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Quantifying the hedge and safe-haven properties of bond markets for cryptocurrency indices

Abstract

Purpose – *This study quantified bond markets' hedge and safe-haven features for multiple cryptocurrency indices from June 2014 to April 2021 to highlight whether bond markets offer hedging capability for uncertainty indices of cryptocurrencies.*

Design/methodology/approach – *We employed the methodology of Baur and McDormett (2010) and AGDCC-GARCH model to measure the hedge and safe-haven characteristics of three bond markets (BBGT, SPGB, and SKUK) for three uncertainty indexes of cryptocurrencies (UCRPR, UCRPO, and ICEA).*

Findings – *We find bond markets are neither hedge nor safe havens except for SKUK, a safe-haven investment for cryptocurrency indices, and offer substantial diversification during periods of economic fragility and COVID-19 in particular. In addition, the hedge effectiveness of SPGB outperforms other bonds during crisis periods and provides sufficient diversification potential for cryptocurrency indices.*

Practical implications – *Our findings are important for policymakers, regulatory bodies, financial firms, and investors in assessing bond markets' hedge and safe-haven characteristics against cryptocurrency indices.*

Originality/value – *Employing the novel methodology of AGDCC-GARCH with three different bond markets and three uncertainty indices of cryptocurrencies, the current study adds to the existing strand of literature in terms of quantifying hedge and safe-haven attributes of bond markets for cryptocurrency uncertainty indexes.*

Keywords: *Bond markets; Cryptocurrency indices; Diversification; Hedge avenues; Safe-haven features*

Article Type: *Research Paper*

1. Introduction

With the increasing financialization and integration of markets, it is fundamental to assess hedge and safe-haven characteristics of financial markets. Given the growing challenges that appeared out of uncertain economic circumstances, it is becoming essential for policymakers, investors, and regulatory authorities to cautiously monitor the hedge and safe-haven features of investments and financial markets. In this regard, several financial markets (Shahzad et al., 2020), precious metals (Naeem et al., 2020), green bonds (Haq et al., 2021; Arif et al., 2021a), and cryptocurrencies (Kurka, 2019) have reported significant hedge and safe-haven attributes of respective markets. The uncertainty raised out of unexpected challenges and turbulent market conditions has fetched the attention of portfolio managers to look for investments that offer diversification and prove to be a hedge and safe-haven instruments when markets are experiencing severe ups and downs.

With the significant proportion of conventional, green and Islamic stocks (Sukuk), Bond markets have appealed to the investors due to their tremendous growth and substantial hedge and safe-haven capacities. Given the shift in the global use of clean energy and demand for clean energy, the earlier empirical work has documented related renewable energy changes (Elsayed et al., 2020). One of the best ways to encourage green energy consumption is to invest in green bonds, which can effectively minimize the risk of CO_2 emissions to rescue the environment. Green bonds, having similar features of conventional bonds, are used to finance environmentally friendly projects (Naeem et al., 2021b, 2021c; Flammer, 2021; Arif et al., 2021b, 2021c; Karim et al., 2021a,b,c). On the other hand, Sukuks are similar to conventional bonds that abide by the Islamic Shari'a (Arif et al., 2021a; Shahzad et al., 2017), which is an Islamic financial instrument that must ensure the real economic linkage and debt avoidance to forbid it from *haram,* (unlawful), *riba* (interest), *gharar* (uncertainty), *maisir* (gambling), alcohol, tobacco, and other unlawful businesses forbidden the law of the land (Azad et al., 2018; Karim et al., 2020a,b,c).

Religious and faith-based investments have been a topic of interest for academic researchers to maximize the investors' returns (Hassan & Girard, 2010). The investors who choose faith-based investment often invest in companies, shares, managers, and investments aligned with their religious or ethical values (Arif et al., 2021c; Alam and Ansari, 2018). Given this, Sukuk service the religious beliefs of investors in terms of low-risk, no interest rates, and underlying assets for investment purposes (Shahzad et al., 2017). Previous studies have argued that trading in green bonds and Sukuk can offer significant hedge and safe-haven potentials in times of uncertainty and economic downfall (Naeem et al., 2021a, 2021b; Nguyen et al., 2020).

Conventional bonds, parallel to green bonds and Sukuk, have provided major evidence of sheltering investments when markets face an economic downturn (Le et al., 2021). Dicle and Levendis (2017) supported that comovement between stock and bonds would be inverse when markets are turbulent, confirming conventional bonds' safe-haven features. Hou et al. (2019) documented that conventional bonds only act as a hedge, as they are prone to significant economic shocks. Contrarily, cryptocurrency uncertainties are highlighted by Lucey et al. (2021a), Corbet et al. (2019; 2018), and Kurka (2019), who reported that investors' fears are elated when cryptocurrencies contain high uncertainties. The rapid growth in the development of cryptocurrencies has evoked investors' concerns regarding their pricing, policy, and environmental attributes (Naeem and Karim, 2021; Lucey et al., 2021a, 2021b; Katsiampa, 2017). Several studies have focused on the dynamics of price and policy uncertainties using numerous approaches such as the GARCH approach (Dyhrberg, 2016), AR-CGARCH (Katsiampa, 2017). However, literature examining the potential hedge and safe-haven features for these cryptocurrency uncertainty indices is significantly lacking.

