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How resilient are Islamic financial markets during the COVID-19 pandemic?

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ABSTRACT

The COVID-19 pandemic has posed a massive disruption to the finance sector. Islamic financial markets are no exception. We explore the resilience of Islamic financial markets to the COVID-19 pandemic vis-à-vis conventional markets. A comparative analysis of the impact of the first and second waves of COVID-19 is also conducted. We use five Dow Jones Islamic stock indices and two bond indices and their conventional counterparts as proxies of Islamic and conventional financial markets. Using wavelet, wavelet-based Granger causality, hedge ratio, optimal weights, and hedging effectiveness methods from January 1, 2019, to February 26, 2021, our empirical estimates indicate that both Islamic and conventional stock indices are almost similarly affected by the extreme market turbulence triggered by COVID-19. Hence, Islamic stock markets fail to provide diversification benefits. We also unveil no significant differences between the first and second waves of COVID-19 in the case of dependency. Conversely, Islamic bonds exhibit low dependence on their conventional counterparts, indicating their diversification benefits. We further demonstrate that Islamic and conventional bond pairs could be utilized as a strong portfolio mix because the least hedging cost and highest hedging effectiveness are observed in those portfolios, especially during COVID-19. Overall, our results suggest that global Sukuk offers more resilience in times of extreme market turmoil than other instruments considered in this study. Our findings present global investors and regulators with new insights on diversification and hedging strategy with Islamic finance during a worldwide, severe economic crisis. We present some policy recommendations in creating a more sustainable financial system post-COVID-19.

1. Introduction

The coronavirus (COVID-19) pandemic has led to an unprecedented contraction in the global economic and financial markets. Though COVID-19 started as a health crisis, it became an economic catastrophe analogous to the 2008 Global Financial Crisis (GFC). In the early phase of the COVID-19 outbreak, IMF (2020) estimated that the world economy would shrink by 3% in 2020 due to COVID-

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19. The unemployment rate in the United States jumped from 3.7% to 14.8% in the early two months of the pandemic (Yarovaya et al., 2021). In the wake of COVID-19, many studies have observed the repercussions of the pandemic to the financial markets (see, e.g., Sharif et al., 2020; Corbet et al., 2020; Akhtaruzzaman et al., 2020; Hasan et al., 2021b; Hasan et al., 2021c; Shafiullah et al., 2021; Zaremba et al., 2021; Umar et al., 2021b). It is also assumed that this pandemic's financial losses would be much more than the earlier crises such as the Great Depression (1930), Black Monday (1987), Asian Financial Crisis (1997), and 2008 GFC (Sharif et al., 2020; Ji et al., 2020).

Therefore, investors across the world are facing massive uncertainty. This uncertainty is further deepened by the recent oil price crisis (Sharif et al., 2020; Hasan et al., 2021d), culminating in a scramble for resilient assets with hedge and safe haven features. Traditionally, gold (Baur and Lucey, 2010; Baur and McDermott, 2010; Umar et al., 2021a; Hassan et al., 2021a), and foreign currencies (Beckmann et al., 2015; Grisse and Nitschka, 2015), have been used for this purpose. More recently, cryptocurrencies are beginning to serve as a hedge and safe haven (Feng et al., 2018; Hasan et al., 2021d; Umar and Gubareva, 2020). Some recent studies such as Ji et al. (2020), Yarovaya et al. (2021), and Hasan et al. (2021d) assess the resilience among different assets, particularly traditional ones, and unveil that they fail to provide protection, especially in times of crisis times. The widespread impact of COVID-19 has re-intensified the need for alternative resilient assets.

In recent years, Shariah-based Islamic financial assets have attracted both Muslim and non-Muslim investors' attention globally due to their resilience against financial crises, particularly in the GFC's wake (Akhtar and Jahromi, 2017; Azad et al., 2018). As a result, Islamic finance grew at about 10.3% annually to reach a US$3.50 trillion global market capitalization in 2020 (Sherif, 2020).

Shariah-based assets are governed by Shariah principles, banning activities like interest, gambling, and precarious transactions—speculation, short-selling, and arbitration (Shahzad et al., 2017; Hasan et al., 2021b; Hasan et al., 2021d). Islamic finance places considerable emphasis on Socially Responsible Investing (SRI) based on the principles of profit-loss sharing principle and sustainability as well as prioritizing the 'real economy' (Paltrinieri et al., 2020; Umar and Gubareva, 2021a). In particular, the Islamic jurisprudence guiding investment—and doing business for that matter—have long been argued to be fully compatible with the Corporate Social Responsibility (CSR) principles outlined by the UN Global Compact (Williams and Zinkin, 2010; Erragraguy and Revelli, 2015). Islamic finance also aligns with the core tenets of 'responsible finance' that has gained popularity in the GFC's aftermath (Ali et al., 2021). As such, Shariah-based assets/investment/businesses often have a favorable standing when screened by Environmental, Social, and Corporate Governance (ESG) criteria (Erragraguy and Revelli, 2015; Hassan et al., 2021b; Qoyum et al., 2021).

The 2008 GFC was brought on mainly due to leveraging sub-prime mortgage securities and derivatives that are virtually absent in Islamic finance, leaving Islamic finance less affected by the GFC (Akhtar and Jahromi, 2017). Due to such unique features and financially conservative nature, Islamic assets are considered safer, stable, and less volatile than their counterparts (Rejeb and Arfaoui, 2019; Hasan et al., 2021a). Shariah-compliant Islamic financial assets and/or stock markets—especially after the GFC—have consistently been found to outperform their conventional counterparts with regard to risk-adjusted returns, lower volatility and beta, hedging and diversification benefits, inter alia (Shahzad et al., 2017; Umar et al., 2018; Umar and Gubareva, 2021a).

Hence, the Islamic assets are expected to be less affected by the COVID-19 pandemic and may act as a safe haven for investors. However, the unprecedented shifts in business dynamics due to the COVID-19 pandemic have raised questions about the efficacy of Islamic finance's resilience. Nevertheless, Islamic finance is preceded by a record of consistently superior performance vis-à-vis conventional counterparts when considering ESG criteria, returns, risk, volatility, and hedging benefits. This conundrum motivates a pertinent and timely question: will Islamic finance provide more resilience to the markets than its conventional counterparts during COVID-19 as it did during the GFC?

Recent empirical findings on the behavior of Islamic financial assets in the context of the COVID-19 pandemic are either inconclusive (Foglie and Panetta, 2020) or contradictory (Ashraf et al., 2022; Sherif, 2020; Yarovaya et al., 2021). Nevertheless, United Nations Development Programme (2020) has recently suggested a few Islamic financing tools—such as Zakat (charity) and Sukuk (Islamic bonds)—to use as a part of an integrated pandemic response plan. Therefore, it is crucial to evaluate the Islamic finance assets' resilience during COVID-19, including its first and second waves in early and late-2020, to demonstrate their reliability as a viable alternative to traditional financial assets. Such an evaluation of Islamic financial assets' efficacy and suitability is expected to assist evidence-based policymaking and diversity in the pandemic response and recovery plan(s) in a contemporary context across the Globe.

Against this backdrop, we attempt to analyze the resilience of Islamic financial assets (both stocks and bonds) and their hedging properties compared to their conventional counterparties before and during COVID-19. In addition, we contrast the findings between the two waves of COVID-19. We use wavelet-based multi-timescales analysis, wavelet-based Granger causality, hedge ratio (HR), optimal weights, and hedging effectiveness (HE). The estimated results demonstrate that Islamic stock indices are highly connected with the conventional stock indices, implying that Islamic stock indices do not provide significant diversification benefits during the whole sample period. However, Islamic bonds have low or no tendency to co-move with their conventional peers, highlighting the diversification opportunities, especially in the pandemic crisis. The optimum portfolio structure is found in the case of Islamic and conventional bond pairs during COVID-19.

Nevertheless, our analysis and findings stand out from the extant literature and make five substantial, novel, and unique contributions. Firstly, existing studies comprehensively explore the influence of the COVID-19 pandemic on conventional financial markets, but we find some but not comprehensive studies on Islamic financial markets. In contrast, this study combines the resilience analysis of the two markets and provides a comparative discussion of COVID-19's impact. Secondly, to the best of our knowledge, we are the first to assess the impact of the first and second waves of COVID-19 on both markets (i.e., conventional and Islamic). Thirdly, we extend the same thread of Yarovaya et al. (2021)'s study by investigating the impact of COVID-19 (including both waves) on the Islamic stock and bond markets and their conventional counterparts with an extended data period from January 1, 2019, to February 26, 2021. Fourthly,

our study also focuses on the GCC markets where, to date, no study has been conducted on the bond and Sukuk markets in terms of resiliency, especially in the COVID-19's wake. Finally, the empirical findings reveal that Islamic financial assets, principally Sukuk, are resilient in the face of the pandemic crisis compared to other assets. The hedging benefit of Islamic bonds is especially suited in the short and medium-run investment horizons, particularly during the pandemic. Further, Islamic and conventional bond pairs are the optimal portfolio mix, where investors can benefit from the lowest hedging cost and highest hedging effectiveness.

The remainder of this study is planned as follows: Section 2 reviews the previous literature, Section 3 describes the data and research methodology, Section 4 delineates the empirical results and economic discussions, and Section 5 concludes the study with policy implications and limitations.

2. Literature review

The extant literature on Islamic finance is extensive. A considerable volume of studies investigated the performance of Islamic finance, particularly Islamic stocks, compared to their conventional peers (e.g., Al-Khazali et al., 2014; Dewandaru et al., 2014; Ho et al., 2014; Akhtar and Jahromi, 2017; Hassan et al., 2020; Alam and Ansari, 2020; Aarif et al., 2020; Hasan et al., 2021b). The comparative performance is measured from diverse perspectives: i.e., risk-adjusted performance, cointegration, and volatility. However, these studies often reveal contradictory and mixed results, creating significant debates concerning these markets' performance, volatility, and co-movement (Foglie and Panetta, 2020).

There are three critical schools of thought in the debate over Islamic stock indices. The first point of contention about Islamic stock indices is that they may be riskier than their conventional peers, as the Shariah screening process decreases the portfolio size of Islamic stock indices (Aarif et al., 2020; Sherif, 2020). The second argument is that Islamic stock indices may outperform their conventional counterparts because the Shariah screening process further screens out poor-performing stocks, which are still included in the conventional ones (Aarif et al., 2020; Sherif, 2020). The decoupling hypothesis of Islamic stock indices from traditional peers, resulting in hedging and safe-haven opportunities, is the latest 'seemingly contradictory' thesis (Foglie and Panetta, 2020). As yet, no school of thought has reached a consensus from the literature (e.g., Boudt et al., 2019; Aarif et al., 2020; Al-Yahyaee et al., 2020; Foglie and Panetta, 2020). Foglie and Panetta (2020) extensively review the growing body of literature on Islamic finance from 2009 to 2019 and report that 42 papers found the hedging, safe-haven, and resilience properties in Islamic stock markets, while 27 studies opposed it and suggested other arguments.

