

Uddin, Mohammed Gazi Salah; Yahya, Muhammad; Park, Donghyun; Hedström, Axel; Tian, Shu

## Working Paper

# Bond market spillover networks during the global pandemic: What we learned from ASEAN-4 markets

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**ADBI Working Paper Series**

**BOND MARKET SPILLOVER  
NETWORKS DURING THE GLOBAL  
PANDEMIC: WHAT WE LEARNED  
FROM ASEAN-4 MARKETS**

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Gazi Salah Uddin, Muhammad Yahya,  
Donghyun Park, Axel Hedström,  
and Shu Tian

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Gazi Salah Uddin is a professor of financial economics at the Department of Management and Engineering, Linköping University, Sweden. Muhammad Yahya is an associate professor at Inland Norway University of Applied Sciences, Campus Lillehammer, Norway. Donghyun Park is an economic advisor (Strategic Knowledge Initiatives) at the Economic Research and Regional Cooperation Department (ERCD), Asian Development Bank (ADB). Axel Hedström is a PhD candidate at the Department of Management and Engineering, Linköping University, Linköping, Sweden. Shu Tian is a senior economist at ERCD, ADB.

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Please contact the authors for information about this paper.

Email: [gazi.salah.uddin@liu.se](mailto:gazi.salah.uddin@liu.se), [muhammad.yahya@inn.no](mailto:muhammad.yahya@inn.no), [dpark@adb.org](mailto:dpark@adb.org),  
[axel.hedstrom@liu.se](mailto:axel.hedstrom@liu.se), [Stian@adb.org](mailto:Stian@adb.org)

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Asian Development Bank Institute  
Kasumigaseki Building, 8th Floor  
3-2-5 Kasumigaseki, Chiyoda-ku  
Tokyo 100-6008, Japan

Tel: +81-3-3593-5500  
Fax: +81-3-3593-5571  
URL: [www.adbi.org](http://www.adbi.org)  
E-mail: [info@adbi.org](mailto:info@adbi.org)

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**Abstract**

During decades of market development, the individual financial markets of the member economies of the Association of Southeast Asian Nations (ASEAN) have been progressively incorporated into regional and international markets. The aim of this study is to explore and measure the strength and direction of the bond market connectedness between Indonesia, Malaysia, the Philippines, and Thailand—collectively known as ASEAN-4—and major global and regional bond markets and to identify various factors affecting spillover effects. This study derives a risk spillover measure based on the attributes of static and dynamic spillover models and empirically examines its role in receiving or transmitting shocks based on different information spillover or contagion channels. In particular, the objective of this study is to evaluate the connectedness dynamics empirically using government bond yields in ASEAN-4 markets, major regional markets (the People's Republic of China, Japan, and the Republic of Korea), and major global markets (the European Union, the United Kingdom, and the United States). We aim to examine risk spillovers in ASEAN-4 bond markets and identify the potential economic and financial fundamentals driving uncertainty spillovers. We find complex intra-group return and volatility connectedness among ASEAN-4 markets and moderate inter-group return and volatility connectedness between ASEAN-4 and regional and global markets at different time horizons.

**Keywords:** ASEAN-4 bond markets, COVID-19, spillover, uncertainty, volatility

**JEL Classification:** F21, G12, G15, J11, M48, N25, O11

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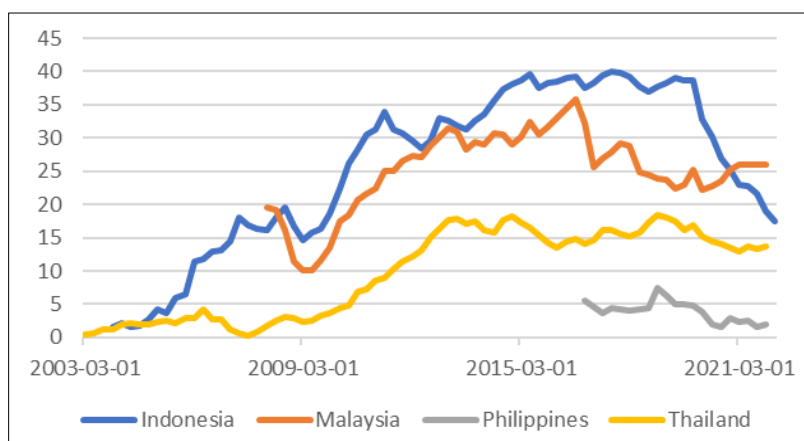
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# 1. INTRODUCTION

During decades of market development, the individual financial markets of member economies of the Association of Southeast Asian Nations (ASEAN) have gradually been incorporated into regional and international markets. Meanwhile, ASEAN economies have developed strong trade connectedness and interdependence with regional and global business cycles. Such connectedness may foster the spread of global shocks to local markets and distress local financial markets. Nevertheless, global shocks exert asymmetric impacts on different markets across different time horizons. Therefore, in this study, we explore and measure the strength and directionality of the bond market spillover effects of ASEAN economies with major global and regional markets and identify various factors affecting the connectedness dynamics.

The economic motivation for this paper is an initiative for the advancement of emerging markets and local currency bond markets, which have generated significant local currency debt issuance in recent years. In 2018, the issuance of USD2.2 trillion raised the region’s local currency bond market stock to USD25.9 trillion at the end of the year (Agur et al. 2019). Emerging bond markets necessitate attention primarily because of the increased demand for emerging market assets from various market participants seeking alternative investment opportunities to attain diversification and risk management benefits. **Figure 1** offers an outline of the foreign holdings in ASEAN-4 bond markets, which have significantly increased over the last two decades.<sup>1</sup> The largest increase was detected with the outbreak of the global financial crisis in 2008–2009. This may be attributed to the increased attention received by these markets from international investors seeking to attain diversification. However, the outbreak of the coronavirus disease (COVID-19) resulted in a decline in foreign holdings in ASEAN-4 markets, which may be attributed to a “flight to safety” (Bams et al. 2017; Elie et al. 2019; Shahzad et al. 2019; Yahya et al. 2019).

**Figure 1: Foreign Holdings of Local Currency Central Government Bonds in ASEAN-4 Markets (%)**



ASEAN = Association of Southeast Asian Nations.

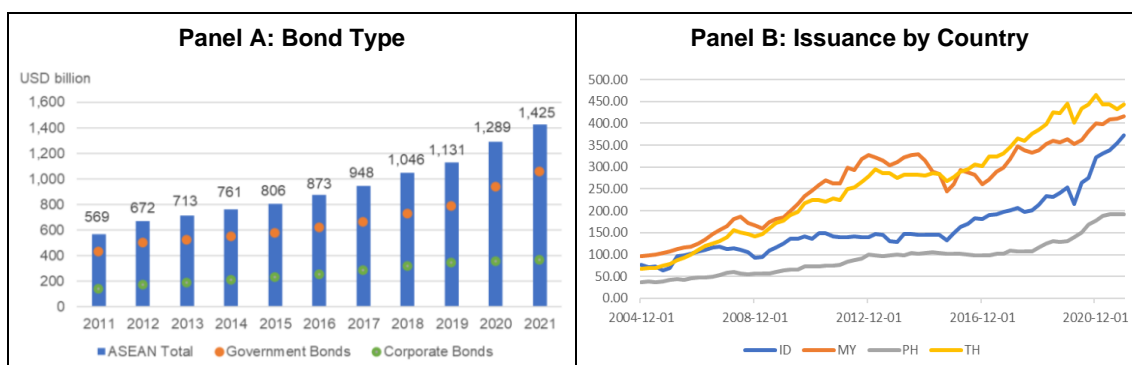
Note: ASEAN-4 includes Indonesia, Malaysia, the Philippines, and Thailand.

Source: Asian Development Bank.

<sup>1</sup> ASEAN-4 includes the markets of Indonesia, Malaysia, the Philippines, and Thailand.