In the light of the above discussion, the current study is motivated to highlight the hedge and safe-haven attributes of bond markets for cryptocurrency uncertainties developed out of price, policy, and environmental concerns. Conventional bonds, Green bonds, and Sukuk are considered significant investment tools that offer greater hedge and safe-haven avenues. For instance, Siahaan and Robiyanto (2021) documented that conventional bonds act as safe-havens for ASEAN countries. Arif et al. (2021a,b) provided evidence that green bonds are effective diversifiers for various investments when unfavorable market circumstances. Naeem and Karim (2021) reported hedge facility of green markets for bitcoin, and Naeem et al. (2021a, 2021b) narrated that green bonds shelter the mainstream investments from unexpected economic shocks. Similarly, Sukuk carries three significant characteristics: interest-free investments, low-risk, and underlying assets for financing the investments (Shahzad et al., 2017). Thus, Sukuk offers diversification benefits and hedge characteristics for various investments (Arif et al., 2021c). Given these unique characteristics, the current study is novel in its contribution by investigating the hedge and safe-haven features of bond markets for cryptocurrency uncertainty indices.

Motivated by the current literature, which examines the hedge and safe-haven properties of numerous financial assets, our study contributes to the existing literature by employing the methodology proposed by Baur and McDermott (2010) and AGDCC-GARCH to quantify whether conventional bonds, green bonds, and Sukuk offer hedge and safe-haven characteristics for cryptocurrency uncertainty indices. In this way, our study is expected to contribute significantly to the existing strand of literature by encouraging investors to explore several bond markets as they provide greater hedge and safe-haven characteristics (Azad et al., 2018) to overcome the intensity of economic shocks on the asset portfolios.

We find that bond markets are neither an effective hedge nor offer safe-haven features for cryptocurrency indices except for SKUK offering safe-haven properties and diversification potential for several cryptocurrency indices during crisis time. The hedge effectiveness reveals SPGB as an effective hedge against several indices of cryptocurrencies when markets are experiencing harsh circumstances. The conventional bond market showed less hedge effectiveness as compared to green bonds. Our findings imply that green bonds carry strong safe-haven characteristics for multiple stocks and cryptocurrency indices and bring substantial diversification potential for risk-averse investors, particularly during intensive economic periods. We devise multiple useful implications for policymakers, investors, regulatory bodies, and portfolio managers to evaluate the hedge and safe-haven features of bond markets which will shield their mainstream investments during crisis times.

The rest of the paper proceeds as follows: Section 2 presents a literature review, Section 3 gives data and empirical methods, Section 4 elaborates the empirical results. Finally, section 5 concludes the study along with policy implications.

2. Literature Review

Literature examining the hedge and safe-haven properties of bond markets, particularly equity indices, Sukuk, and green bonds, for various financial markets is extant (Naeem et al., 2020a; Shahzad et al., 2020; Naeem et al., 2021a; Naeem & Karim, 2021; Karim, 2021a,b). However, the literature examining the hedge and safe-haven features of three various markets for cryptocurrency uncertainty indices is minimal. Lucey et al. (2021a) developed cryptocurrency uncertainty indices, namely, uncertainty in the cryptocurrency price (UCRPR) and uncertainty in the cryptocurrency policy (UCRPO), whereas Lucey et al. (2021b) developed a cryptocurrency environmental policy index (ICEA) based on the arguments that cryptocurrencies are highly uncertain and more susceptible to shocks and unexpected energy concerns raised out of a single transaction of cryptocurrencies respectively. In this way, examining the hedge and safe-haven characteristics of bond markets for cryptocurrency uncertainty indices highlights whether these markets offer sheltering facilities to overcome uncertainty in the cryptocurrency indices.

Several studies figured out hedge and safe-haven properties of various financial assets and offer useful implications for the investors, policymakers, and portfolio managers to overcome the intensity of uncertain shocks. For instance, Arif et al. (2021a) examined the safe-haven and diversification opportunities of Sukuk for G7 stocks and reported safe-haven characteristics of Islamic stocks for G7 markets. Yarovaya et al. (2021) examined the spillovers between conventional equities and Sukuk and concluded that Sukuk offers safe-haven properties for various fixed-income conventional equity markets. In another study, Arif et al., (2021b) assessed the safe-haven features of green bonds for other financial markets and reported that green bonds hold significant hedge and safe-haven characteristics that shield the investments from uncertain circumstances. Kinateder et al. (2021) analyzed the safe-haven properties of the world's dominant financial asset classes, including the sovereign bond, and found that sovereign bonds emerged as the safe-haven option for the investors.

Given the above evidence, the bond markets prove to be a hedge and safe-haven for numerous financial markets. Thus, our study is a step in this direction to provide further evidence on the safe-haven potential of bond markets for cryptocurrency uncertainty indices. The rest of the related studies are given in Table 1 in a summarized form.

[Table 1 about here]

3. Data and empirical methods

3.1. Data and preliminary statistics

This study uses the data of cryptocurrency indices such as cryptocurrency uncertainty index of policy (UCRY Policy-UCRPO) and cryptocurrency uncertainty index of price (UCRY Price-UCRPR) developed by Lucey et al. (2021a) and Environmental Attention Index (ICEA) provided by Lucey et al., (2021b). The data of Bloomberg Barclays Global Treasury (BBGT) and Dow Jones Global Sukuk (SKUK) is fetched from the Bloomberg Database, and the data of S&P Green Bonds (SPGB) is obtained from Datastream. We used the daily returns of bonds and cryptocurrency indices from June 1, 2014 to April 24, 2021. Table 2 presents the descriptive statistics of the variables where mean returns of BBGT are higher, followed by SKUK, ICEA, UCRPO, and UCRPR whereas SPGB yields negative average returns. The variability in return series is higher in the returns of BBGT followed by SPGB, UCRPO, UCRPR, SKUK, and ICEA. The Jarque-Bera normality test displays abnormal values revealing that bond markets and cryptocurrency indices are not normally distributed.

<< Table 2 about here >>

Table 3 presents the correlation analysis where the correlations of UCRPO and UCRPR with bond markets are relatively high, whereas ICEA has smaller correlation values with bond markets indicating slight relationship of ICEA with bond markets.