In the aftermath of the GFC, however, Islamic finance drew more attention from investors, academics, and policymakers because of its resilience feature, particularly in times of financial unsteadiness, compared to their traditional peers (Akhtar and Jahromi, 2017; Azad et al., 2018). Due to Shariah principles, the conservative nature of the Islamic stock market may provide greater resilience to the Islamic stock market (Akhtar and Jahromi, 2017). However, there are also opposing views in this regard. Rejeb (2017) reveals heavy interdependence between Islamic and traditional financial markets, suggesting that Islamic financial assets do not offer a strong cushion against financial shocks than their conventional opposite parts. Similar findings are revealed by Dewandaru et al. (2014), Shahzad et al. (2017), Umar and Suleman (2017), and Foglie and Panetta (2020).

Another vital Islamic financial asset—the Islamic bond (Sukuk)—has spotlighted investors and policymakers for its international financial system entrance. However, some earlier studies attempt to distinguish Sukuk from conventional bonds (e.g., Alam et al., 2013; Azmat et al., 2014). Their results indicate that Sukuk may differ from traditional bonds due to contractual arrangements. Recently, Pirgaip et al. (2020) studied the diversification behavior of bond portfolios (both traditional and Sukuk) in Turkey. In a similar vein, Ali et al. (2021) perform a wavelet analysis of portfolio diversification benefits of Islamic and responsible finance. Both studies confirm the presence of these benefits in times of economic downfalls. Paltrinieri et al. (2019) uncover a wide range of literature (80 papers) connected with Sukuk research spanning 1950–2018. Their literature review suggests that some studies find Sukuk a hedging or safe-haven tool against their conventional peers, even though the opposite is evidenced in some other studies. Therefore, the findings on the resilience properties of Sukuk are yet to be convincing.

Although the COVID-19 pandemic is still underway, an increasing body of research has explored its impact on financial markets (e.g., Ashraf, 2020; Sharif et al., 2020; Zhang et al., 2020; He et al., 2020; Hasan et al., 2021b; Hasan et al., 2021c) and found a significant adverse effect. These studies' generality implements wavelet analysis of time series data before and after the onset of the COVID-19 pandemic. Umar and Gubareva (2020) conclude that pre-COVID currency and cryptocurrency hedging strategies implemented during the post-pandemic era will be ineffective. Subsequent studies by Gubareva and Umar (2020), Umar et al. (2021e), and Umar and Gubareva (2021b) analyze the volatility connectedness of COVID-19's media coverage to various markets/financial indices. Gubareva and Umar (2020) find low coherence between media coverage of COVID-19 and emerging market assets, implying their diversification potential in the wake of the pandemic. Similarly, Umar et al. (2021e) also observe low coherence between yield curves of BRICS economies and media coverage of the coronavirus. Furthermore, low volatility connectedness between COVID-19 media coverage and ESG leaders equity indices is observed by Umar and Gubareva (2021b).

Some of the recent post-COVID non-wavelet analysis studies are a contrast. Umar and Gubareva (2021a) do not find precious metals to hold safe have properties in the wake of COVID-19 induced economic uncertainties. Umar et al. (2021d) find increased and time-varying volatility in the agricultural commodities, often corresponding with the different waves of COVID-19 and policy responses (i.e., lockdowns, flight bans, etc.).

However, only a few studies have looked into the impact of the COVID-19 on Islamic finance. For example, Ashraf et al., 2022 examine the hedging capabilities of Islamic equity indices (Global, the US, and European markets) during COVID-19. Their result confirms the existence of hedging benefits of the indices. Conversely, Hasan et al. (2021b) find no hedging benefit in Islamic stocks during COVID-19, as the Islamic and conventional stock markets are highly associated. Umar and Gubareva (2021a) conduct a wavelet

analysis of the volatility relationship between Islamic equity indices and media coverage of the COVID-19 pandemic. The authors find downside risk hedging and diversification benefits of Islamic equities in the wake of the pandemic.

Likewise, Yarovaya et al. (2020) look at the risk-adjusted performance of Islamic equity funds compared to their conventional counterparts in different Islamic countries during the pandemic. Their findings demonstrate that Islamic equity funds surpass their conventional counterparts during the peak periods of COVID-19. Conversely, Yarovaya et al. (2021) investigate the spillover between Islamic (stock & bond) and conventional markets during the COVID-19 period. Although Islamic bond (Sukuk) exhibits safe-haven nature, the spillover between Islamic and conventional indexes has intensified at the same time. They report that the Sukuk index is comparatively less affected by COVID-19 than other indices.

From our review of the extant literature, it is apparent that the comparison between Islamic and conventional finance is evaluated in many aspects. However, the findings are highly contradictory, and no consensus has yet been achieved. Besides, only a few studies contrast Islamic finance's resilience and hedging properties to traditional finance during the COVID-19 crisis, and the results on Islamic finance's resilience are not persuasive. Moreover, in the event of a pandemic, no research has yet been done to evaluate the resilience and hedging properties of GCC Sukuk compared to conventional bonds. Furthermore, the studies relating to the comparative assessment of the first and second waves of the ongoing COVID-19 pandemic for Islamic finance are still absent. Our study, however, endeavors to close these gaps in the literature by addressing the issues above.

3. Data and methodology

3.1. Data

This study examines the resilience of Islamic financial markets (both stock and bond), in contrast to their conventional counterparts, in the wake of COVID-19. Although the COVID-19 initially hit China in December 2019, it started spreading exponentially to other regions, mainly Europe, North America, Latin America, the Middle East, and South Asia, transforming into a pandemic from March 2020 onwards (Hasan et al., 2021b). Stock markets of these regions were severely affected by it, but interestingly, the resurgence patterns of these markets are diverse (Hasan et al., 2021b).

We have considered five regions—World, Europe, developed excluding the US, emerging, and the US for stock markets (both Islamic and conventional)—to explore each market individually and comprehend their response to COVID-19. The Dow Jones equity index series are used to represent each stock market. The Dow Jones Islamic and conventional equity indices will hereafter be termed DJI and DJ, respectively. Conversely, two regions are considered for bond markets: the world and Gulf Cooperation Council (GCC). For Islamic bonds (Sukuk), Dow Jones Global Sukuk Index and GCC Sukuk Index are selected. The S&P International Corporate Bond Index and Gulf Cooperation Council (GCC) bond Index are chosen for their corresponding conventional bond markets.

However, we gather the daily price data for all indices from two sources: the five pairs of stock indices are from www.investing.com, and the two pairs of bonds are from http://us.spindices.com. The data period for all seven time-series pairs starts from January 1, 2019, to February 26, 2021. We divide our entire sample period into two sub-periods: i.e., January 1, 2019 – December 31, 2019 (pre-COVID-19 period) and January 1, 2020 – February 26, 2021 (COVID-19 period). The COVID-19 period is split into two sub-periods: January 1, 2020 – September 30, 2020 (first wave of COVID-19) and October 1, 2020 – February 26, 2021 (second wave of COVID-19). The second wave starting date is suggested by Yarovaya et al. (2020). It is also perceived from the curve of the daily COVID-19 cases globally.[1] The indices' daily returns are estimated by taking the first difference in the logarithms.

The price variations of seven Islamic and conventional stock and bond indexes are plotted in Fig. 1. We see a significant decline in the prices of all selected indices throughout the first quarter of the COVID-19 periods, particularly in March and April of 2020.

3.2. Wavelet-based approach

Our study evaluates the resilience of Islamic financial markets (both stock and bond) in the aftermath of COVID-19 compared to their conventional counterparts. We take great care in selecting an appropriate and sophisticated approach. However, we choose wavelet-based techniques—continuous wavelet transforms (CWT), wavelet coherence (WC), and discrete wavelet transforms (DWT)—for a couple of reasons to study the interaction between variables.

First, the wavelet approach can generate findings in the form of time-frequency heat maps using wavelet techniques, which include information on both coherence and time differences of the analyzed pairs of variables (Umar et al., 2021c). Using the CWT, we can examine how each variable changes or fluctuates over time and frequency ranges. Furthermore, the WC technique allows us to analyze distinct patterns of Islamic and conventional financial assets' return movements and co-movements in a single dimension of time as well as across multiple investment time scales. The WC also captures the lead/lag relationships between the variables, allowing us to make the appropriate decision. To estimate the wavelet-based Granger causality analysis between variables, we employ the DWT approach to divide our datasets into multiple time scales—short, medium, and long-run. Furthermore, we are encouraged to use these methods because they have been employed in a number of recent studies (e.g., Al-Yahyaee et al., 2020; Gubareva and Umar, 2020; Bouri et al., 2020; Umar and Gubareva, 2021b; Umar and Gubareva, 2021a; Hasan et al., 2021b). However, the following are the detailed explanation of those techniques.

[1] See the COVID-19 cases graph at: https://www.worldometers.info/coronavirus/worldwide-graphs/

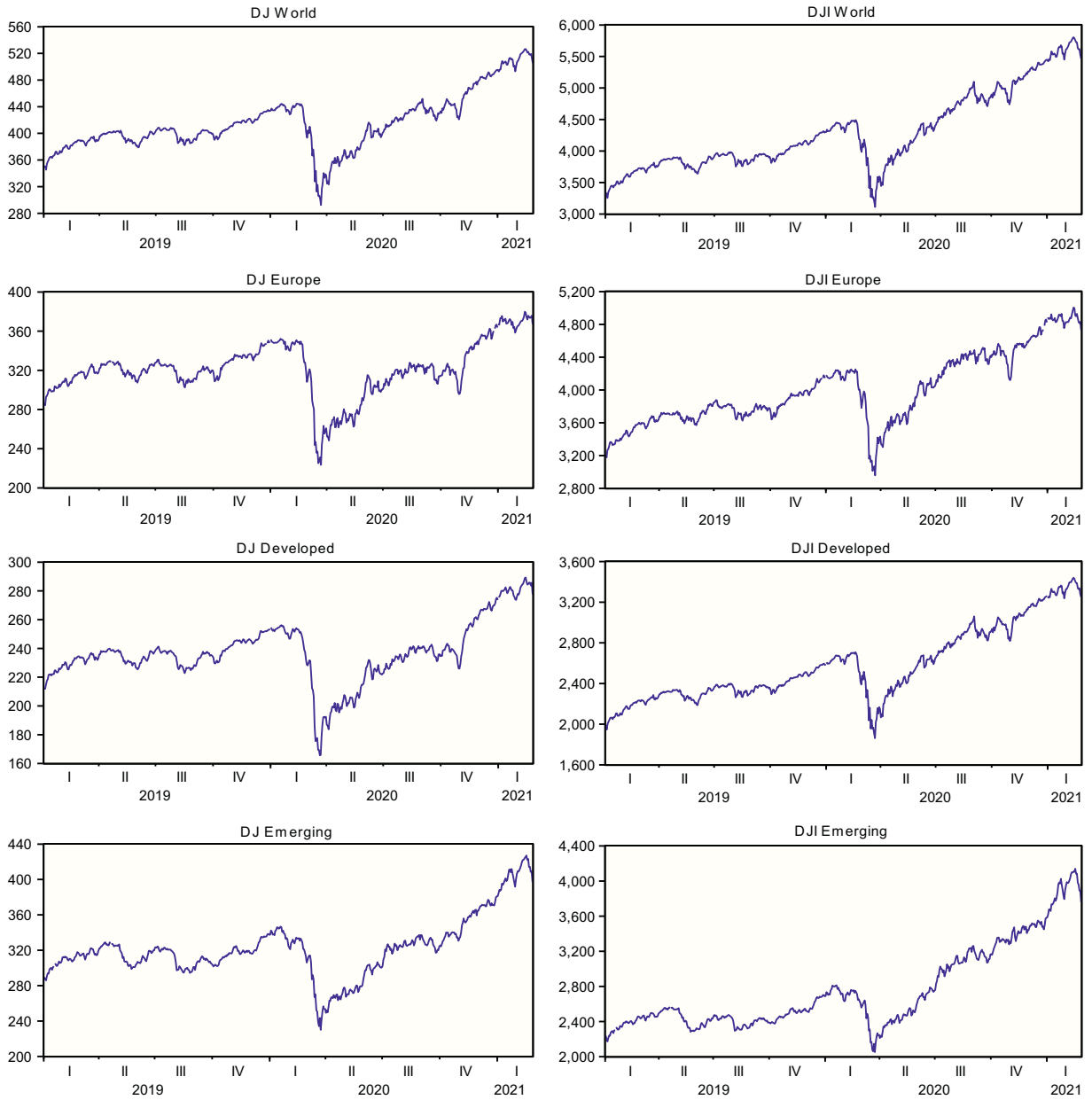

Fig. 1. Price movements of Islamic stocks and bonds and their conventional counterparts.