Over the last two decades, emerging market bonds have attracted significant attention from the global investment community due to several factors. First, emerging markets have exhibited significant growth and continue to grow at a rapid pace. Second, since the 1990s, emerging market bonds have been a second major financing source to stimulate business activities in emerging markets. Finally, over the last decade, market transparency and liquidity in emerging market bonds have been significantly enhanced (see, e.g., Agur et al. 2019; Ahmad et al. 2018; Hyun et al. 2017; Piljak 2013; Volosovych 2011). The increased liquidity reflects investors' confidence in emerging market bonds, resulting in increased transparency in the issuance mechanisms of various types of bonds in emerging markets. Panels A and B of **Figure 2** illustrate the development of ASEAN-4 local currency bond markets by bond type and country, respectively. According to Panel A, local currency bonds outstanding exhibited year-on-year growth of around 15% between 2011 and 2021. The most rapid growth in the number of bonds outstanding occurred during the COVID-19 pandemic, indicating that the pandemic resulted in increased issuance of government bonds. Panel B shows that the largest issuer of local currency bonds during the review period was Indonesia. Notably, the growth is apparent across all ASEAN-4 bond markets. Overall, this increase may be attributed to government policies of raising capital to mitigate the negative impacts of the pandemic-induced shutdowns of these economies.

**Figure 2: ASEAN-4 Local Currency Bonds Outstanding by Bond Type and Country**



ASEAN = Association of Southeast Asian Nations, USD = United States dollar.

Note: ASEAN-4 includes Indonesia (ID), Malaysia (MY), the Philippines (PH), and Thailand (TH).

Source: Asian Development Bank.

Despite significant growth in emerging market bonds, bond market research has primarily focused on developed bond markets in several areas, such as (i) return and volatility modeling of bond market spillovers and integration (Antonakakis and Vergos 2013; Claeys and Vašíček 2014); (ii) local and global macroeconomic fundamentals of the yield curve (Bhatt et al. 2017; Costantini and Sousa 2022; Dewachter et al. 2015); (iii) regularity and policy-related factors of bond yields (Afonso et al. 2018; Alter and Beyer 2014; de Santis 2014); and (iv) measures of uncertainty in bond market predictability (Bernal et al. 2016). In summary, previous research has indicated a substantial time variation in the co-movements and determinants of bond markets and economic fundamentals. Only a handful of papers have investigated the relationships between global and regional bond markets with emerging markets, particularly ASEAN-4 countries, despite the increasing importance of emerging market bonds. Therefore, in this paper, we address a long-standing disparity in the literature by evaluating the bond market spillover network.

The purpose of this study is twofold. We first examine the time–frequency return and volatility connectedness of government bond yields in ASEAN-4 markets (Thailand, Malaysia, Indonesia, and the Philippines); major regional markets (the People’s Republic of China [PRC], Japan, and the Republic of Korea); and major global markets (the European Union [EU], the United Kingdom [UK], and the United States [US]). Specifically, we investigate the risk spillover in ASEAN bond markets using the forecast error variance decomposition (FEVD) of a vector autoregression (VAR) model, as in Diebold and Yilmaz (2012, 2014), and wavelet-based, longer-horizon procedures, as in Baruník and Křehlík (2018), for the return and volatility spillover analysis. Both approaches enable us to distinguish the net transmitter and receiver of shocks among the underlying markets at various investment horizons. Second, we evaluate the primary drivers of ASEAN-4 bond markets by utilizing global and ASEAN-4 macroeconomic indicators and uncertainty measures in explaining variations in the spillover dynamics. This is crucial because understanding the impact of macroeconomic indicators and the uncertainty indices on emerging market bonds can assist regulators and policymakers in making timely decisions.

Our paper adds to the existing literature on several fronts. First, while the prior literature in this strand has predominantly concentrated on developed markets, our study focuses on the less-explored emerging market bonds. While the incorporation of developed market bonds adds diversification benefits to portfolios, it has reduced significantly since the global financial crisis (Agyei-Ampomah et al. 2014; Basher and Sadorsky 2016; Chaieb et al. 2021; Hunter and Simon 2005). Therefore, increased attention has been devoted to the connectedness dynamics of alternative asset classes and markets that may serve as a complementary source to attain diversification benefits. Hence, our study provides a new perspective on the connectedness dynamics of emerging market bonds.

Second, while prior studies on emerging market bonds have focused mainly on understanding the uncertainty and time-varying correlations with international markets, we evaluate the drivers of time variation of the bond return spillovers. Specifically, we examine the impact of both domestic macroeconomic fundamentals and global uncertainty measures in describing fluctuations in emerging market bond returns. This is of significant interest as investments in emerging market bonds have significantly increased in recent years and therefore there is increased urgency to evaluate the spillover dynamics.

Third, our study adds to the literature by evaluating the influence of different global uncertainty indices on the dynamic connectedness in ASEAN-4 bond markets. Therefore, our paper broadens the prior literature on spillover and connectedness dynamics (Andersson et al. 2008; Boubaker et al. 2019; Connolly et al. 2007; Piljak 2013) by constructing a bond market spillover network for both the pre-pandemic period and the global pandemic subsample. Additionally, we employ an autoregressive distributed lagged model (ARDL) to investigate the financial and economic drivers of the total, short-term, and long-term connectedness of ASEAN-4 bond markets. Understanding the key drivers of network spillovers among ASEAN-4 bond markets allows regulators and policymakers to devise a roadmap to disentangle the potential negative impacts from regional and global uncertainty measures.

Our empirical analysis based on the time domain return spillovers indicates strong inter-country connectedness among the underlying bond markets. Furthermore, the largest links are observed in the US market with the bond maturities of 7 and 10 years. However, for the case of ASEAN-4 and other developing countries, we do not report any significant connectedness flowing to or from these countries’ markets, indicating the strong diversification potential of investing in these markets. We report similar



findings for the full sample period over the frequency domain. However, the COVID-19 sample indicates an increase in interconnectedness among the underlying bond markets. The results from time domain volatility spillovers indicate relatively strong interconnectedness among the three underlying bond markets in the full-sample analysis. For the COVID-19 sample, we observe strong interconnectedness among ASEAN-4 markets with regional and global bond markets at the 10% and 25% threshold levels. In terms of dynamic interconnectedness among bond markets, we observe significant fluctuations in the total connectedness index for both returns and volatilities. Our findings indicate significant asymmetric connectedness among the underlying bond markets. Notably, they show that the periods of turmoil and economic prosperity significantly alter the spillover dynamics among these markets. Furthermore, our findings reveal that the time-varying return and volatility connectedness exhibit crisis jumps and different macroeconomic fundamentals exert an influence on the ASEAN-4 markets, which can rationalize the heterogeneity in the cross-border transmission of the US and Japan uncertainty shock to these ASEAN-4 markets.

The rest of the paper is structured as follows. Section 2 offers an overview of the employed frameworks. The data utilized are presented in section 3. The empirical findings of the paper are provided in section 4. Section 5 presents concluding remarks and policy strategies.

## 2. PILLOVER METHODOLOGY

In this section, we first introduce the network spillover approach of Diebold and Yilmaz (2012, 2014) to examine the return and volatility interconnectedness among the underlying bond markets. Later, we present the time–frequency network spillovers of Baruník and Křehlík (2018) to examine the long-run interconnectedness among the ASEAN-4, the regional, and the global bond markets.

### 2.1 Time Domain Network Spillover Framework

We follow the static and dynamic approach proposed by Diebold and Yilmaz (2012, 2014) to estimate the time domain network spillovers by utilizing a generalized VAR framework with  $p$  order as follows:

$$x_t = \sum_{i=1}^p \Phi_i x_{t-i} + \varepsilon_t, \quad \text{where } \varepsilon(0, \sigma),$$

where  $x_t = (R_{it}, \dots, R_{nt})$  is an  $n \times 1$  vector of underlying bond returns. Following Koop et al. (1996) and Pesaran and Shin (1998), we accomplish a variance error decomposition in the VAR framework. We let the H-step-ahead FEVD be denoted by

$$\theta_{ij}^g(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' \theta_h \sum e_j)^2}{\sum_{h=0}^{H-1} (e_i' \theta_h \sum \theta_h' e_i)},$$

where  $\theta_{ij}^g(H)$  is a generalized form of FEVD.

