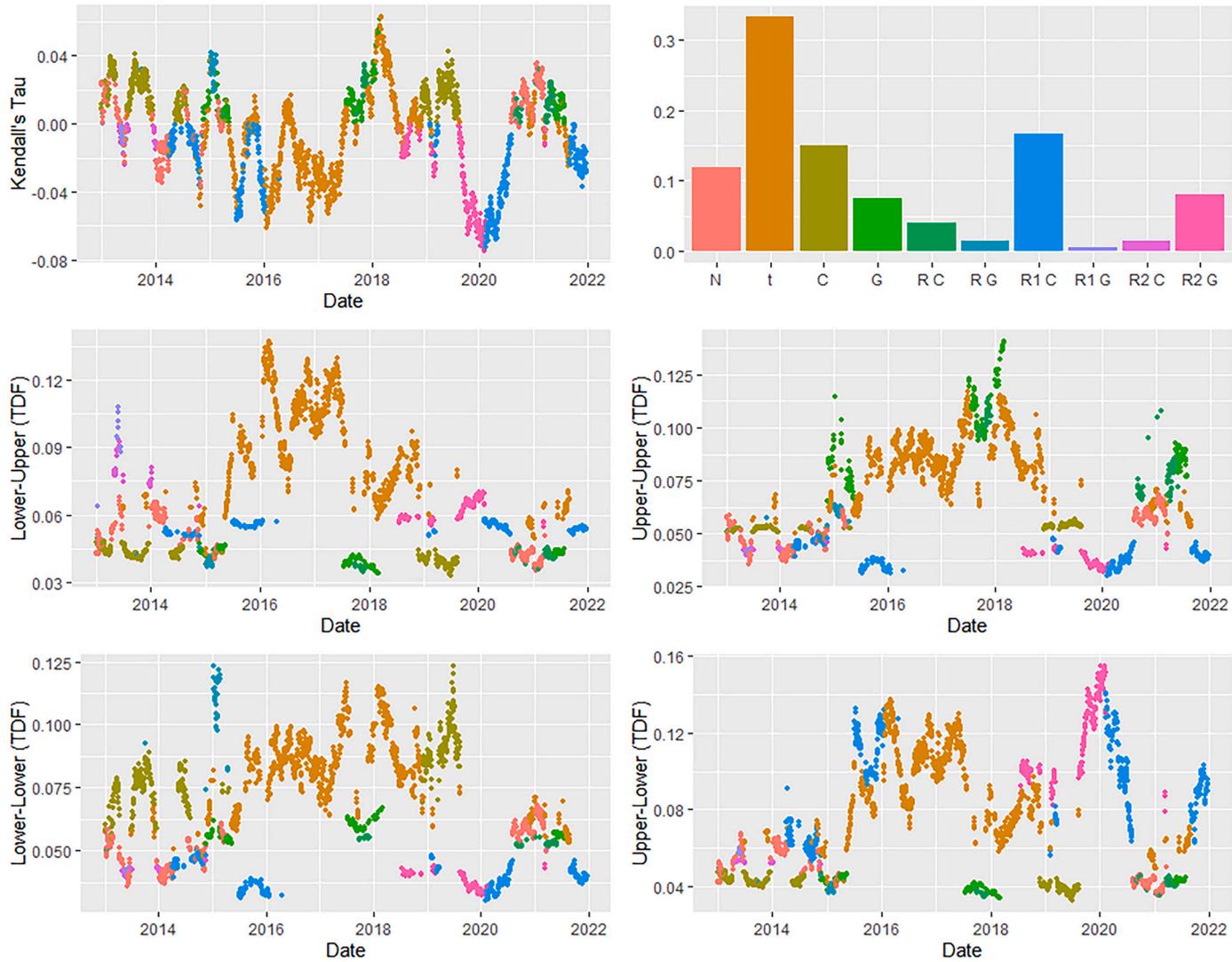


Fig. 6. Time-varying optimal copula estimates for Bitcoin returns and Korean Islamic returns. Note: Refer to note in Fig. 2.