3.2.1. The continuous wavelet transforms (CWT)

Generally, the wavelet-transforms are of two types: DWT and CWT. The CWT has been extensively used in finance and economics research during the last decade (Aguiar-Conraria and Soares, 2014). The CWT $R_a(x,y)$ displays the estimation of a wavelet ψ (.) against the time sequence $a\ (t) \in K^2(\underline{R})$, (i.e)

$$\mathrm{Ra}\ (\mathrm{x}, \mathrm{y}) = \int_{-\infty}^{\infty} a(t) \frac{1}{\sqrt{y}} \psi \left(\frac{\overline{t-P}}{S} \right) dt \tag{1}$$

An advantage of the CWT is the ability to decompose as well as reconstruct a time series $a\ (t) \in K^2(\underline{R})$ into the first inverse continuous wavelet transform:

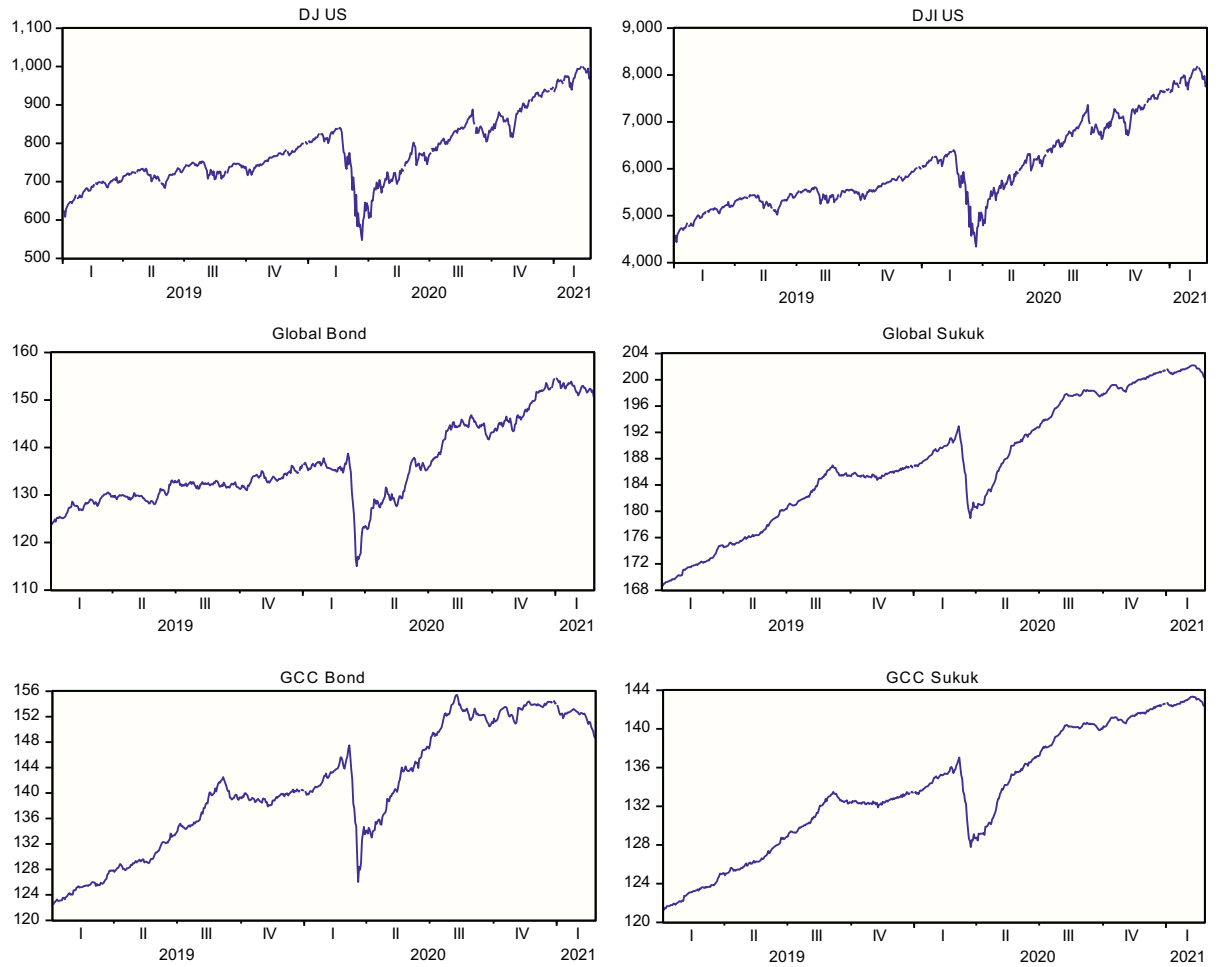

Fig. 1. (*continued*).

$$a(t) = \frac{1}{C_\psi}\int_0^\infty \left[\int_{-\infty}^\infty R_a(x,y)\psi_{x,y}(t)du\right]\frac{dq}{S^2}, S > 0 \tag{2}$$

Furthermore, the CWT conserves the power of the experimented time sequence, as expressed in the following equation:

$$\|a\|2 = \frac{1}{C_\psi}\int_0^\infty \left[\int_{-\infty}^\infty |R_a(x,y)|^2 dp\right]\frac{dq}{S^2} \tag{3}$$

We apply these characteristics to explain wavelet coherence (WC), which shows the connectedness between two-time series.

3.2.2. *The wavelet coherence (WC)*

The relationship between Islamic finance (Islamic stocks and bonds) and conventional finance (conventional stocks and bonds) can be investigated by applying WC, a widely used model for financial time-series analysis. To outline the wavelet coherence method, it is essential to explain the cross-wavelet power and cross wavelet transform. The cross-wavelet transform can be justified through a couple of time sequences, a (t) and b (t) (Torrence and Compo, 1998):

$$R_{ab}(x,y) = R_a(x,y)R_b^*(x,y), \tag{4}$$

where a (t) and b (t) are represented to two continuous transforms through $R_a(x,y)$ and $R_b(x,y)$, respectively, where x, y, and $(*)$ reveal the location of the index, measure, and composite conjugate, respectively. To calculate $|R_a(x,y)|$, the cross-wavelet transform is used. On the other hand, the cross-wavelet power spectra segregate the domain relevant to the timeframe of data (Sharif et al., 2020). The definite sections of the time-frequency and the co-movement patterns are discovered through the wavelet coherence analysis of the time series being analyzed. Torrence and Webster (1998) unveil the wavelet coherence adjusted equation as represented below:

$$N^2(x,y) = \frac{\left|S\left(S^{-1}R_{ab}(x,y)\right)\right|^2}{S\left(S^{-1}|R_a(x,y)|^2\right)S\left(S^{-1}|R_b(x,y)|^2\right)}, \tag{5}$$

where S indicates the smoothing mechanism. The series of squared wavelet coherence coefficients are identified by $0 \leq N^2(x,y) \leq 1$. A high correlation and an absence of correlation are identified from its magnitudes closest to unity and zero (or closest to zero), respectively. The hypothetical allocation of wavelet coherence is investigated using the Monte Carlo method.

3.2.3. Discrete wavelet transforms (DWT) and wavelet-based granger causality test

The test for the direction of Granger causality between the five stock and two bonds is implemented in the different frequency bands generated from the DWT. The DWT decomposes the variables into different frequency bands (i.e., short-, medium-, and long-runs) and can be expressed as follows:

$$p(t) = \sum_k R_{J,k}\phi_{J,k}(t) + \sum_k d_{J,k}\Psi_{J,k}(t)\sum_k d_{J-1,k}\Psi_{J-1,k}(t) + \cdots + \sum_k d_{1,k}\Psi_{1,k}(t), \tag{6}$$

where two fundamental functions of wavelets are donated by ϕ and ψ, indicating the low (smooth) and high (detailed) frequency components of the series, respectively. The wavelet functions' contribution to the overall signal is measured by the coefficients ($R_{J,\,k}$, $d_{J,\,k}$, …,$d_{1,\,k}$) of the wavelet transform.

Therefore, a time series $p(t)$ can be represented in terms of those signals using J-level multi-resolution decomposition analysis:

$$p(t) = R_j(t) + D_j(t) + D_{j-1}(t) + \cdots + D_1(t) \tag{7}$$

where D_j exhibits the frequency domains which relate to short, medium, and long-run scales derived from 2^j time domains. After eliminating D_1, …,D_j from the time series, R_j is generated as a residual. However, our datasets are daily, and we choose $J = 6$ to decompose the multi-resolution level J.

The econometric specification for wavelet-based Granger causality between two stationary time-series (such as Islamic and conventional stock and bond indices) can be expressed as follows:

$$m_t = a_1 + \sum\nolimits_{i=1}^{k}\alpha_i m_{t-i} + \sum\nolimits_{i=1}^{k}\beta_i n_{t-i} + \in_{it}, \tag{8}$$

$$n_t = a_2 + \sum\nolimits_{i=1}^{k}\gamma_i m_{t-i} + \sum\nolimits_{i=1}^{k}\delta_i n_{t-i} + \in_{2t}, \tag{9}$$

where the lag lengths of the m_t and n_t variables are denoted by the k. Therefore, we check two null hypotheses, such as

$$\begin{cases} n \text{ does not cause } m : H_0^1 = \beta_1 = \cdots = \beta_k = 0; \\ m \text{ does not cause } n : H_0^2 = \gamma_1 = \cdots = \gamma_k = 0; \end{cases}$$

In the first scenario, the causality runs from n_t to m_t at the time of the rejection of null hypotheses. Accordingly, the causality runs from m_t to n_t in the second case, when the null hypotheses are rejected. Lastly, bivariate causality is a rejection of both hypotheses. The statistical tests have a standard F-distribution with (k, $T - 2k - 1$) degrees of freedom for the hypotheses, and T indicates the total observations.