## 2.2 Frequency Domain Spillovers

Similar to the time domain connectedness, we begin with the VAR expressed in equation 1 to attain the frequential network connectedness. The connectedness dynamics of the frequency (short, medium, and long term) utilizes the spectral interpretation of variance decomposition based on frequency responses instead of impulse responses to shocks. Following Baruník and Křehlík (2018), we utilize a frequency response function,  $\Psi(e^{-i\omega}) = \sum_h e^{-i\omega h} \Psi_h$ , attained through Fourier transformation of the coefficient  $\Psi_h$ , with  $i = \sqrt{-1}$ . The frequential density of  $x_t$  at frequency  $\omega$  can be defined as a Fourier transform of MA( $\infty$ ) filtered series as  $S_x(\omega) = \sum_{h=-\infty}^{\infty} E(x_t x'_{t-h}) e^{-i\omega h} = \Psi(e^{-i\omega}) \Sigma \Psi'(e^{+i\omega})$ . The variable  $j$ 's impact on the variance error of variable  $i$  is estimated as follows:

$$\vartheta_{ij}(\omega) = \frac{1}{\sigma_{jj}} \times \frac{|(\Psi(e^{-i\omega}) \Sigma)_{ij}|^2}{(\Psi(e^{-i\omega}) \Sigma \Psi'(e^{i\omega}))_{ii}} = \frac{1}{\sigma_{jj}} \times \frac{\sum_{h=0}^{\infty} (\Psi(e^{-i\omega h}) \Sigma)_{ij}^2}{\sum_{h=0}^{\infty} (\Psi(e^{-i\omega h}) \Sigma \Psi'(e^{i\omega h}))_{ii}}$$

## 2.3 Time Domain and Frequency Domain Connectedness Framework

In **Table 1**, we present a comprehensive overview of the various measures of time domain (Diebold and Yilmaz 2012, 2014) and frequency domain (Baruník and Křehlík 2018) spillovers. It is obvious from Table 1 that both measures diverge purely in computations of the influence of series  $j$  to predict the variance error of series  $i$ .

**Table 1: Time and Frequency Domain Spillover Frameworks**

Measures of Spillovers	Temporal Domain Spillovers	Frequential Domain Spillovers
Pairwise spillover	$\theta_{ij} = \frac{\theta_{ij}}{\sum_{j=1}^n \theta_{ij}}$	$\vartheta_{ij}(\omega) = \frac{\vartheta_{ij}(\omega)}{\sum_{j=1}^n \vartheta_{ij}(\omega)}$
Total system spillover	$C = \frac{1}{n} \sum_{i \neq j} \sum_{j=1}^n \theta_{ij}$	$C(\omega) = \frac{1}{n} \sum_{i \neq j} \sum_{j=1}^n \vartheta_{ij}(\omega)$
Net pairwise spillover	$C_{ij,net} = \theta_{ij} - \theta_{ji}$	$C_{ij,net}(\omega) = \vartheta_{ij}(\omega) - \vartheta_{ji}(\omega)$
From others spillover	$C_{i \leftarrow \cdot} = \frac{1}{n} \sum_{j \neq i} \theta_{ij}$	$C_{i \leftarrow \cdot}(\omega) = \sum_{j \neq i} \vartheta_{ij}(\omega)$
To others spillover	$C_{i \rightarrow \cdot} = \frac{1}{n} \sum_{j \neq i} \theta_{ji}$	$C_{i \rightarrow \cdot}(\omega) = \sum_{j \neq i} \vartheta_{ji}(\omega)$
Net overall spillover	$C_{i,net} = \frac{1}{n} \sum_{j \neq i} \theta_{ji} - \frac{1}{n} \sum_{j \neq i} \theta_{ij}$	$C_{i,net}(\omega) = \sum_{j \neq i} \vartheta_{ji}(\omega) - \sum_{j \neq i} \vartheta_{ij}(\omega)$

Source: Authors' calculations based on Diebold and Yilmaz (2012, 2014) and Baruník and Křehlík (2018).

## 3. DATA AND SUMMARY STATISTICS

We utilize the daily bond data for six emerging markets (the PRC, India, Indonesia, Malaysia, the Philippines, and Thailand) for five different maturities that are among the primary constituents of the emerging market bond index. Furthermore, to examine the level of connectedness of these markets with the bond markets of developed countries, we use data for the EU, Japan, the Republic of Korea, the UK, and the US. All bond data were downloaded from *AsianBondsOnline*. To utilize the data in our analysis further, we calculate the simple returns of all the underlying series in our dataset.

**Table 1** provides an overview of the descriptive statistics of the emerging economies and developed bond markets for the whole sample period. In terms of emerging markets, we report that all the average return series are negative. The return series varies from  $-0.12\%$  for India with a 1-year bond maturity to  $-0.016\%$  for Malaysia with a 7-year bond maturity. Regarding the standard deviation, we report a minimum standard deviation of 1.53 for Thailand with a 1-year bond maturity and a maximum of 12.04 for the Philippines with a 1-year bond maturity. In relation to developed markets, we report a minimum return of  $-0.137$  for the European Union with a 10-year bond maturity and a maximum return of 0.005 for the US with a 1-year bond maturity, whereas the minimum and maximum standard deviations are 0.90 and 6.26 for Japan with a 1-year bond maturity and the Republic of Korea with a 1-year bond maturity, respectively. Despite negative mean returns for nearly all the underlying assets, the value of skewness is positive for most bonds across both the developing and the developed markets. Furthermore, the estimate of kurtosis is greater than 3 for all the underlying bonds, suggesting that the return series of the bonds across these markets are positively skewed and exhibit leptokurtic return distribution behavior, indicating asymmetrical return distributions and fatter tails than the normal distribution. A formal Jarque–Bera test affirms this non-Gaussian hypothesis and rejects the null hypothesis of normality at the 1% significance level. The estimates from augmented Dickey–Fuller and Phillips–Perron unit root tests indicate that most of the returns follow an  $I(1)$  process. Furthermore, the null hypothesis of stationarity is not rejected in the case of the Kwiatkowski–Phillips–Schmidt–Shin test. Additionally, the ARCH effect with five lags rejects the null hypothesis of homoscedasticity for most of the series.

In addition to the whole sample period, we estimate the descriptives for the COVID-19 subsample (**Table 2**). In contrast to the full sample, we observe a significant increase in the mean returns in the COVID-19 subsample. For instance, the average return for Indonesia has decreased from  $-0.081\%$  to  $-0.430\%$  for the 1-year bond maturity. Similar findings are reported for other emerging markets. In contrast to the emerging economies, our findings indicate an increase in the mean returns for the COVID-19 subsample. For example, the returns for the Republic of Korea increased from  $-0.077\%$  to  $0.02\%$  for the 1-year bond maturity. Similar movements in the returns are observed for other developed countries' bonds. Regarding the standard deviation, we do not observe a significant fluctuation in uncertainty between the two sample periods, with the exception of the Philippines. Similar to the full-sample findings, we report positive values of skewness and larger values of kurtosis, indicating deviation from Gaussianity. The Jarque–Bera test rejects the null hypothesis of normality, and the augmented Dickey–Fuller and Phillips–Perron tests indicate an  $I(1)$  process. The Kwiatkowski–Phillips–Schmidt–Shin test shows that the null hypothesis of stationarity is not rejected for most of the underlying series in our sample. In addition, the ARCH effect with five lags rejects the null hypothesis of homoscedasticity for the COVID-19 subsample.

**Table 3** shows the unconditional correlation from the Pearson, Kendall, and Spearman tests (so that we have both parametric and non-parametric estimates of correlation) between ASEAN-4 and other underlying bond markets for three different maturities. In general, we observe moderately weak to significantly strong dependence among the ASEAN-4 economies and other underlying economies in our sample. For instance, in the case of Thailand, we observe that the connectedness varies from  $-0.18$  for the US to 0.95 for the Republic of Korea for the 1-year maturity bond. This may be attributed to a disentangling short-term variation in Thailand that returns weak connectedness with the US. However, for the bonds with longer maturities, we observe a significant increase in connectedness across all the markets. Similar connectedness is observed between other ASEAN-4 economies and the developed markets. Overall, these

findings indicate strong long-run connectedness between ASEAN-4 economies and developed markets.