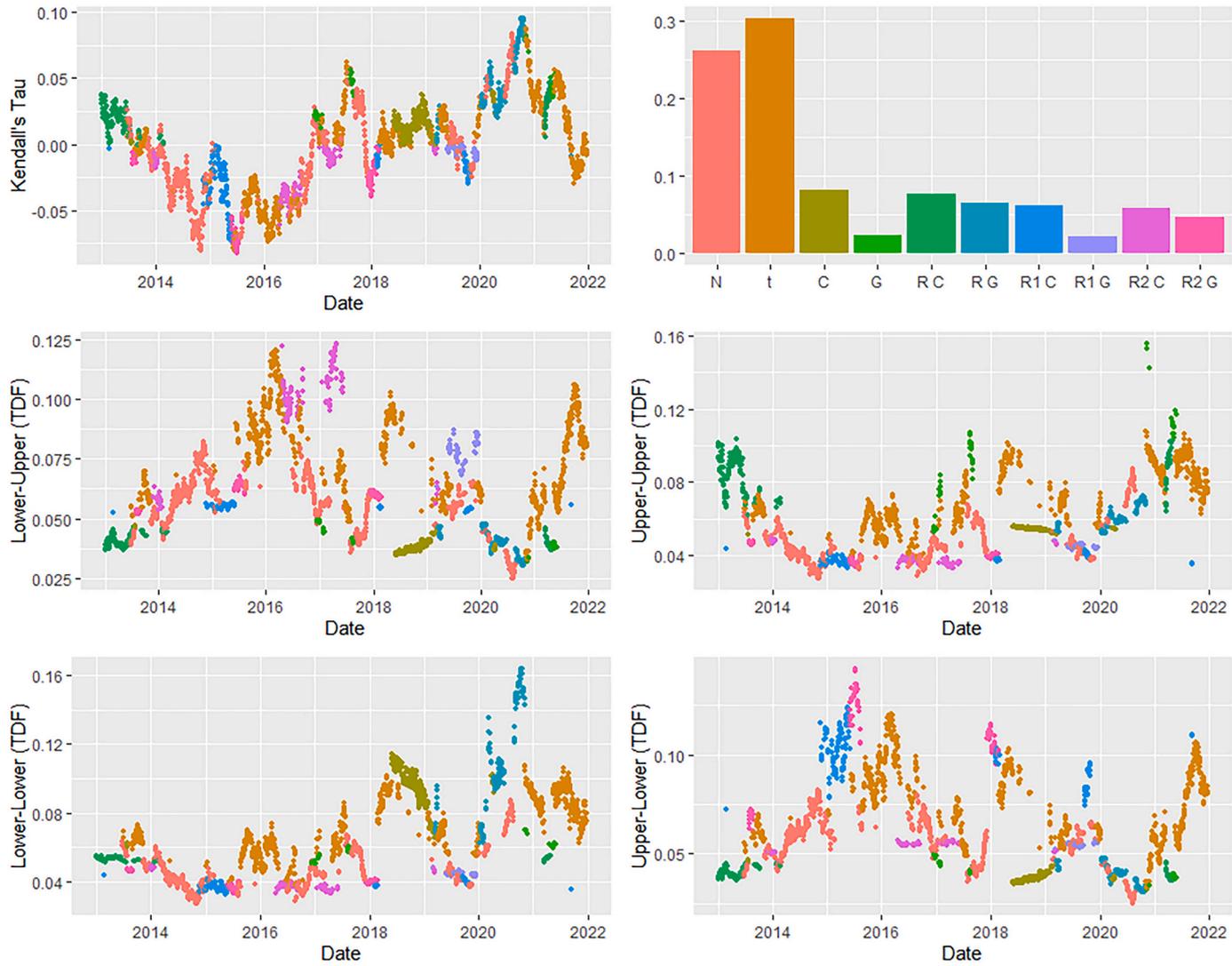


Fig. 7. Time-varying optimal copula estimates for Bitcoin returns and Malaysian Islamic returns. Note: Refer to note in Fig. 2.