3.3. Hedge ratio, optimal portfolio weights, and hedging effectiveness

We further estimate the hedge ratio (HR), optimal portfolio weights, and hedging effectiveness (HE) to provide better hedging strategy and portfolio implications to the investors and portfolio managers (Umar, 2017; Antonakakis et al., 2019; Yousaf and Yarovaya, 2021). However, we estimate the HR, proposed by Kroner and Sultan (1993), based on the conditional variance and covariances of the DCC-GARCH t-Copula. The HR calculates the hedging cost of USD 1 long position in asset i with a β_{ijt} USD short position in asset j, in this case, Islamic and conventional finance. The specification is expressed as follows:

$$\beta_{ijt} = \frac{h_{ijt}}{h_{jjt}}. \tag{10}$$

This means that larger conditional variances lead to reduced long position hedging costs, while higher conditional covariances lead to higher long position hedging costs.

We also use the DCC-GARCH t-Copula technique to estimate the optimal portfolio weights (developed by Kroner and Ng (1998)), W_{ijt}. The optimal portfolio weights between Islamic/conventional or conventional/Islamic pairs can be estimated through the following specification:

$$W_{ijt} = \frac{h_{jjt} - h_{ijt}}{h_{iit} - 2h_{ijt} + h_{jjt}}, \tag{11}$$

where W_{ijt} could be more than one or less than zero. We set the following constraints to account for this shortcoming:

Table 1
Descriptive statistics.

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Sharpe Ratio	Jarque-Bera
Panel A: Entire sample (January 1, 2019 - February 26, 2021)						
DJ World	0.0648	1.2520	−1.7269	22.0565	0.0518	8798.7*
DJ Europe	0.0448	1.3840	−1.9715	25.9120	0.0323	12,521.7*
DJ Developed	0.0481	1.0790	−1.7236	26.7272	0.0446	13,413.4*
DJ Emerging	0.0564	1.1141	−1.5674	13.1408	0.0506	2628.8*
DJ US	0.0809	1.6195	−1.2197	18.9575	0.0500	5895.9*
Global Bond	0.0352	0.5209	−1.7776	21.8061	0.0676	8516.6*
GCC Bond	0.0347	0.3983	−2.2339	31.2303	0.0871	18,993.0*
DJI World	0.0873	1.2743	−1.3271	18.9747	0.0685	6151.6*
DJI Europe	0.0698	1.2228	−1.6755	21.5007	0.0571	8189.4*
DJI Developed	0.0875	1.3367	−1.2159	18.4497	0.0655	5707.4*
DJI Emerging	0.0927	1.1444	−1.0906	9.0995	0.0810	979.1*
DJI US	0.0971	1.6293	−1.0066	17.3111	0.0596	4725.4*
Global Sukuk	0.0308	0.1564	−2.5152	23.3300	0.1972	10,197.7*
GCC Sukuk	0.0288	0.1541	−1.9304	17.3769	0.1867	5152.2*
Panel B: Pre-COVID-19 (January 1, 2019 - December 31, 2019)						
DJ World	0.0818	0.6085	−0.4614	5.2583	0.1344	64.4*
DJ Europe	0.0766	0.7320	−0.1923	4.5467	0.1046	27.4*
DJ Developed	0.0688	0.5374	−0.1784	3.6644	0.1280	6.2*
DJ Emerging	0.0593	0.6726	−0.4725	4.4695	0.0882	32.8*
DJ US	0.1000	0.7952	−0.6203	6.0806	0.1258	115.3*
Global Bond	0.0380	0.3034	0.4298	3.9851	0.1252	18.4*
GCC Bond	0.0528	0.2114	0.0291	4.3180	0.2498	18.7*
DJI World	0.0970	0.6813	−0.5557	5.2708	0.1424	69.2*
DJI Europe	0.1001	0.7243	−0.2999	4.0366	0.1382	15.4*
DJI Developed	0.1014	0.7024	−0.5700	5.3506	0.1444	73.6*
DJI Emerging	0.0711	0.7258	−0.5393	4.1974	0.0980	27.9*
DJI US	0.1093	0.8661	−0.6146	5.9538	0.1262	107.0*
Global Sukuk	0.0393	0.1025	0.1858	4.2884	0.3834	19.4*
GCC Sukuk	0.0371	0.1085	0.1291	4.2956	0.3419	18.7*
Panel C: First wave of COVID-19 (January 1, 2020 - September 30, 2020)						
DJ World	−0.0037	1.9122	−1.2688	11.3859	−0.0019	626.8*
DJ Europe	−0.0547	2.0360	−1.6214	15.3253	−0.0269	1312.9*
DJ Developed	−0.0393	1.6144	−1.3082	14.8936	−0.0243	1204.9*
DJ Emerging	−0.0208	1.5911	−1.3472	8.4638	−0.0131	301.5*
DJ US	0.0228	2.4840	−0.8624	9.6799	0.0092	374.8*
Global Bond	0.0248	0.7576	−1.6570	13.6794	0.0327	1015.8*
GCC Bond	0.0375	0.6068	−1.8438	16.6015	0.0618	1613.6*
DJI World	0.0633	1.9107	−1.0523	10.5899	0.0331	506.6*
DJI Europe	0.0292	1.7566	−1.4977	14.0334	0.0166	1056.5*
DJI Developed	0.0614	2.0111	−0.9437	10.1514	0.0305	444.4*
DJI Emerging	0.0834	1.5466	−1.0852	7.0681	0.0539	172.7*
DJI US	0.0736	2.4552	−0.7618	9.4730	0.0300	348.2*
Global Sukuk	0.0292	0.2291	−2.3054	14.2467	0.1275	1200.4*
GCC Sukuk	0.0247	0.2221	−1.8409	11.1203	0.1112	645.8*
Panel D: Second wave of COVID-19 (October 1, 2020 – February 26, 2021)						
DJ World	0.1489	0.8144	−0.4721	4.3624	0.1828	12.2*
DJ Europe	0.1490	1.0807	−0.4352	4.9332	0.1379	19.6*
DJ Developed	0.1584	0.8032	−0.5795	5.1316	0.1972	26.0*
DJ Emerging	0.1899	0.8865	−0.6025	4.0704	0.2142	11.5*
DJ US	0.1418	1.0063	−0.7266	4.3361	0.1409	16.5*
Global Bond	0.0483	0.3924	−0.1374	3.4835	0.1231	1.3
GCC Bond	−0.0152	0.2214	0.5642	5.2618	−0.0687	27.9*
DJI World	0.1079	0.8707	−0.3760	4.3569	0.1239	10.7*
DJI Europe	0.0688	0.9727	−0.4820	4.6762	0.0707	16.3*
DJI Developed	0.1018	0.9085	−0.4221	4.6316	0.1121	14.9*
DJI Emerging	0.1615	1.1160	−0.6059	3.6333	0.1447	8.3**
DJI US	0.1122	1.0801	−0.6041	4.4194	0.1039	14.7*
Global Sukuk	0.0127	0.0804	−0.3748	3.7552	0.1580	4.9**
GCC Sukuk	0.0159	0.0760	−0.2179	3.3461	0.2092	1.3

Notes: This table reports the descriptive statistics of the return series of all selected assets and risk-adjusted returns (Sharpe ratio). The sample period begins from January 1, 2019, to February 26, 2021. Sharpe ratio is estimated as dividing the mean returns of an asset by its standard deviation following Shahzad et al. (2020) and Bouri et al. (2020). *, **, *** indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

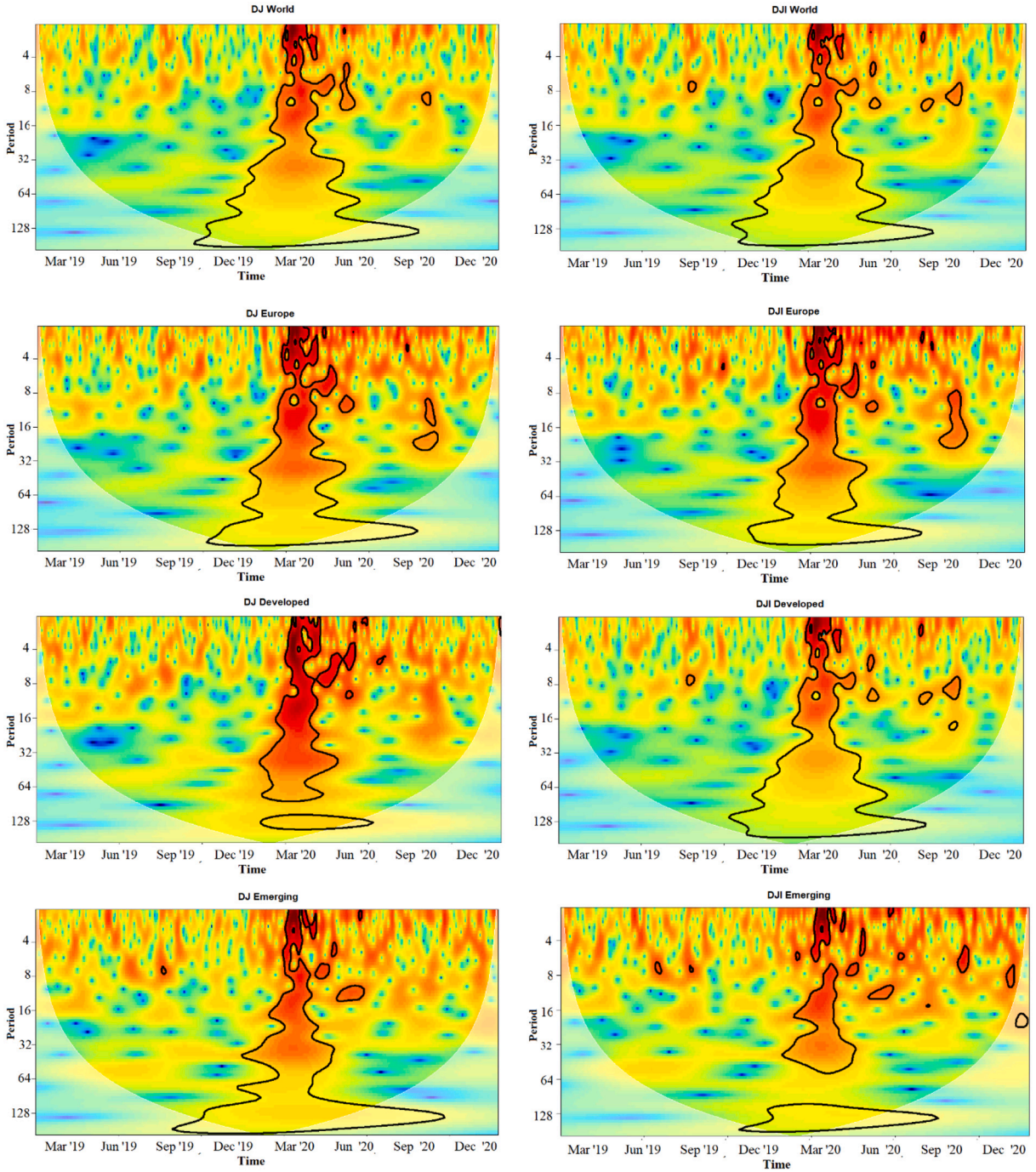

Fig. 2. Continuous wavelet transform plots.
Notes: This figure reports the CWT plots for seven Islamic assets and their conventional counterparts. The vertical axis depicts the period in days, while the horizontal axis exhibits the time frames. The 5% significant level is represented by the thick black contour against the red color.