**Table 2: Descriptive Statistics for the Full Sample Period**

		Obs.	Mean (%)	Std Dev.	Skew.	Kurt.	JB	ADF	PP	KPSS	ARCH(5)
Indonesia	IDN1YR	2681	-0.08	8.56	0.22	20.4	0.00***	-21.63(4)***	-51.85***	0.18	192.2***
	IDN3YR	2681	-0.09	5.69	0.36	12.6	0.00***	-20.73(3)***	-41.52***	0.14	301.2***
	IDN5YR	2681	-0.07	5.69	0.15	14.5	0.00***	-21.09(3)***	-36.85***	0.11	301.1***
	IDN7YR	2681	-0.06	6.20	-0.01	12.2	0.00***	-25.39(2)***	-37.47***	0.07	154.7***
	IDN10YR	2681	-0.05	6.13	0.09	10.4	0.00***	-28.30(1)***	-36.16***	0.06	179***
Malaysia	MYS1YR	2681	-0.04	2.11	2.69	67.2	0.00***	-27.30(1)***	-38.75***	0.19	397.9***
	MYS3YR	2681	-0.02	2.56	2.70	48.5	0.00***	-24.22(2)***	-41.15***	0.06	356.7***
	MYS5YR	2681	-0.02	2.81	1.86	33.0	0.00***	-41.20(0)***	-41.51***	0.05	699.9***
	MYS7YR	2681	-0.02	2.94	0.86	20.3	0.00***	-42.06(0)***	-42.52***	0.05	379.9***
	MYS10YR	2681	-0.02	2.98	0.35	22.5	0.00***	-31.34(1)***	-44.90***	0.05	288.1***
Philippines	PHL01YR	2681	-0.03	12.04	0.50	27.4	0.00***	-18.67(6)***	-73.60***	0.1	473.8***
	PHL03YR	2681	-0.07	5.86	0.02	18.9	0.00***	-17.27(5)***	-57.29***	0.19	594.5***
	PHL05YR	2681	-0.07	11.20	0.40	865.7	0.00***	-50.75(1)***	-81.52***	0.16	1,111.2***
	PHL07YR	2681	-0.05	7.65	0.26	519.4	0.00***	-18.69(5)***	-66.04***	0.20	1,100.1***
	PHL10YR	2681	-0.07	6.19	0.18	140.2	0.00***	-17.83(5)***	-57.56***	0.26	975.2***
Thailand	THA1YR	2681	-0.09	1.53	-4.18	160.2	0.00***	-25.76(2)***	-54.39***	0.17	359.5***
	THA3YR	2681	-0.08	2.50	-0.22	37.7	0.00***	-18.77(6)***	-49.35***	0.07	30.1***
	THA5YR	2681	-0.07	3.46	1.07	52.3	0.00***	-21.55(5)***	-51.01***	0.07	427.1***
	THA7YR	2681	-0.07	3.46	-2.13	79.7	0.00***	-32.51(1)***	-47.25***	0.05	3.5
	THA10YR	2681	-0.07	3.81	-0.01	23.4	0.00***	-45.67(0)***	-45.78***	0.05	130.8***
PRC	CHN1YR	2681	-0.03	4.24	-0.57	21.2	0.00***	-46.96(0)***	-47.75***	0.06	7.5
	CHN3YR	2681	-0.03	3.25	1.47	23.8	0.00***	-46.26(0)***	-46.85***	0.07	10.7*
	CHN5YR	2681	-0.04	3.32	0.11	24.3	0.00***	-47.28(0)***	-47.48***	0.06	6.2
	CHN7YR	2681	-0.04	2.85	0.31	15.9	0.00***	-49.32(0)***	-49.40***	0.07	23.4***
	CHN10YR	2681	-0.04	2.70	-0.39	12.2	0.00***	-48.05(0)***	-48.08***	0.07	31.2***
India	IND1YR	2681	-0.12	8.46	4.70	140.7	0.00***	-35.91(2)***	-61.42***	0.12	74.9***
	IND3YR	2681	-0.09	5.64	4.56	134.7	0.00***	-51.76(0)***	-51.78***	0.10	16.5***
	IND5YR	2681	-0.08	5.31	1.23	26.2	0.00***	-52.85(0)***	-52.91***	0.10	178.6***
	IND7YR	2681	-0.06	5.59	0.86	46.3	0.00***	-38.89(1)***	-50.18***	0.08	198.5***
	IND10YR	2681	-0.06	5.16	0.29	21.4	0.00***	-39.42(1)***	-49.14***	0.06	267.4***
US	US1YR	2681	0.01	1.81	-1.51	21.8	0.00***	-18.96(3)***	-46.70***	0.55**	679.1***
	US3YR	2681	-0.01	3.45	-0.30	7.1	0.00***	-54.70(0)***	-54.61***	0.20	314.6***
	US5YR	2681	-0.04	4.37	-0.10	6.0	0.00***	-56.31(0)***	-56.24***	0.15	299.3***
	US7YR	2681	-0.06	4.80	0.13	7.3	0.00***	-56.25(0)***	-56.25***	0.13	340.9***
	US10YR	2681	-0.08	4.88	0.24	8.5	0.00***	-55.72(0)***	-55.84***	0.12	410.7***
European Union	EU1YR	2681	-0.08	1.78	-0.30	27.1	0.00***	-31.37(1)***	-46.46***	0.45*	510.1***
	EU3YR	2681	-0.11	2.75	-0.22	10.7	0.00***	-51.37(0)***	-51.59***	0.65**	339.9***
	EU5YR	2681	-0.12	3.54	-0.01	7.4	0.00***	-51.90(0)***	-52.11***	0.50**	297.5***
	EU7YR	2681	-0.13	3.80	0.12	6.9	0.00***	-51.42(0)***	-51.59***	0.42*	218.1***
	EU10YR	2681	-0.14	4.06	0.23	6.4	0.00***	-51.66(0)***	-51.82***	0.29	202.1***
Japan	JPN1YR	2681	-0.01	0.90	0.44	16.3	0.00***	-61.05(0)***	-61.02***	0.11	111.8***
	JPN3YR	2681	-0.01	0.97	0.73	15.1	0.00***	-53.37(0)***	-53.50***	0.11	262.9***
	JPN5YR	2681	-0.02	1.28	0.59	10.9	0.00***	-55.76(0)***	-56.28***	0.15	340.6***
	JPN7YR	2681	-0.04	1.75	0.86	10.2	0.00***	-55.32(0)***	-55.93***	0.17	307.8***
	JPN10YR	2681	-0.05	1.64	0.48	10.7	0.00***	-55.66(0)***	-56.21***	0.30	240.5***
Republic of Korea	KOR1YR	2681	-0.08	6.26	-0.70	96.1	0.00***	-32.98(3)***	-85.68***	0.09	675.1***
	KOR3YR	2681	-0.07	3.27	-0.15	34.7	0.00***	-56.09(0)***	-56.45***	0.29	21.4***
	KOR5YR	2681	-0.08	3.05	-0.45	17.4	0.00***	-49.93(0)***	-49.97***	0.31	16.3***
	KOR10YR	2681	-0.09	3.83	-9.75	299.7	0.00***	-50.15(0)***	-50.19***	0.21	0.03
United Kingdom	UK1YR	2681	-0.01	2.58	1.29	32.7	0.00***	-57.12(0)***	-57.73***	0.12	33.2***
	UK3YR	2681	-0.04	3.56	0.05	8.8	0.00***	-53.86(0)***	-54.32***	0.24	77.1***
	UK5YR	2681	-0.06	4.11	0.03	7.3	0.00***	-52.34(0)***	-52.54***	0.18	67.2***
	UK7YR	2681	-0.09	4.47	0.03	5.8	0.00***	-52.70(0)***	-52.95***	0.19	99.1***
	UK10YR	2681	-0.11	4.70	0.14	6.0	0.00***	-53.38(0)***	-53.66***	0.17	76.2***

Abbreviations list: 01YR, 03YR, 05YR, 07YR, and 10YR correspond to the bond maturities of 1-, 3-, 5-, 7-, and 10-year horizons, respectively, for the corresponding economies. JB, ADF, PP, KPSS, and ARCH represent the Jarque–Bera normality, augmented Dickey–Fuller, Phillips–Perron, Kwiatkowski–Phillips–Schmidt–Shin, and autoregressive conditional heteroscedasticity tests, respectively.