<< Table 3 about here >>

3.2. Empirical Method

3.2.1. AGDCC-GARCH model

The AGDCC-GARCH model put forward by (Cappiello et al., 2006) builds upon (Engle 2002's) previous standard dynamic conditional correlation (DCC) model, enabling the acquisition of the asymmetric correlations occurring at different times between every respective stock index and the Sukuk and Green bonds. There are two stages in estimating the AGDCC-GARCH process: every series is fitted with univariate GARCH models; the AGDCC model process is utilized to model the conditional correlation. [1] The model is indicated by in this paper

$$r_t|I_{t-1} \sim N(0,H_t) \quad (1)$$

[1] We check for other distributions, such as student's t and GED, and the overall conclusions remain the same.

$$H_t = D_t R_t D_t \quad (2)$$

$$\varepsilon_t = H_t^{1/2} z_t \quad (3)$$

$$R = [diag(Q_t)^{-1/2}] Q_t [diag(Q_t)^{-1/2}] \quad (4)$$

In these equations, the time-varying conditional correlation matrix is signified by R_t, H_t represents the conditional covariance matrix of r_t, $r_t = [r_{1t}, r_{2t}]'$ which, in turn, is a $2x1$ vector of returns including Bond markets returns (r_{2t}) and the respective uncertainty index return (r_{1t}), and Dt denotes the diagonal matrix where the conditional standard deviations from the univariate GARCH models reside. Additionally, the conditional correlation matrix of the standardized residuals is denoted by Q_t, a $2x1$ $i.i.d.$ vector of the standardized residuals is represented by z_t, and finally, $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]'$ which is a $2x1$ vector of residuals conditional on the data set at the time $t-1$.

The asymmetric univariate GARCH (1,1) model of (Cappiello et al., 2006), otherwise known as the GJR-GARCH, is used to identify the components of H_t, in line with (Glosten et al., 1993):

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t} + d_i \varepsilon_{i,t-1}^2 I(\varepsilon_{i,t-1}) \quad (5)$$

In this equation, the asymmetric term is denoted by $d_i$the conditional variance of the return series is represented by $h_{i,t}$, the persistence of the volatility process is measured by βi, the ARCH effect is recorded by α_i, and ω_i signifies a constant term. If $\varepsilon_{i,t-1} < 0$, then the indicator function $I(\varepsilon_{i,t-1})$ equals one, and if these conditions are not met, then it equals zero. If the conditions $\alpha_i + \beta_i < 1$ and $\alpha_i > 0$ are met, then steadiness and positivity are guaranteed. The standardized residuals are utilized to compute the conditional correlation parameters, following the univariate GARCH models' estimation. Within the AGDCC-GARCH model, Q 's dynamics are portrayed in the following manner:

$$Q_t = (1-\theta_1-\theta_2)Q - \varphi N + \theta_1(z_{t-1}z'_{t-1}) + \theta_2 Q_{t-1} + \varphi(\eta_{t-1}\eta'_{t-1}) \quad (6)$$

η_t's unconditional correlation matrix is denoted as $N_j = E[\eta_t \eta'_t]$ while the unconditional correlation matrix of z_t is represented by $Q_j = E[z_t z'_t]$. The indicator function $\eta_t = I(z_t < 0) \circ z_t$ assumes the value of zero if the argument is false and one is true, parameter matrices are denoted by θ_1, θ_2 and φ, and the Hadamard product is signified by " $\circ$ ". A reduction to the standard DCC-GARCH model from the AGDCC-GARCH model occurs without asymmetric effect in the conditional correlation if $\varphi = 0$.

The representation of the AGDCC-GARCH model's time-varying correlation matrix lies below:

$$R_t = Q_t^* Q_t Q_t^{*-1} \quad (7)$$

In this equation, the diagonal matrix is denoted by Q_t^* where Q_t^* it has a square root of the ith diagonal of Q_t in its ith diagonal position.

Model (7) is used to separate every stock market's time series following the deduction of the time-varying correlations R_t, as per the GARCH estimation. Individual uncertainty index risk and bond markets, which represent safe-haven assets, are put to the test by regressed R_t values on dummy variables to simulate market chaos:

$$R_{i,t} = c_0 + c_1 D(r_{Crypto\_indicesi,q90}) + c_2 D(r_{Crypto\_indicesi,q95}) + c_3 D(r_{Crypto\_indicesi,q99}) \quad (8)$$

Substantial movements of underlying uncertainty indices occurring within the 1%, 5%, and 10% percentiles of the most negative bond market returns are recorded by dummy variables that are denoted by D. When c_0 is negative for the individual uncertainty index, bond markets are a strong hedge, and when c_0 is zero, then the bonds are a weak hedge. Similarly, if the coefficients $c_1, c_2, or\ c_3$ are negative, bond markets are a strong safe-haven, yet when the coefficients are insubstantially different from zero, they are a weak safe-haven[2].

We also considered the COVID-19 pandemic period following the study of Naeem et al., (2021d) for testing the hedge and safe-haven features of bond markets for cryptocurrency indices by the following equation:

$$R_{i,t} = c_0 + c_1 D(r_{COVID}) \quad (9)$$

For Eq. (9), we have taken a period commencing from March 2020 by setting a dummy variable[3]. If c_0 is negative for the cryptocurrency indices, then bond markets are a strong hedge, yet when c_0 is negative is insubstantially different from zero, then they are a weak hedge. Similarly, when c_1 is negative for the cryptocurrency indices, bond markets are a strong safe-haven, whereas the bond markets are a weak safe-haven when c_1 is insignificantly different from zero.