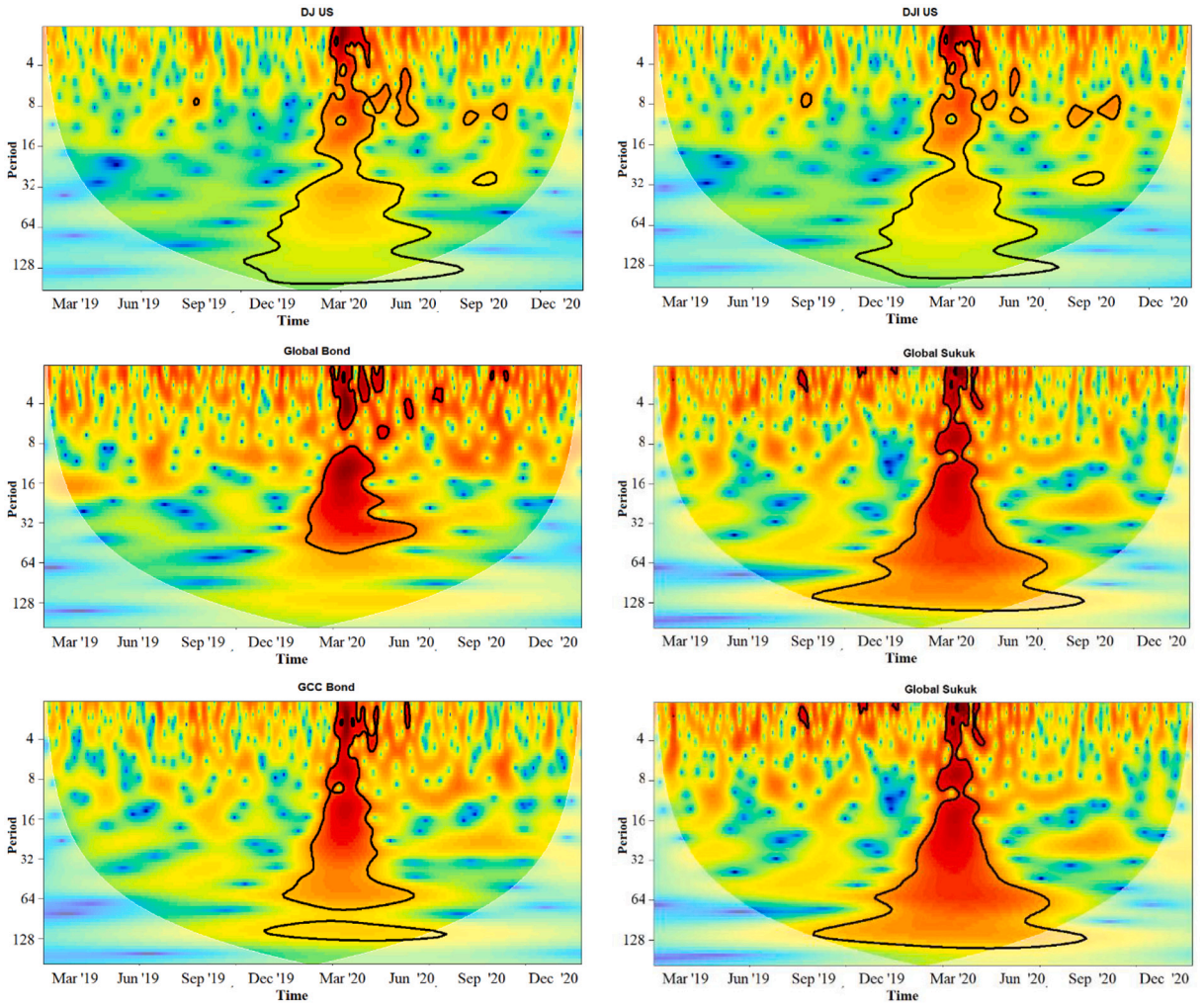

Fig. 2. (*continued*).

$$W_{ijt} = \begin{cases} 0, \text{if } W_{ijt} < 0 \\ W_{ijt}, \text{if } 0 \leq W_{ijt} \leq 1 \\ 1 \text{ if } W_{ijt} > 1 \end{cases}$$

Finally, Ederington's (1979) HE technique is used to assess hedging effectiveness and different portfolio strategies between Islamic and conventional finance. This can be expressed as follows:

$$HE_i = 1 - \frac{V(r_{\beta,w})}{V(r_{unhedged})} \tag{12}$$

where the $r_{\beta,\, w}$ can be computed as

$$\begin{cases} r_\beta = y_{it} - \beta_{ijt} y_{jt} \\ r_w = w_{ijt} y_{it} + (1 - w_{ijt}) y_{jt} \end{cases}$$

HE_i indicates the percent reduction in the unhedged position's variance. The variance of the unhedged position of asset i is denoted by $V(r_{unhedged})$. $V(r_{\beta,\, w})$ denotes the hedged portfolio variance either from the optimal HR or weight strategy. The greater risk reduction in the portfolio is associated with higher HE_i.

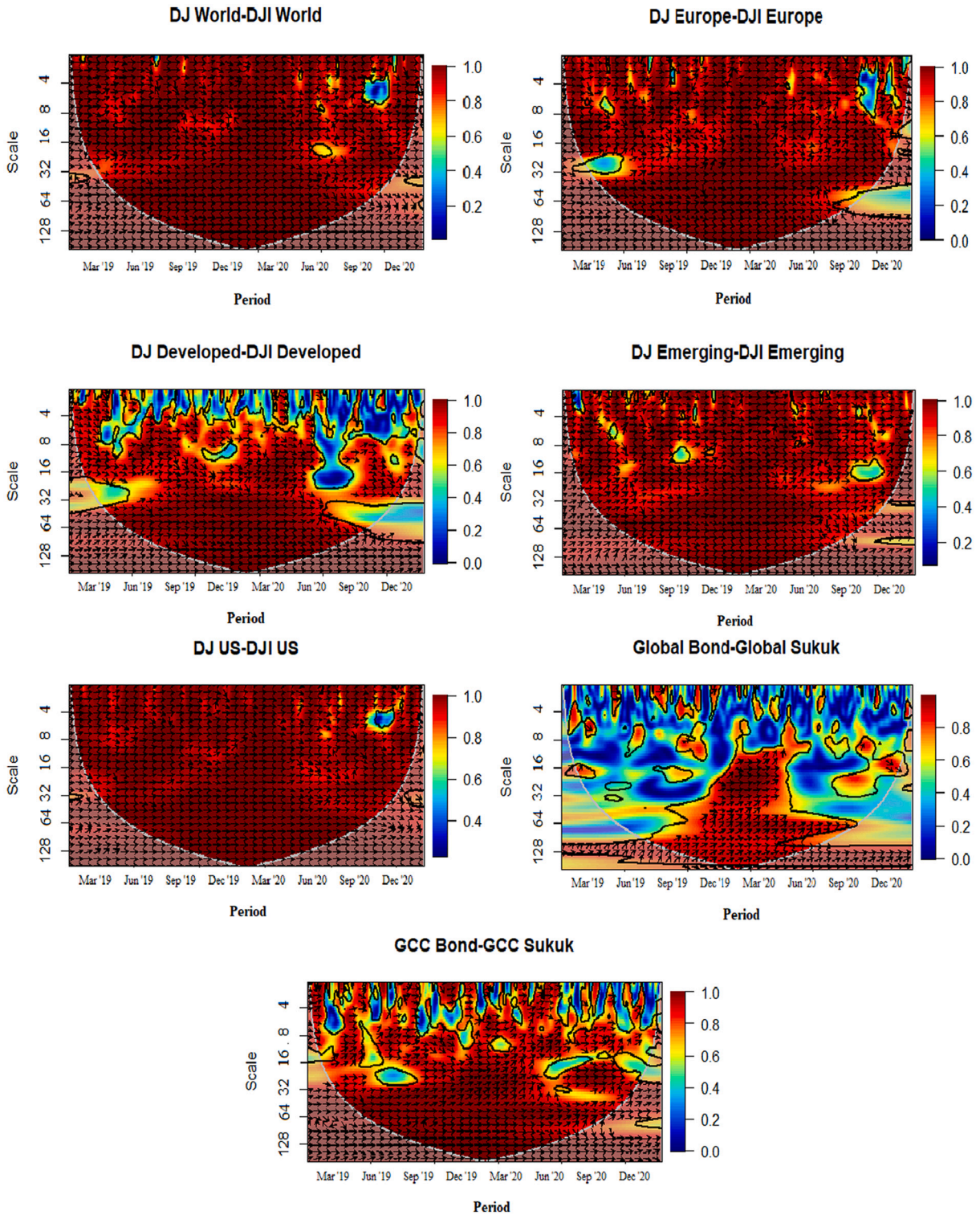

Fig. 3. Wavelet coherence plots.

Notes: This figure depicts the WC pairwise plots during our sample period. The range of power is represented through blue (low) to red (high) color, displayed in the right of all plots. The arrows discern the phase differences between the pairs of variables. The arrows on the right side (left side) mean an in-phase (anti-phase) relationship between the two series. The cyclical effect (anti-cyclical) is indicated through the in-phase (out-phase) relationship with each other. The arrows are right side down (up) and left side up (down) refer to the first (second) variable is leading.

4. Empirical results

4.1. Summary statistics

Table 1 presents descriptive statistics with risk-adjusted returns (Sharpe ratio) for four sample periods: entire sample, pre-COVID-19, first wave, and second wave of COVID-19. For the entire period, all assets have positive mean returns. Interestingly, all the Islamic stock indices outperform their conventional peers based on both mean and risk-adjusted returns. Even though Islamic bonds (Sukuk) underperform conventional bonds in terms of mean returns, the risk-adjusted returns show that Sukuks outperform traditional bonds by a large margin. These observations hold for the pre-COVID-19 and the COVID-19 first wave periods. Most conventional stock indices have negative mean returns during the first wave of COVID-19, while all Islamic indices have positive mean returns.

Conversely, all the conventional stock indices outperformed their Islamic stock indices counterparts during the second wave of the COVID-19 crisis, based on both the mean and risk-adjusted returns. Conventional stock markets were more affected by the first wave of COVID-19 than Islamic stock markets. As a result, when the markets started recovering, the conventional stock markets gained more than the Islamic stock markets, resulting in the outperformance of the traditional markets over the Islamic market in the second wave. On the other hand, the risk-adjusted returns of Sukuks exceed their conventional counterparts during the second wave, albeit the mean returns show mixed results. Overall, the Islamic financial markets outperform their traditional peers, with Sukuks performing the best.

The negative skewness and high kurtosis values are observed for all assets, indicating the return series are symmetric with heavy fat tails. The Jarque-Bera test statistic is rejected at the 5% significance level for most assets except global bond and Sukuk in the second wave, highlighting that the return series are non-normally distributed.

4.2. Continuous wavelet transforms analysis

The plots of continuous wavelet transform (CWT) for each variable are depicted in Fig. 2. The CWT measures the movement or variation of the Islamic and conventional markets in the time scales and frequency domains. There is no significant variation in the whole frequency bands except DJI World, DJI Developed, DJI Emerging, and DJI US indices during the pre-COVID-19 period for both Islamic and conventional equity indices. In contrast, between March and April 2020 (i.e., the first wave of COVID-19), all markets (Islamic and conventional) notice a strong and significant variation in the short and medium-run frequency bands, whereas the low volatility is observed in the long and very long-run frequency domains at the same periods. Afterward, the low volatility is detected in the medium-run (8–16-day frequency bands) for all the stock market indices except DJ Developed index. In contrast, the early second wave of COVID-19 has a minor influence on DJ Europe, DJI Europe, and DJI Emerging indices in the medium ranges.