**Table 3: Descriptive Statistics for the COVID-19 Sample Period**

		Obs.	Mean (%)	Std Dev.	Skew.	Kurt	JB	ADF	PP	KPSS	ARCH(5)
Indonesia	IDN1YR	490	-0.43	6.81	1.33	24.8	0.00***	-13.15(1)***	-23.13***	0.1	100.11***
	IDN3YR	490	-0.34	5.63	1.45	21.8	0.00***	-7.90(3)***	-22.17***	0.09	115.29***
	IDN5YR	490	-0.25	5.25	1.89	18.6	0.00***	-7.75(3)***	-16.37***	0.08	140.40***
	IDN7YR	490	-0.19	5.47	1.61	17.2	0.00***	-15.54(0)***	-15.59***	0.08	159.09***
	IDN10YR	490	-0.14	5.37	1.67	17.0	0.00***	-15.76(0)***	-15.72***	0.07	157.32***
Malaysia	MYS1YR	490	-0.22	2.19	-0.04	26.6	0.00***	-14.57(0)***	-14.74***	0.66**	60.54***
	MYS3YR	490	-0.04	3.61	2.23	33.1	0.00***	-10.17(3)***	-17.11***	0.52**	158.84***
	MYS5YR	490	-0.01	4.23	2.03	26.6	0.00***	-18.27(0)***	-18.54***	0.39*	160.67***
	MYS7YR	490	0.02	4.10	1.05	16.1	0.00***	-17.76(0)***	-17.95***	0.31	99.90***
	MYS10YR	490	0.05	3.95	0.31	13.3	0.00***	-18.53(0)***	-18.81***	0.23	45.82***
Philippines	PHL01YR	490	-0.34	3.96	0.20	12.0	0.00***	-6.26(4)***	-18.61***	0.59**	124.91***
	PHL03YR	490	-0.12	4.39	0.03	17.1	0.00***	-8.10(3)***	-14.09***	0.48**	31.81***
	PHL05YR	490	0.03	5.16	-0.93	16.4	0.00***	-14.70(0)***	-15.01***	0.50**	16.04***
	PHL07YR	490	0.07	5.44	-1.08	14.9	0.00***	-15.28(0)***	-15.51***	0.49**	12.16**
	PHL10YR	490	0.07	5.70	-0.29	19.1	0.00***	-16.80(0)***	-17.29***	0.44*	4.41
Thailand	THA1YR	490	-0.14	1.17	-3.22	72.4	0.00***	-11.40(3)***	-19.65***	1.13***	67.60***
	THA3YR	490	-0.09	2.08	-0.52	15.7	0.00***	-12.48(1)***	-18.83***	0.32	78.48***
	THA5YR	490	0.03	2.96	0.07	23.0	0.00***	-17.70(0)***	-17.68***	0.3	83.23***
	THA7YR	490	0.06	2.54	1.06	70.2	0.00***	-11.16(3)***	-19.56***	0.04	34.64***
	THA10YR	490	0.09	4.22	2.13	24.6	0.00***	-21.66(0)***	-21.69***	0.07	145.55***
PRC	CHN1YR	490	-0.02	4.26	1.59	24.5	0.00***	-18.49(0)***	-18.69***	0.12	0.18
	CHN3YR	490	-0.06	3.40	1.22	16.6	0.00***	-18.77(0)***	-19.04***	0.19	17.54***
	CHN5YR	490	-0.07	3.34	0.02	7.9	0.00***	-19.53(0)***	-19.65***	0.17	33.13***
	CHN7YR	490	-0.05	2.84	0.55	10.3	0.00***	-20.90(0)***	-20.90***	0.16	10.60*
	CHN10YR	490	-0.07	2.57	0.13	7.1	0.00***	-21.60(0)***	-21.60***	0.19	22.70***
India	IND1YR	490	-0.22	6.25	1.02	20.3	0.00***	-17.42(1)***	-27.43***	0.66**	3.29
	IND3YR	490	-0.19	6.27	-0.02	17.5	0.00***	-20.09(0)***	-20.25***	0.34	0.37
	IND5YR	490	-0.12	5.32	0.52	13.1	0.00***	-14.69(1)***	-21.62***	0.23	31.76***
	IND7YR	490	-0.06	4.78	0.97	15.5	0.00***	-15.46(1)***	-23.52***	0.15	50.33***
	IND10YR	490	-0.01	4.24	-0.99	18.6	0.00***	-23.82(0)***	-24.02***	0.25	26.04***
US	US1YR	490	-0.24	2.19	-3.47	31.9	0.00***	-8.17(1)***	-13.86***	1.04***	208.42***
	US3YR	490	-0.13	3.39	-0.48	15.8	0.00***	-23.32(0)***	-23.96***	1.41***	175.84***
	US5YR	490	-0.08	4.30	-0.12	12.6	0.00***	-25.37(0)***	-25.80***	1.04***	144.52***
	US7YR	490	-0.07	4.97	0.58	17.8	0.00***	-25.33(0)***	-25.69***	0.68**	118.43***
	US10YR	490	-0.08	5.40	0.77	18.3	0.00***	-25.11(0)***	-25.44***	0.47**	120.12***
European Union	EU1YR	490	-0.01	1.16	0.96	13.3	0.00***	-12.33(1)***	-19.31***	0.03	92.17***
	EU3YR	490	-0.01	2.23	0.22	10.5	0.00***	-20.55(0)***	-20.55***	0.05	42.04***
	EU5YR	490	0.01	2.80	0.56	10.3	0.00***	-20.40(0)***	-20.38***	0.08	85.85***
	EU7YR	490	0.01	3.13	0.64	9.0	0.00***	-20.07(0)***	-20.01***	0.08	98.91***
	EU10YR	490	0.01	3.45	0.76	9.5	0.00***	-20.14(0)***	-20.09***	0.09	121.19***
Japan	JPN1YR	490	0.01	0.97	0.38	7.6	0.00***	-29.29(0)***	-29.41***	0.05	46.07***
	JPN3YR	490	0.01	1.01	1.59	19.0	0.00***	-26.97(0)***	-27.23***	0.04	18.54***
	JPN5YR	490	0.01	1.19	1.48	18.2	0.00***	-11.11(2)***	-26.44***	0.01	96.43***
	JPN7YR	490	0.01	1.57	1.26	19.8	0.00***	-11.60(3)***	-23.30***	0.01	93.36***
	JPN10YR	490	0.02	1.30	2.54	26.8	0.00***	-11.16(2)***	-27.04***	0.02	103.82***
Republic of Korea	KOR1YR	490	0.02	4.85	-1.69	63.2	0.00***	-29.10(0)***	-29.74***	0.48**	88.70***
	KOR3YR	490	0.11	3.73	2.49	49.8	0.00***	-25.45(0)***	-25.68***	0.36*	0.94
	KOR5YR	490	0.11	2.74	1.88	22.2	0.00***	-21.46(0)***	-21.47***	0.2	6.06
	KOR10YR	490	0.12	3.44	0.92	19.2	0.00***	-25.15(0)***	-24.94***	0.1	13.44**
United Kingdom	UK1YR	490	-0.02	2.98	-0.70	18.9	0.00***	-21.91(0)***	-22.19***	0.62**	33.45***
	UK3YR	490	0.05	3.21	-0.30	10.0	0.00***	-21.63(0)***	-21.99***	0.64**	66.45***
	UK5YR	490	0.05	3.51	0.36	11.3	0.00***	-21.43(0)***	-21.64***	0.50**	55.59***
	UK7YR	490	0.04	3.89	0.81	12.9	0.00***	-21.72(0)***	-21.82***	0.27	78.17***
	UK10YR	490	0.04	4.22	1.17	13.9	0.00***	-22.03(0)***	-22.11***	0.24	46.32***

Abbreviations list: See the notes in Table 2.