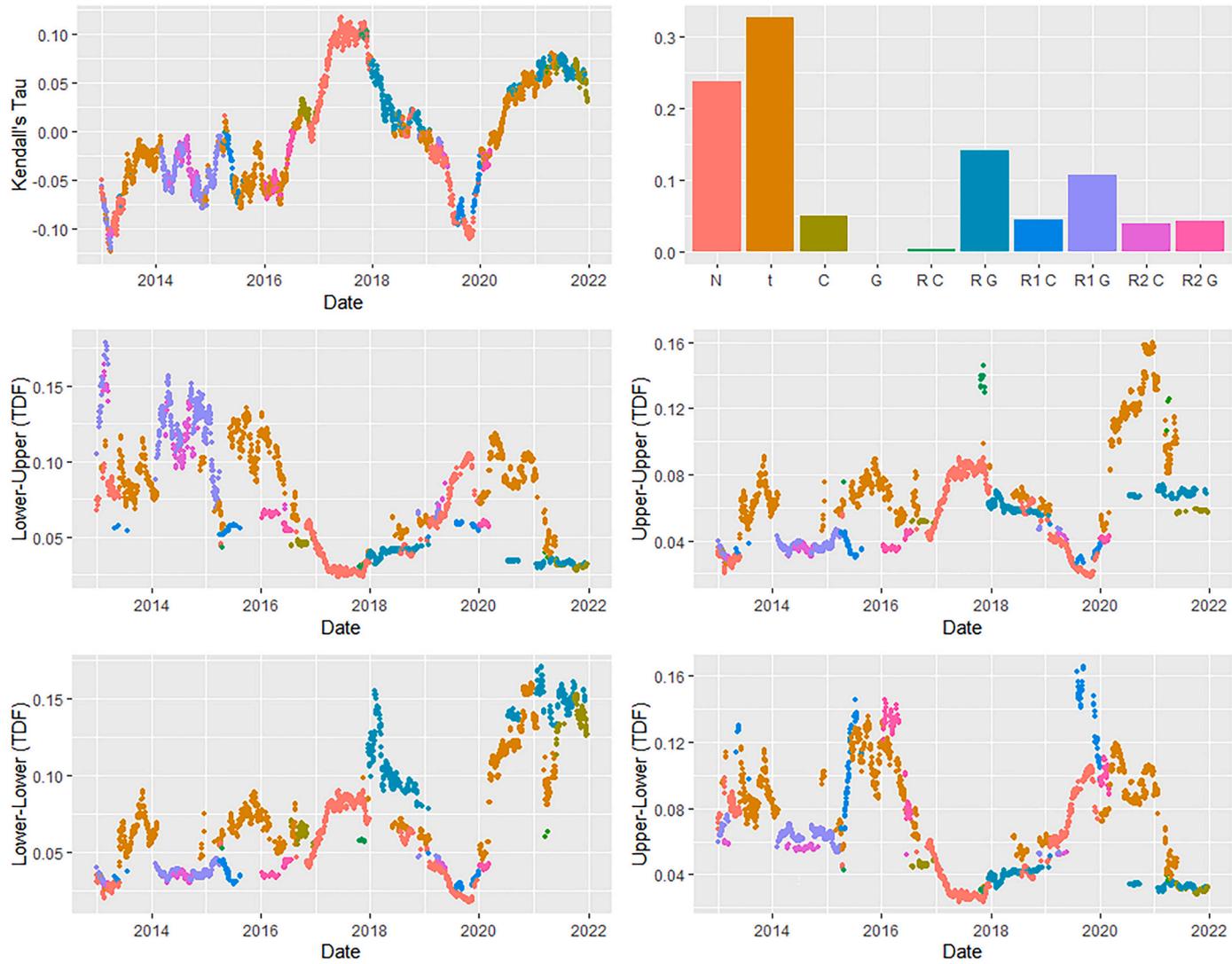


Fig. 8. Time-varying optimal copula estimates for Bitcoin returns and Philippine Islamic returns. Note: Refer to note in Fig. 2.

the predominance of negative asymmetries following the volatility and sharp decline in the cryptocurrencies' prices (Naeem and Karim, 2021), signaling the safe-haven features of INS market during the tumultuous time scales. During COVID-19, the dependence between INS and BTC mainly showed the dominance of Clayton copula with remarkable positive dependence. However, the copulas remained closer to zero implying a stronger diversification potential of INS market against BTC. Afterward, as illustrated in panel (a), the copulas mainly indicated the dominance of Student's t copula with few traces of Gumbel copula echoing asymmetric positive dependence.

Our findings are aligned with Azad et al. (2018), who contend that a stronger investment shield exists in the Islamic markets' stocks against conventional markets. Interestingly, our findings negate the findings of Rejeb and Arfaoui (2019), who inferred Islamic stocks are not completely immune to external shocks and are equally exposed to the volatilities persisting in the economic environment. Fig. 5c-f represent the organization of copulas in the four tails which reiterate our results of the panel (a) with pronounced dominance of R1 Gumbel and R2 Gumbel in the Lower-Upper and Upper-Lower tails while Student's t copula is predominant in the extreme upper and extreme lower tails. With these findings, we conclude that INS market offers greater diversification potential against BTC and safe-haven features are dominated during the crisis period of the cryptocurrencies price bubble burst.

Time-varying extreme tail dependence between BTC and KOR market is exhibited in Fig. 6, which signifies the dominance of various copulas, for instance, Student's t (symmetric tail-dependent), R1 Clayton and R2 Gumbel (asymmetric negative dependence), Clayton and Gumbel (asymmetric positive dependence), and Normal (symmetric without tail-dependence). Panel (a) demonstrates fluctuations in the copula arrangement following various periods where copulas are mainly residing in the negative territories showing inverse asymmetries. During the European Debt Crisis, the predominance of R2 Gumbel copula is observed with negative asymmetric dependence portraying weak safe-haven avenues of KOR market against BTC as copulas are maintaining their position near zero. Further, Shale oil crisis and Chinese stock market crash denote the predominance of R1 Clayton, symbolizing the strong safe-haven characteristics of KOR for BTC. Soon after the markets stabilized from these crisis episodes, copula switched to Student's t with the symmetric arrangement. Notably, the copulas during 2017 retained their neutral position shadowing the diversification potential of KOR market against BTC to rescue the investors from the price anomalies of cryptocurrencies. The onset of COVID-19 embarks R1 Clayton and R2 Gumbel copula composition with pronounced negative tail-dependencies during this global crisis period. The negative dependence during the COVID-19 pandemic echoes strong safe-haven features of KOR Islamic market against BTC in line with Naeem et al. (2021a), who also reported stronger safe-haven attributes of Islamic stocks against financial markets following the pandemic. Fig. 6c-f split the copulas based on their respective extreme tails, mirroring our findings as explained earlier. The R1 Clayton and R2 Gumbel copulas mainly reflect the COVID-19 pandemic in the extreme upper and lower tails and the lower-upper tails. Overall, a stronger safe-haven feature persists in the Islamic stock market of KOR against BTC to shield the investments from unintended economic and financial consequences.

