Network connectedness of the term structure of yield curve and Sukuks

Zaghum Umar
College of Business, Zayed University,
Abu Dhabi, United Arab Emirates,
Institute of Business Research, University of Economics Ho Chi Minh City,
Ho Chi Minh City, Vietnam;
Email: zaghum.umar@gmail.com.
Yasir Riaz
Department of Business Studies
Namal University, Mianwali, Pakistan
Email: yasir.riaz@namal.edu.pk
Yasir Shahab
Associate Professor
School of Accounting, Xijing University
Xi'an, Shaanxi, China
Contact Number: +8613126584641
roulett360@yahoo.com; 20180223@xijing.edu.cn
Tamara Teplova
National Research University Higher School of Economics,
Russian Federation
Email: tteplova@hse.ru

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Abstract

This paper explores the connectedness between the returns and volatilities of the conventional and Islamic bond markets. We use the level, slope, and curvature of the US yield curve and estimate the connectedness of these factors with the Dow Jones Islamic indices (of 3 to 10 years of maturity). The static analysis shows that level and slope of the conventional yield curve are the net transmitters of shocks while the Islamic indices have been mostly at the receiving end. The dynamic connectedness analysis shows a varying degree of the connectedness over the full sample period characterized by distinctive trajectories of booms and busts. The pairwise connectedness analysis also confirms that level and slope are the net transmitters in the system with an exception in most recent times of Covid-19 pandemic. The findings have implications for the researchers, policy makers, regulators, shariah boards, investors, and fund managers.

Keywords: Spillover, Connectedness, Yield curve, Sukuk bonds, Financial crisis
JEL Codes: C53, E43, G12, G15

1 Introduction

In recent decades, the tremendous surge in the instigation of different Islamic-based financial instruments has attracted international investors, and consequently, the Islamic financial system has yielded significant growth[1] (El-Hawary et al., 2007; Gazdar et al., 2019; Trabelsi, 2011; Umar, 2017). In particular, Islamic equities and Sukuks (the shariah compliant alternative for bonds) have gained a lot of prominence in the capital markets (Asutay and Hakim, 2018; Balli et al., 2020; Naifar et al., 2017). One of the core reasons for this enhanced prominence is the inherent decoupling of Islamic financial assets from conventional alternatives. Thus, exhibiting potential diversification as well as better returns benefits.

Theoretically, Sukuk and conventional bonds have a number of differences as identified in the literature (Mimouni et al., 2019; Razak et al., 2019; Halim et al., 2017; Smaoui and Khawaja, 2017; Mohamed et al., 2015; and Alam et al., 2013). First, Sukuk grants the investor a portion of the ownership in the underlying asset whereas the bonds are purely a debt obligation and do not offer ownership benefits. Second, the underlying asset in Sukuk should be a Shariah complaint whereas bonds can be issued for any projects allowed by the local laws. Third, Each unit of Sukuk represents a share of ownership in the underlying asset whereas a bond represents a share of the debt. Fourth, The value of the Sukuk depends on the value of the underlying asset whereas the value of bonds depends on the creditworthiness of the issuer. Fifth, the Sukuk holder receives a share of the profit from the underlying asset whereas the bondholder receives fixed payment and principal. Sixth, the return on Sukuk is influenced by the performance of the underlying asset whereas the return on a bond is not affected by the underlying asset but the holder will receive the promised reward in any case. Based on these arguments, the two asset classes seem very different and there should be minimum connectedness between the two asset classes.

On the other hand, the literature has also identified similarities between the two securities. The investors receive regular payments from both securities. Both are issued in order to raise funds and compared to stocks, both are thought to be safer investments. Both make payments on a regular basis. According to the argument, Islamic financial activities are remarkably similar to conventional financial practices since the former imitates the latter and places less emphasis on the substance and more on the form of Shariah (Onder, 2016; Azmat et al., 2015; Khan, 2010). Consequently, the empirical evidence in favor of the decoupling hypothesis is mixed (Cakir and Raei, 2007; Godlewski et al., 2013; Grassa and Miniaoui, 2018; Hassan et al., 2018; Miller et al., 2007; Usmani, 2007; Wilson, 2008).

This study contributes to the existing literature on the decoupling hypothesis of conventional fixed-income markets and Sukuks. We disentangle the yield curve into its three components slope, curvature, and level that represents the short-, medium- and long-term interest rate and economic activity. Prior related studies have mainly focused on a limited aspect of the yield curve (i.e., for bonds of specific maturity) while undermining the importance of the full yield curve and its consequences on the Islamic financial markets. To mention, Samitas et al. (2021) explore the

[1] In particular, Alrifai (2015) highlights that the adoption of Islamic finance principles, though in nascent stage, have the potential to be influential in future regulatory decisions and can help avoid future financial crises and shocks globally.

connectedness between the five international Sukuk indices and the five international conventional indices. Maghyereh and Awartani (2016) have studied the international Sukuk indices and their connectedness with the stock market. Balcilar et al. (2016) examine the connectedness of international Sukuk indices with conventional bond indices and equity indices. To the best of our knowledge, this is the first study to investigate the relationship between Islamic and conventional markets for the complete term structure of the yield curve for both markets. The investment horizon and time-varying dynamics play a pivotal role in the financial markets and therefore, we argue that accounting for these important aspects will give us new insights into the underlying relationship between Islamic and conventional markets. Thus, this study contributes by examining the connectedness between the U.S. yield curve (its level, slope, curvature) and the Sukuk yield curve (i.e., the Dow Jones Sukuk indices of different maturities).

The existing literature on the nexus between the sovereign yield curve and Sukuk bonds is underdeveloped due to the focus on only limited aspect(s) of bond yields and neglecting the properties of the whole yield curve. The relationship between the two has been investigated in relevance to (a) the factors (e.g., Sukuk's and issuer's characteristics) determining the selection between Sukuk and conventional bonds and the role of credit ratings (Grassa and Miniaoui, 2018; Mohamed et al., 2015), (b) conditional correlations and volatility using multivariate GARCH technique (Hassan et al., 2018), (c) volatility and returns (Maghyereh and Awartani, 2016), (d) dynamics of co-movement (Bhuiyan et al., 2019; Samitas et al., 2021), (e) corporate governance mechanism (Saad et al., 2020) and (f) economic uncertainties (Naifar et al., 2017). However, the previous literature is still silent on a detailed relationship between the components of the yield curve and Sukuk bonds.

We employ a different two-step methodology in this study, in contrast to prevailing literature. In particular, we employ the dynamic Nelson-Siegel model of Diebold and Li (2006) to estimate the level, slope and curvature of the yield curve and then use connectedness methodology of Diebold and Yilmaz (2009, 2012, 2014) to estimate the static and dynamic connectedness (return and volatility spillovers) between the U.S. yield curve and the Dow Jones (DJ) Sukuk indices with maturities of 1–3-year (DJ13), 3–5-year(DJ35), 5-7 year(DJ57), and 7-10 years(DJ710). Thus, we account for the term structure of both the conventional and Islamic bonds.

The static connectedness estimates show 54.95% of the total connectedness of the system for returns while 57.51% for the volatilities of the two markets. The slope factor has shown the highest net directional connectedness to the system in case of both the return and volatility shock transmission. The DJ 5-7 years Sukuk indices and the curvature factor are the top net receivers in the system for the returns and volatilities, respectively. The dynamic connectedness analysis for returns shows a varying nature of connectedness of the system identified by high peak cycles during 2017 to 2019 and low levels of connectedness at the start and end of the sample period. However, in case of volatilities the connectedness has shown distinctive peaks and troughs throughout the studied period. Overall, the level and slope factors have been the net transmitters of shocks while the curvature has been the net receiver of the shocks.

Rest of the paper is structured as follows: Section 2 presents the literature review, section 3 discusses methodology, section 4 describes data, section 5 explains the results, and section 6 concludes the paper with implications for several stakeholders.

2 Literature Review:

Sukuk bonds emerged as an attractive alternate instrument to conventional bonds in the financial markets in recent decades. In particular, since the introduction of Sukuk, the peculiar disagreement pertains to whether Sukuk truly conforms to Shariah's guidelines or these are simply some minor modifications in those conventional western instruments. To reflect on this conundrum, Miller et al. (2007) argue that Sukuk differs from the conventional bond as Sukuk's returns are made from an underlying asset rather from the commitment to pay interests at regular intervals. Wilson (2008) debates that financiers put more effort in offering Sukuk mirroring conventional securities (which negate the essence of Islamic financing) just to please the investors.