**Table 3: Correlation Structure of ASEAN-4 with Other Financial Markets**

		1-Year Maturity			5-Year Maturity			10-Year Maturity		
		Pearson	Kendall	Spearman	Pearson	Kendall	Spearman	Pearson	Kendall	Spearman
Indonesia	US	0.30***	0.25***	0.35***	0.54***	0.36***	0.56***	0.44***	0.33***	0.52***
	EU	-0.01	0.12***	0.15***	-0.02	0.08	0.08	-0.02	0.06	0.05
	UK	0.44***	0.29***	0.42***	0.44***	0.29***	0.47***	0.25***	0.17***	0.26***
	JPN	-0.11***	-0.11***	-0.17***	-0.12***	-0.07	-0.10***	-0.16***	-0.06	-0.10***
	CHN	0.19***	0.12***	0.16***	0.21***	0.12***	0.20***	0.19***	0.10***	0.16***
	KOR	0.03	0.07	0.10***	-0.14***	-0.05	-0.08	-0.03	-0.01	-0.02
	IND	0.49***	0.29***	0.39***	0.30***	0.21***	0.28***	0.22***	0.18***	0.23***
Malaysia	US	0.45***	0.35***	0.50***	0.75***	0.61***	0.81***	0.84***	0.61***	0.81***
	EU	0.25***	0.08	0.14***	0.33***	0.22***	0.33***	0.39***	0.29***	0.40***
	UK	0.64***	0.38***	0.52***	0.67***	0.44***	0.61***	0.59***	0.36***	0.49***
	JPN	0.15***	-0.07	-0.07	0.17***	0.04	0.07	0.15***	0.10***	0.16***
	CHN	0.43***	0.28***	0.45***	0.46***	0.34***	0.52***	0.47***	0.32***	0.46***
	KOR	0.49***	0.21***	0.35***	0.35***	0.19***	0.29***	0.40***	0.21***	0.32***
	IND	0.73***	0.27***	0.36***	0.66***	0.31***	0.44***	0.57***	0.31***	0.43***
Philippines	US	0.84***	0.61***	0.80***	0.71***	0.45***	0.59***	0.61***	0.35***	0.49***
	EU	-0.18***	-0.12***	-0.16***	0.20***	0.17***	0.25***	0.29***	0.19***	0.27***
	UK	0.62***	0.40***	0.57***	0.25***	0.17***	0.25***	0.24***	0.13***	0.18***
	JPN	-0.33***	-0.21***	-0.33***	0.00	0.03	0.03	0.16***	0.12***	0.17***
	CHN	-0.15***	-0.06	-0.09***	0.13***	0.11***	0.18***	0.20***	0.17***	0.25***
	KOR	-0.05	0.03	0.03	0.25***	0.24***	0.35***	0.45***	0.33***	0.45***
	IND	-0.03	-0.12***	-0.15***	0.28***	0.18***	0.24***	0.32***	0.19***	0.27***
Thailand	US	-0.18***	-0.08***	-0.14***	0.12***	0.10***	0.13***	0.63***	0.43***	0.60***
	EU	0.83***	0.64***	0.83***	0.86***	0.75***	0.92***	0.91***	0.76***	0.93***
	UK	0.34***	0.18***	0.29***	0.74***	0.55***	0.74***	0.92***	0.76***	0.93***
	JPN	0.72***	0.50***	0.69***	0.82***	0.59***	0.79***	0.84***	0.64***	0.85***
	CHN	0.44***	0.32***	0.47***	0.60***	0.42***	0.61***	0.76***	0.54***	0.76***
	KOR	0.95***	0.78***	0.92***	0.90***	0.69***	0.88***	0.89***	0.69***	0.89***
	IND	0.84***	0.65***	0.85***	0.89***	0.70***	0.89***	0.88***	0.71***	0.89***

Note: This table presents the correlation structure between the underlying markets.

## 4. EMPIRICAL FINDINGS

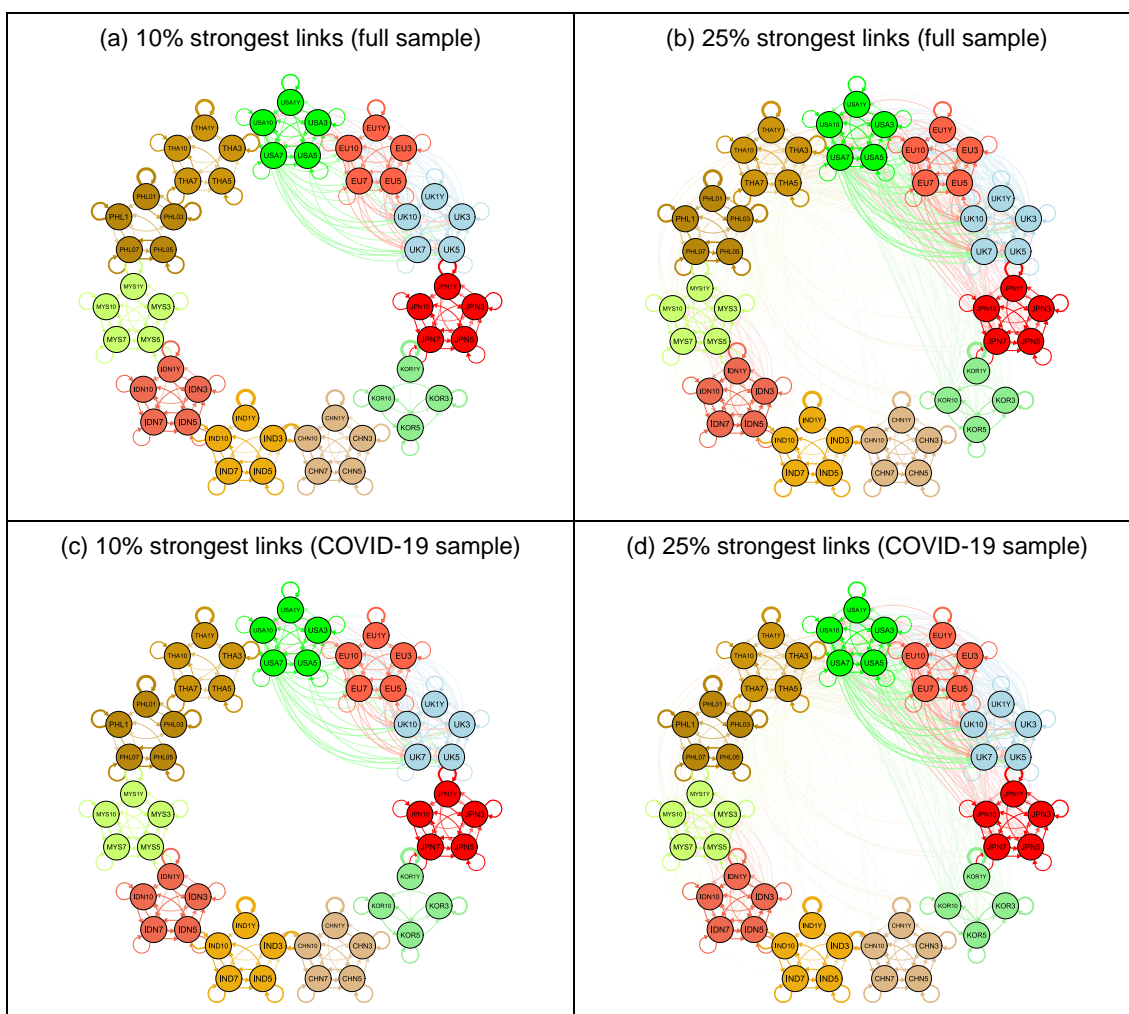
We first examine the return network connectedness among the underlying bond markets using the Baruník and Křehlík (2018) and Diebold and Yilmaz (2014) network spillover approaches. Furthermore, we examine the spillover dynamics within ASEAN-4 bond markets. Later, we utilize these approaches to evaluate the volatility connectedness among all the assets in our sample. In addition, we estimate the dynamic return and uncertainty spillovers to examine the overall linkage structure. We then employ an ARDL framework to examine the role of macroeconomic fundamentals and global uncertainty measures in network connectedness.