The results for bond markets are somewhat different from stock markets. The CWT plots reveal that the conventional bonds (both global and GCC) are highly volatile during the 1–32-day frequency bands (short- and medium-run) in March and April 2020. The volatility, however, is absent in the long-run frequency domains. During the same period (March–April 2020), the Islamic bonds show considerable volatility in the short, medium, and long-run time frequencies. It is observed that the conventional bond markets are less volatile than the Islamic bonds in the long-run frequency bands. We also notice that the second wave of COVID-19 does not impact the bond markets.

Overall, the highest volatility was observed in the early stages of the first wave of COVID-19 for all markets. However, from May 2020 onwards, the volatility smoothed out, as the markets rebounded after being heavily impacted by the pandemic outbreak in the prior months. Looking at the CWT plots for each index, we also find a notable difference in volatility between the first and second waves of COVID-19 for both markets.

4.3. Wavelet coherence analysis

Fig. 3 depicts the wavelet coherence plots for each pair of assets. The wavelet coherence analyzes the relationship or co-movement between the two-time series variables. This model also captures an asset's hedging or safe-haven characteristics (Bouri et al., 2020; Goodell and Goutte, 2020). However, the DJ World-DJI World indices plot indicates that all the arrows are in-phase relationship with cyclic effect, meaning the strong positive co-movement between these two variables during the whole time and frequency bands. We also notice that some arrows are right side up during short-run scales (0–8 days) from June–July 2020, where the DJI World index is leading.

Nevertheless, during 8–32 scales (medium-run) in July 2020, the cyclic effect is also observed with right-side down arrows, where the DJ World index leads over the DJI World index. However, no significant lead/lag relations are found. Strong interactions between the indices are exhibited in the long-run periods during the first and second waves of COVID-19.

Like the DJ World-DJI World indices, the plot of DJ Europe-DJI Europe indices also shows the strong cyclic effect in the whole frequency bands during the entire sample period. Besides, the lead/lag relations of DJ Europe and DJI Europe are mixed (both indices lead/lag to each other) during pre-COVID-19 with strong coherency. Moreover, on the scales of 0–8 over May–June 2020 (first wave), some of the arrows are directed to the upward right side, highlighting the in-phase relationship with the leading effect by DJI Europe. In the same frequency domains during October–December 2020 (early second wave), a few arrows are also right side up, suggesting that the DJI Europe is leading. We also find the directions of arrows are in-phase relationship with the right side upward (DJI Europe is leading) in the medium-run (8–32 days) over August–September 2020 (first wave). All the arrows move horizontally in the long-run scales, suggesting that no lead/lag relations are observed during the entire period.

Moreover, the coherence for DJ Developed-DJI Developed exhibits that most of the arrows are in-phase with moving right side

Table 2
Wavelet-based Granger causality analysis.

Time scales	H_0: Conventional finance does not Granger cause Islamic finance		H_0: Islamic finance does not Granger cause conventional finance	
Panel A: Pre-COVID-10				
DJ World & DJI World	*F*-statistic	*P*-value	*F*-statistic	P-value
D1	3.889**	0.049	3.781**	0.052
D2	0.634	0.426	0.445	0.505
D3	0.261	0.609	0.416	0.519
D4	1.307	0.253	1.505	0.221
D5	1.309	0.253	1.406	0.236
D6	8.011*	0.005	0.880	0.348
DJ Europe & DJI Europe				
D1	0.105	0.745	0.112	0.738
D2	2.495	0.115	3.114***	0.078
D3	0.928	0.336	0.705	0.401
D4	4.233*	0.000	3.226***	0.092
D5	14.533*	0.000	15.825*	0.000
D6	21.539*	0.000	71.759*	0.000
DJ Developed & DJI Developed				
D1	4.266	0.235	0.065	0.797
D2	8.817*	0.000	11.450*	0.000
D3	32.026*	0.000	23.324*	0.000
D4	2.884***	0.091	2.538	0.112
D5	7.947*	0.010	12.573*	0.001
D6	0.603	0.438	8.461*	0.003
DJ Emerging & DJI Emerging				
D1	0.225	0.635	1.082	0.299
D2	2.525	0.113	1.552	0.214
D3	0.724	0.395	0.439	0.508
D4	34.451*	0.000	39.487*	0.000
D5	37.904*	0.000	31.708*	0.000
D6	15.673*	0.000	6.259**	0.013
DJ US & DJI US				
D1	1.288	0.226	1.130	0.337
D2	1.785***	0.052	1.548	0.108
D3	3.527*	0.000	3.206*	0.000
D4	3.431*	0.000	3.422*	0.000
D5	2.236**	0.011	2.285*	0.009
D6	4.337*	0.000	3.236*	0.000
Global Bond & Global Sukuk				
D1	0.284	0.888	0.915	0.455
D2	0.554	0.696	1.073	0.370
D3	3.006**	0.019	0.867	0.485
D4	1.752	0.139	3.047**	0.017
D5	9.063*	0.000	4.025*	0.003
D6	7.615*	0.000	1.974***	0.099
GCC Bond & GCC Sukuk				
D1	0.005	0.942	0.977	0.323
D2	8.542*	0.003	7.639*	0.006
D3	1.971	0.162	1.780	0.183
D4	9.943*	0.002	8.497*	0.004
D5	43.964*	0.000	46.023*	0.000
D6	53.275*	0.000	104.104*	0.000
Panel B: First wave of COVID-19				
DJ World & DJI World				
D1	10.278*	0.000	5.649*	0.004
D2	4.082**	0.018	4.283**	0.015
D3	0.784	0.458	0.497	0.609
D4	3.594**	0.029	4.165**	0.017
D5	7.733*	0.001	8.297*	0.000
D6	7.699*	0.001	7.566*	0.001
DJ Europe & DJI Europe				
D1	2.538	0.113	2.276	0.133
D2	3.269***	0.072	4.646**	0.032
D3	7.570*	0.007	6.594**	0.011
D4	2.990***	0.085	3.039***	0.083
D5	8.748*	0.004	9.010*	0.003
D6	17.919*	0.000	1.670	0.198
DJ Developed & DJI Developed				

(*continued on next page*)

Table 2 (*continued*)

Time scales	H_0: Conventional finance does not Granger cause Islamic finance		H_0: Islamic finance does not Granger cause conventional finance	
D1	0.262	0.853	3.068**	0.029
D2	23.013*	0.000	11.377*	0.000
D3	8.041*	0.000	12.298*	0.000
D4	14.305*	0.000	5.787*	0.001
D5	6.997	0.000	17.379*	0.000
D6	9.097*	0.000	1.394	0.246
DJ Emerging & DJI Emerging				
D1	2.190***	0.072	1.365	0.247
D2	1.425	0.227	1.100	0.358
D3	6.703*	0.000	4.758*	0.001
D4	8.547*	0.000	6.644*	0.000
D5	1.797	0.131	0.945	0.438
D6	7.539*	0.000	5.796*	0.000
DJ US & DJI US				
D1	6.761*	0.001	3.554**	0.030
D2	2.546***	0.081	3.373**	0.036
D3	0.874	0.418	1.056	0.349
D4	2.914***	0.056	3.627**	0.028
D5	3.886**	0.022	3.917**	0.021
D6	4.058**	0.018	3.850**	0.023
Global Bond & Global Sukuk				
D1	1.355	0.290	2.754	0.101
D2	1.152	0.318	2.307	0.102
D3	2.133	0.119	0.804	0.449
D4	7.787*	0.000	1.623	0.200
D5	13.063*	0.000	9.096*	0.000
D6	5.890*	0.003	2.075	0.128
GCC Bond & GCC Sukuk				
D1	2.405	0.135	1.037	0.285
D2	1.460	0.234	1.790	0.169
D3	16.254*	0.000	15.438*	0.000
D4	19.080*	0.000	22.511*	0.000
D5	25.229*	0.000	14.162*	0.000
D6	12.194*	0.000	36.853*	0.000
Panel C: Second wave of COVID-19				
DJ World & DJI World				
D1	0.238	0.915	1.888	0.118
D2	2.098***	0.087	0.974	0.425
D3	2.264***	0.068	1.451	0.223
D4	0.273	0.894	2.954**	0.023
D5	0.705	0.589	0.597	0.665
D6	8.496*	0.000	8.636*	0.000
DJ Europe & DJI Europe				
D1	3.569**	0.031	0.106	0.898
D2	1.142	0.323	0.332	0.717
D3	11.64*	0.000	7.278*	0.001
D4	0.549	0.578	0.373	0.689
D5	8.943*	0.000	8.127*	0.000
D6	5.770*	0.004	6.183*	0.003
DJ Developed & DJI Developed				
D1	0.881	0.453	0.840	0.475
D2	6.492*	0.000	1.942	0.127
D3	0.776	0.510	5.927*	0.000
D4	1.995***	0.093	1.546	0.207
D5	4.465*	0.005	0.365	0.778
D6	7.049*	0.000	2.733**	0.047
DJ Emerging & DJI Emerging				
D1	3.269**	0.024	1.863	0.140
D2	2.922**	0.041	1.931	0.129
D3	2.750**	0.046	2.986**	0.034
D4	2.230***	0.089	0.703	0.552
D5	1.255	0.292	1.593	0.195
D6	5.251*	0.002	6.466*	0.000
DJ US & DJI US				
D1	1.848	0.143	2.784**	0.045
D2	2.731**	0.048	1.696	0.173
D3	1.779	0.156	0.806	0.493

(*continued on next page*)

Table 2 (*continued*)

Time scales	H_0: Conventional finance does not Granger cause Islamic finance		H_0: Islamic finance does not Granger cause conventional finance	
D4	2.429*	0.002	2.719***	0.058
D5	3.898*	0.000	0.896	0.446
D6	2.585***	0.057	2.819**	0.043
Global Bond & Global Sukuk				
D1	0.100	0.959	1.375	0.127
D2	3.170**	0.027	1.892	0.136
D3	2.372***	0.075	1.558	0.204
D4	9.146*	0.000	7.363*	0.000
D5	4.850*	0.003	4.749*	0.003
D6	4.853*	0.003	6.746*	0.000
GCC Bond & GCC Sukuk				
D1	1.470	0.227	0.503	0.680
D2	5.080*	0.002	1.768	0.158
D3	2.919**	0.038	0.867	0.460
D4	0.866	0.461	3.531**	0.017
D5	5.168*	0.002	5.266*	0.002
D6	7.770*	0.000	10.126*	0.000

Notes: This table reports the wavelet-based Granger causality test between Islamic and conventional finance in different frequency domains (D1 to D6). D1-D2, D3-D4, and D5-D6 represent short, medium, and long-run investment horizons, respectively. *, **, *** indicate rejection of respective H_0 at the 1%, 5%, and 10% levels, respectively.

down in the short- and medium-term during pre-COVID-19, suggesting the DJ Developed index is leading, while a few arrows are pointing to the right side up (DJI Developed leads DJ Developed) during the same time frequencies. During the first wave of COVID-19, we find some of the arrows, on 16–32 days frequency over March–June 2020, are directed to the right side up, indicating the in-phase relationship again with the leading effect of the DJI Developed index. On the frequency band 32, a few arrows during May–July 2020 move right side down, highlighting the cyclical effect explaining the lead role from the DJ Developed index. We also notice that some of the arrows show the right side up during 8–16 frequencies between the first and second waves (September–October 2020), reflecting an in-phase relationship with the leading effect by DJI Developed index. Conversely, during the second wave of COVID-19 on the 16–32 frequency domains, some arrows are right sight down with cyclic effect (in-phase relationship), where the DJ Developed index is leading. However, the strong coherency between this pair of variables and no lead/lag relations are observed in the very long-run frequency domains for the whole period.