Shari'a scholars have also criticized such formation of Islamic financial instruments (due to the concerns of incorporating the conventional and prohibited interest payments) and dismiss the requirement of resemblance with the conventional bonds (Godlewski et al., 2013). In particular, a renowned Shari'a scholar, Usmani (2007), criticizes the Sukuk due to its closeness with conventional bonds in terms of fixed return, guaranteed repayment of principal amount and no ownership. Contrary, proponents of Sukuk bonds present a different view. For instance, Cakir and Raei (2007) examine a sample of Sukuk and Eurobonds from the same issuer and estimate value-at-risk (VaR) for a combined portfolio (which comprises both instruments) to a portfolio with Eurobond only. They argue that Sukuks are entirely different from conventional bonds as their findings depict a decrease in VaR with the addition of Sukuk to the portfolio of fixed-income Eurobonds.

Noticeably, the existing studies on the determinants and outcomes of Sukuk (Islamic bonds) have grown over the recent years (e.g., Godlewski et al., 2013; Grassa and Miniaoui, 2018; Hassan et al., 2018, among others). In particular, Godlewski et al. (2013) provide evidence that the stock market has a negative reaction towards the announcements pertaining to the Sukuk issues (due to increased demand for Sukuk certificates) in contrast to the neutral reaction towards conventional bond issues. Grassa and Miniaoui (2018) explore the determinants of choice to employ Sukuk bond structure instead of conventional bonds, and their findings show that such choices are linked with Sukuk's specific characteristics and to the issuer's attributes. Moreover, they find that the quality of the credit ratings is negatively (positively) associated with the issuance of Sukuk (conventional) bonds.

While employing a multivariate GARCH technique, Hassan et al. (2018) investigate the nexus of conditional correlations and volatility between the Sukuk and conventional bonds in the international markets. Their key findings show that there is less volatility in Sukuk returns in comparison to conventional investment-grade bonds. Maghyereh and Awartani (2016) find weak spillovers of volatility and returns as well as weak co-jumps between Sukuk and global bonds. Furthermore, while employing different methodologies, the dynamics of Sukuk and conventional bonds have been explored in connection with (i) regional and global economic uncertainties (Naifar et al., 2017) (ii) pecking order for the firm financing choice (Mohamed et al., 2015), (iii) co-movement dynamics (Bhuiyan et al., 2019; Samitas et al., 2021) and (iv) corporate governance mechanism (Saad et al., 2020).

In relevance to conventional bonds, prior literature has widely investigated the nexus among interest rates, conventional bond/equity markets and different macroeconomic phenomena, mainly in developed markets (Bansal et al., 2014; Jammazi et al., 2017; Kenourgios et al., 2020; Riaz et al., 2020, Umar et al., 2019; 2021). In particular, Bansal et al. (2014) examine the role of the dynamics of asset-class risk in the negative stock-bond return nexus. Their findings show that in the presence of risk movements, the negative relationship between stock and bond return mainly disappears (at both weekly and monthly time periods). While using the Granger causality test, Jammazi et al. (2017) investigate the link between variations in the yield of 10-year Treasury bonds and the stock return of S&P 500 U.S. firms. They focus on time variation, smooth government change and stress factors and find a bidirectional causal relationship between the yield curve and stock return. In another study, Umar et al. (2019) explore the returns and volatility connectedness between sovereign yield curve's components (level, slope and curvature) and equity indices in China and find a strong relationship between the two. In particular, their findings reveal that "the level" is a net transmitter of return, while "curvature" is a net transmitter of volatility.

Moreover, Kenourgios et al. (2020) investigate the impact of credit rating statements on 10-year sovereign bond yields for international data. They mainly find that the negative outlooks and downgrades increase the bond yields, while the upgrade announcements tend to discount the bond yields in the international market. Riaz et al. (2020), while employing Nelson-Siegel model and autoregressive model, examine the impact of sovereign credit ratings on the shape of the yield curve (outlook changes) in five countries from the European market. Their findings divulge: (a) a substantial impact of rating downgrades, (b) insignificant effect of rating upgrades and (c) mixed results for the effect of outlook changes.

In addition, several other studies investigate the antecedents and consequences of the movement in the yield curve from a different perspective. In particular, different components of the yield curve (e.g., interest rates, long-term yields, slope, curvature, level etc.) are found to be associated with different aspects of equity returns using the DCC-GARCH model (Andersson et al., 2008; Dajcman, 2012; Fernandez-Perez et al., 2014) or AR-EGARCH model (Tamakoshi and Hamori, 2014) or cross-wavelet approach (Ferrer et al., 2016) in both developed and developing markets. In particular, in the context of developing markets, prior studies have mainly employed DCC-GARCH or GARCH model to examine the volatility in the financial markets underpinned by movements in the sovereign yield curve (e.g., see Bianconi et al., 2013; Lee et al., 2019; Li and Zou, 2008; Wang and Wang, 2018; Umar et al., 2021).

The above literature review depicts that the existing research on sovereign yield curve components and Sukuk indices have evolved over the recent years (but in different directions), and the studies connecting the nexus between these two are rather scarce. This study fills the void in the prevailing research by examining the connectedness between the U.S. yield curve and the Dow Jones Sukuk indices by employing a more robust empirical approach. Consequently, we empirically extend the prior related work (Bhuiyan et al., 2019; Samitas et al., 2021) by employing a different approach. In particular, we employ the latest methodology of the dynamic Nelson-Siegel model of Diebold and Li (2006) and examine the components of the U.S. yield curve (its level, slope, curvature). We further use the connectedness methodology of Diebold and Yilmaz (2009, 2012, 2014) to estimate the static and dynamic connectedness (return and volatility spillovers) between the U.S. yield curve (its level, slope, curvature) and the Dow Jones Sukuk indices (with 1-3 year maturity, 3-5 year maturity, 5-7 year maturity, and 7-10 years maturity).

3 Methodology

We explain our two-step methodology in this section. First, we use the dynamic Nelson-Siegal model for the estimation of the yield curve latent factors (Diebold and Li, 2006). This model offers several added advantages over the other techniques for estimating the yield curve factors. To mention, it has demonstrated an excellent predictive capacity to model any type of yield curve that can be observed in the real world. It is one of the best parsimonious model for modelling yield curve. Further, with the rise in the maturity, the discount factor of Nelson-Siegal model approaches zero and it is a fundamental property required by the economic theory.

Second, we introduce these estimated yield components along with Sukuk indices into forecast error variance-based decomposition model proposed by Diebold and Yilmaz (2014). This model allows us to study not only the full sample connectedness between the conventional yield curve factors and the Sukuk indices but also to explore the evolution of connectedness between the series over time, i.e., dynamic nature of system connectedness. We provide the details on the mathematical estimations of the model below:

3.1 Estimating Yield Curve Factors

The dynamic Nelson-Siegal model can be specified in a state-space representation as demonstrated below[2];

$$\boldsymbol{y_t(\tau)} = \begin{pmatrix} 1 & \left(\frac{1-e^{-\lambda\tau_1}}{\lambda\tau_1}\right) & \left(\frac{1-e^{-\lambda\tau_1}}{\lambda\tau_1} - e^{-\lambda\tau_1}\right) \\ 1 & \left(\frac{1-e^{-\lambda\tau_2}}{\lambda\tau_2}\right) & \left(\frac{1-e^{-\lambda\tau_2}}{\lambda\tau_2} - e^{-\lambda\tau_2}\right) \\ \vdots & \vdots & \vdots \\ 1 & \left(\frac{1-e^{-\lambda\tau_N}}{\lambda\tau_N}\right) & \left(\frac{1-e^{-\lambda\tau_N}}{\lambda\tau_N} - e^{-\lambda\tau_N}\right) \end{pmatrix}' \boldsymbol{f_t} + \boldsymbol{\varepsilon_t}, \quad \boldsymbol{\varepsilon_t}\widetilde{\boldsymbol{N}}(\boldsymbol{0}, \boldsymbol{R}) \qquad (1)$$

$$\widetilde{\boldsymbol{f}}_{\boldsymbol{t}} = \boldsymbol{\Psi}\widetilde{\boldsymbol{f}}_{\boldsymbol{t-1}} + \boldsymbol{\mu_t}, \quad \boldsymbol{\mu_t}\widetilde{\boldsymbol{N}}(\boldsymbol{0}, \boldsymbol{G}) \qquad (2)$$

Where, equation (1) relates the N yields to the three latent factors of the curve and is known as the measurement equation. Equation (2) demonstrates the dynamic movement of the yield curve factors and is kanown as the transition equation. $\boldsymbol{y_t(\tau)}$ demonstrates a vector of raw bond yields of an N*1 dimension, $\boldsymbol{f_t}$ is a vector of the level ($\boldsymbol{L_t}$), slope ($\boldsymbol{S_t}$), and curvature ($\boldsymbol{C_t}$) factors of the yield curve in 3*1 dimension such that $\boldsymbol{f_t} = [\boldsymbol{L_t}, \boldsymbol{S_t}, \boldsymbol{C_t}]$, $\boldsymbol{\varepsilon_t}$ represents error terms vector of N*1 dimension. In equation (2), $\widetilde{\boldsymbol{f}}_{\boldsymbol{t}}$ is defined as a first difference of the yield curve factors such that $\widetilde{\boldsymbol{f}}_{\boldsymbol{t}} = \boldsymbol{f_t} - \boldsymbol{f_{t-1}}$. $\widetilde{\boldsymbol{f}}_{\boldsymbol{t}}$ is a matrix of time-varying demeaned yield curve factors and the time-varying relationship across shape factors is given by $\boldsymbol{\Psi}$. $\boldsymbol{\mu_t}$ contains error terms of the transition equation

[2] Please refer to Diebold and Li (2006) for a detailed description.

and is 3*1 dimensional vector. We also assume that error terms in both equations are independent following the economic literature. $\boldsymbol{R}$ is variance-covariance matrix and $\boldsymbol{G}$ is a diagonal matrix of 3*3 and N*N dimensions, respectively.

