Received: 22 October 2019 | Revised: 31 March 2020 | Accepted: 2 April 2020

DOI: 10.1111/1467-8454.12178

ORIGINAL ARTICLE

AUSTRALIAN ECONOMIC PAPERS WILEY

Bitcoin—A hype or digital gold? Global evidence

Md Akther Uddin[1] | **Md Hakim Ali**[2] | **Mansur Masih**[3]

[1]School of Business, University of Creative Technology, Chittagong, Bangladesh

[2]Taylor's Business School, Taylor's University, Subang Jaya, Malaysia

[3]UniKL Business School, University Kuala Lumpur, Malaysia

Correspondence
Md Akther Uddin, School of Business, University of Creative Technology, Chittagong, Bangladesh.
Email: aktherpu@gmail.com

Abstract

This study explores whether Bitcoin constitutes as a hedging instrument whilst seeking portfolio diversification opportunities among sustainable, conventional and Islamic asset classes since Bitcoin emerges as a distinct alternative investment and asset class across the world. We apply multivariate generalised autoregressive conditional heteroscedastic-dynamic conditional correlation and continuous wavelet transforms based on the recent data set ranging from August 18, 2011, to September 10, 2018. First, our findings show that Bitcoin returns are mean-reverting which implies that its value tends to come down to mean value in the long run and not completely crushed to zero irrespective of price changes suggesting Bitcoin as a sustainable asset class. Second, the time-invariant model shows that Bitcoin offers portfolio diversification opportunities with almost all equity indices, in particular, Dow Jones Islamic followed by FTSE 4 Good index. Finally, the time-variant analysis reconfirms that Bitcoin offers portfolio diversification benefits both in the short and long run. These findings carry meaningful policy considerations for fund managers and cross-country investors.

KEYWORDS

Bitcoin, Islamic equity, MGARCH-DCC, portfolio diversification, sustainable equity, wavelet

1 | INTRODUCTION

Bitcoin (also called *cryptocurrency* or *decentralised digital currency* or *peer-to-peer currency*) allows instant payments to any party in the global market. The transaction process of Bitcoin[1]

is usually based on revolutionary blockchain technology where every transaction is recorded chronologically in a publicly distributed ledger and thereby conducts the transaction between two parties directly across the world without any involvement of financial intermediaries. Its intrinsic value derives mainly from the trust of its users and also gets protected by its limited nature. In addition, the cryptography provides the security as well as authentication to this currency. Nakamoto (2008) an anonymous scientist first introduced the concept of Bitcoin and afterwards it draws colossal attention across the globe and emerges as an independent payment system. By realising the momentum of this currency, Japan and Germany acknowledge Bitcoin as a legal form of payment. European Central Bank is considering its digital currency. Even lately, it has rolled out as an investment asset and is currently being regulated as a commodity in the United States and many other countries. Therefore, traders across the world transact Bitcoin using traditional currencies. Moreover, Bitcoin outspreads faster although, currently there are other types of cryptocurrencies emerging in this new field of the digital currency market, for instance, Ethereum, Zcash, Bitcoin, Ripple among others.

A strand of scholars claim Bitcoin as a digital gold, because it has the characteristics of a safe haven asset like gold (Bouri, Jain, Biswal, & Roubaud, 2017; Bouri, Jalkh, Molnár, & Roubaud, 2017; Bouri, Molnár, Azzi, Roubaud, & Hagfors, 2017; Corbet, Lucey, & Yarovaya, 2018; Corbet, Meegan, Larkin, Lucey, & Yarovaya, 2018; Dyhrberg, 2016b; Selmi, Mensi, Hammoudeh, & Bouoiyour, 2018). Others consider it as speculative bubble and Ponzi scheme as it has very weak or even no fundamental value (Baek & Elbeck, 2015; Baur, Hong, & Lee, 2018). In this respect, the high volatility of Bitcoin price is shown in Figure 1. Surprisingly, Bitcoin price has skyrocketed from less than 10 US$ from August 2011 to 18,940.57 US$ on December 18, 2017. At the end of August 2018, it is traded at 7017.35 US$ and shows an upward trend. The collective market capitalisation of all cryptocurrencies has plunged to $186 billion on Wednesday, September 12, 2018, from its January peak of $831 billion. Many investors and researchers see the high volatility as a consequence of speculation. Consequently, it would be a financial catastrophe if someone adopts it as a currency. Although Bitcoin seems to be highly volatile, its inclusion in the diversified portfolio could be highly profitable from portfolio diversification perspective in case of sustainable, *Shariah*-compliant financial securities, which is yet to be examined.

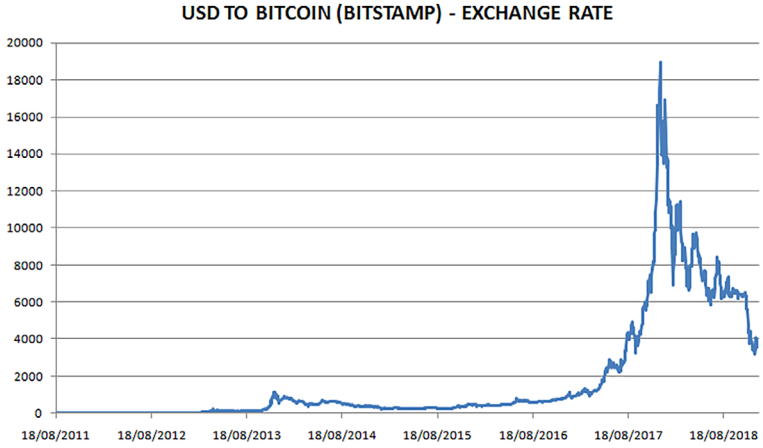

FIGURE 1 Bitcoin price from 2011 to 2018

The asset under socially responsible investment (SRI) principles has been growing exponentially across the world. A recent YouGov poll reported that Millennial savers are twice as likely as older generations to want their pension to be invested responsibly (Williams, 2018). At the same time, a recent report on the State of the Global Islamic Economy estimates that total assets of the Islamic finance industry reached 2.4trillion US$ in 2017 and is forecast to grow to $3.8 trillion by 2023. Rating agency Moody's is predicting that Islamic finance will continue to outgrow conventional assets in core Islamic markets as the appetite for *Shariah*-compliant financial services increases. *Shariah*-compliant assets include asset classes based on specific *Shariah* screening criteria to confirm *Shariah*-compliance. Moreover, asset-backed financing and exclusion of sin stock have given a competitive advantage to *Shariah*-compliant equities (Ashraf & Mohammad, 2014; Ho, Rahman, Yusuf, & Zamzamin, 2014). The global equity market including Islamic equity has also been volatile since the global financial crisis of 2008/2009. Investors have already started to look for safe-haven like gold and commodity equities and many are leaving emerging markets for flights to quality. The situation has even further exacerbated in the recent past due to the outbreak of coronavirus, high volatility in oil price, intense political instability in the Middle East, Brexit and most recently intense trade war between the United States and China (The Economist, 2018).