TVOC estimates between MAL and BTC markets are exhibited in Fig. 7, where copulas are dominant in the Student's t copula and Normal copulas showing symmetric composition with and without tail-dependence, respectively. Following this, Clayton and Rotated Clayton copulas are dominant, revealing asymmetric positive dependence. Meanwhile, traces of rotated Gumbel, R1 Clayton, R2 Clayton, and R2 Gumbel are also reported. Corresponding to the time-varying Kendall's Tau attributes, the copulas initially showed positive co-movement between BTC and MAL. During the Shale oil crisis, the dominant copulas are R1 Clayton and R2 Gumbel, signifying asymmetric negative dependence, which ultimately echoes strong safe-haven features of MAL Islamic stock market against BTC. Surprisingly, copulas moved to a neutral position during 2017, reflecting the cryptocurrency price bubble burst with the pre-eminence of Clayton and R2 Clayton shadowing the diversification potential of MAL Islamic stock for BTC given the uncertainty in the cryptocurrencies. In this way, intriguing results are manifested for investors of cryptocurrencies to consider the MAL Islamic stock market to avoid exponential losses as rational investors fly-to-safety options under irregular market circumstances.

Similarly, during COVID-19, copulas retained their neutral position, which suddenly jumped to a positive time-varying plot symbolizing dissipating diversification potential after the markets started recovering from the surmounted challenges faced by COVID-19. Corroborating our results with Shahzad et al. (2017), Alam and Ansari (2020), and Arif et al. (2021), Islamic stocks possess a greater diversification cushion against conventional markets and BTC in our case. The disintegrated copulas in Fig. 7c-f validate our findings by demonstrating the dominance of Student's t , Normal, and Clayton copulas, given lower-upper, upper-upper, lower-lower, and upper-lower tails. In addition, few traces of rotated Clayton, rotated Gumbel, R1 Clayton, R2 Clayton and R2 Gumbel are displayed in the plots signaling toward diversification benefit of MAL market for BTC and safe-haven features during 2017 conquering the cryptocurrencies price burst (Karim et al., 2022a, 2022b; Naeem and Karim, 2021).

The time-varying optimal copulas revealing extreme dependence between BTC and PHL Islamic stock market in Fig. 8 display the majority of Student's t copula followed by Normal, rotated Gumbel, R1 Gumbel, whereas meager portions of Clayton, R1 and R2 Clayton, and R2 Gumbel copulas are also reported in the plot. Panel (a) corresponding to each copula in panel (b) represents the negative persistence of copulas in the graph, suddenly shifting toward the positive side of the plot until COVID-19, which again tossed to negative dependence, and finally exhibited positive dependence at the end of the sample period. The negative dependence in panel (a) until 2017 manifests dominance of R1 Gumbel blended with Normal copula reflecting European Debt Crisis which resulted in asymmetric negative dependence between BTC and PHL Islamic stocks implying strong safe-haven characteristics of PHL market against BTC. Further, copulas maintained a near to zero position in the graph signaling weaker safe-haven and stronger diversification benefits of PHL market. After the crash of the cryptocurrency price bubble in 2017, copulas are assembled in a perfect positive co-movement echoing symmetric arrangement without tail-dependent features.

With the onset of COVID-19, copulas regained the negative dependence on the dominance of R Gumbel copula necessitating strong safe-haven avenues offered by PHL market against BTC during the pandemic of coronavirus. Afterward, copulas exhibited positive dependence till the end of the graph. Conquering the results of Azad et al. (2018), Arif et al. (2021), and Naeem et al. (2021a), our