### 4.1 Return Connectedness

Using the Diebold and Yilmaz (2014) spillover framework, we first examine the return network connectedness among ASEAN-4, regional, and global bond markets for the full and COVID-19 sample periods. Panels A and C of **Figure 3** provide the 10% strongest links for the full sample, respectively, and Panels B and D provide the return network connectedness of the 25% strongest links for the full sample and COVID-19, respectively. In Panel A, we observe strong inter-country connectedness among the underlying bond markets. More specifically, global (US, EU, and UK) markets exhibit strong interconnectedness with each other. It is noteworthy that the largest links flow from the US market with the bond maturities of 7 and 10 years. However, we do not

observe any significant connectedness between the developed economies and the ASEAN-4 and other developing countries. This is indicative of diversification potential for various market participants by holding assets in both the developed economies and the developing nations’ bonds. Similar findings are observed for the COVID-19 sample period in Panel C, exhibiting strong interconnectedness among the developed countries’ bond markets. However, despite an increase in the linkage structure during the COVID-19 pandemic among various asset classes (Ahundjanov et al. 2021; Chang et al. 2020; Corbet et al. 2020, 2021; Guo et al. 2021; Salisu et al. 2020; Sharif et al. 2020; Zhang and Hamori 2021), we report a strong disconnection between ASEAN-4 and emerging markets with developed countries’ bond markets, indicating strong diversification potential for investments for various market participants.

**Figure 3: Return Connectedness Network among ASEAN-4, Regional, and Global Bond Markets**



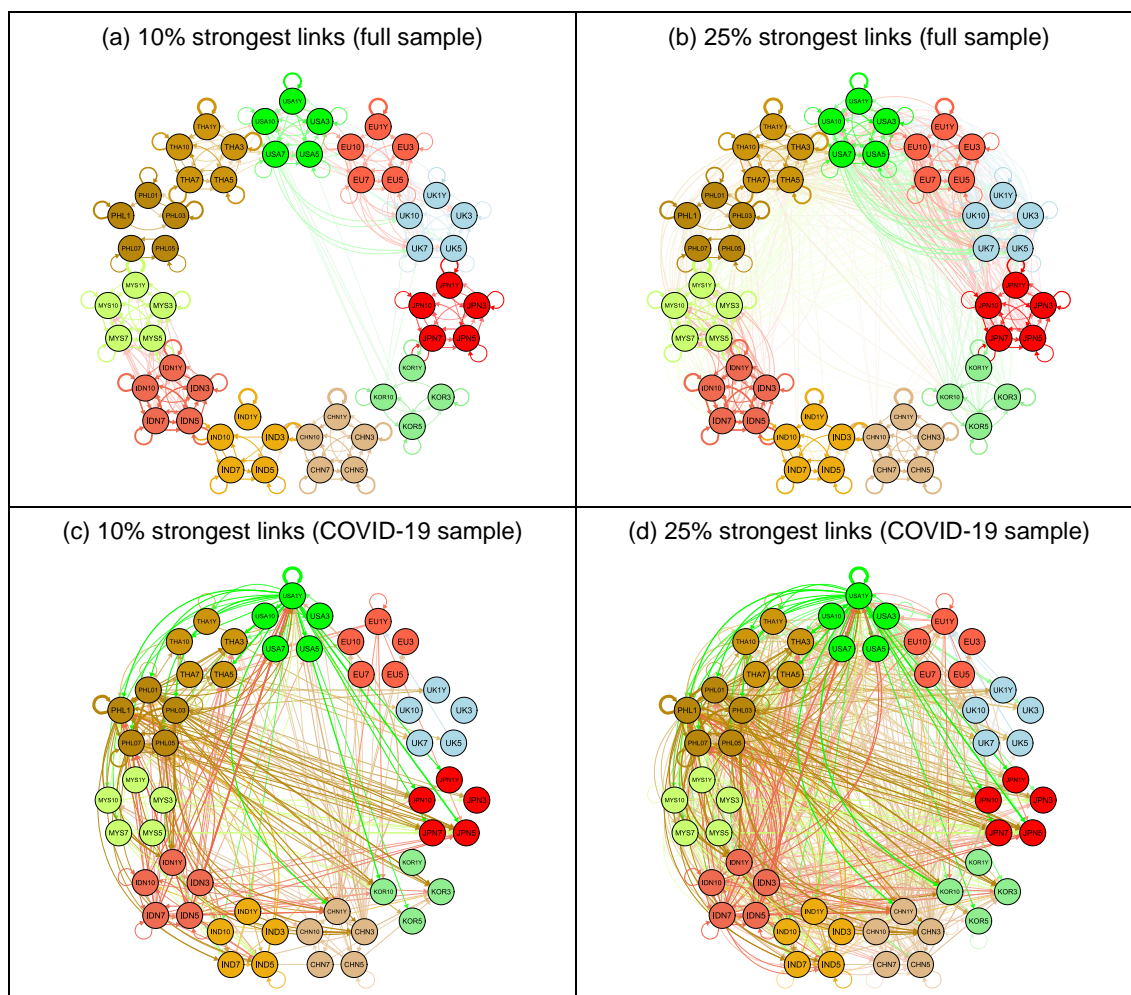
Abbreviations list: See the notes in Table 2.

Note: The total network connectedness is estimated utilizing the Diebold and Yilmaz (2012) framework.

Panels A and C provide an overview of the connectedness dynamics with the 10% strongest links. To provide a detailed understanding of the connectedness, we estimate and present the 25% strongest links among the underlying bond markets in Panels B and D. In terms of the 25% connectedness threshold level, we observe an increase in

the interconnectedness among developed markets. Furthermore, we report increased (albeit weak) linkages flowing from and to developing countries. A similar increase in the interconnectedness among markets is observed for the case of the COVID-19 sample in Panel D. Notably, we observe strong within-ASEAN-4 linkages together with an increase in the linkages of the Philippines and Thailand with other developed countries. Overall, these findings indicate that the return-level spillovers among ASEAN-4 and developing economies are characterized by weak interconnectedness and exhibit potential for diversification for various market participants.

**Figure 4: Long-Run Connectedness Network among ASEAN-4, Regional, and Global Bond Markets**



Abbreviations list: See the notes in Table 2.

Notes: Long-run connectedness networks are estimated using 22–252-day frequency within the Baruník and Křehlík (2018) framework.