Markowitz's modern portfolio theory assumes the expected portfolio returns in a given portfolio risk tends to be maximised or the risk of a portfolio in a given portfolio return tend to be minimised compared to the investment into the security or commodity individually (Lintner, 1965; Miller, 1977). Many international investors have already shown great enthusiasm as the Bitcoin has already started showing upward trends. Following Monzer Kahf's rulings in 2014, many *Shariah* scholars from Malaysia, Indonesia, South Africa and the United Arab Emirates, among others have already issued *fatwa* (propositions) by accepting cryptocurrency as a *Shariah*-compliant currency and commodity (Abubakar, Ogunbado, & Saidi, 2018; Mahomed & Mohamad, 2017). Therefore, we try to address two research questions: (a) whether Bitcoin can be considered as an asset class? If yes, (b) does it offer portfolio diversification benefits to sustainable, Islamic and conventional equity investors. Moreover, we study the volatility of Bitcoin market return and their short, mid and long-term dynamic correlations with sustainable, Islamic and conventional equity markets. To the best of our knowledge, this will be one of the few studies which investigate the possibility of portfolio diversification benefits of Bitcoin from sustainable and *Shari'ah* compliant investors perspective.

This study applies advanced methods such as multivariate generalised autoregressive conditional heteroscedastic-dynamic conditional correlation (MGARCH-DCC) and continuous wavelet transforms (CWTs). Our findings show that Bitcoin returns are mean-reverting which confirms that its value tends to come down to mean value in the long run and not completely crushed to zero irrespective of price changes. Therefore, we intuitively argue that even though Bitcoin price is highly volatile but due to its mean reverting feature it can be classified as an innovative investment asset. Additionally, Bitcoin shows the highest volatility whilst Dow Jones Islamic shows the lowest volatility. Moreover, the time-invariant model clearly shows investors with exposure to Islamic and sustainable equities can get better diversification benefits by including Bitcoin in their portfolios. In other words, Bitcoin, as a hedge risk management technique, could be used to reduce any substantial losses or gains in the capital market. The time-variant analysis reconfirms that Bitcoin offers portfolio diversification benefits both in the short-run (16–32 days) and long-run (64–256 days) across different investment holding periods. As such, fund managers, investors and policymakers can potentially apply our findings in investment and policy decision making.

The rest of the paper is organised as follows. Section 2 reviews the relevant theoretical and empirical literature. The theoretical model specification, data and econometric methodology are explained in Section 3. The empirical results and discussions are presented in Section 4. The last section ends with concluding remarks and policy recommendations.

2 | THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 | Modern portfolio theory

Earning positive equity return is the main wealth-building mechanism for equity investors, because the investors target to optimise return by reducing the risk. Investment policy therefore plays a significant role in bringing this about. Consequently, this paper adopts Markowitz's modern portfolio theory of 1959, which assumes that the predicted portfolio returns in a given portfolio risk tend to be maximised or that the risk of a portfolio in a given portfolio return tends to be minimised relative to the investment in individual securities (Lintner, 1965; Miller, 1977). Moreover, the theory suggests that each individual security has its own idiosyncratic risk that a portfolio of different securities may result in lower risk than a single investment in security. Thus, the model explains:

$$\sigma_p^2 = \left(\sum W_i^2 \sigma_i^2 + \sum W_i W_j \mathrm{Cov}_{ij} \right) \tag{1}$$

Here, W_i indicates proportion of the portfolio in asset i, σ_i implies the standard deviation of expected returns of asset i and Cov_{ij} means the covariance of expected return of assets of i and j. Rationally, conjecturing that the covariance remains less than one (which is always true), and hence, that would be no more than the weighted average standard deviation of expected stock return. Diversification thus leads to the risk reduction.

In concomitant with our research issue stated before, quite a few studies such as Bouri, Jain, et al. (2017); Bouri, Jalkh, et al. (2017); Bouri, Molnár, et al. (2017); Bouri, Das, Gupta, and Roubaud (2018) and Guesmi, Saadi, Abid, and Ftiti (2018) attempt to examine the possibility of the portfolio diversification benefits of Bitcoin for the investors. Nevertheless, none of the prior studies explore the nature of Bitcoin's portfolio diversification advantages for investors who have already invested or are interested in securities that comply with SRI and Shariah. Unlike previous research, we use both time invariant correlations and time variant correlations to see relationships in various time horizons for investment.

2.2 | Literature review

As stated earlier, Bitcoin is based on revolutionary blockchain technology where every transaction is recorded chronologically in a publicly distributed ledger. It enables the worldwide transaction between two parties directly without any financial intermediaries. Bitcoin has gained considerable attention worldwide after it was introduced in 2008. In the beginning, technical, safety, ethical, regulatory aspects were the focus of research interest followed by economics and financial aspects.

Bitcoin literature is still at the infancy stage. Many contemporary economists are sceptical whilst some others consider Bitcoin as "Evil" (Krugman, 2013). It is considered as a speculative bubble and has no or very weak fundamental as money (Baek & Elbeck, 2015; Baur et al., 2018; Bouoiyour & Selmi, 2015; Cachanosky, 2019; Cheah & Fry, 2015; Corbet, Lucey, & Yarovaya, 2018; Corbet, Meegan, et al., 2018). The high volatility of Bitcoin is associated with speculative trading (Brandvold, Molnár, Vagstad, & Valstad, 2015). However, some argue its price volatility is not from speculation (Blau, 2017). Past realised volatility predicts its future realised volatility and trading volume improves volatility predictions (Aalborg, Molnár, & de Vries, 2018). Feng, Wang, and Zhang (2018) find strong evidence of informed trading in Bitcoin. However, the Bitcoin market is becoming gradually more efficient (Jiang, Nie, & Ruan, 2018).

Polasik, Piotrowska, Wisniewski, Kotkowski, and Lightfoot (2015) consider Bitcoin an investment asset. Bitcoin can be considered as a synthetic asset as it combines features from gold and sovereign currencies (Selgin, 2015). Bitcoin as an asset class has gained considerable attention and consequently, it is important to study from international portfolio diversification benefits (Urquhart, 2017). Some researchers find hedging power of Bitcoin as it is uncorrelated or weakly correlated with major equities, oil, currencies. By using GARCH models to study Bitcoin, gold and dollar return it is found that Bitcoin may be useful in risk management and ideal for risk-averse investors in anticipation of negative shocks to the market. Furthermore, Bitcoin can be classified in between gold and the U.S. dollar on a scale from the pure medium of exchange advantages to the pure store of value advantages (Dyhrberg, 2016a, 2016b). He further argues that high-frequency trading of Bitcoin creates appropriate conditions for such hedging to be conducted. He concludes that Bitcoin has a clear place in the market for portfolio analysis and risk management, moreover, as Bitcoin is traded at high and continuous frequencies with no days where trading is closed, like other assets, Bitcoin has specific speed advantages and adds to the already rich list of hedging tools available to analysts.