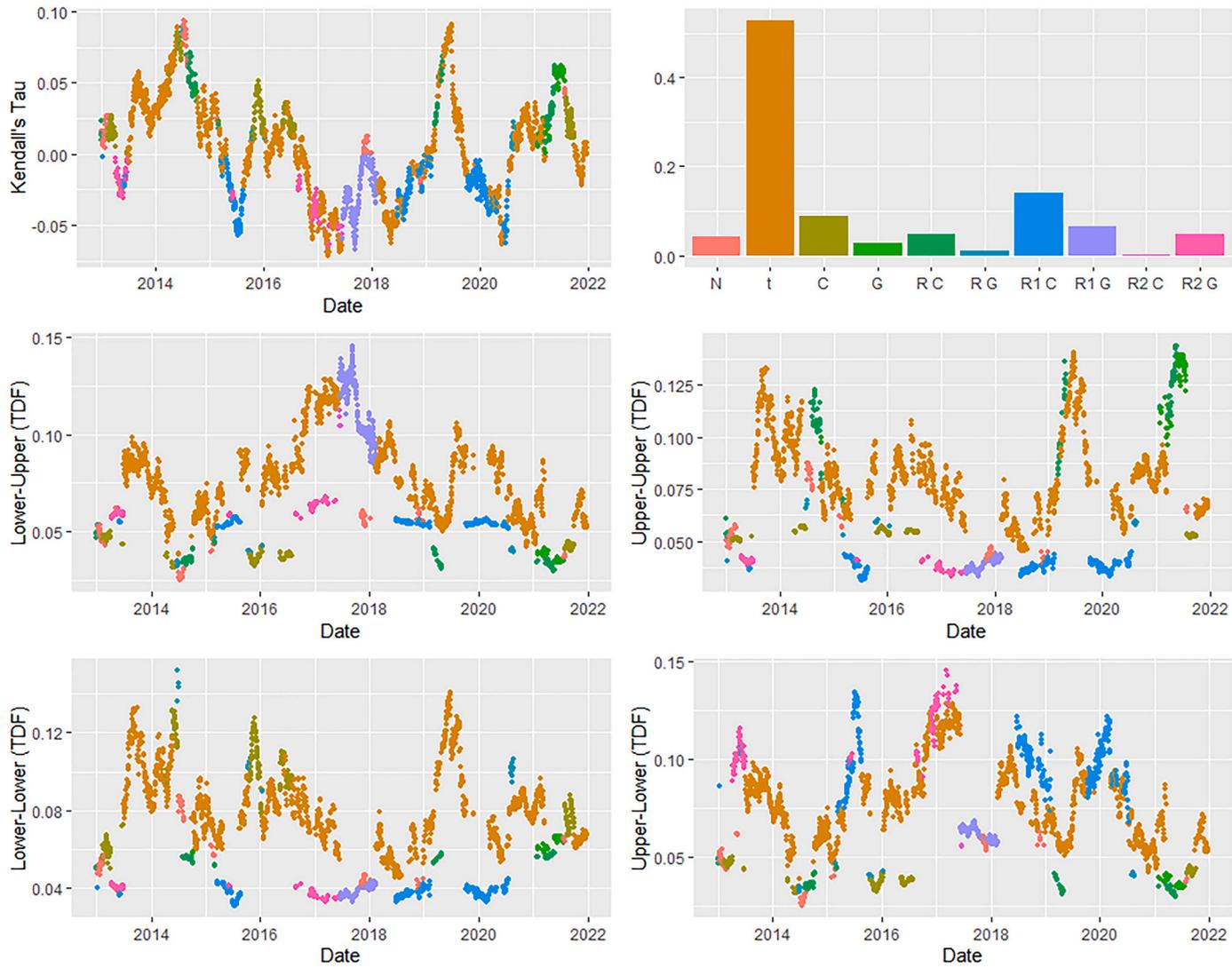


Fig. 9. Time-varying optimal copula estimates for Bitcoin returns and Taiwanese Islamic returns. Note: Refer to note in Fig. 2.