3.2 Estimating the system Connectedness

We estimate the connectedness of the yield curve and Sukuk bond indices using the approach of Diebold and Yilmaz (2014). It is based on Vector Autoregressive (VAR) model framework and follow the forecast error variance decomposition procedure. A N variable Var model of q-th order is specified as:

$$\boldsymbol{Y_t} = \sum_{\boldsymbol{q=1}}^{\boldsymbol{Q}} \boldsymbol{\Gamma_q Y_{t-q}} + \boldsymbol{\varepsilon_t} \qquad (3)$$

Where, $\boldsymbol{Y_t}$ represents a vector of endogenous variables such that $\boldsymbol{Y_t} = \boldsymbol{y_{1t}}, \boldsymbol{y_{2t}}, \dots, \boldsymbol{y_{Nt}}$; $\boldsymbol{\Gamma_q}$ represents the coefficient matrices of N*N dimensions; and $\boldsymbol{\varepsilon_t}$ is a vector containing independent error terms.

Following Diebold and Yilmaz (2014), we use the generalized forecast error variance decomposition technique They have proposed a representative table for estimating the connectedness between the variables of a system. We present the table below:

Table 1: Schematic table of connectedness

	x_1	x_2	…	x_N	From others
x_1	d_{11}^H	d_{12}^H	…	d_{1N}^H	$\sum_{j=1}^{N} d_{1j}^H, j \neq 1$
x_2	d_{21}^H	d_{22}^H	…	d_{2N}^H	$\sum_{j=1}^{N} d_{2j}^H, j \neq 2$
⋮	⋮	⋮	⋱	⋮	⋮
x_N	d_{N1}^H	d_{N2}^H	…	d_{NN}^H	$\sum_{j=1}^{N} d_{Nj}^H, j \neq N$
To others	$\sum_{i=1}^{N} d_{i1}^H$ $i \neq 1$	$\sum_{i=1}^{N} d_{i2}^H$ $i \neq 2$	…	$\sum_{i=1}^{N} d_{iN}^H$ $i \neq N$	$\frac{1}{N}\sum_{i,j=1}^{N} d_{ij}^H$ $i \neq j$

Note: This table shows formulas used in a schematic diagram for calculating the directional connectedness between the elements of the system.

In the Table 1, the upper-left N*N cells represent the variance decomposition matrix denoted by $D^H = [d_{ij}^H]$. d_{ij}^H is the H-step variance decomposition of variable i in response to shocks in j such that i,j, = 1,…, N and i≠j. From connectedness perspective, the off-diagonal elements of D^H measure the pairwise directional connectedness from elements j to i given as: $C_{i\leftarrow j}^H = d_{ij}^H$, such that, $C_{i\leftarrow j}^H \neq C_{j\leftarrow i}^H$. Whereas the net pair-wise directional connectedness is given as: $C_{ij}^H \neq C_{j\leftarrow i}^H - C_{i\leftarrow j}^H$.

The bottom row (and right-most column) supplements D^H with off-diagonal column (and row) sums, respectively. These are labelled as "To others" (and "From others") to show the share of the H-step forecast-error variance transmitted to (and received from) other factors of the system. The total connectedness from others to i and from j to others is given as: $C_{i\leftarrow \bullet}^H = \sum_{\substack{j=1 \\ j\neq i}}^{N} d_{ij}^H$ and $C_{\bullet\leftarrow j}^H =$

$\sum_{\substack{i=1 \\ j\neq i}}^{N} d_{ji}^{H}$, respectively. Similarly, net total directional connectedness is defined as $C_i^H = C_{\bullet\leftarrow i}^H - C_{i\leftarrow\bullet}^H$.

The bottom-right cell of Table 1 provides the overall total connectedness of the system. It is the grand total of the values in the bottom row and the right-most column. The total connectedness becomes: $C^H = \frac{1}{N}\sum_{\substack{i,j=1 \\ j\neq i}}^{N} d_{ij}^{H}$.

We use the generalized forecast error variance decomposition technique of Pesaran and Shin (1998) and Koop, Pesaran, and Potter (1996). This technique has an added advantage that it is not sensitive to variable ordering for estimating orthogonal innovations as observed by Cholesky factorization and other traditional techniques. The H-step generalized variance decomposition matrix is given as $D^{gH} = [d_{ij}^{gH}]$, where

$$d_{ij}^{gH} = \frac{\sigma_{jj}^{-1}\sum_{h=0}^{H-1}(e_i^{'}\Theta_h \sum e_j)^2}{\sum_{h=0}^{H-1}(e_i^{'}\Theta_h \sum \Theta_h^{'} e_j)} \quad (4)$$

Where, σ_{jj} represents an element of $\sum$ at j-th position, $\sum$ is the covariance matrix in the non-orthogonalized VAR of the error term in the model, e_j is a selection vector with zeros everywhere and unity for j-th element. In the generalized forecast error decomposition, the shocks are not necessarily orthogonal. It implies that the forecast error variance contributions (i.e., row sums of D^g) are not necessarily unity. Consequently, we use $\widetilde{D}^g = [\tilde{d}_{ij}^g]$ for the generalized connectedness index and not on D^g. The $\tilde{d}_{ij}^g$ is given as $\tilde{d}_{ij}^g = \frac{d_{ij}^g}{\sum_{j=1}^{N} d_{ij}^g}$. Where, $\sum_{j=1}^{N}\tilde{d}_{ij}^g = 1$ and $\sum_{i,j=1}^{N}\tilde{d}_{ij}^g = N$ by the nature of construction. Now, we can easily estimate generalized connectedness of the components of the system using $\widetilde{D}^g$.

4 Data

To study the connectedness between the conventional and Islamic bond markets, we obtain the data for US bonds raw yields and the Sukuk indices from the Bloomberg. We extract the raw yields for the 15 available maturities for the following tenors: 3, 6, 12, 24, 36,48,60, 72, 84, 96, 108, 240, and 360 months to estimate the yield curve factors of the US yield curve. We use the dynamic Nelson and Siegal model of Diebold and Li (2006) for yield curve's factors estimation. In addition, we obtain the data at daily frequency for the Dow Jones Sukuk 1-3 Year Index (DJ13), Dow Jones Sukuk 3-5 Year Index (DJ35), Dow Jones Sukuk 5-7 Year Index (DJ57), and Dow Jones Sukuk 7-10 Year Index (DJ710). The data period is from July 7, 2014, to November 30, 2021. We use both the returns and volatility of the Dow Jones sukuk indices to study the connectedness between the sukuks and yield curve components. The price series are presented in Figure 1 and the returns in the Figure 2.