4. Empirical Results

4.1 Testing hedge and safe-haven properties for Bond Markets

Table 4 gives the hedge and safe-haven characteristics of bond markets against cryptocurrencies indices. Baur & McDermott (2010) suggested that assets be a strong hedge if there is a negative correlation between two assets or a set of assets during stable economic periods. Conversely, an asset carries safe-haven properties if negatively correlated with other assets during a crisis. Following these definitions, Panel A of Table 4 reveals positive values of BBGT index for cryptocurrency indices suggesting non-hedge properties of BBGT in-line

[2] The dummy variable regression is loosely based on Baur and McDermott (2010) who utilize time varying betas calculated from rolling regression to represent comovement. We instead use GARCH-generated AGDCC.
[3] Baur and McDermott (2010) identify the start of the U.S. financial crisis with the collapse of Lehman Brothers in September 2008 and maintain an "effect" window of 20 trading days.

with Nguyen et al. (2020), Ciner et al. (2013), and Baur & McDormett (2010), claiming that conventional bonds offer no hedging facility for multiple stocks and financial instruments and we also find similar evidence for cryptocurrency indices. Meanwhile, BBGT is a strong safe-haven for UCRPO, implying BBGT ability to function as a safe-haven against uncertainty in the cryptocurrency policy index. In addition, BBGT is a weak safe-haven for UCRPR, indicating the weaker ability of BBGT to cope with the uncertainty of the economic times. Moreover, BBGT is neither a hedge nor safe-haven instrument for ICEA revealing that BBGT is insensitive to the market variations given the ICEA index of cryptocurrency.

Correspondingly, Panel B of Table 4 illustrates positive hedge values revealing that SKUK is not a hedge for cryptocurrency indices corroborating Shahzad et al. (2020), who contend that SKUK does not offer hedging characteristics during stable economic circumstances. Contrarily, SKUK act as a strong safe-haven for cryptocurrency indices consistent with Arif et al. (2021c) who claim that SKUK provides sufficient shelter to several stock markets following the period of economic downfall and is a safe-haven investment offering significant diversification potential to investors. This is due to the inherent nature of SKUK in providing lower leverage and responding slowly to economic shocks.

Finally, Panel C of Table 4 reveals the non-hedging capacity of SPGB for cryptocurrency indices concurrent with Reboredo & Ugolini (2020) and Reboredo (2018), indicating little comovement between SPGB and stock markets during the unwavering economic conditions. Further, the table reveals weak safe-haven properties of SPGB for UCRPR index, whereas SPGB does not provide safe-haven features for UCRPO and ICEA. Our findings coincide with Kuzemko et al. (2020) and Arif et al. (2021b), who suggest that SPGB does not provide any hedging or safe-haven investment opportunity during the short and medium-run diversification potential incurs losses for the short-term investors. Meanwhile, SPGB is a substantial hedge and diversifier for long-term investors (Reboredo & Ugolini, 2020). Overall, our findings imply that SKUK offers greater diversification benefits for investors and policymakers to diversify their portfolios by including SKUK in their cryptocurrency indices to avoid potential losses in the face of uncertain economic conditions.

<< Table 4 about here >>

Considering the COVID-19 period, Table 5 illustrates the evidence of bond markets as hedge and safe-haven for cryptocurrency indices. Panel A reveal that BBGT is neither a hedge nor safe-haven for cryptocurrency indices except for UCRPR where it offers strong safe-haven features. Conversely, SKUK does not provide hedging facility to all indices of cryptocurrencies but it acts as a strong safe-haven during COVID-19 crisis conquering the findings of Shahzad et al., (2020). Regarding SPGB, it is evident from the table that it neither offers hedging characteristics nor provide safe-haven avenues during COVID-19. Thus, SPGB can act as a strong diversifier for cryptocurrency indices following the ongoing global pandemic in line with Arif et al., (2021a, 2021b).

<<Table 5 about here>>

4.2 Hedge Effectiveness

A perfect hedge assumes a value of 1 and 0 if it depicts no effectiveness (Batten et al., 2021). Figure 1 provides hedge effectiveness of bond markets for UCRPO index where SPGB observes high hedge effectiveness during 2015-2016, denoting Shale Oil Revolution where unusual market conditions spiked the hedge effectiveness of SPGB followed by BBGT and SKUK. Moreover, the hedge effectiveness revealed a spike during 2019-2020, displaying volatile market conditions due to COVID-19, where BBGT showed higher hedge effectiveness followed by SPGB and SKUK. The lower hedge effectiveness of SKUK during the study period shows that faith-based investments are potential diversifiers for stock markets conquering Saiti et al. (2019) and Trabelsi & Naifer (2017). Alternatively, SPGB illustrated greater hedge effectiveness corroborating Naeem et al. (2021), who reported significant linkage of SPGB with international stock indices offering sufficient hedge properties for several investments.

<< Figure 1 about here >>

Concurrently, the hedge effectiveness of bond markets for UCRPR (Figure 2) shows similar results where a spike in the hedge effectiveness of SPGB is illustrated, followed by BBGT and SKUK. Another spike was observed during 2017, pointing towards US interest rate hike (Elsayed et al., 2020), where SPGB retained its higher hedger effectiveness. The graph displays the upward trend of BBGT and SPGB during 2019, denoting the volatility in the financial markets due to the coronavirus pandemic. The hedge effectiveness of SPGB during uncertain economic conditions ascertains the greater diversification potential of SPGB during Shale Oil Revolution and US interest rate hike. In contrast, a slightly higher *HE* of BBGT during COVID-19 pandemic confirms the findings of Rejeb (2017) and Ratner & Chiu (2013), where conventional bonds offer significant diversification capability for the investors during abnormal economic operations.