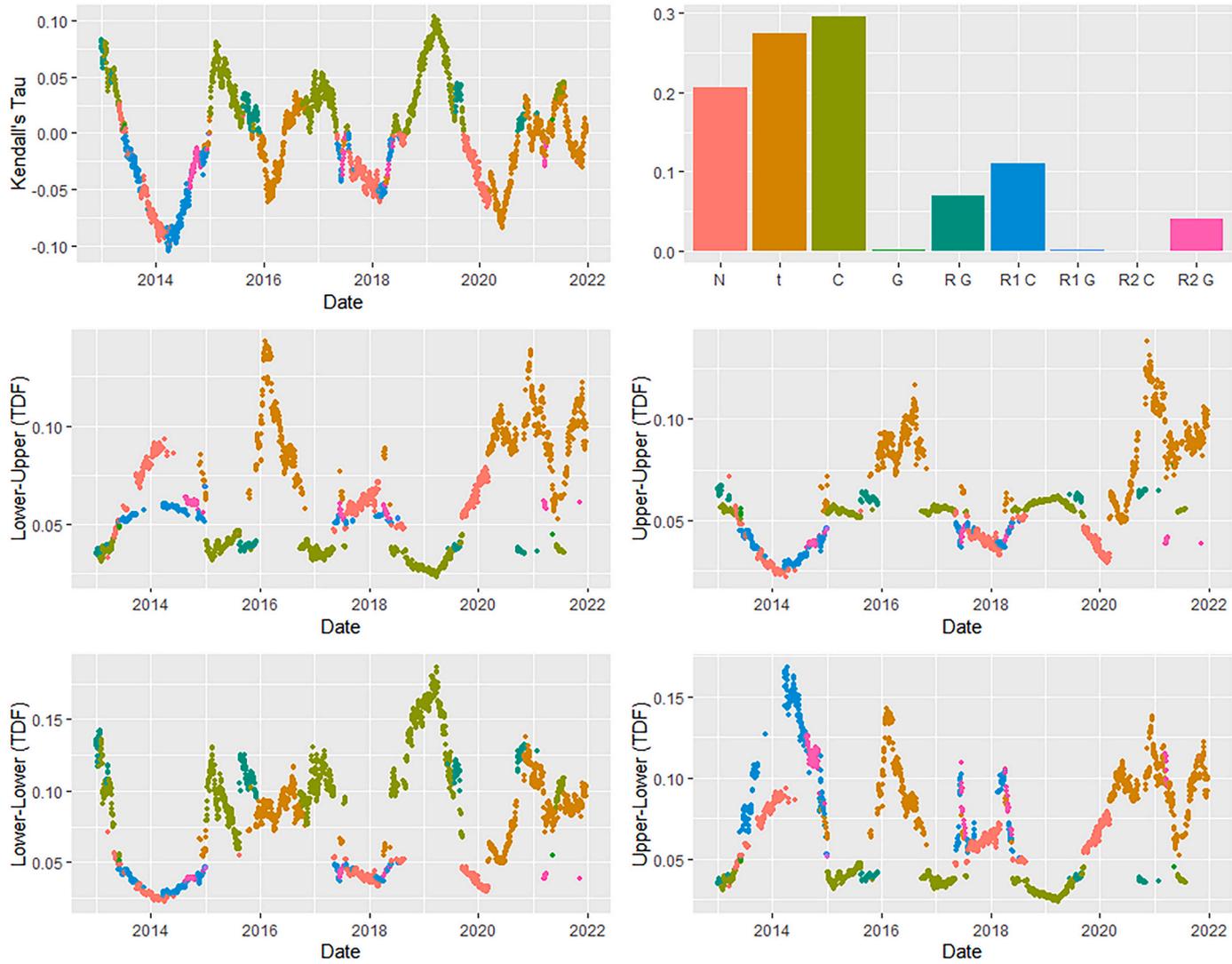


Fig. 10. Time-varying optimal copula estimates for Bitcoin returns and Thailand Islamic returns. Note: Refer to note in Fig. 2.

findings also support the argument that Islamic stocks offer a greater investment shield against conventional markets due to their low-risk bearing potential. Moreover, disintegrated copulas arrangement in panels (c–f) demonstrates the dominance of R1 Gumbel in the lower-upper tail while Normal copula superseded all copulas in all extreme tails indicating positive dependence.

Consistent with other EAIs, the results in Fig. 9 reveal that tail-dependence between BTC and the TAI market indicates prime supremacy of Student's t copula while substantially lower fractions of R1 Clayton, Clayton, and R1 Gumbel copulas are reported in the figure. Corresponding to the graphical visualization in panel (a), it is noted that copulas depict positive dependence until Shale oil crisis, where copulas twisted to negative dependence with the dominance of R1 Clayton, displaying asymmetric negative dependence with pronounced safe-haven features of TAI market against BTC. Interestingly, the cryptocurrencies bubble burst during 2017 showed the dominance of R1 Gumbel, echoing extreme negative dependence reiterating safe-haven aspects of Islamic stocks. Consecutively, the COVID-19 outbreak demonstrated negative dependence with R1 Clayton mirroring negative dependencies during the global pandemic period. All distressed events between the pair of BTC-PHL represented strong safe-haven features of PHL market for BTC to overcome the ethical risk of cryptocurrencies. Literature supports that Islamic stocks outperformed during the COVID-19 pandemic (Nomran and Haron, 2021). The current study embraces this argument by implying strong safe-haven characteristics of Islamic stocks when an abnormal condition prevails.

The extreme tail-dependence between BTC and THL Islamic market in Fig. 10 represents the dominance of Clayton, Student's t , and Normal copulas followed by R1 Clayton, rotated Gumbel, and R2 Gumbel. Corresponding to the panel (a) of time-varying trends, Shale oil crisis manifested negative dependence between BTC and THL market, connoting safe-haven avenues of THL market for BTC during the stressful economic episode. Alongside, copulas shifted toward positive dependence, which again shifted to negative dependence. The copulas in this regime are symmetric with the dominance of tail-dependence, indicating weaker safe-haven properties of THL for BTC. Accordingly, markets demonstrated near to zero dependence following the Shale oil crisis, implying diversification benefits of Islamic stock even during the cryptocurrency bubble burst. However, during COVID-19, the dependence is mainly negative, but copulas belong to a symmetric class with and without tail-dependence, echoing that the pair of BTC-THL does not manifest asymmetric arrangement; instead, both markets are symmetrically arranged, suggesting neither safe-haven nor diversification benefits offered during the global pandemic by THL Islamic market against BTC. In line with Usman et al. (2019) and Ahmad et al. (2018), we reported significant safe-haven features during Shale oil crisis with significant decoupling patterns during COVID-19.