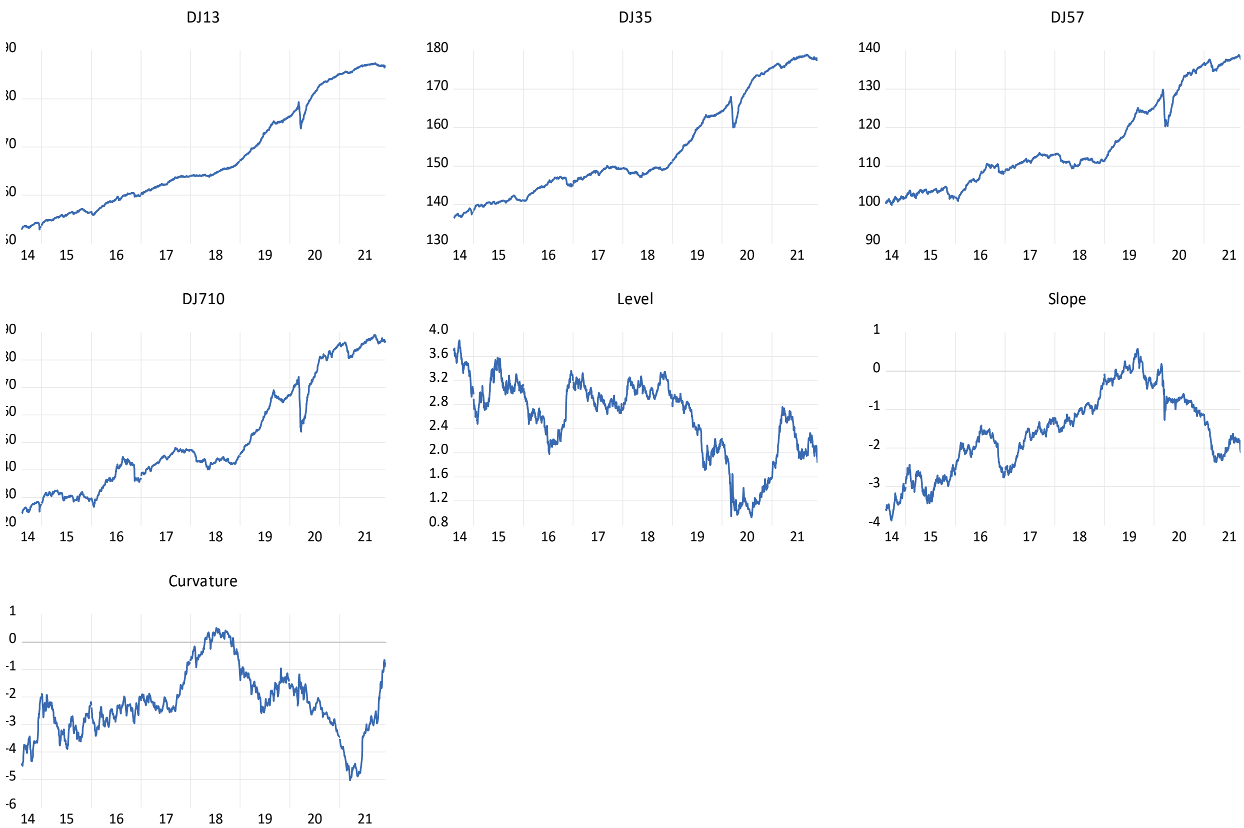

Figure 1: Sukuk indices and the yield curve factor series.

DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

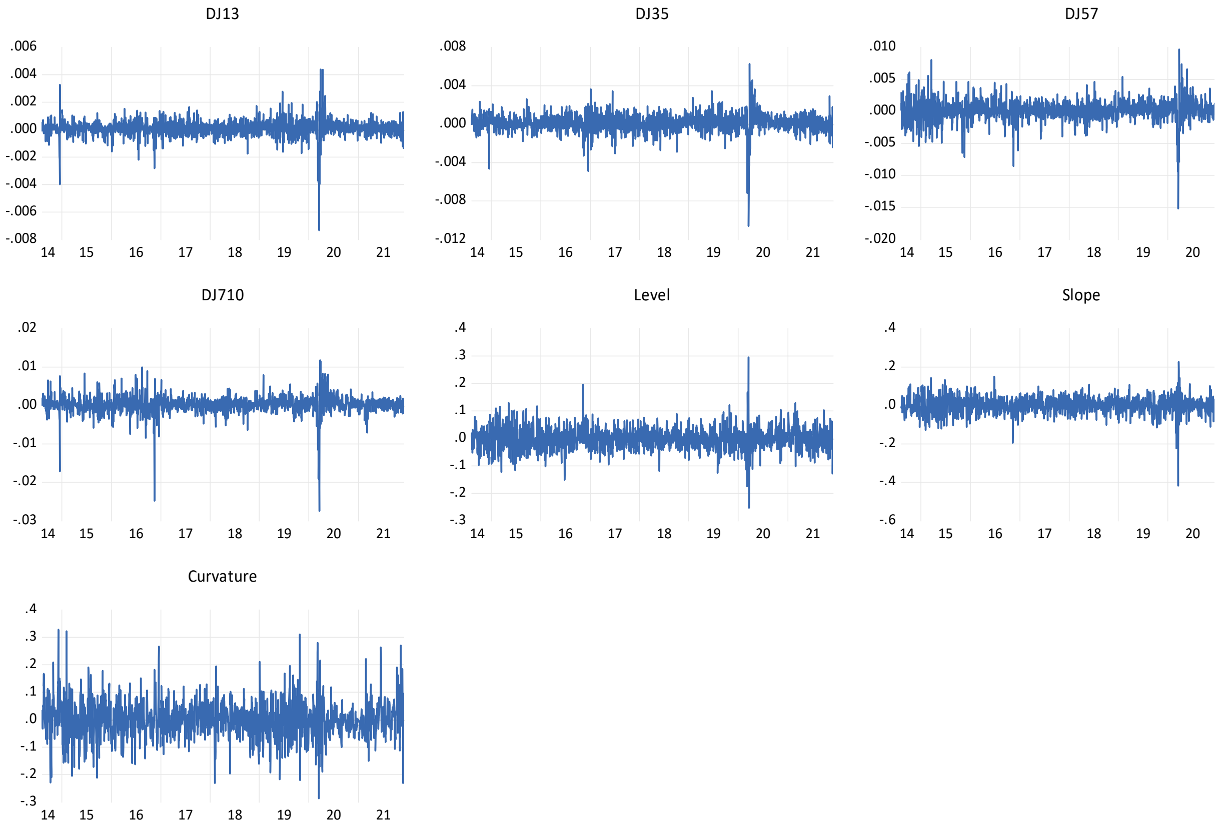

Figure 2: Return series of the Sukuk indices and the yield curve factor
DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

4.1 Descriptive Statistics

We present the summary statistics for the returns of the Sukuk Indices and the latent factors of the US yield curve in the Table 1. DJ710 shows the highest mean returns while DJ13 shows the lowest mean returns between the four sukuk indices used in this study. It represents a normal upward sloping yield curve for the Sukuk bonds. The maximum and minimum values are also largest for the DJ710 Sukuk index showing the highest variability between the four indices. It is also demonstrated by the standard deviation of the DJ710 index that is highest in the sample indices. Similarly, the standard deviation of DJ13 is lowest in the sample. As expected, the short maturities have shown low standard deviation as compared to the long maturities of the Sukuk bonds.

When comparing across the conventional latent yield curve factors, curvature shows highest mean returns followed by level and slope factors. Curvature also shows the highest maximum value between the yield curve factors and the slope factor has the lowest minimum value. The curvature also has the highest standard deviation among the three factors followed by slope and level, respectively. The Jarque-Bera test for normality is also significant for all the Sukuk indices as well as the yield curve factors.

Table 1: Summary Statistics

	DJ13	DJ35	DJ57	DJ710	Level	Slope	Curvature
Mean	0.0001	0.0001	0.0002	0.0002	-0.0010	0.0009	0.0020
Median	0.0001	0.0001	0.0002	0.0003	-0.0020	0.0024	0.0012
Maximum	0.0044	0.0063	0.0097	0.0118	0.2958	0.2274	0.3283
Minimum	-0.0073	-0.0106	-0.0152	-0.0275	-0.2530	-0.4178	-0.2873
Std. Dev.	0.0006	0.0009	0.0016	0.0022	0.0396	0.0433	0.0652
Skewness	-1.3944	-1.4730	-0.9111	-2.3860	0.1461	-0.7270	0.2541
Kurtosis	25.9758	19.7532	12.6608	31.2536	6.7163	9.8164	5.3464
Observations	1892	1892	1892	1892	1892	1892	1892

Notes: This table displays the sample statistics of the return series. DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

5 Results

This section presents a discussion on the results of this study for the connectedness between Sukuk indices and the US yield curve factors. First, we discuss the static connectedness and then, we consider dynamic connectedness between the series.

5.1 Static Connectedness

Table 2 presents the static connectedness for the returns and volatility of the yield curve factors and the sukuk indices in Panel A and Panel B, respectively. From Panel A of Table 2, the total connectedness of the system is 54.95% for the full sample. The slope shows highest-level of spillover (i.e., 65.74%) to the system (row TO) while curvature has the lowest percentage of connectedness (i.e., 29.08%) to the system. Whereas DJ710 and DJ35 have the highest percentage of spillover from (last column named FROM) the system (i.e., 61.89% and 61.56%), respectively. Again, curvature has the lowest level of connectedness from the system (i.e., 35.22%). It shows that both asset classes are quite interconnected and receives as well as transmit spillover to each other. It provides support to the literature studying the relationship between the two asset classes (Hassan et al., 2018). When we look at the net directional connectedness of the series (row NET), we find that slope as the major transmitter of spillover with the highest positive net directional connectedness of 9.88% followed by the level, DJ35, and DJ710 with magnitudes of 6.66%, 2.23%, and 0.28%, respectively. Contrarily, DJ57 has the highest recipient of spillover with negative net directional connectedness followed by DJ13, and Curvature with the magnitudes of -6.49%, -6.43%, and -6.14%, respectively.