Recently, by applying a dynamic conditional correlation model with daily and weekly data from July 2011 to December 2016 Bouri, Molnár, et al. (2017) find that Bitcoin is a poor hedge and appropriate for diversification purposes only. Interestingly, they find that Bitcoin can only serve as a strong safe haven against weekly extreme down movements in Asian stock. However, they conclude that Bitcoin hedging and safe haven properties vary between horizons. Bouri, Jalkh, et al. (2017) investigate the relationship between Bitcoin and energy commodities and find that Bitcoin is a strong hedge and a safe-haven against movements in commodities. Moreover, they also find that Bitcoin enjoys hedging and safe-haven properties before December 2013 crash and no such advantage exists in the post-crash period. As an emerging asset class, it deserves much attention from not only policymakers but also international investors, portfolio and hedge fund managers.

In addition, Bouri, Jain, et al. (2017) examine the nonlinear, asymmetric and quantile effects of aggregate commodity index and gold prices on the price of Bitcoin. They find that it is possible to predict Bitcoin price movements based on price information from aggregate commodity index and gold prices. It is also found that the relationship between Bitcoin and gold is asymmetric, nonlinear and quantile dependent. However, they conclude that the relationship between Bitcoin and asset classes are complex and hidden, therefore, nonstandard cointegration models can provide better results. In their recent study, Bouri et al. (2018) find that Bitcoin returns are related quite closely to financial assets, particularly commodities. Moreover, they find that the Bitcoin receives more volatility than it transmits. They conclude that Bitcoin market is not isolated completely. Guesmi et al. (2018)argue that MGARC-DCC is the best-fit model for modelling the joint dynamics of different financial variables with Bitcoin. They find that a short position in the Bitcoin market allows hedging the risk investment for financial assets,

moreover, hedging strategies involving gold, oil, developing stocks and Bitcoin reduce considerably the portfolio's risk (variance).

Although there is no issue of Bitcoin's inclusion in a sustainable equity portfolio, there is some doubt on whether Shari'ah-compliant investors can invest in Bitcoin. Undoubtedly, Bitcoin is a new and recent phenomenon. There is no direct or indirect reference in the Holy Quran and Sunnah (practices of the Prophet) regarding this. However, one of the key principles of Shari'ah states that everything is permissible (halal) unless proven impermissible (haram). There is no fatwah which declares Bitcoin is impermissible. Moreover, as stated earlier Monzer Kahf's fatwah motivated The Fiqh Council of North America and many *Shariah* scholars from Malaysia, Indonesia, South Africa, and the United Arab Emirates to issue a similar *fatwa* (propositions) by accepting cryptocurrency as a *Shariah*-compliant currency and commodity (Abubakar et al., 2018; Mahomed & Mohamad, 2017).

3 | DATA AND METHODOLOGY

3.1 | Data

Table 1 shows the variables used in the study. BIT represents the daily return series of USD to Bitcoin (Bitstamp)—exchange rate, DJI—Dow Jones Islamic—price index, SPT—S&P 500 Composite—price index and FTG—FTSE 4 GOOD Global (US$)—price index. We have taken daily data of all the variables from August 18, 2011 to September 10, 2018. Time period of this study is restricted due to nonavailability of Bitcoin price for a longer period of time. However, we still have 1842 observations which would well capture the time-varying volatilities and correlation dynamics of market returns. The full data set has been collected from Thomson Reuters DataStream. The stock indices and Bitcoin returns were calculated as difference of the logarithmic daily closing prices of indices $[\ln(p_t) - (\ln p_{t-1})]$ where p is an index value. The conversion is necessary to get stationarity in variance (Engle, 2002).

3.2 | Methodology

This research employs two methods to investigate how volatility and correlation change over time and how outcomes vary at different stock holding periods: MGARCH-DCC and CWT wavelet, respectively. The portfolio diversification benefits at multiple investment horizons using MGARCH-DCC and wavelet methods compared to cointegration test, generalised VAR, BEKK-GARCH, ARMA, VEC, Copula, and EGARCH models, are more effective and efficient to estimate, whereas the rest methods seem to offer poor fitness of the model (see Sadorsky, 2012). Details of both of the above methods are discussed below.

TABLE 1 Bitcoin and selected stock indices

Symbol	Bitcoin and stock indices
BIT	USD to Bitcoin (Bitstamp)—exchange rate
DJI	Dow Jones Islami—price index
SPT	S&P 500 Composite—price index
FTG	FTSE4GOOD Global (US$)—price index

3.2.1 | Multivariate generalised autoregressive conditional heteroscedastic-dynamic conditional correlation

This research adopts the MGARCH-DCC model suggested by Engle (2002) and Pesaran and Pesaran (2010) to explore how variability and correlations between the assets vary over time including the directions (positive or negative) as well as the scale (strong or weak).There are a number of advantages that inspire us to use it in our study; first, DCC enables the analysis of time variation in both mean and variance equation; second, DCC enables investors to figure out how correlations between assets shift over time; third, DCC approach is relatively robust in modelling individual volatility and can be applied to portfolios with broad assets (Pesaran & Pesaran, 2010). Since then the MGARCH-DCC model has been widely used to explore the prevalence of portfolio diversification opportunities, therefore, we make a humble attempt to use this recent model to address our research goal of detecting portfolio diversification opportunities in the context of Bitcoin with Islamic and Responsible equity indices. This model[2] can be laid down as follows (Figure 1):

$$r_t = \beta_0 + \sum_{i=1}^{k} \beta_i r_{t-1} + u_t = \mu_t + u_{t.}$$

$$\mu_t = \mathrm{E}\left[r_{t|\Omega_{t-1}|}\right]$$

$$u_t \mathrm{I}\Omega_{t-1} \backsim \mathrm{N}(0, \mathrm{H_t})$$

$$H_t = G_t R_t G_t$$

$$G_t = \mathrm{diag}\left\{\sqrt{h_{ii,t}}\right\}$$

$$Z_t = G_t^{-1} u_t$$

Hence, $h_{ii,\ t}$ represents the estimated conditional variance of the single univariate GARCH model, G_t refers to the diagonal matrix of contingent standard deviations, R_t implies the time-varying conditional correlation coefficient matrix of stock returns, and finally Z_t indicates the standardised residual vector along with mean-zero and variance-one. With the accomplishment of this basic construction, the dynamic correlation coefficient matrix of the DCC model can be specified further by following Hsu Ku and Wang (2008):

$$R_t = (\mathrm{diag}(Q_T))^{-1/2} Q_t (diag(Q_t))^{-1/2}$$

$$Q_t = \left(q_{ij,t}\right)$$

$$(\mathrm{diag}(Q_t))^{-1/2} = diag\left(\frac{1}{\sqrt{q_{11,t}}}, \frac{1}{\sqrt{q_{nn,t}}}\right)$$

$$q_{ij,t} = \bar{p}_{ij} = \alpha\left(Z_{i,t-1}Z_{j,t-1} - \bar{p}_{ij}\right) + \beta\left(q_{ij,t-1} - \bar{p}_{ij}\right)$$

where $\bar{p}_{ij}$ is the unconditional correlation coefficient and the time-varying conditional correlation coefficient is $p_{i,j,t} = q_{i,j,t}\mathrm{I}\sqrt{q_{ii,t}q_{jj,t}}$. Meanwhile, the returns of financial assets often appear to be fat-tailed where the assumption of normal distribution is invalid. To that end, one plausible treatment might be the usage of the Student's *t*-distribution. That means the conditional distribution $u_t \,|\, \Omega_{t-1} \sim N(0, H_t)$takes the place of $u_t \,|\, \Omega_{t-1} \sim \int \mathrm{Student}'\mathrm{s} - t(u_t; v),\ (0, H_t)$ hence v constitutes the parameter for the degree of freedom.