<< Figure 2 about here >>

Similarly, Figure 3 also gives the same results of hedge effectiveness of bond markets for ICEA index, reiterating the results of Yousaf et al. (2021) and Albuquerque et al. (2020) SPGB outperform other stocks given the crisis. In line with Nguyen et al. (2021) and Jin et al. (2020), SPGB can be a probable substitute for conventional stocks and bonds, facilitating better diversification opportunities for overall investment portfolios.

<< Figure 3 about here >>

4. Conclusion

Our study quantified the hedge and safe haven properties of bond markets for cryptocurrency indices from June 2014 to April 2021 using AGDCC-GARCH model. Our findings show that bond markets are neither effective nor offer safe-haven features for cryptocurrency indices except for SKUK where it provides properties and diversification potential for several cryptocurrency indices during crisis time. The hedge effectiveness reveals SPGB as an effective hedge against several indices of cryptocurrencies during turbulent times. BBGT showed less hedge effectiveness as compared to SPGB. Our findings imply that SPGB carries strong safe-haven characteristics for multiple stocks and cryptocurrency indices and brings substantial diversification potential for risk-averse investors, particularly during intensive economic periods.

Our findings have significant implications for policymakers, financial institutions, regulatory bodies, and investors where SKUK acts as a safe haven investment during crises and gives sufficient diversification buffer to investors for cryptocurrency indices. Meanwhile, SPGB also offers significant hedge effectiveness where investors can include these investment strands into their mainstream investment portfolios to avoid financial losses during crisis times. Policymakers and regulatory bodies can direct financial companies to add these diversifiers into their investment and asset portfolios to avert their financial risk during periods of economic fragility and turbulence.

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Table 1: Summarized Literature Review				
No.	**Author(s)**	**Method(s)**	**Sample Period**	**Findings**
1.	Ferrer et al. (2021)	Wavelet Analysis	2010-2020	Green bonds are strongly related to treasury and investment-grade bonds, whereas green ones are strongly connected with general ones. There is no linkage between green bonds and green stocks.
2.	Arif et al. (2021b)	Time-frequency analysis	2008-2020	There is low connectedness between green bonds and conventional financial markets. Connectedness is more pronounced during short-run as compared to long-run.
3.	Naeem et al. (2021a)	Time-frequency analysis; hedge ratios and hedge effectiveness	2013-2020	Green bonds reveal a significant weight in the overall network and are strongly connected with the USD and bond index. Green bonds can act as hedgers for some assets and can provide safe-haven features during tumbled time periods.
4.	Haq et al. (2021)	DCC-MGARCH	2014-2020	Green bonds offer sufficient diversification and hedge facility for US and Chinese stocks.
5.	Bouri et al. (2021)	TVP-VAR	2011-2020	The equity and USD indices are net emitters of spillovers before the pandemic, whereas bond index emits spillovers after COVID-19 pandemic.
6.	Yousaf et al. (2021)	DCC-GARCH	2012-2020	Green bonds offer a significant safe-haven feature for large stock markets during COVID-19.
7.	Alam and Ansari (2020)	Risk-adjusted measures	2006-2018	Returns of Islamic stocks are slightly higher than conventional stocks. However, using various techniques of risk-return, an insignificant performance effect is observed.
8.	Reboredo et al. (2020)	Wavelet Coherence Analysis and network connectedness	2014-2018	There is strong connectedness between green bonds and conventional bonds during short- and long-run whereas there is low connectedness between green bonds and high-yield corporate bonds for different time scales.

9.	Reboredo & Ugolini (2019)	VAR model	2014-2019	Green bond market is closely connected with fixed-income and currency market whereas it is weakly linked to stock, energy, and high-yield corporate bonds.
10.	Elsayed et al. (2020)	Time-frequency connectedness	2000-2018	External factors are causing oil shocks and the contribution of oil market to the volatility is insignificant.

Table 2: Descriptive statistics							
	Symbol	Mean	Maximum	Minimum	Std. Dev.	Jarque-Bera
UCRY Policy	UCRPO	0.013	2.318	-1.788	0.496	224.327***
UCRY Price	UCRPR	0.012	3.855	-1.811	0.466	5056.778***
Environmental Attention	ICEA	0.016	1.686	-0.850	0.219	6942.940***
Bloomberg Barclays Global Treasury	BBGT	0.039	3.997	-4.646	0.866	314.859***
Dow Jones Global Sukuk	SKUK	0.022	1.065	-3.509	0.383	16637.920***
S&P Green Bonds	SPGB	-0.006	3.043	-5.289	0.779	1545.467***

Note: *** indicates significance at 1%

Table 3: Correlation analysis			
	UCRPO	UCRPR	ICEA
BBGT	0.175	0.167	0.006
SKUK	0.091	0.114	0.010
SPGB	0.148	0.142	0.020

Table 4: Bond markets as hedge and safe-haven for cryptocurrency indices

A) Bloomberg Barclays Global Treasury Index

	Hedge (C0)	0.90 (C1)	0.95 (C2)	0.99 (C3)
UCRPO	0.251**	-0.174**	-0.280***	-0.718***
	(0.100)	(0.086)	(0.042)	(0.033)
UCRPR	0.215**	-0.054	-0.302***	-0.335***
	(0.094)	(0.133)	(0.087)	(0.068)
ICEA	0.034	-0.023	0.035	0.201***
	(0.195)	(0.211)	(0.167)	(0.037)

B) Dow Jones Global Sukuk Index

	Hedge (C0)	0.90 (C1)	0.95 (C2)	0.99 (C3)
UCRPO	0.055***	-0.081***	-0.102***	-0.146***
	(0.001)	(0.002)	(0.003)	(0.006)
UCRPR	0.063***	-0.034***	-0.102***	-0.094***
	(0.005)	(0.002)	(0.003)	(0.003)
ICEA	0.058***	-0.0002***	0.084***	-0.089***
	(0.000)	(0.000)	(0.005)	(0.006)