Panel B of Table 2 shows the connectedness of the volatility of the two asset classes. The slope exhibit 57.51% spillover to the system followed by level (53.55%), DJ35 (46.92%), DJ710 (40.41%), DJ57 (37.84%), DJ13(32.57%), and curvature (24.31%). The findings are comparable to the connectedness between the returns of the two asset classes. They show a strong level of connectedness between the volatilities. Maghyereh and Awartani (2016) also find spillovers of volatility between Sukuk and the equity markets. The slope shows the highest degree of spillover to the system (row TO) and curvature demonstrates the lowest level of spillover. Talking in terms of receiving side of the system, slope and level of the yield curve factors leads the system with magnitudes of 52.34% and 52.16%, respectively. The other series like DJ35 (42.60%), DJ710 (42.19%), DJ57 (38.00%), DJ13 (35.39%), and Curvature (30.44%) follows the slope and level and are at the lower levels of receiving end. The highest recipient of spillover is (row NET) is of the curvature factor (-6.13%), whereas the slope is the highest transmitter of spillover (5.17%). DJ35 (4.33%) is another major transmitter of spillover, whereas, DJ13 (-2.82%) is another major recipient of spillover. The total connectedness of the system is 41.87%.

Table 2: Static Connectedness

	DJ13	DJ35	DJ57	DJ710	Level	Slope	Curvature	FROM
Panel A: Returns								
DJ13	45.2	20.56	12.33	17.57	1.55	1.63	1.16	54.8
DJ35	18.2	38.44	15.38	19.23	3.15	3.29	2.31	61.56
DJ57	11.64	16.45	40.56	20.17	4.42	4.47	2.28	59.44
DJ710	15.4	19.06	18.26	38.11	3.88	4.07	1.21	61.89
Level	1.11	2.56	2.41	2.05	44.09	37.3	10.48	55.91
Slope	0.88	2.46	2.51	2.12	36.25	44.15	11.64	55.85
Curvature	1.13	2.69	2.07	1.02	13.32	14.98	64.78	35.22
TO	48.37	63.78	52.95	62.16	62.58	65.74	29.08	384.67
NET	-6.43	2.23	-6.49	0.28	6.66	9.88	-6.14	
Total Connectedness								**54.95**
Panel B: Volatility								
DJ13	64.61	16.4	7.13	11.69	0.06	0.07	0.03	35.39
DJ35	14.5	57.4	14.34	12.93	0.1	0.5	0.24	42.6
DJ57	6.83	15.15	62	15.6	0.07	0.26	0.08	38
DJ710	10.98	14.9	16.18	57.81	0	0.11	0.02	42.19
Level	0.09	0.09	0.04	0.07	47.84	40.52	11.35	52.16
Slope	0.11	0.26	0.11	0.08	39.18	47.66	12.59	52.34
Curvature	0.06	0.12	0.04	0.04	14.13	16.04	69.56	30.44
TO	32.57	46.92	37.84	40.41	53.55	57.51	24.31	293.1
NET	-2.82	4.33	-0.15	-1.78	1.39	5.17	-6.13	
Total Connectedness								**41.87**

Notes: This table displays the static connectedness of the return (top panel) and volatility (bottom) of Sukuks with the components of the yield curve. DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

We present the network connectedness of the system in Figure 3. It presents the network structure of pair-wise connectedness of each element in the system for returns in the left panel and for volatilities in the right panel. The arrows represent net positive direction connectedness from tail of the arrow to the head of the arrow. The higher number of arrows show higher connectedness with the system. It is evident from the Figure 3 that the level and slope (i.e., the long and short ends of the conventional yield curve) are the net transmitter to the system. Whereas the DJ13 is the net receiver of the system. It does not transmit spillovers to any other factors in the system. Among the conventional yield curve factors, curvature is the only factor that receives shocks from the Islamic indices (i.e., DJ35). It shows that the medium-term factor of the Islamic yield curve transmits to medium-term factor of the conventional yield curve. DJ710 transmits shocks to Islamic counterparts only while is at the receiving end in case of conventional yield curve factors. DJ57 is overall a receiver of the shocks and transmits shocks only to DJ13. These results are interesting in a sense that conventional bond market is found to be a transmitter of shocks to the Islamic bond markets with one exception in case of the curvature factor.

From the right panel of the Figure 3, none of the element in the system is a universal transmitter or receiver. Every component act as a transmitter in one case while is a receiver in the other. The slope factor transmits shocks to all the other components of the system except DJ13. DJ13 transmits shocks to the conventional yield curve factors while receives shocks from its compeer indices. DJ35 acts exactly opposite to DJ13. It transmits shocks to its compeer indices while receives shocks from the conventional yield curve factors. DJ57 also behaves similarly with an exception in case of DJ35 where it receives the shocks from this index. Curvature factor receives shocks from the slope, level, and DH13 index and transmits shocks to the DJ57 and DJ35. It shows that curvature factors receive shocks from the short and long ends of the both conventional and Islamic yield curves while transmits shocks to the medium term bonds of the Sukuk bonds. The long ends of both the conventional (i.e., level factor) and Islamic (i.e., DJ710) markets behave variably and acts as both receiver and transmitter in different cases.

The varying levels of connectedness across the factors and indices warrants the study of the dynamics of the connectedness over time. We present the results for the dynamic connectedness for the returns of the two asset classes in the next subsection.

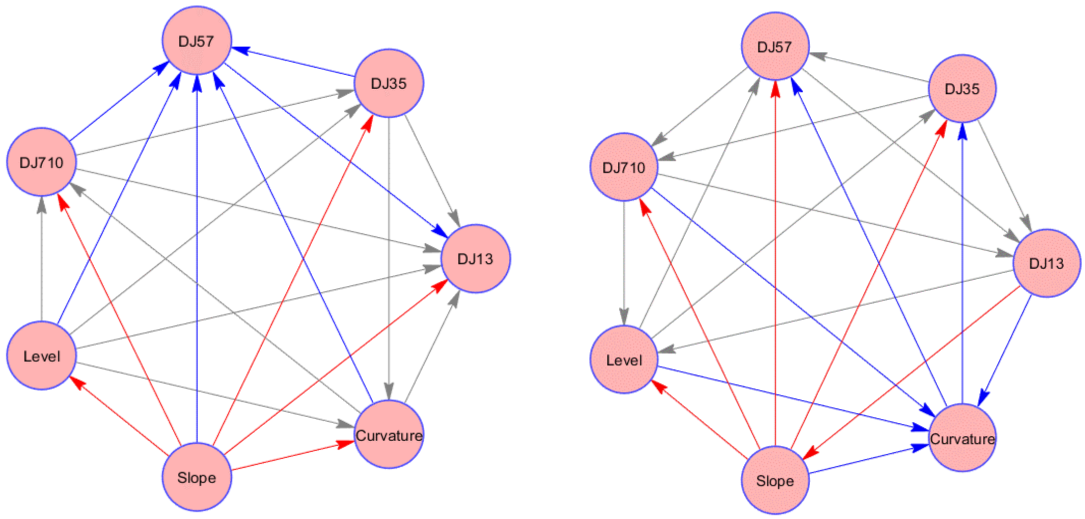

Figure 3: Network Connectedness of the system.

The left chart shows the network connectedness of returns, and the right chart shows the network connectedness of volatilities of the conventional yield curve factors and the Sukuk bond indices. DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

5.2 Dynamic Connectedness

The connectedness levels do not remain constant over time due to the changing global as well as local circumstances in the financial markets. Therefore, in this section, we estimate and present the total dynamic connectedness, and the dynamic connectedness to and from the system for the Sukuk indices and conventional yield curve factors. We select 180-days rolling window to study the dynamic connectedness over the given period.

5.2.1 Returns

Figure 4 presents the total connectedness of the returns over the sample period we study in this paper. Initially, at the start of 2015, the total connectedness stood at around 54.15% and followed by varying movement identified by small peaks and troughs. it touched the lowest levels in (April) 2016, i.e., 48.78%. The connectedness again rises back and the historically highest point (66.87%) in (July) 2017 and started decreasing. With a number of peaks and troughs in the total connectedness of the markets, the highest ever connectedness is observed in September of 2019, and it is 67.42%. However, with the start of the Covid-19 pandemic in 2020, the overall connectedness index starts falling and touched the lowest boundary of the year, i.e., 52.24%, in the February of 2020. It quickly rises again and reaches to 66.24%. Afterwards, it remains below the average level of the total dynamic connectedness over the full sample. During the sample period, we observe 58.69% average with a 4.8% standard deviation of the total dynamic connectedness of the system. It varies between a maximum value of 67.43% and a minimum value of 48.78%. Though, it remains low after the Covid-19 fiasco. The results are in line with Umar et al. (2022).