3.2.2 | Continuous wavelet transformation

Stock market investors have different priorities about time scales or investment horizons or holding periods of stocks. In and Kim (2013) stressed that the detection of true dynamics and relationships of co-movement between different markets is feasible if the financial markets are decomposed into various time scales or equity holding periods. Wavelet takes care of the heterogeneity of investment horizons, taking into consideration the data's time and frequency domain aspect. CWT has been applied by a variety of studies (Aloui & Hkiri, 2014; Buriev, Dewandaru, Zainal, & Masih, 2018; Madaleno & Pinho, 2010; Rahim & Masih, 2016; Vacha & Barunik, 2012) to identify heterogeneity in investment horizons. This study applies CWT to explore how the international portfolio diversification opportunities change over time, considering the various investment holding horizons. The continuous wavelet transform $w_{x(u,\ s)}$ is obtained by projecting a mother wavelet Ψ onto the examined time series $x(t) \in l^2(R)$ (see Najeeb, Bacha, and Masih (2015), that is

$$W_x(u,s) = \int_{-\infty}^{\infty} x(t)\frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right)dt.$$

Here, u refers to the time domain and s refers to its position in the frequency domain. Therefore, the wavelet transforms, by mapping the original series into a function of u and s, give us information simultaneously on time and frequency. For finding the interaction between two-time series (e.g., how closely X and Y are interrelated by liner transformation), this study applied a bivariate framework called wavelet coherence. Like Torrence and Webster (1999), the wavelet coherence of two time series can be defined as follows:

$$R_n^2(s) = \frac{\mathrm{I}S\left(s^{-1}W_n^{xy}(s)\right)\mathrm{I}^2}{S\left(s^{-1}\mathrm{I}W_n^{x}(s)\right)\mathrm{I}^2 \cdot S\left(s^{-1}\mathrm{I}W_n^{y}(s)\right)\mathrm{I}^2}$$

whilst S is a smoothing operator, s is a wavelet scale, $W_n^x(s)$ is the continuous transform of the time series X, $W_n^y(s)$ is the continuous wavelet transform of the time series Y, $Y_n^{xy}(s)$ is a cross wavelet transform of the two time series X and Y (see details Madaleno & Pinho, 2010; In & Kim, 2013.

4 | RESULTS AND DISCUSSION

In this section, we report the statistical results and analysis of the test findings. After removing the outliers and ensuring data normality, let us first consider the descriptive statistics presented in Table 2.

4.1 | Results of MGARCH-DCC

At this stage, we need to see whether there is a relationship among the Bitcoin and three equity indices for the purpose of portfolio diversification. The maximum likelihood estimates of lambda (λ) and delta (δ) for four assets returns have been summarised in Table 3. Moreover, *t*-statistic indicates the volatility decay over the long period. The *t*-tests show that all parameters are highly significant.

The results in Table 3 indicate that the volatility parameters are highly significant that confirms gradual volatility decay in which for example the riskiness involved in the returns gradually cancels out after following a shock in the market. Even after adding lambda1_BIT and lambda2_BIT (0.80728 + 0.17835 = 0.98563), by following this equation $H_0 : \lambda_1 + \lambda_2 = 1$. The same applies to other three remaining stock indices. The result of the summation is still less than 1 or unity which tells us that the volatility of Bitcoin return together with other returns are not following the integrated GARCH (IGARCH) or in simple language, shocks to the volatilities are not permanent and mean reverting. In other words, Bitcoin price may go ups and downs considerably but in the long run it tends to converge to mean value and not completely crushed to zero. Theoretically, the diffusion and noise make the deviation, but a strong elastic force make the volatility back to the long term value (Merville & Pieptea, 1989). Otherwise, Investors and portfolio managers would have high possibility to loss their investment provided that the shocks are permanent.

If shocks were permanent, investors and portfolio managers would have high probability of losing their investment. On the contrary, speculators would be welcoming such conditions with temporary shocks that are favourable to their interests. This confirms that Bitcoin can be considered as a safe asset class regardless of its higher volatility in the short run. Aalborg et al. (2018) argued that past realised volatility predicts Bitcoin's future realised volatility. Economic theory implies that the Bitcoin's volatility will decrease when its usage increases as it would reduce the sensitivity of the exchange rate to the beliefs of speculators about the future value of the cryptocurrency. Our finding also corroborates the findings of Blau (2017) which argue that price volatility of Bitcoin is not erupting from speculation. Moreover, previous studies found strong evidence of informed trading in Bitcoin (Feng et al., 2018; Jiang et al., 2018).

TABLE 2 Descriptive statistics (n = 1,842)

	Mean	*SD*	Min	Max	Skewness	Kurtosis
BIT	0.0052747	0.060268	−0.485	0.624	0.7337167	20.58929
SPT	0.0005445	0.008359	−0.041	0.043	−0.2620673	6.152268
DJI	0.0003692	0.007463	−0.047	0.038	−0.3325532	7.135172
FTG	0.0003572	0.007914	−0.057	0.045	−0.3567201	7.875886

TABLE 3 MGARCH with underlying multivariate *t*-distribution

Parameter	Estimate	Standard error	*T*-ratio (Prob)
lambda1_BIT	0.80728	0.019771	40.831 (.000)
lambda1_DJI	0.88265	0.018561	47.553 (.000)
lambda1_FTG	0.88804	0.018932	46.906 (.000)
lambda1_SPT	0.83266	0.027895	29.850 (.000)
lambda2_BIT	0.17835	0.017373	10.266 (.000)
lambda2_DJI	0.075666	0.010244	7.3866 (.000)
lambda2_FTG	0.074607	0.011120	6.7090 (.000)
lambda2_SPT	0.10161	0.014395	7.0586 (.000)
delta1	0.86365	0.034945	24.715 (.000)
delta2	0.027652	0.004616	5.9898 (.000)
df	6.1383	0.35831	17.131 (.000)

Abbreviation: MGARCH, multivariate generalised autoregressive conditional heteroscedastic.
Note: Volatility decay factors unrestricted, different for each variable. Correlation decay factors unrestricted, same for all variables. Maximised log-likelihood = 25,651.8; *df* is the degrees of freedom of the multivariate t distribution. lambda1 and lambda2 are decay factors for variance and covariance, respectively.