C) S&P Green Bond Index

	Hedge (C0)	0.90 (C1)	0.95 (C2)	0.99 (C3)
UCRPO	0.132*	-0.064	-0.161*	-0.282
	(0.079)	(0.122)	(0.093)	(0.379)
UCRPR	0.164***	-0.011	-0.167**	-0.334***
	(0.062)	(0.959)	(0.086)	(0.070)
ICEA	0.150	-0.011	-0.084	-0.059
	(0.207)	(0.051)	(0.209)	(0.162)

Note: This table provides estimations for the following

$R_{i,t} = c_0 + c_1 D(r_{Crypto\_indices_{i,q90}}) + c_2 D(r_{CCrypto\_indices_{i,q95}}) + c_3 D(r_{CCrypto\_indices_{i,q99}})$

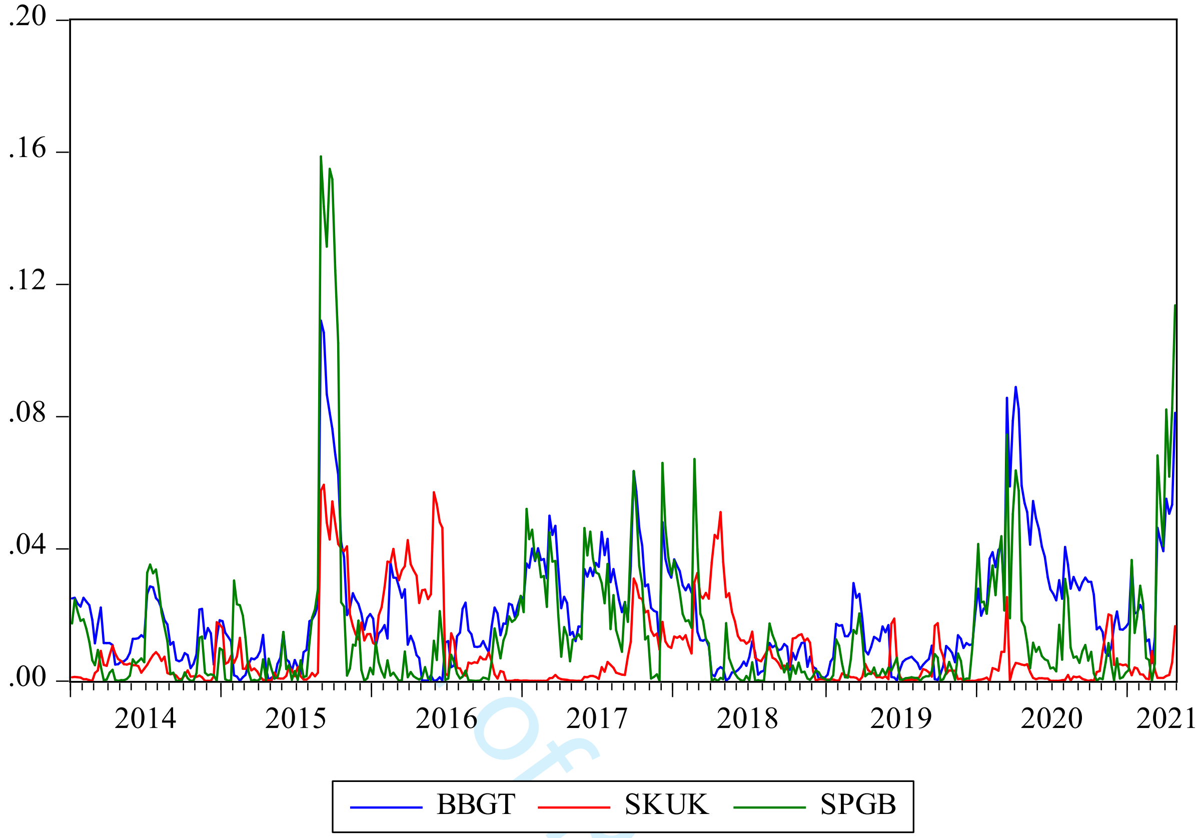
***, **, * indicates significance at 1%, 5%, and 10%, respectively.

Table 5: Bond markets as hedge and safe-haven for cryptocurrency indices

A) Bloomberg Barclays Global Treasury Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.250*	0.002
	0.152	0.214
UCRPR	0.387***	-0.199***
	0.010	0.004
ICEA	0.214	-0.219
	0.618	0.654
B) Dow Jones Global Sukuk Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.072***	-0.019***
	0.001	0.000
UCRPR	0.073***	-0.013***
	0.005	0.001
ICEA	0.094***	-0.038***
	0.001	0.000
C) S&P Green Bond Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.108	0.058
	0.098	0.183
UCRPR	0.207	-0.067
	0.162	0.205
ICEA	0.218	-0.105
	0.356	0.436