The total connectedness shows an overall picture of the interrelationship and interdependence of the system. However, it is also important to study and identify the transmitters and receivers of the shocks in a system. For this purpose, we estimate and present the directional connectedness to and from each element of the system in Figure 5. The graph in left column shows the transmission of

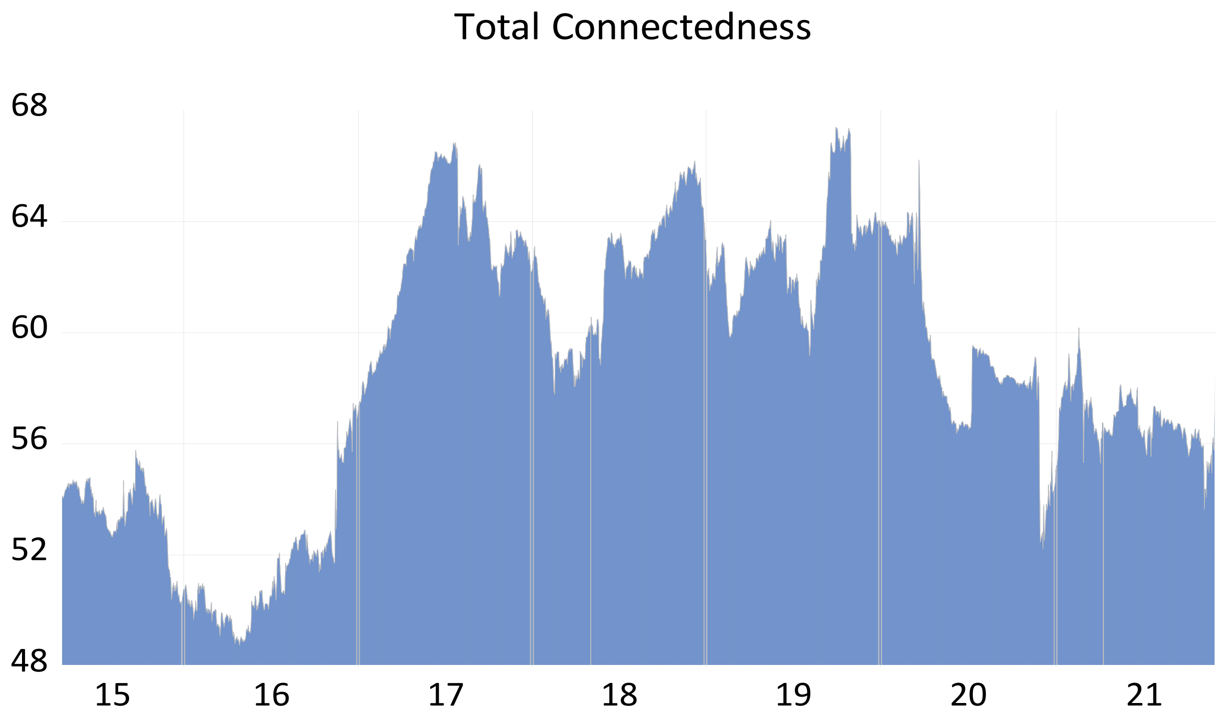

Figure 4: Total connectedness of returns of sukuk and yield curve components

shocks to the system from each element whereas the graphs in right column demonstrate the reception of shocks from the system. Seemingly, DJ13 has been a weak transmitter of shocks to the system as compared to the reception of shocks, that has been higher and consistent. DJ35 and DJ57 also appear to follow the pursuit whereas, for DJ710, the transmission and receival of shocks seems comparable. The level and slope factors have higher percentage of connectedness on the transmission end, i.e., around 30% for level and 11% for the slope. However, the level factor has comparable level of shock transmission as well as receival from the system.

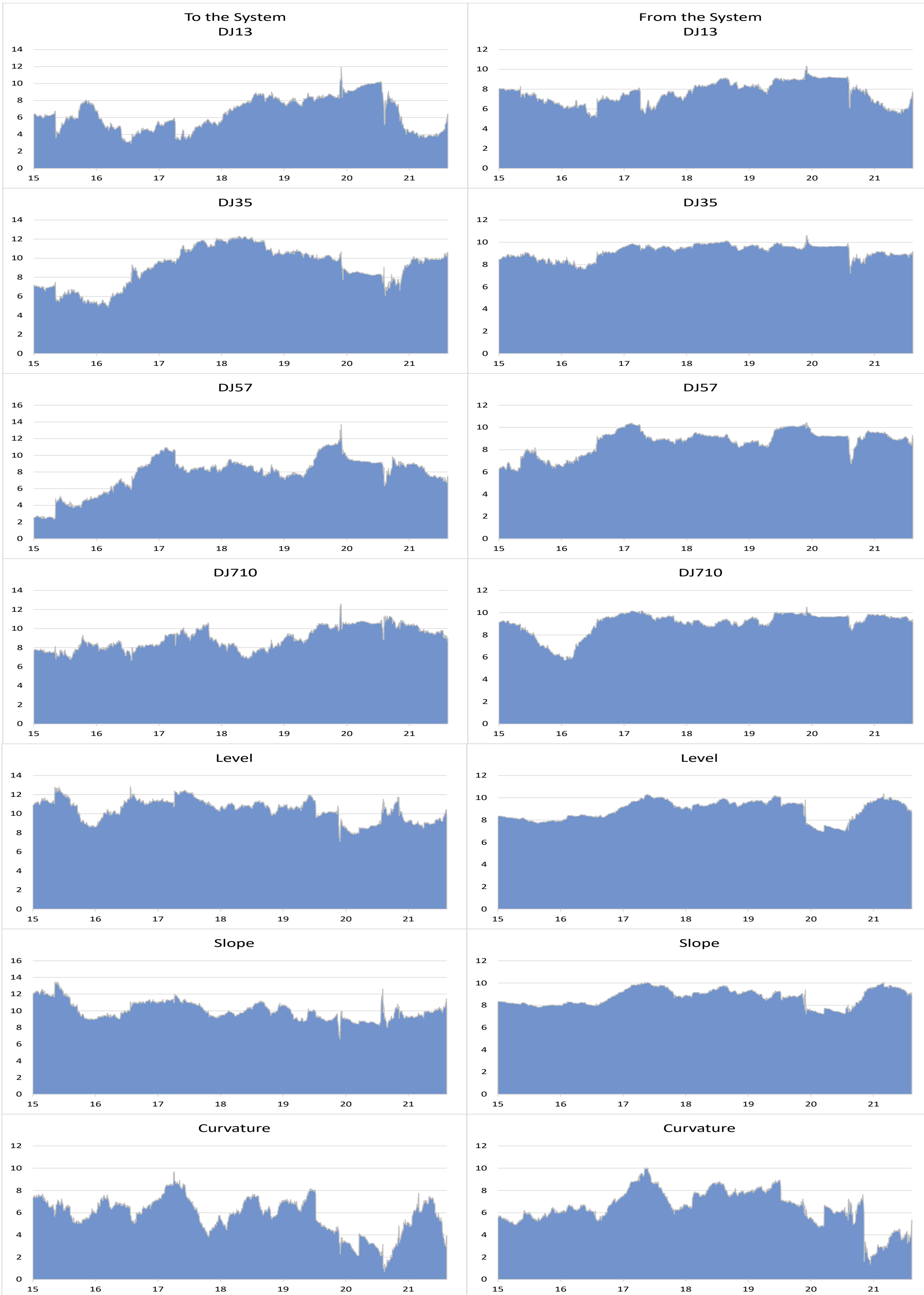

Figure 5: connectedness to and from the system for each returns series.

DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity

To quantitively measure the net effect of the shocks transmission and reception by each element, we present the net directional connectedness graphs in Figure 6. If we look at the graphs one by one, we see that DJ13 has been a net receiver of shocks most of the time with few small and unique net transmissions in the years 2016, 2019, and 2020, also asserted in Figure 5. DJ35 has been net receiver of shocks till mid-2017 and then turns out to be a net transmitter of shocks. It again acted as receiver in 2020 during the COVID-19 period followed by net transmission of shocks in 2021. Overall, DJ57 has been a net receiver of shocks from the system with few small episodes of transmission in 2017 and 2020. DJ710 has shown a varying nature of net directional connectedness with the system. Initially, it behaves as a net receiver till 2016, and then turn into a net transmitter followed by similar episodes of varying nature after 2016. Level and slope have been the net transmitters of shocks through the period till 2021. In 2021, they have been net receivers and that again changed to be net transmitters to the end of the year. This shows that Conventional bond markets lead the Islamic bond markets from their short and long ends of the yield curve to all the maturities of the Sukuk bonds. The Curvature factor has been net receiver most of the time while transmits shocks to the system at the start and end of the sample period. Similarly, Umar et al. (2022) propose that level has been the net transmitter of shocks to Islamic equities, whereas slope and curvature have been the net receiver of shocks from the system.