4.2. Conditional diversification benefits (CDB)

For devising an equally weighted portfolio of BTC and EAIs, we computed the conditional diversification benefits of Bitcoin and Emerging Asian Islamic markets to propose portfolio implications for investors, portfolio managers, financial markets participants, faith-based investors, and policymakers. Based on Christoffersen et al. (2018), we utilized the conditional diversification benefit (CDB) approach for expected shortfall given the probability threshold ($p = 5\%$) in a portfolio of BTC and EAIs as this measure is considered consistent with the original measure. Since the diversification benefits vary with the changing portfolio composition and probability value, the CDB is computed following the passive trading strategy, assuming that the weights remain constant over time, corresponding to the lower distribution tails.

Fig. 11 illustrates the time-varying attributes of CDB for an equally adjusted portfolio of BTC and EAIs. The graph spots four time

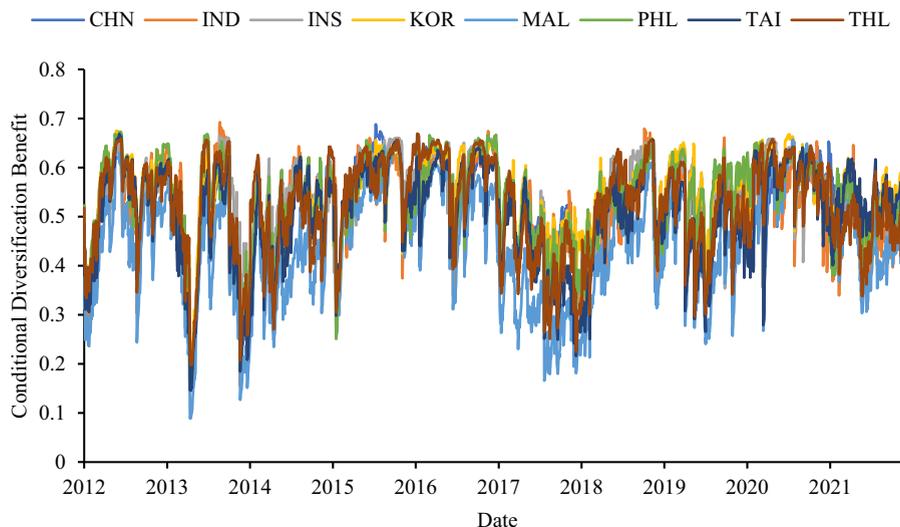


Fig. 11. Conditional diversification benefits from adding Emerging Asian Islamic markets to Bitcoin portfolio (at 5% level - equally-weighted portfolios).

Note: Time series plot of the conditional diversification benefits (CDB) of Emerging Asian Islamic (EAI) markets for Bitcoin. Equally weighted portfolios consisting of 50% EAI and 50% of Bitcoin are examined to estimate the conditional diversification benefit at a 5% level.

periods where CDB varied between percentages: 1) during 2012–2013, 2) during 2013–2014, 3) during 2014–2018, and 4) during 2018–2021. The first period corresponds to European Debt Crisis and its aftermath, where CDB ranges between 0.3 to 0.65. A declining CDB trend was observed in the second period when the Shale oil crisis started and the value of CDB differed between 0.1 to 0.7, substantiating greater diversification benefits of EAI's for BTC following the intense circumstances of the Shale oil revolution. Afterward, the third period demonstrates the variation in the CDB between 0.1 to 0.7 following Chinese stock market crash, the cryptocurrencies price bubble burst, and US interest rate hike. All these events conspicuously explain the stronger diversification benefits of EAIs for BTC in line with Naeem et al. (2021a), Arif et al. (2021), Usman et al. (2019). Finally, the last period fluctuates in the CDB between 0.2 to 0.7, resonating diversification benefit of Islamic markets to overcome the risk of BTC during COVID-19 outbreak and cryptocurrencies price volatilities during the first half of 2021 (Karim et al., 2022a).

Fig. 12 visualizes the CDB controlled analysis at a 5% level, reflecting extreme left tail distribution for multiple portfolio weights. Generally, all EAIs demonstrate gradual growth with an inclining proportion of BTC in a portfolio to reach an optimal diversification level at 60%, after which the CDB tends to decrease gradually. Overall, it is implied that EAI's offer greater diversification benefits for BTC particularly when markets are undergoing external market pressures, pandemic situations, or any other financial distressing event.