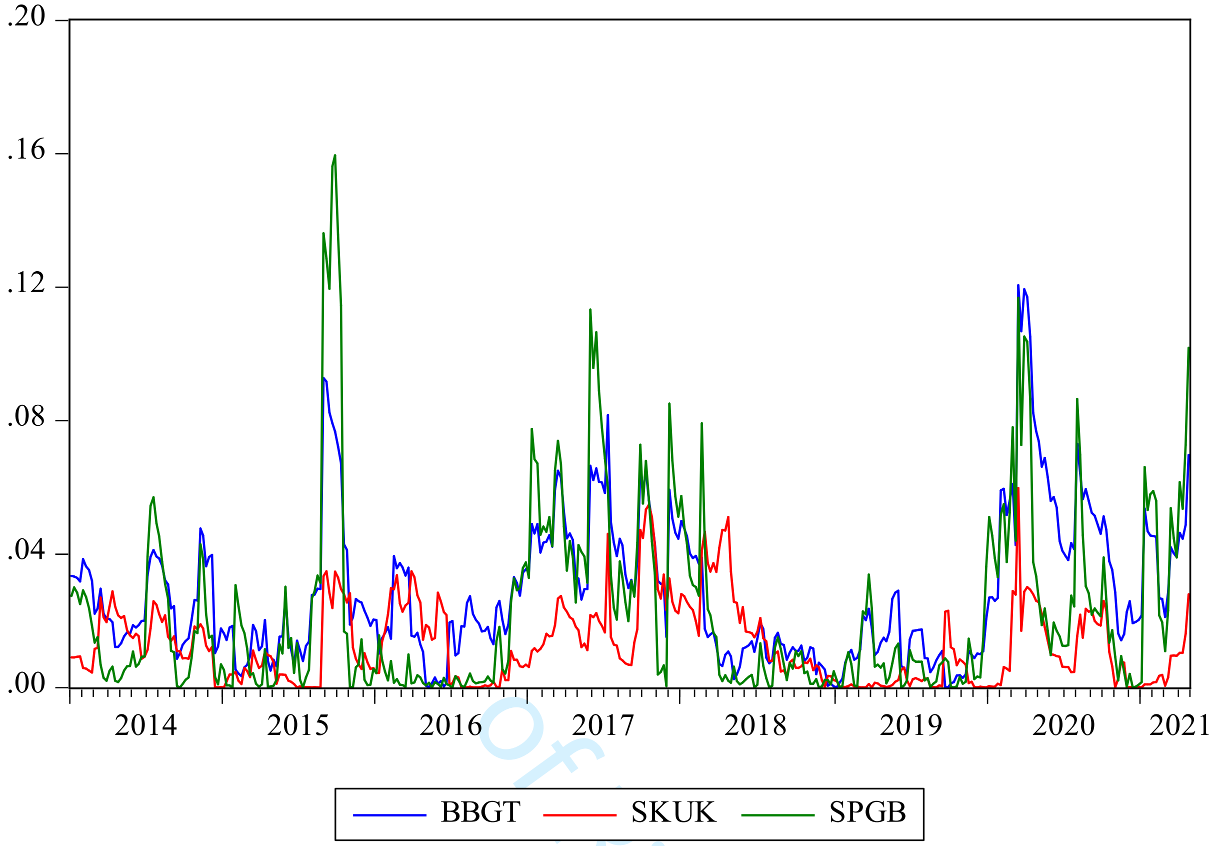
Note: This table provides estimations for the following
$R_{i,t} = c_0 + c_1 D(r_{COVID})$
***, **, * indicates significance at 1%, 5%, and 10%, respectively.

Figure 1: Hedge effectiveness of BBGT, SKUK, and SPGB for UCRPO Index



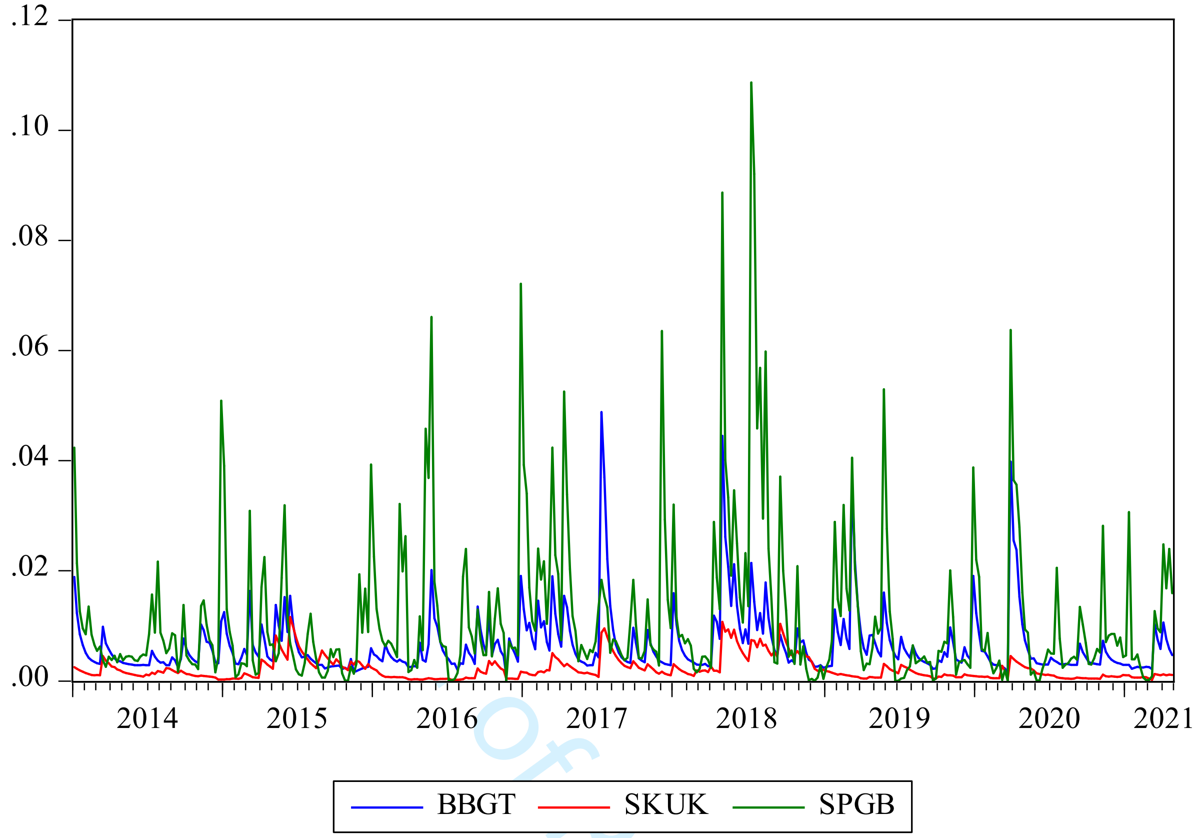
Note: This figure provides the estimations for hedge effectiveness of bond markets for UCRPO Index.