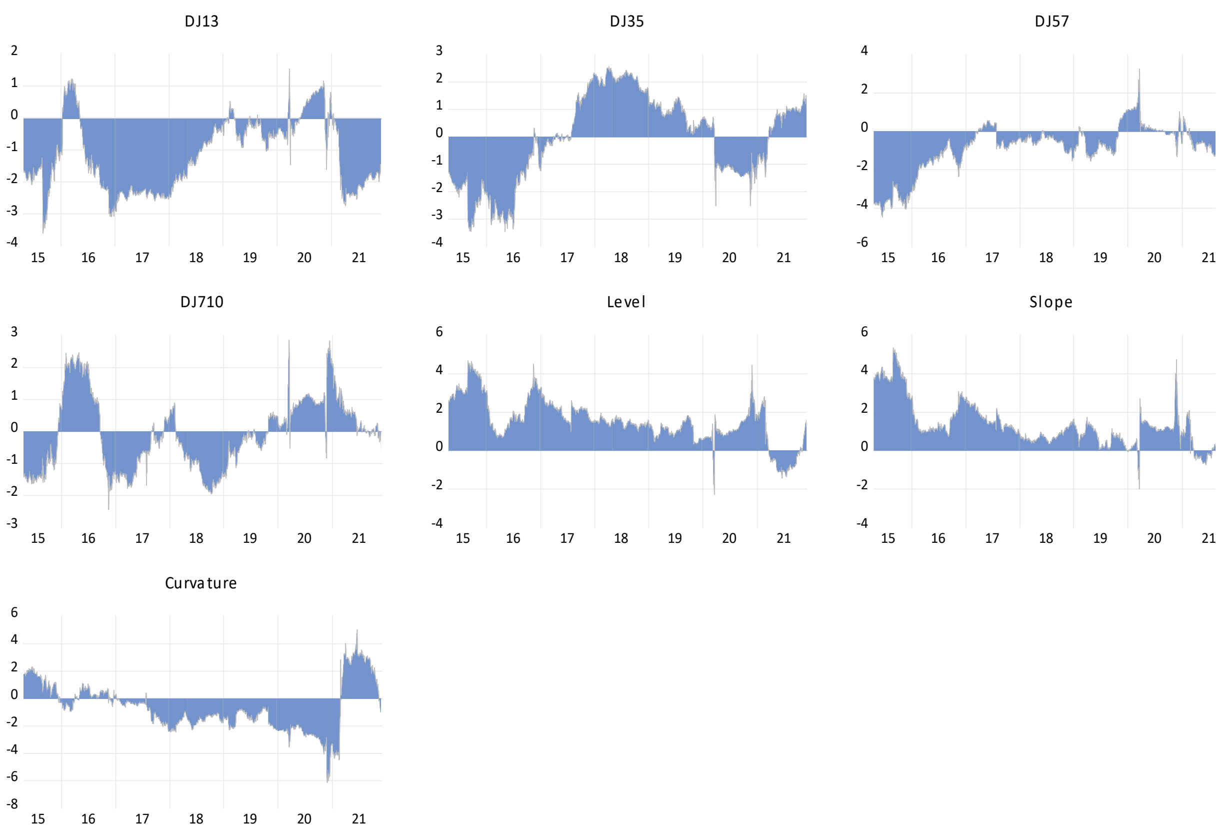

Figure 6: Net directional connectedness of each series in the system.
DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity.

5.2.2 Volatilities

We present the dynamic connectedness analysis of volatilities across the US yield curve factors and the DJ Islamic indices in this section. Figure 7 presents the total connectedness of the system over the total sample period. Initially, the level of connectedness was higher and above 50% that fall to lowest levels in 2016. It again sees a hump upward but remains below the 50% level of connectedness. Generally, the connectedness index show cycles of connectedness where we can identify peeks, recession, trough and then recovery in the total connectedness index. The overall cycles of the connectedness of the volatilities correspond with the cycle (i.e., peaks and troughs) in the connectedness of returns of the two asset classes. However, the highest level of connectedness has been found in the system (i.e., 52.82%) during the Covid19 period. Further, the index of total connectedness also shows abrupt movements during the period. The total connectedness has also decreased to the lowest levels in the most recent times studied.

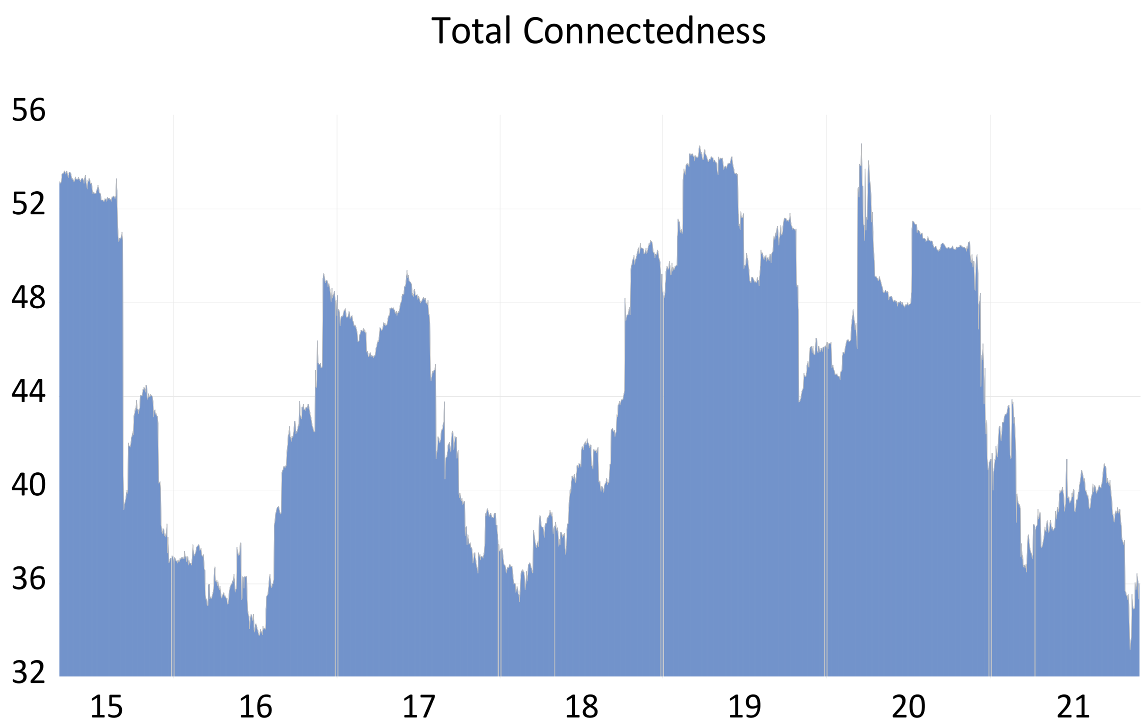

Figure 7: Total Connectedness of volatility

To identify and explore the transmitters and receivers in the system, we present the graphs of connectedness for each component to and from the system in Figure 8 (in left and right columns, respectively). We find that for DJ Islamic indices the connectedness to and from the system follows a same pattern. Surprisingly, the connectedness to the system is higher when the connectedness from the system is higher and vice versa for all the DJ Islamic indices. However, in case of the conventional yield curve factors, the connectedness to and from the system is more consistent and higher as compared to Islamic indices.