The plot of DJ Emerging-DJI Emerging shows the strong cyclic effect during the whole time and frequencies, indicating the in-phase relationship with strong co-movement. Besides, during March–June 2019 (pre-COVID-19) and May–July 2020 (first wave) on the 16–32 scales, we witness that many arrows are right side up, suggesting in-phase and the cyclic effect with the leading effect by DJI Emerging. Similarly, during the October–December 2020 (second wave) on the 8–16 days, DJI Emerging leads (some arrows are pointed to the right sight up) with an in-phase relationship. However, in the long-run scales during the entire time frequencies, all the arrows move horizontally, highlighting that no significant lead/lag relations are observed with a strong cyclic effect between these two variables.

The connectedness of DJ US-DJI US is strong with cyclic effect (in-phase relationship) during the entire period and frequency bands. Besides, the lead/lag relations are mixed between these two variables. For instance, some of the arrows are right side up (in-phase) as well as left side down (anti-phase or out-phase) over October 2020 (early second wave) on the 0–4 frequency bands, where DJI US leads DJ US. The DJ US is also leading (arrows are right side down) during 4–16 days over May–June 2020 (second wave). The lead/lag relations in the long-term frequencies over the whole sample period are not found.

We notice no coherency in the short-run scales over the whole-time frequencies for the Global Bond-Global Sukuk couple. While at the inception of the pandemic, no significant lead/lag relation and cyclic/anti-cyclic effect are observed in the short-run frequency bands. However, surprisingly, all the arrows point to the right side up during the 8–32-day (short- and medium-run) frequency band between January and May 2020. This highlights their in-phase relationship, where the Global Sukuk consistently leads the Global Bond. As noted, this period constitutes an extreme meltdown, and all the financial markets are negatively affected by the COVID-19 pandemic.

Furthermore, most arrows in the long-run scales are also directed to the right side up, signifying that Global Sukuk leads Global Bond (32–128 frequency domains) noticeably during the October 2019–June 2020 period. This leading behavior of Global Sukuk is consistent in the medium- and long-run frequency domains during the COVID-19 period, especially in the first wave. This implies that Global Sukuk is predominantly leading over Global Bond. On the other hand, only a few arrows are directed to the right side down, resulting in the Global Bond leading with cyclic effect during January and February 2021 in 16 scales.

Regarding the GCC Bond-GCC Sukuk's pair during pre-COVID-19, a few arrows are right side up (over the March–September 2019 period) and down (between October and November 2019), meaning that both the variables have exchanged their lead/lag relations in 0–16-day frequency bands. We also notice that the directions of most of the arrows are right side up in the periods of short and medium-run (0–32 days) during the first and second waves of the COVID periods, suggesting the in-phase relationship with cyclic effect, where GCC Sukuk leads GCC Bond. However, no arrows are found in the lead/lag situations; instead, these two variables have a strong coherency in the long-run frequency domains during our entire sample period.

4.4. Wavelet-based granger causality analysis

Finally, we perform the wavelet-based Granger causality tests for the robustness of our results, reported in Table 2. We apply six frequency domains (D1 to D6), which cover the short- (D1-D2), medium- (D3-D4), and long-term (D5-D6) investment horizons for testing the causality between Islamic and conventional finance (both stocks and bonds). The causalities between the Islamic and conventional stock indices are diverse during pre-COVID-19, first, and second waves of the COVID-19 pandemic. For instance, Europe, developed, emerging, and US stock (both Islamic and conventional) indices Granger cause each other, especially in the medium- and long-runs (D3-D6) scales during pre-COVID-19. Conversely, the bidirectional causalities between the DJ world and DJI world stock indices are less prevalent in the medium- and long-run frequency bands.

During the first wave of the COVID-19 pandemic, both Islamic and conventional stock indices Granger causes each other in most of the time scales. However, in the second wave of the COVID-19 pandemic, we find a mixed direction of causation between the Islamic and conventional stock indices. The causalities run from the conventional stock indices to the Islamic stock indices in most frequency

Table 3
Hedge ratio, optimal weights, and hedging effectiveness.

Variables	Hedge ratio			Optimal weights		
	β	HE	P-value	w	HE	P-value
Panel A: Pre-COVID-19						
DJ World/DJI World	0.88	0.95*	0.00	0.95	−0.01	0.92
DJI World/DJ World	1.08	0.96*	0.00	0.05	0.19***	0.09
DJ Europe/DJI Europe	0.99	0.90*	0.00	0.34	0.02	0.86
DJI Europe/DJ Europe	0.92	0.90*	0.00	0.66	0.00	0.99
DJ Developed/DJI Developed	0.61	0.52*	0.00	0.72	−0.04	0.75
DJI Developed/DJ Developed	0.88	0.51*	0.00	0.28	0.39*	0.00
DJ.Emerging/DJI Emerging	0.86	0.85*	0.00	0.71	−0.03	0.84
DJI Emerging/DJ Emerging	1.02	0.86*	0.00	0.29	0.12	0.30
DJ US/DJI US	0.91	0.98*	0.00	0.99	0.00	0.99
DJI US/DJ US	1.07	0.97*	0.00	0.01	0.16	0.17
Global Bond/Global Sukuk	1.09	0.17	0.13	0.00	0.89*	0.00
Global Sukuk/Global Bond	0.16	0.17	0.13	1.00	0.00	1.00
GCC Bond/GCC Sukuk	1.44	0.65*	0.00	0.00	0.74*	0.00
GCC Sukuk/GCC Bond	0.46	0.65*	0.00	1.00	0.00	1.00
Panel B: First wave of COVID-19						
DJ World/DJI World	0.93	0.96*	0.00	0.56	0.02	0.90
DJI World/DJ World	1.02	0.97*	0.00	0.44	0.02	0.88
DJ Europe/DJI Europe	1.08	0.94*	0.00	0.08	0.25**	0.05
DJI Europe/DJ Europe	0.86	0.94*	0.00	0.92	0.00	0.99
DJ Developed/DJI Developed	0.53	0.35*	0.00	0.70	−0.01	0.97
DJI Developed/DJ Developed	0.79	0.30*	0.01	0.30	0.36*	0.00
DJ.Emerging/DJI Emerging	0.94	0.95*	0.00	0.67	0.11	0.43
DJI Emerging/DJ Emerging	1.01	0.95*	0.00	0.33	0.06	0.67
DJ US/DJI US	0.94	0.97*	0.00	0.60	0.04	0.79
DJI US/DJ US	1.04	0.98*	0.00	0.40	0.02	0.89
Global Bond/Global Sukuk	1.53	0.30*	0.01	0.00	0.90*	0.00
Global Sukuk/Global Bond	0.09	0.27**	0.03	1.00	−0.04	0.77
GCC Bond/GCC Sukuk	2.17	0.59*	0.00	0.00	0.87*	0.00
GCC Sukuk/GCC Bond	0.32	0.51*	0.00	1.00	0.00	1.00
Panel C: Second wave of COVID-19						
DJ World/DJI World	0.90	0.74*	0.00	0.48	−0.02	0.91
DJI World/DJ World	0.99	0.82*	0.00	0.52	0.10	0.57
DJ Europe/DJI Europe	0.89	0.63*	0.00	0.37	0.13	0.49
DJI Europe/DJ Europe	0.79	0.69*	0.00	0.63	−0.12	0.57
DJ Developed/DJI Developed	0.51	0.31***	0.06	0.55	0.35**	0.03
DJI Developed/DJ Developed	0.55	0.34**	0.04	0.45	0.27	0.11
DJ.Emerging/DJI Emerging	0.72	0.83*	0.00	1.00	0.00	1.00
DJI Emerging/DJ Emerging	1.15	0.83*	0.00	0.00	0.39*	0.01
DJ US/DJI US	0.70	0.58*	0.00	0.64	0.03	0.89
DJI US/DJ US	0.82	0.58*	0.00	0.36	0.13	0.47
Global Bond/Global Sukuk	0.66	0.03	0.87	0.04	0.92*	0.00
Global Sukuk/Global Bond	0.04	0.02	0.92	0.96	−0.15	0.49
GCC Bond/GCC Sukuk	1.82	0.41*	0.01	0.00	0.88*	0.00
GCC Sukuk/GCC Bond	0.26	0.46*	0.00	1.00	0.00	1.00

Notes: The table reports the hedge ratio, optimal weights, and hedging effectiveness between Islamic and conventional finance. The hedge ratio and optimal weights are represented by β and w, respectively. HE represents hedging effectiveness. *, **, *** indicate the significance at the 1%, 5%, and 10% levels, respectively.

domains. Overall, we notice that bidirectional causality is observed between the Islamic and conventional stock indices in most frequency domains during the first wave of the COVID-19 pandemic compared to the pre-COVID-19 period or the second wave of COVID-19.

The results for Islamic and conventional bond (global and GCC) indices are mixed across different time scales. During pre-COVID-19, global and GCC bonds do not Granger cause global and GCC Sukuk in the short-run scales (except D2 for GCC bond and Sukuk). However, in the long-run frequency bands (D5-D6), there is evidence of bidirectional causality between Islamic and conventional bond indices. Global bond and Sukuk do not cause each other in the short- and medium-run time scales amid the first wave of the pandemic. Contrarily, we observe the significant bidirectional causality between the GCC bond and Sukuk indices during the first wave of the pandemic in all frequency bands (except D2).

There is no causality between Islamic and conventional bond indices in the D1 scale during the second wave of the pandemic. In contrast, conventional bonds (both global and GCC) Granger cause Islamic bonds in the D2 and D3 scales, while the causality is bidirectional in the long-run frequency bands. Finally, we can observe the hedging benefit of Islamic bonds suited in the short- and medium-run investment horizons, especially during the pandemic phase. Overall, the results of wavelet-based Granger causality support the observations from the CWT and WC analyses.

4.5. Portfolio implications: Hedge ratios, optimal weights, and hedging effectiveness

Table 3 represents the hedge ratio (HR), optimal weights, and hedging effectiveness (HE) for Islamic and conventional finance pairs during the pre-COVID-19 (Panel A), first (Panel B), and second (Panel C) wave of COVID-19. The left sight and right sight of Table 3 present the HR, and optimal weights, respectively.