Figure 2: Hedge effectiveness of BBGT, SKUK, and SPGB for UCRPR Index



Note: This figure provides the estimations for hedge effectiveness of bond markets for UCRPR Index.

Figure 3: Hedge effectiveness of BBGT, SKUK, and SPGB for ICEA Index



Note: This figure provides the estimations for hedge effectiveness of bond markets for ICEA Index.

Responses to the Reviewer Comments

Manuscript ID: JRF-09-2021-0158.R1

Title: Quantifying the hedge and safe-haven properties of bond markets for cryptocurrency indices

Journal: Journal of Risk Finance

The authors wish to thank the Editors for giving us another opportunity to further revise, improve, and resubmit our paper according to the reviewer comments.

Reviewer 2:

Comments:

In general terms, the authors have substantially improved the manuscript in the revised version. There are a few comments as follows:

1.- The parameters gama_0, gama_1, gama_2, and gama_3 (Page 9 and 10) presented in the text do not appear in any of the equations. Please clarify.

Authors' response:

We would like to thank the reviewer for the comment. The authors have made the following changes:

When c_0 is negative for the individual uncertainty index, bond markets are a strong hedge, and when c_0 is zero, then the bonds are a weak hedge. Similarly, if the coefficients $c_1, c_2, or\ c_3$ are negative, bond markets are a strong safe-haven, yet when the coefficients are insubstantially different from zero, they are a weak safe-haven[1].

2.- The authors use dummy variables defined on threshold values to capture safe-haven effects. Unless I'm mistaken, I don't where they explain in the text why they do not use alternatively dummy variables for observed crisis periods (e.g., covid-19) to capture such effects.

Authors' response:

[1] The dummy variable regression is loosely based on Baur and McDermott (2010) who utilize time varying betas calculated from rolling regression to represent comovement. We instead use GARCH-generated AGDCC.

We would like to thank the reviewer for the comment. For dummy variable COVID-19, following methodology is added:

We also considered the COVID-19 pandemic period following the study of Naeem et al., (2021d) for testing the hedge and safe-haven features of bond markets for cryptocurrency indices by the following equation:

$$R_{i,t} = c_0 + c_1 D(r_{COVID}) \qquad (9)$$

For Eq. (9), we have taken a period commencing from March 2020 by setting a dummy variable[2]. If c_0 is negative for the cryptocurrency indices, then bond markets are a strong hedge, yet when c_0 is negative is insubstantially different from zero, then they are a weak hedge. Similarly, when c_1 is negative for the cryptocurrency indices, bond markets are a strong safe-haven, whereas the bond markets are a weak safe-haven when c_1 is insignificantly different from zero.

For empirical analysis, Table 5 is added.

Table 5: Bond markets as hedge and safe-haven for cryptocurrency indices

A) Bloomberg Barclays Global Treasury Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.250*	0.002
	0.152	0.214
UCRPR	0.387***	-0.199***
	0.010	0.004
ICEA	0.214	-0.219
	0.618	0.654
B) Dow Jones Global Sukuk Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.072***	-0.019***
	0.001	0.000
UCRPR	0.073***	-0.013***
	0.005	0.001
ICEA	0.094***	-0.038***

[2] Baur and McDermott (2010) identify the start of the U.S. financial crisis with the collapse of Lehman Brothers in September 2008 and maintain an "effect" window of 20 trading days.

	0.001	0.000
C) S&P Green Bond Index		
	Hedge (C0)	Safe-Haven (C1)
UCRPO	0.108	0.058
	0.098	0.183
UCRPR	0.207	-0.067
	0.162	0.205
ICEA	0.218	-0.105
	0.356	0.436

Note: This table provides estimations for the following
$R_{i,t} = c_0 + c_1 D(r_{COVID})$
***, **, * indicates significance at 1%, 5%, and 10%, respectively.

Explanation of Table 5 is given as follows:

Considering the COVID-19 period, Table 5 illustrates the evidence of bond markets as hedge and safe-haven for cryptocurrency indices. Panel A reveal that BBGT is neither a hedge nor safe-haven for cryptocurrency indices except for UCRPR where it offers strong safe-haven features. Conversely, SKUK does not provide hedging facility to all indices of cryptocurrencies but it acts as a strong safe-haven during COVID-19 crisis conquering the findings of Shahzad et al., (2020). Regarding SPGB, it is evident from the table that it neither offers hedging characteristics nor provide safe-haven avenues during COVID-19. Thus, SPGB can act as a strong diversifier for cryptocurrency indices following the ongoing global pandemic in line with Arif et al., (2021a, 2021b).

3.- One of the main results of your analysis is that you find that "SKUK does not offer hedging characteristics during stable economic conditions circumstances and act as a strong safe-haven for cryptocurrency indices." Unless I'm mistaken, I don't where you elaborate on the novelty of this result regarding the papers by Arif et al. (2021a) and Azad et al. (2018).

Authors' response:

We would like to thank the reviewer for the comment. The authors have made the following changes in the in-text citations:

SKUK act as a strong safe-haven for cryptocurrency indices consistent with Arif et al. (2021c) who claim that SKUK provides sufficient shelter to several stock markets following the period of economic downfall and is a safe-haven investment offering significant diversification potential to investors. This is due to the inherent nature of SKUK in providing lower leverage and responding slowly to economic shocks.