TABLE 4 Unconditional volatility and correlation

	BIT	DJI	FTG	SPT
BIT	0.057249	0.0082874	0.010649	0.018440
DJI	0.0082874	0.0067712	0.95267	0.91288
FTG	0.010649	0.95267	0.0071917	0.82842
SPT	0.018440	0.91288	0.82842	0.0077315

In order for finding the portfolio diversification benefits of Bitcoin for sustainable, Islamic, and conventional equity investors, this study applied the MGARCH-DCC approach. Initially we conducted MGARCH-DCC analysis on all indices returns (discussed in the previous section). Thereupon, we first look at the unconditional volatilities and correlations given in Table 4.

On-diagonal elements in Table 4 show the unconditional volatilities of the assets, whilst off-diagonal elements represent the unconditional correlation between assets. If the unconditional volatility is near to zero, it can be said that the particular asset has the least volatility whereas if the unconditional volatility is near to 1, it shows higher volatility levels. The results show that Dow Jones Islamic index return has the lowest volatility (0.0067712) and Bitcoin return has the highest volatility (0.057249). The results are consistent with the existing literature and it is observed that Bitcoin has experienced several major market corrections followed by Mt Gox scandal in 2013 and the Great Crypto Crash of 2018.Thereafter, regarding the correlation, Bitcoin market has the least correlations with Dow Jones Islamic index and FTSE 4 Good index, on the other hand relative highest positive correlation is obvious with S&P 500 Composite index.

The lower volatility of Islamic and sustainable equity can be justified on the ground of strict screening criteria. For example, screening of the compliance on whether the company's transaction is Shari'ah compliant or not go through two step: first, sector based screening where they

confirm that business activities are not involved in Non Shari'ah compliant activities such as interest based finance, conventional insurance, gambling and gaming, dealing with pork, alcohol, and tobacco, and pornographic activities. In some jurisdictions, sectors such as hotels, entertainment, and weapons manufacturing are also precluded. Thereafter, accounting based screening in financial ratios, especially in capital structure where debt to equity ratio must be less than 33%. Cash and interest-bearing securities to equity also must be less than 33% and the maximum of 5% non-Shari'ah compliant income to revenue is allowed (Ho, Rahman, & Hafizha, 2011; Masih, Kamil, & Bacha, 2018). At the same time, ethical and sustainable equity index like FTSE 4 Good excludes companies which are involved in detrimental activities against society and environment (Schueth, 2003).

We summarise the findings in Table 5. This is important to perform before proceeding to t-DCC because it shows the accuracy and relevance of the method applied in this study. Hence, Kolmogorov–Smirnov (KS) test statistics is 0.0345 which is lower than 5% critical value. This implies that the study cannot reject the null hypothesis of uniformly distribution of the probability integral transforms. Mean hit rate (pihat statistic) of tolerance probability is 0.98842 which is very close to the expected value of (0.99000) and the *p*-value is not significant, supporting the validity of *t*-DCC model. Moreover, the coefficient of Lagrange multiplier test is 39.1351 which is statistically significant. Thus, the diagnostic test supports that the MGARCH model with asymptotic properties are not influenced by the serial correlations, since the presence of the serial correlation adversely affects model specification and estimation errors. We provide Table 5 and Figure 2.

From the above results we can argue that Islamic investors and socially responsible investors can get positive diversification benefits by investing in Bitcoin. However, this result is time-invariant which means the above-stated correlations are constant or static, unfortunately that is not the case in financial markets of the present world economy (Whitelaw, 1994). This intuition particularly motivates us to explore the dynamic conditional correlation that captures the time-varying correlation and volatilities.

Figure 3 and 4 show the time-varying volatilities and correlations among Bitcoin and three equity indices ranging from December 30, 2011 to September 10, 2018. The conditional volatilities of all stock return move together closely during the observation period except Bitcoin which is consistent with our earlier results driven by unconditional volatility and correlation matrix table. Moreover, the correlation among Bitcoin and all equity indices varies overtime. Bitcoin and the Dow Jones Islamic have the lowest positive correlation, sometime even negative correlation with Shariah equity index. This implies the existence of greater portfolio

TABLE 5 Robustness check

Lagrange multiplier test	Coefficient	*p*-value
	39.1351	(.000)
Kolmogorov–Smirnov (KS) test	*t*-Statistics	Critical value
	0.0345	0.1014
Tolerance probability	Mean hit rate (pihat statistic)	*p* value
	0.98842	(.520)

Abbreviation: MGARCH, multivariate generalised autoregressive conditional heteroscedastic.

Note: The result is based on the test of the validity of MGARCH using estimated volatilities (VaR diagnostics), test based on probability integral transforms, LM test of serial independence of the PIT and Kolmogorov–Smirnov test of uniformity of the PIT by applying the Microfit statistical package.