5. Conclusion and portfolio implications

Higher involvement of Bitcoin investing in illicit activities, such as human trafficking, terrorism, black e-commerce, child abuse, and cybercrimes, has nurtured investors' ethical risk, which can be mitigated through ethical investments. Motivated by this argument, the current study examined the extreme tail-dependence between Bitcoin and Emerging Asian Islamic markets for the period encompassing January 2, 2012 to December 23, 2021 to investigate whether EAIs hedge/diversify the dark side of Bitcoin.

We proposed useful implications for policymakers, governments, regulatory bodies, ethical investors, and portfolio managers. The study connotes effective policymaking strategies regarding EAIs and Bitcoin for policymakers. Policymakers can re-design their existing cryptocurrency investing policies and encourage the institutions to consider the avenues of EAIs to avoid substantial monetary losses and reduce illicit activities of BTC investing. Similarly, the governments' role is considered an effective tool in devising future policies of ethical investing where EAIs can be added to a portfolio of cryptocurrencies for mitigating ethical risk. On the other hand, regulatory bodies need to ponder the unregulated nature of cryptocurrencies with their decentralized system of transactions to protect the stakes of institutional investors, investors, and stakeholders against unintended losses raised out of illegal activities financed through BTC and cryptocurrencies.

Further, the study splits the implications for both types of investors, for instance, Islamic stock investors and cryptocurrencies investors. Both differ in their mainstream investment strategies, devising portfolio risk management tools, ethical concerns, and planning their future portfolios to shelter their investments. Our findings present intriguing implications for Islamic stock (faith-based/ethical) investors to continue investing in their current investment avenues as ethical investments possess low risk, lower leverage involvement, and underlying asset presence to back up their ethical investments. Contrarily, for Bitcoin investors, the findings provoke the investors to include EAIs in their investments to lower the ethical risk of Bitcoin. In these circumstances, portfolio managers can assign weights to the ethical risk of each investment, re-develop their portfolios, and avoid those investments that provide extreme losses to society overall and investors under various economic, financial, and pandemic-oriented contagions due to pronounced darker

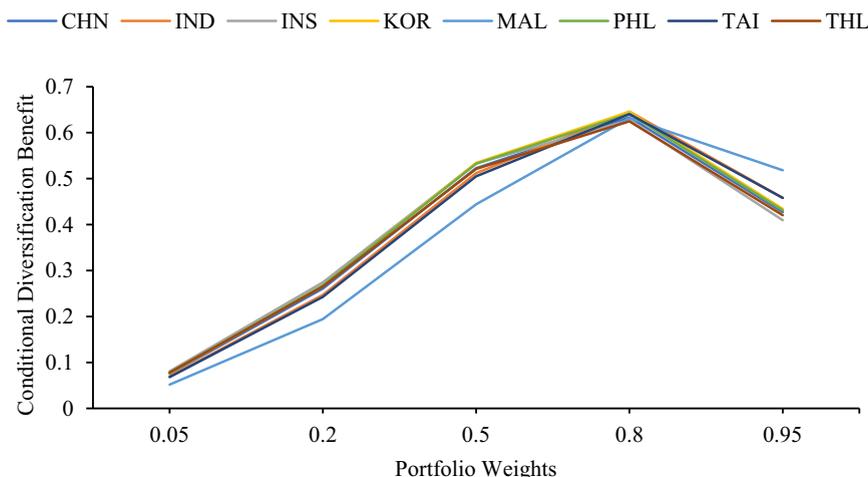


Fig. 12. Diversification benefits (at 5% level) of Emerging Asian Islamic markets for Bitcoin portfolio weight compositions. Note: These figures show the conditional diversification benefit for portfolios composed of Emerging Asian Islamic markets and Bitcoin. Portfolio weights for the Emerging Asian Islamic markets are indicated on the horizontal axis. The diversification benefit is computed by considering expected shortfall values at the 5% probability level. For each portfolio, the figures report the time average of the conditional diversification benefit.

sides of Bitcoin.

As part of future research avenues, the current research is limited to Bitcoin, while other cryptocurrencies with similar ethical risk exposure can be addressed in the upcoming studies. Moreover, future studies can employ sustainable investments and global markets instead of EAls to unveil whether the ethical risk of Bitcoin can be minimized using other investment streams.

CRedit authorship contribution statement

Sitara Karim: Conceptualization, Writing – original draft, Writing – review & editing, Methodology. **Brian M. Lucey:** Conceptualization, Writing – review & editing, Supervision, Project administration. **Muhammad Abubakr Naeem:** Conceptualization, Writing – review & editing, Methodology, Software, Formal analysis, Visualization, Funding acquisition. **Samuel A. Vigne:** Conceptualization, Writing – review & editing, Methodology, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ememar.2022.100921>.

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