Figure 9 presents the net directional connectedness measures for each component of the system. The graph for DJ13 shows that it acts as a net receiver with three small contradictory episodes during the whole sample period. The DJ35 and DJ 57 shows a changing level and direction of connectedness with the system. On the other hand, DJ710 is a net transmitter shocks in the start followed by small windows of shocks reception from the system. It also receive shocks from the system during Covid-19 period where all other Islamic indices perform as net transmitters. Overall, the conventional yield curve factors (i.e., level and slope) are the net transmitters throughout the period and acts as net receivers during 2021. The curvature factor has been net receiver during the whole sample period whereas it turned to be net transmitters towards the end of the sample period. The result for volatility connectedness is comparable with our estimates for the returns connectedness of the conventional yield curve factors and the Islamic indices. However, we find that spillover from conventional yield curve to the Islamic bond markets is more prevalent (Samitas et al., 2021)

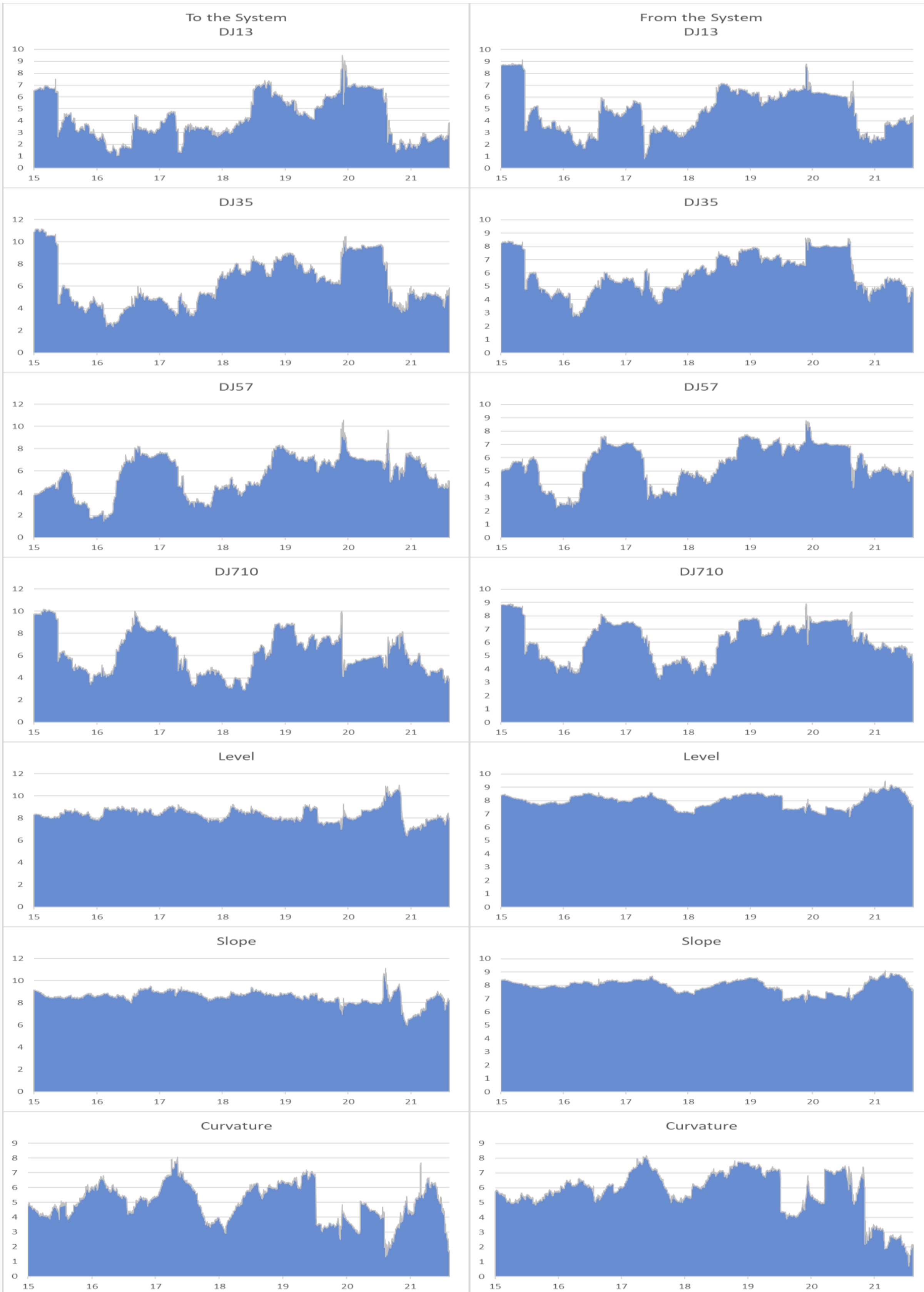

Figure 8: connectedness to and from the system for the volatility of each series.

DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity.

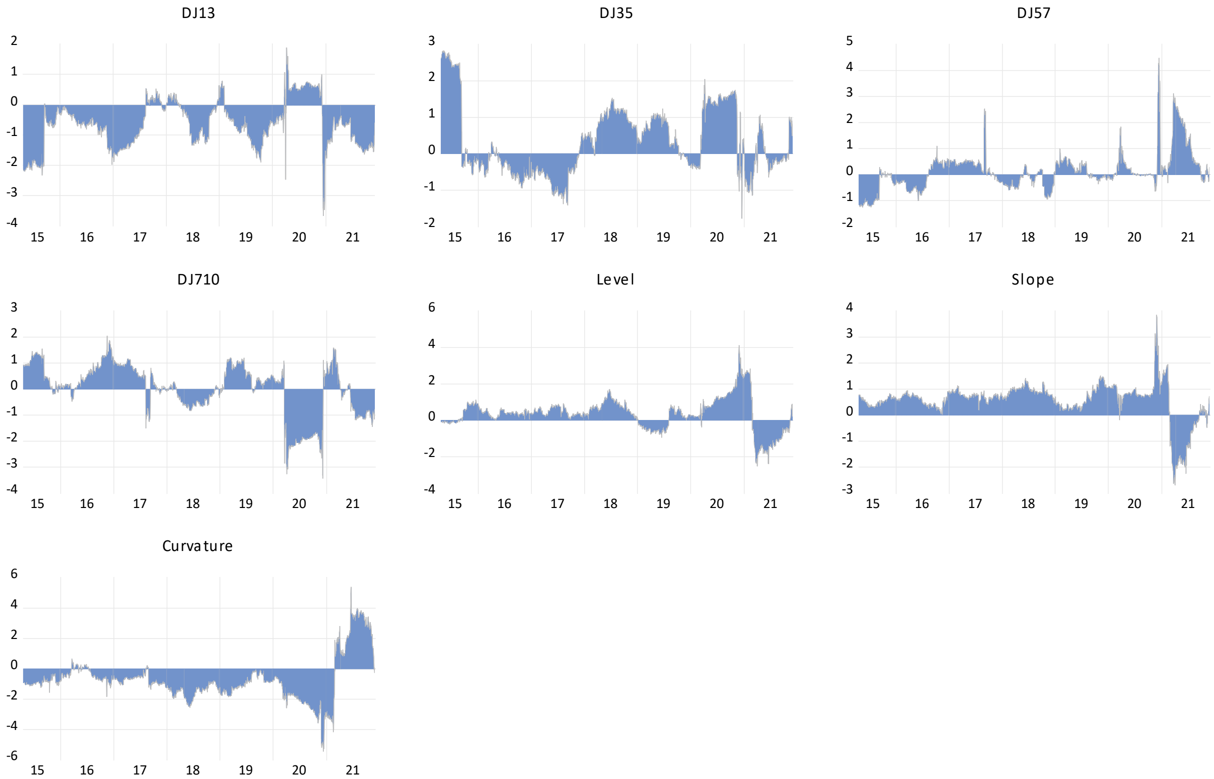

Figure 9: Net directional connectedness of each series in the system.

DJ13 denotes Dow Jones sukuk index of 1-3years maturity, DJ35 denotes Dow Jones sukuk index of 3-5years maturity, DJ57 denotes Dow Jones sukuk index of 5-7 years maturity and DJ510 denotes Dow Jones sukuk index of 5-10 years maturity.

6 Conclusion

The conventional and Islamic bonds have appeared as the two most important counterparts in the international financial markets. Literature has explored the similarities and differences in the two types of bonds, the effects of bond issue on the stock markets, and corporate governance mechanisms etc. However, In this paper, we study the connectedness between the US conventional yield curve and DJ Islamic indices. Initially, dynamic Nelson Siegal model has been used to estimate the level, slope, and curvature of the US yield curve. Then, we employ the connectedness measures of Diebold and Yilmaz (2014) to study the connectedness between the yield curve latent factors and the DJ Islamic Indices. Diebold and Yilmaz (2014) methodology allows us to analyze static as well as dynamic connectedness of the system over the full sample period.

The results show varying levels of total connectedness index for both the returns and volatilities of the Islamic and conventional bond markets. In general, the level and slope have been net transmitters of the shocks while the curvature has been the net receiver from the system. Furthermore, the DJ Islamic indices have shown varying episodes of transmission and reception of shocks to and from the system over the whole period. Overall, the two asset classes seem to be related to each other; however, the degree of connection varies over time (Umar et al., 2022; Samitas et al., 2021).

The findings have significant implications for the literature exploring similarities and differences between the Islamic and conventional markets. It also has implications for making asset allocation decision by the fund managers and investors. It can help regulators and policy makers in making stable and effective policies by knowing the connectedness of different markets and the possible contagion of information especially during the financial crisis. It is also useful for Shariah boards in understanding the applications of the Shariah laws and the aftermath of such applications. It is equally important for the bond issuers in understanding the nature of the two asset classes and selecting the optimal debt instrument for their firms.

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