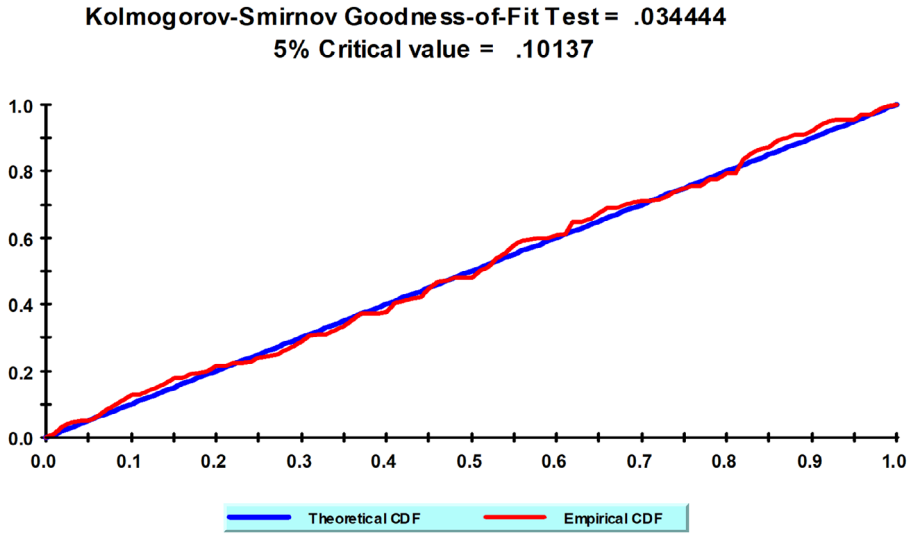

FIGURE 2 Goodness of fit

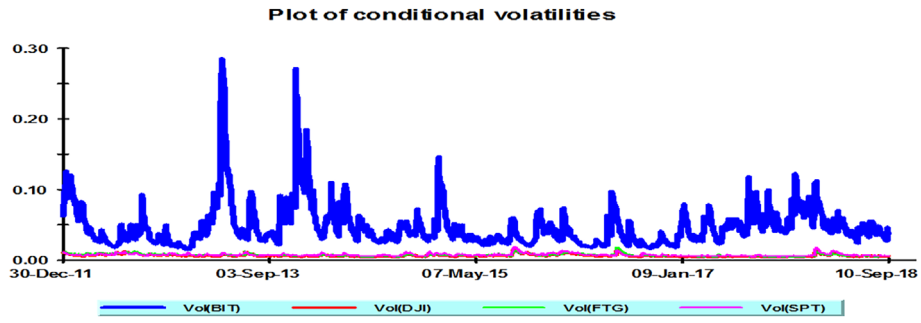

FIGURE 3 Plot of conditional volatilities

diversification benefits for the investors and fund managers who are already exposed to Dow Jones Islamic index. Moreover, the deeper sight at Bitcoin shows that there was a great volatility in 2013 and 2018. However, during 2013 dynamic conditional correlations were negative between Bitcoin and Dow Jones Islamic index but it becomes positive during 2018. These two points indicate the Bitcoin crash in 2013 and 2018. Interestingly, the correlations of all *assets* maintain lower than 0.30 which support the prevalence of portfolio diversification benefits. Our findings are consistent with the following researches (Bouri et al., 2018; Dyhrberg, 2016a, 2016b; Urquhart, 2017).

4.2 | Results of continuous wavelet transform

As stated earlier in the methodology section that CWT can describe the prevalence of portfolio diversification opportunities at different investment horizons, therefore, we apply it in

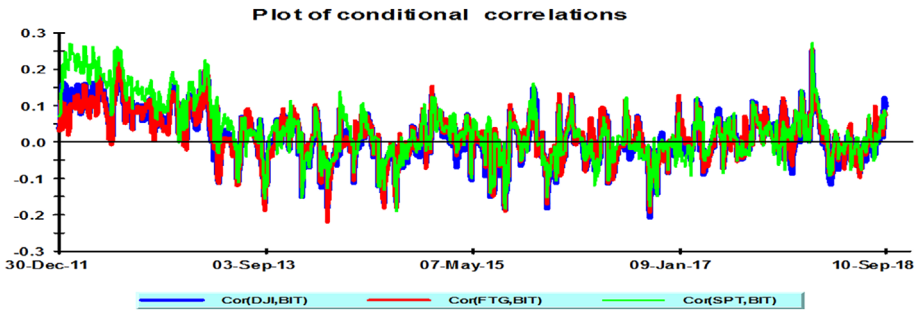

FIGURE 4 Plot of conditional correlations

FIGURE 5 Continuous wavelet transform Bitcoin versus Dow Jones Islamic index

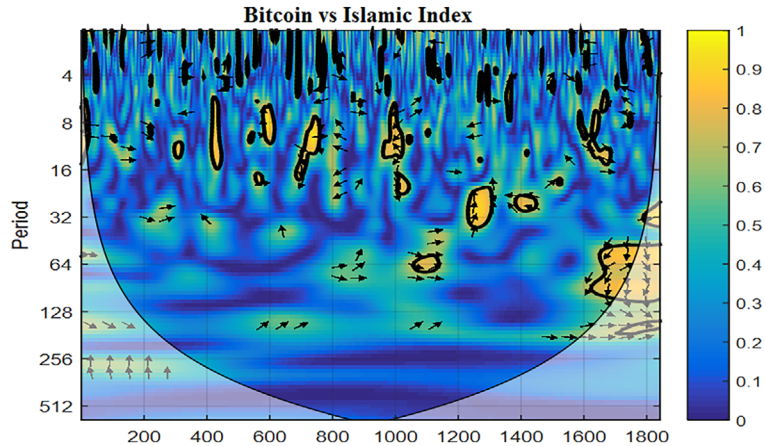

FIGURE 6 Continuous wavelet transform Bitcoin versus FTSE 4 Good index

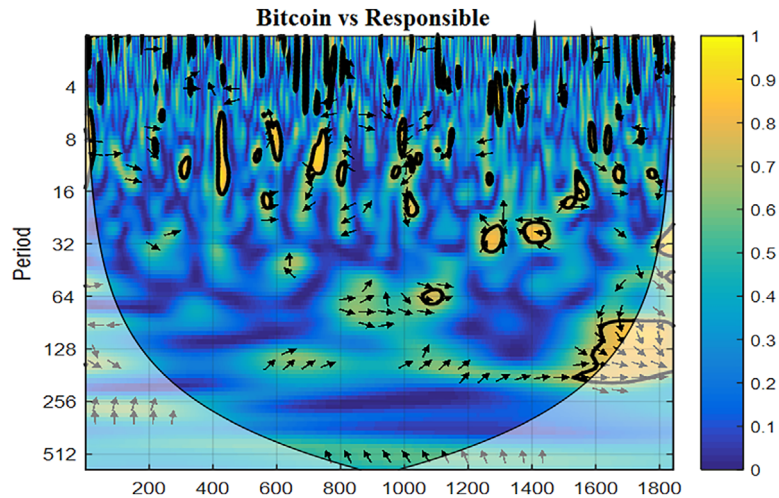

Figure 5–7 for portfolio diversification for the bitcoin. There, the horizontal axis indicates time (number of trading days), whereas, the investment horizon is on the vertical axis. The thick black line in the coherency plots indicates the statistical significance at 5%

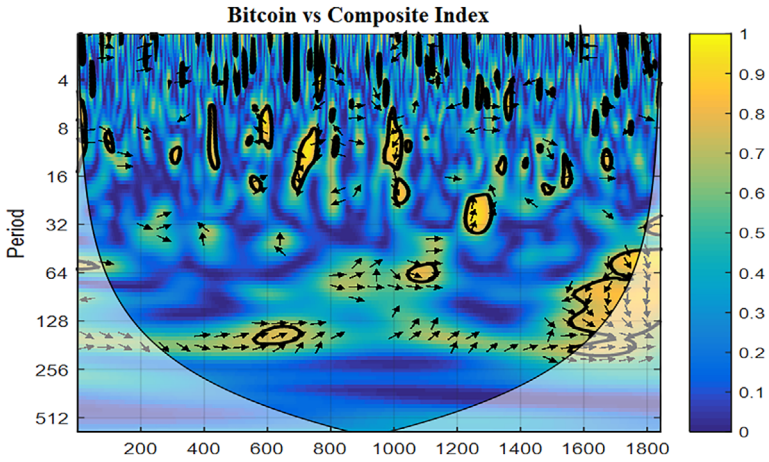

FIGURE 7 Continuous wavelet transform Bitcoin versus S&P 500 Composite index

significance level determined by using Monte Carlo methods. Hence, the colour code for power ranges from blue (low coherence) to red (high coherence). The vector pointing to the right indicates the indexes are in phase, left indicates just the opposite.