We proceed with the HR analysis by looking at long/short positions and find that most HRs between Islamic and conventional stock indices (excluding the DJ Developed/DJI Developed pair) are higher during the pre-COVID-19 and first wave of COVID-19 periods, implying higher hedging costs. In this instance, investors require high costs to hedge their relative pairs. Interestingly, HR in the second wave of COVID-19 is lower than in the pre-COVID-19 and first wave of COVID-19. Even yet, to hedge USD 1 of their respective pairs—Islamic/conventional or conventional/Islamic stock—investors need at least 70 cents (except in the DJ Developed/DJI Developed pair). When looking at the HR of the DJ Developed/DJI Developed pair, the HR is relatively lower during the second wave, inferring that investors can hedge a USD 1 long position in DJ Developed stock by investing 51 cents in a short position in DJI Developed stock, reducing the DJ Developed stock's return variance by around 31%. However, this is not an effective hedge position because investors would still need about 50% of their funds to hedge the same.

Concerning Islamic and conventional bond pairs, we observe that HRs of Global Sukuk/Global Bond and GCC Sukuk/GCC Bond pairs are comparatively lower during the first and second waves of COVID-19 than pre-COVID-19. Hence, investors should construct Islamic and conventional bond portfolios to hedge their relative pairs better during those periods. The greater hedging combination is evidenced in the global Sukuk-bond pair, especially during COVID-19, as investors only require around 5–10 cents to hedge USD 1 long position of global Sukuk.

Furthermore, the results of optimal portfolio weights are presented on the right sight of Table 3. The results reveal that in the case of Islamic and conventional stock pairs during pre-COVID-19, the optimal weights between DJI World/DJ World and DJI Developed/DJ Developed pairs are 0.05 and 0.28, respectively. This entails that investors should invest around 95% and 72% of their funds in DJ World and DJ Developed stock to reduce the return variance by approximately 19% and 39%, respectively, as the HE scores are higher and significant of those portfolio combinations. This scenario is almost identical in the case of the DJI Developed/DJ Developed pair during the first wave of COVID-19. Conversely, the reverse scenario is observed during the second wave of COVID-19, with investors investing around 65% of their funds in DJI Developed stock. The results also vary in the case of DJ Europe/DJI Europe and DJI Emerging/DJ Emerging pairs during the COVID-19 crisis.

Accordingly, about bond portfolio weights, our results indicate that maximum HE is found for Global Bond/Global Sukuk and GCC Bond/GCC Sukuk pairs during the three sample periods, while this effectiveness is stronger during COVID-19 (both first and second waves). Therefore, the results of optimal weights suggest that investors should invest 100% of their funds in both global and GCC Sukuk to reduce the maximum returns variance of those portfolio mixes during COVID-19.

From the analysis discussed above, in the case of Islamic and conventional stock pairs, only DJI developed and DJ developed stocks pair can be the optimal portfolio structure for minimizing their portfolio return variance. Furthermore, we observe that Islamic and conventional bond portfolios (both global and GCC) have the lowest hedging costs to hedge their respective pairs, which is more prominent during COVID-19. Similarly, when investors utilize their funds entirely in Islamic bonds, the maximum HE is obtained for conventional/Islamic bond portfolios. Overall, investors and portfolio managers should establish a portfolio mix of Islamic and conventional bonds to diversify their portfolio risk, particularly during the COVID-19 crisis. These findings corroborate the findings of the analysis discussed above. However, the result is also supported by Yarovaya et al. (2021).

4.6. Results discussion

Overall, the findings of the CWT imply that both the Islamic and conventional markets emanate significant volatility during the first wave of COVID-19 (March–April 2020). This suggests that both the stock and bond markets plunged following the two months of the COVID-19 outbreak. The plunge is attributable to the unprecedented uncertainty and panic that the pandemic outbreak wreaked on business activities worldwide, driving the global financial markets and economy into a great recession (Choi et al., 2020; Corbet et al., 2020). Nevertheless, the volatility of all markets began to smooth out from May onwards, as the markets started to recover after being

battered by the pandemic in March and April 2020.

We notice little volatility in the second wave of the pandemic in both Islamic and conventional stock markets—which is substantially lower than in the first wave. Investors, fund managers, and policymakers have already adjusted the pandemic situation caused by the early outbreak of COVID-19 may lead to lower volatility in the second wave. In addition, despite being affected less by the first wave than the conventional stock markets, Islamic stock markets are afflicted more by the second wave. The conservative approach of Islamic stock markets may be a potential cause of their immunity in the early stages of the COVD-19 crisis compared to the conventional ones. However, the relatively small size of the Islamic portfolio ultimately could not sustain its performance in the long run (second wave).

The bond markets are not affected by the second wave of COVID-19, suggesting that the bond markets are relatively more resilient during the crisis than stock markets. However, in terms of the negative impact of financial markets triggered by COVID-19, our findings are consistent with the recent literature such as Sharif et al. (2020), Ashraf (2020), Zhang et al. (2020), He et al. (2020), and Hasan et al. (2021b). Our results are also in accordance with Trabelsi et al. (2020) and Hasan et al. (2021b), who document comparable volatility between Islamic and conventional stock markets.

The results of the WC analysis show that the Islamic and conventional stock indices have a high tendency to be connected during the whole sample period. The strong co-movement between the Islamic and conventional stock indices is anticipated since the Islamic stock indices are a subclass of their conventional counterparts. Furthermore, Aloui et al. (2016) also observe that Shariah laws do not differentiate the returns between the Islamic and conventional equity indices. Therefore, both markets can be influenced similarly by financial and economic shocks (Rejeb, 2017). Recently, COVID-19 spills over from one market to another—as seen in the lead-lag relationship between the Islamic and non-Islamic financial markets. Therefore, Islamic and non-Islamic stock markets are not dissociated from each other. Islamic stocks may not serve as a hedge or safe-haven tool for conventional stocks, aligning with Rejeb (2017), Umar and Suleman (2017), Shahzad et al. (2017), Umar et al. (2018), and Yarovaya et al. (2021). This result contradicts Umar and Gubareva's (2021a) findings because they examine the hedging tool of Islamic stocks against the media coverage index (MCI), not against the conventional counterparts like ours. When comparing portfolios between Islamic and conventional stock pairs, our HR findings imply that hedging costs are considerably high. However, the results of optimal portfolio weights show that only the developed stock pair offers greater HE prospects across all sample periods.

Unlike stocks indices, global Sukuk consistently dominates the global bond through the return arrows and has low or no coherency with conventional bonds in all times scales, suggesting that the global Sukuk can be used as a hedge or safe-haven asset for investors across the world, especially during bearish periods like the COVID-19 crisis. However, the findings are consistent with Yarovaya et al. (2021). The findings may be explained by the fact that global Sukuk is less affected by COVID-19 than other assets, owing to their conservative disposition and low connection to the business cycle (Yarovaya et al., 2021). When we look at the portfolio management estimates, we see that the global Sukuk/bond and global bond/Sukuk portfolios have the lowest hedging costs and the highest HE benefits during COVID-19.

By contrast, GCC Sukuk is highly interconnected with GCC bonds in the long and very long run scales. The possible explanation for such findings is that the economies of the GCC countries are heavily reliant on the global oil market, which has lately plummeted owing to the Russia-OPEC price war and the trade war between the US and China (Sharif et al., 2020; Hasan et al., 2021c). The oil price crisis is further deepened by COVID-19, leading the financial markets of the GCC countries into a crisis. However, our portfolio management approaches reveal that the GCC Sukuk-GCC bond pair produces the lowest hedging cost, with the highest HE.

Finally, our results show no noticeable differences between the first and second waves of the COVID-19 pandemic in the case of coherency and Granger causality. However, Islamic bonds can be used as a potential hedge or resilient property that will suit short- and medium-term investment horizons during the regular and pandemic periods. These results are further supported by our portfolio management estimations, as Islamic and conventional bond pairs reveal the least hedging cost and highest HE during the sample periods. This is more pronounced during both the first and second waves of COVID-19. These findings are essential and noteworthy for the investors (both Islamic and non-Islamic) to protect themselves from turbulent states by designing investment and portfolio strategies since this pandemic is still underway.

5. Conclusion

Since the onset of the COVID-19 pandemic, wary investors are questing assets with resilience properties to safeguard their investments from the unprecedented risks triggered by the pandemic. In this work, we examine the resiliency of Islamic financial markets compared to their traditional counterparties during COVID-19. We also compare results between the first and second waves of COVID-19. Our results show that Islamic stock indices are highly associated with their comparable traditional stock indices, suggesting that Islamic stocks do not provide significant diversification benefits during the studied periods. We also observe no significant difference in results between the pre-and post-COVID-19 periods.

Conversely, Islamic bonds show low or no interaction with non-Islamic bonds, signifying that Islamic bonds have robust hedging and diversification potential. Besides, the results of risk-adjusted returns (Sharpe ratios) unveil that Islamic finance (both stocks and bonds) outperforms their conventional pairs during the whole sample period. Furthermore, our HR, portfolio weights, and HE estimates imply that Islamic and conventional bond pairs could be used as an effective portfolio mix because those portfolios have the lowest hedging cost and highest HE, especially during COVID-19. The DJ developed-DJI developed indices' pair offer some HE benefits as well. Our overall findings suggest that Islamic bond, particularly global Sukuk, offers more resilience to the investors than other assets investigated in this study during the regular and financial downturn.

Our findings can benefit investors in several ways. Firstly, 'conservative investors' are likely to benefit financially from investing in

Islamic assets, as the latter outperform their conventional counterparts. Secondly, our results may help investors hedge their investments against financial crises like COVID-19 with Islamic assets, particularly Sukuk. During the COVID-19 crisis, our portfolio management estimates would assist investors in doing the same. To gain the lowest hedging cost and the most HE benefits, they should build portfolios combining Islamic and conventional bonds (both global and GCC). With this hedging strategy, investors can make appropriate resilience plans for future catastrophic events to protect their assets from financial losses. Thirdly, investors can use Islamic bonds as the most effective alternative investments, particularly in the bearish states.

Our study has some important and necessary policy implications. Our results suggest that policymakers build a sustainable world financial system by integrating Islamic and traditional financial markets. The policy makers' role in increasing awareness of Islamic bonds stabilizes markets in both Muslim-majority and non-Muslim-majority economies. Stable and less volatile markets require less intervention by the government in COVID-19 bailout/stimulus, reducing strain(s) on public finance (Mensi et al., 2021; Shafiullah et al., 2021).

Islamic finance may also help improve financial inclusion owing to its outperformance over traditional assets and its underlying Shariah principles (Foglie and Panetta, 2020). Our comparative analysis between the first and second waves of COVID-19 may help both regulators and policymakers better understand the resilience of financial markets in the face of pandemic shocks. Accordingly, they may formulate an appropriate resilience plan for the possible third wave of the pandemic or any upcoming downfall events to shield the financial system through a hedging and diversification strategy with Islamic finance. This is applicable in the global, European, developed, emerging, United States, and GCC markets contexts.

Our study opens the door for the forthcoming researchers to investigate other individual countries' Islamic financial markets, subindices, and the rest of the Islamic financial products, especially Islamic banks and mutual funds. Also, upcoming researchers can compare the other financial markets between the impacts of the first and second waves of COVID-19. Finally, we cover only Shariah-based faith investments; future analyses may incorporate other faith-based investments.

CRediT authorship contribution statement

Md. Bokhtiar Hasan: Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Resources. **Md. Mamunur Rashid:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – original draft. **Muhammad Shafiullah:** Methodology, Writing – review & editing. **Tapan Sarker:** Writing – review & editing, Supervision, Funding acquisition.

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