We need to bear in mind for the understanding of the lead/lag relationship that: right (left) arrow means the two variables are in "anti-phase." When the arrows point up and right this means that the first series leads. The first series lags, when they point to the right and down. When the arrows are up and down, this means that second series leads and if they are to the left and down, second series lags (Ali, Uddin, Chowdhury, & Masih, 2019; Gallegati, Ramsey, & Semmler, 2014). This analysis divided the series into various holding periods from short to long time spans such as 4–16, 16–32, 32–64 and 64–256 trading days in order to find the portfolio diversification. As seen in Figure 5–7, the correlation between Bitcoin and three stock indices is found to be very weak.

We have noticed that the connection between Bitcoin and three stock indices varies depending on the investment horizon. For example, the relative low correlation occurs between 16 and 32 days at the observational points. It means that the investment, which is in line with our expectations, favours speculators who choose to invest in that holding period (very short period). This is in line with the previous study by Bouri et al. (2018) who argue that the correlations between Bitcoin and equities tend to vary depending on the investment holding periods. Moreover, the findings also show that the Bitcoin and Dow Jones Islamic index returns appears to maintain lower correlation compared to the Bitcoin correlation and two other equity indices. Bitcoin and Dow Jones Islamic index correlations are also relatively small during the 360–620 observational scales. This is perhaps because this time represents the first major crypto-monetary crash in 2013. To this point, Bouri, Jain, et al. (2017); Bouri, Jalkh, et al. (2017); Bouri, Molnár, et al. (2017) document that Bitcoin enjoys hedging and safe-haven properties before December 2013 crash and no such benefit prevails in post-crash period.

On the contrary, we have observed relative higher correlation between Bitcoin and Dow Jones Islamic index during the observation points 1600–1800 (year 2016 and 2017). This is time period when the second major crash in cryptocurrency has taken place. This result is also consistent with our earlier findings in time varying conditional correlation analysis. Moreover, our findings support the previous findings of Bouri, Jain, et al. (2017); Bouri, Jalkh, et al. (2017); Bouri, Molnár, et al. (2017). This could

be due to the fact that Shariah compliant investors have started to invest more in Bitcoin. As mentioned earlier, MonzerKahf's rulings on acceptability of cryptocurrency as Shariah complaint asset in 2014 have motivated The Fiqh Council of North America and many Shariah scholars from Malaysia, Indonesia, South Africa and United Arab Emirates to issue similar fatwas.

The results obtained from the CWT suggests that the Bitcoin still offers portfolio diversification benefits both in the short run (16–32) days and long run (64–256 days) investment holding periods. So, the result could be beneficial for the investors, portfolio managers, hedge fund managers, institutional investors and policy makers for capital budgeting and investment decisions on portfolio diversification.

5 | CONCLUSION

This paper addresses a considerable void in the literature by assessing whether Bitcoin can be considered as an asset class in the first place. Then we examine whether it can offer portfolio diversification benefits to conventional, *Shariah*, and responsible investors in the short and long run. We use MGARCH-DCC and CWT to examine volatility, unconditional and conditional correlations along with different investment horizon periods.

In summary, our findings indicate that Bitcoin returns are mean-reverting which confirms that we can still consider it as an asset class despite being highly volatile. Not surprisingly, Bitcoin shows the highest volatility, whilst Dow Jones Islamic followed by FTSE 4 Good index show the lowest volatility. Moreover, the time-invariant model shows that Bitcoin offers portfolio diversification opportunities with almost all equity indices but more specifically, Dow Jones Islamic followed by FTSE 4 Good index. This clearly shows investors who are already exposed to Islamic and sustainable equities can get more diversification benefits by including Bitcoin in their portfolio. In this respect, we estimate that Bitcoin, as an innovative hedge risk management technique, might be applied to reduce any substantial losses or gains in the capital market. The time-variant analysis shows Bitcoin offers portfolio diversification benefits both in the short-run (16–32 days) and long-run (64–256 days) investment holding periods. Hence, different stakeholders such as fund managers, investors, and policymakers can potentially apply our findings in investment and policy-making decisions. This study has opened a new frontier of research for future studies to investigate Bitcoin and its various attributes as an innovative asset class.

ORCID

Md Akther Uddin https://orcid.org/0000-0002-2134-6073

ENDNOTES

[1]In a nutshell, a Bitcoin uses public-key cryptography, peer-to-peer networking, and proof-of-work to process and verify payments. At first, Bitcoins are sent from one address to another with each user potentially having many addresses. Each payment transaction is broadcast to the network and included in the blockchain so that the included bitcoins cannot be delivered twice. After an hour or two, each transaction is locked in time by the massive amount of processing power that continues to extend the blockchain. Hence, using these techniques, Bitcoin provides a fast and extremely reliable payment network in the global market.

[2]The model development and application for detecting portfolio diversification opportunities across different asset classes, has been widely discussed by the previous studies such as; Hsu Ku and Wang (2008), Najeeb et al. (2015) and Ali et al. (2019).

REFERENCES

Aalborg, H. A., Molnár, P., & de Vries, J. E. (2018). What can explain the price, volatility and trading volume of Bitcoin? *Finance Research Letters*, *29*, 255–265.

Abubakar, Y. S., Ogunbado, A. F., & Saidi, M. A. (2018). Bitcoin and its legality from Shariah point of view. *SEISENSE Journal of Management*, *1*(4), 13–23.

Ali, M. H., Uddin, M. A., Chowdhury, M. A. F., & Masih, M. (2019). Cross-country evidence of Islamic portfolio diversification: Are there opportunities in Saudi Arabia? *Managerial Finance*, *45*(1), 36–53.

Aloui, C., & Hkiri, B. (2014). Co-movements of GCC emerging stock markets: New evidence from wavelet coherence analysis. *Economic Modelling*, *36*, 421–431.

Ashraf, D., & Mohammad, N. (2014). Matching perception with the reality—Performance of Islamic equity investments. *Pacific-Basin Finance Journal*, *28*, 175–189.

Baek, C., & Elbeck, M. (2015). Bitcoins as an investment or speculative vehicle? A first look. *Applied Economics Letters*, *22*(1), 30–34.

Baur, D. G., Hong, K., & Lee, A. D. (2018). Bitcoin: Medium of exchange or speculative assets? *Journal of International Financial Markets, Institutions and Money*, *54*, 177–189.

Blau, B. M. (2017). Price dynamics and speculative trading in bitcoin. *Research in International Business and Finance*, *41*, 493–499.

Bouoiyour, J., & Selmi, R. (2015). What does Bitcoin look like? *Annals of Economics & Finance*, *16*(2), 449–492.

Bouri, E., Das, M., Gupta, R., & Roubaud, D. (2018). *Spillovers between Bitcoin and other assets during bear and bull markets*.

Bouri, E., Jain, A., Biswal, P., & Roubaud, D. (2017). Cointegration and nonlinear causality amongst gold, oil, and the Indian stock market: Evidence from implied volatility indices. *Resources Policy*, *52*, 201–206.

Bouri, E., Jalkh, N., Molnár, P., & Roubaud, D. (2017). Bitcoin for energy commodities before and after the December 2013 crash: Diversifier, hedge or safe haven? *Applied Economics*, *49*(50), 5063–5073.

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., & Hagfors, L. I. (2017). On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? *Finance Research Letters*, *20*, 192–198.

Brandvold, M., Molnár, P., Vagstad, K., & Valstad, O. C. A. (2015). Price discovery on Bitcoin exchanges. *Journal of International Financial Markets, Institutions and Money*, *36*, 18–35.

Buriev, A. A., Dewandaru, G., Zainal, M.-P., & Masih, M. (2018). Portfolio diversification benefits at different investment horizons during the Arab uprisings: Turkish perspectives based on MGARCH–DCC and wavelet approaches. *Emerging Markets Finance and Trade*, *54*(14), 3272–3293.

Cachanosky, N. (2019). Can Bitcoin become money? The monetary rule problem. *Australian Economic Papers*, *58*(4), 365–374.

Cheah, E.-T., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economics Letters*, *130*, 32–36.

Corbet, S., Lucey, B., & Yarovaya, L. (2018). Datestamping the Bitcoin and Ethereum bubbles. *Finance Research Letters*, *26*, 81–88.

Corbet, S., Meegan, A., Larkin, C., Lucey, B., & Yarovaya, L. (2018). Exploring the dynamic relationships between cryptocurrencies and other financial assets. *Economics Letters*, *165*, 28–34.

Dyhrberg, A. H. (2016a). Bitcoin, gold and the dollar–a GARCH volatility analysis. *Finance Research Letters*, *16*, 85–92.

Dyhrberg, A. H. (2016b). Hedging capabilities of bitcoin. Is it the virtual gold? *Finance Research Letters*, *16*, 139–144.

Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics*, *20*(3), 339–350.

Feng, W., Wang, Y., & Zhang, Z. (2018). Informed trading in the Bitcoin market. *Finance Research Letters*, *26*, 63–70.

Gallegati, M., Ramsey, J. B., & Semmler, W. (2014). Interest rate spreads and output: A time scale decomposition analysis using wavelets. *Computational Statistics & Data Analysis*, *76*, 283–290.

Guesmi, K., Saadi, S., Abid, I., & Ftiti, Z. (2018). Portfolio diversification with virtual currency: Evidence from bitcoin. *International Review of Financial Analysis*, *63*, 431–437.

Ho, C. S., Rahman, N. A. A., & Hafizha, N. (2011). Comparison of quantitative Sharôñah-compliant screening methods. *International Journal of Islamic Finance*, *3*(2), 91–109.

Ho, C. S. F., Rahman, N. A. A., Yusuf, N. H. M., & Zamzamin, Z. (2014). Performance of global Islamic versus conventional share indices: International evidence. *Pacific-Basin Finance Journal*, *28*, 110–121.

Hsu Ku, Y.-H., & Wang, J. J. (2008). Estimating portfolio value-at-risk via dynamic conditional correlation MGARCH model—An empirical study on foreign exchange rates. *Applied Economics Letters*, *15*(7), 533–538.

In, F., & Kim, S. (2013). *An introduction to wavelet theory in finance: A wavelet multiscale approach*. Singapore: World Scientific.

Jiang, Y., Nie, H., & Ruan, W. (2018). Time-varying long-term memory in Bitcoin market. *Finance Research Letters*, *25*, 280–284.

Krugman, P. (2013). Bitcoin is evil. *The New York Times*, *28*, 2013.

Lintner, J. (1965). Security prices, risk, and maximal gains from diversification. *The Journal of Finance*, *20*(4), 587–615.

Madaleno, M., & Pinho, C. (2010). Relationship of the multiscale variability on world indices. *Revista De Economia Financiera*, *20*(2), 69–92.

Mahomed, Z., & Mohamad, S. (2017). *Crypto mania: The Shariah verdict*. Malaysia: Centre For Islamic Asset And Wealth Management (CIAWM).

Masih, M., Kamil, N. K., & Bacha, O. I. (2018). Issues in Islamic equities: A literature survey. *Emerging Markets Finance and Trade*, *54*(1), 1–26.

Merville, L. J., & Pieptea, D. R. (1989). Stock-price volatility, mean-reverting diffusion, and noise. *Journal of Financial Economics*, *24*(1), 193–214.

Miller, E. M. (1977). Risk, uncertainty, and divergence of opinion. *The Journal of Finance*, *32*(4), 1151–1168.

Najeeb, S. F., Bacha, O., & Masih, M. (2015). Does heterogeneity in investment horizons affect portfolio diversification? Some insights using M-GARCH-DCC and wavelet correlation analysis. *Emerging Markets Finance and Trade*, *51*(1), 188–208.

Nakamoto, S. (2008). Bitcoin: a peer-to-peer electronic cash system. Retrieved from http://www.bitcoin.org/bitcoin.pdf

Pesaran, B., & Pesaran, M. H. (2010). *Time series econometrics using Microfit 5.0: A user's manual*. Oxford, England: Oxford University Press.

Polasik, M., Piotrowska, A. I., Wisniewski, T. P., Kotkowski, R., & Lightfoot, G. (2015). Price fluctuations and the use of Bitcoin: An empirical inquiry. *International Journal of Electronic Commerce*, *20*(1), 9–49.

Rahim, A. M., & Masih, M. (2016). Portfolio diversification benefits of Islamic investors with their major trading partners: Evidence from Malaysia based on MGARCH-DCC and wavelet approaches. *Economic Modelling*, *54*, 425–438.

Sadorsky, P. (2012). Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics*, *34*(1), 248–255.

Schueth, S. (2003). Socially responsible investing in the United States. *Journal of Business Ethics*, *43*(3), 189–194.

Selgin, G. (2015). Synthetic commodity money. *Journal of Financial Stability*, *17*, 92–99.

Selmi, R., Mensi, W., Hammoudeh, S., & Bouoiyour, J. (2018). Is bitcoin a hedge, a safe haven or diversifier for oil price movements? A comparison with gold. *Energy Economics*, *74*, 787–801.

The Economist. (2018). *The next recession*. London, England: Author.

Torrence, C., & Webster, P. J. (1999). Interdecadal changes in the ENSO—Monsoon system. *Journal of Climate*, *12*(8), 2679–2690.

Urquhart, A. (2017). Price clustering in Bitcoin. *Economics Letters*, *159*, 145–148.

Vacha, L., & Barunik, J. (2012). Co-movement of energy commodities revisited: Evidence from wavelet coherence analysis. *Energy Economics*, *34*(1), 241–247.

Whitelaw, R. F. (1994). Time variations and covariations in the expectation and volatility of stock market returns. *The Journal of Finance*, *49*(2), 515–541.

Williams, A. (2018). UK ethical funds surge in popularity. *Financial Times*. Retrieved from www.ft.com

How to cite this article: Uddin MA, Ali MH, Masih M. Bitcoin—A hype or digital gold? Global evidence. *Aust Econ Pap*. 2020;1–17. https://doi.org/10.1111/1467-8454.12178