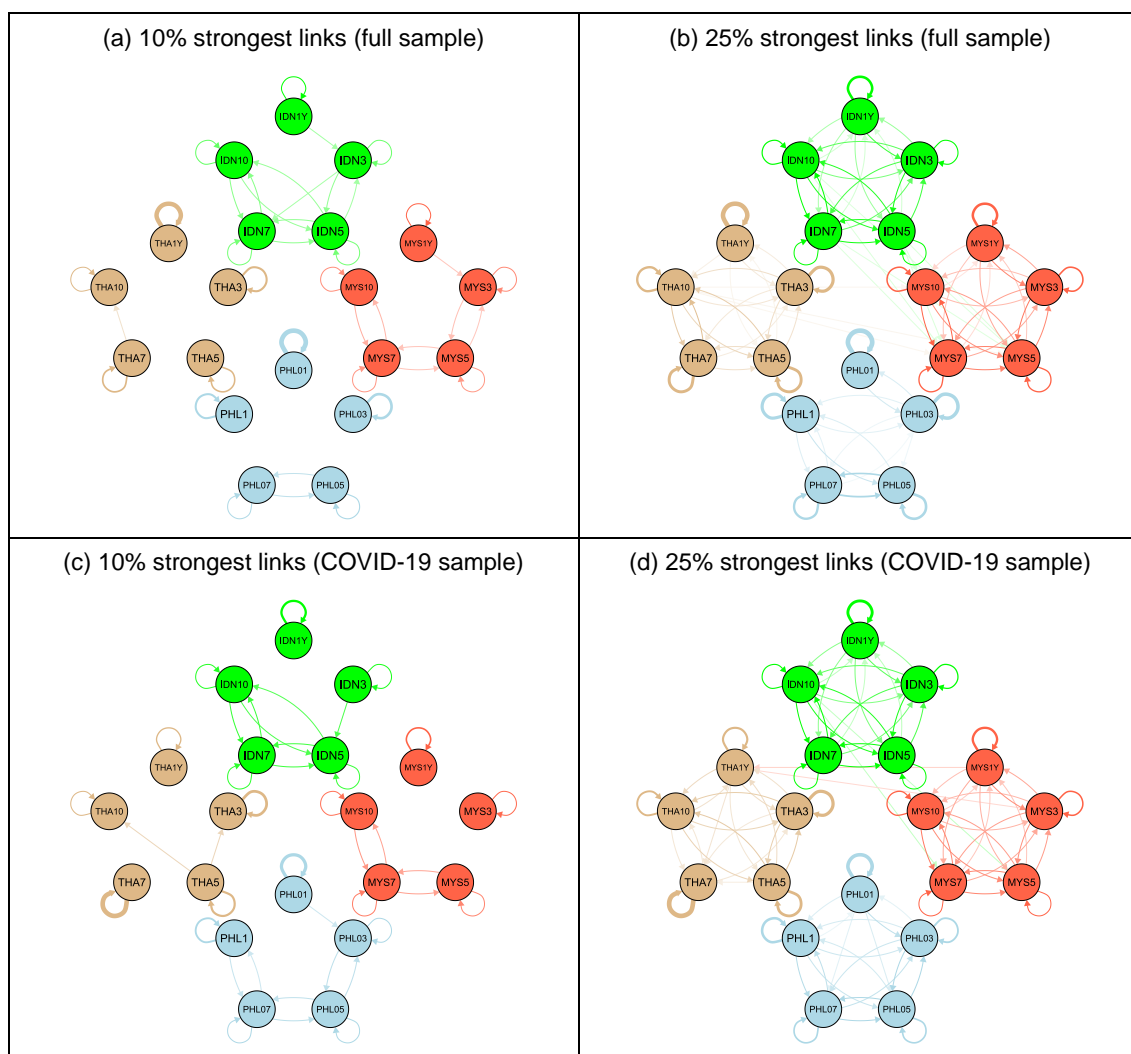
In addition to return-level connectedness, we estimate the long-term connectedness network among ASEAN-4, regional, and global bond markets. **Figure 4** presents the long-run network connectedness using 22–252-day frequency, estimated using the Baruník and Křehlík (2018) time–frequency spillover approach among the underlying bond markets. Similar to the return-level connectedness, we do not observe significant spillovers among the underlying series for the full sample period when the threshold level is 10%. However, the COVID-19 sample shows increased interconnectedness



among the underlying series with a 10% threshold level. This may be attributed to the fact that the market perceived that the pandemic’s outbreak would affect all the underlying markets over the long-run horizon.

Similar to the return-level connectedness, we estimate the long-run network connectedness among the assets with a 25% threshold level. In terms of the higher threshold, we observe a relative increase in intergroup connectedness among the markets for the full-sample analysis, whereas, for the COVID-19 sample with a 25% threshold level, we observe that the connectedness pattern in the long run shows strong intergroup connectedness and weak intra-group spillovers. Overall, we report strong inter-country connectedness except for Malaysia–Indonesia and the Republic of Korea–US. Furthermore, the global (EU, UK, and US) markets show strong interconnectedness. In addition, during the pandemic, ASEAN-4 exhibited stronger integration with global and regional markets. The strong intergroup connectedness among markets concurs with the results of Baruník and Křehlík (2018) and Baruník et al. (2015), who reported strong spillovers for the long-run horizon.

**Figure 5: Return Connectedness Network among ASEAN-4 Bond Markets**

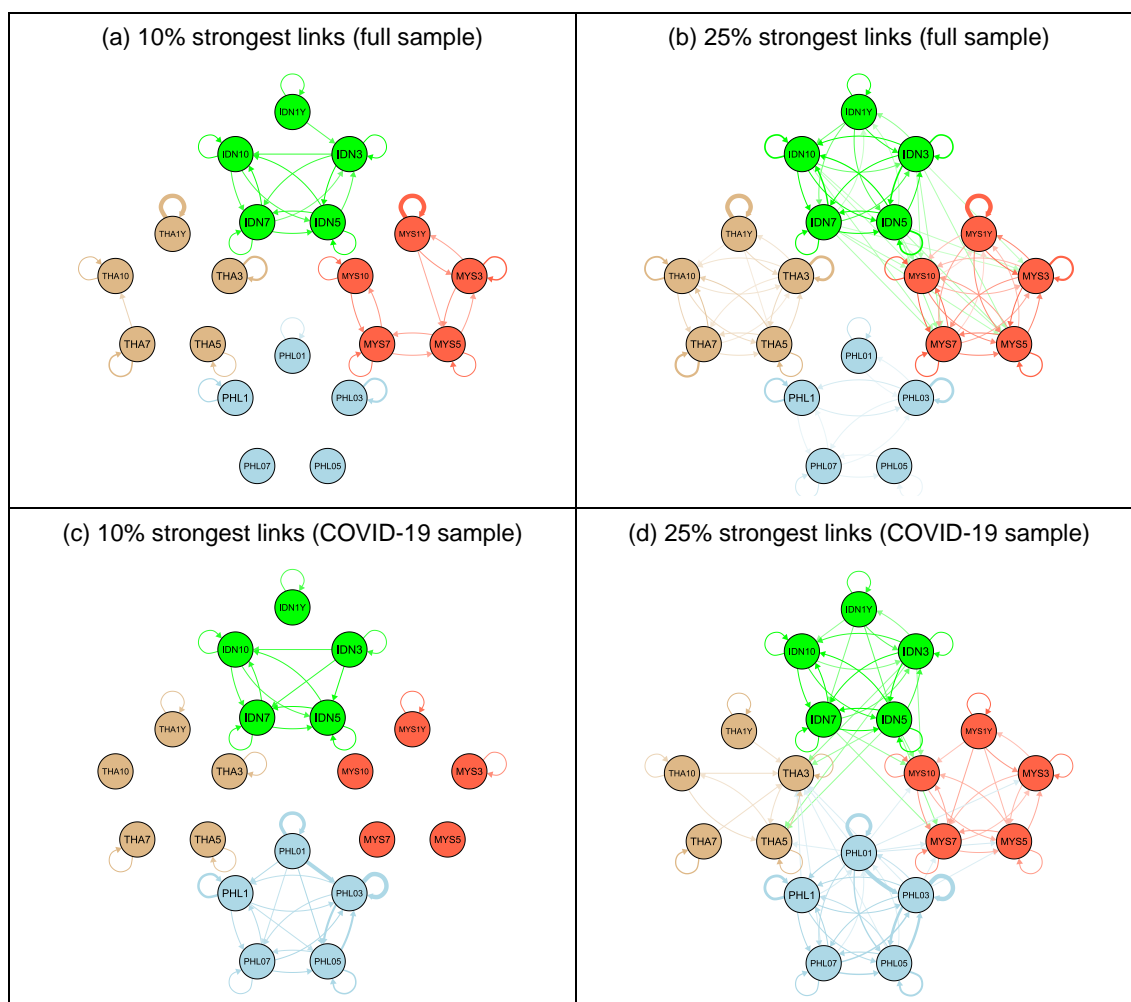


Abbreviations list: See the notes in Table 2.

Note: Total network connectedness is estimated utilizing the Diebold and Yilmaz (2012) framework.

Both the return-level and long-run network connectedness indicate weak to moderate interconnectedness among the ASEAN-4 bond markets. Therefore, to attain a better overview of the network connectedness among ASEAN-4 bond markets, we estimate the Baruník and Křehlík (2018) and Diebold and Yilmaz (2014) spillover measures for these markets. **Figures 5 and 6** provide an overview of the network connectedness among ASEAN-4 bond markets for the returns and long-run network connectedness, respectively. These findings corroborate the earlier findings of Agur et al. (2019); Agyei-Ampomah et al. (2014); Ahmad et al. (2018); Bhattacharyay (2013); Chaieb et al. (2021); and Park (2017). Specifically, the primary source of connectedness is the within-country variations in other bonds.

**Figure 6: Long-Run Connectedness Network among ASEAN-4 Bond Markets**



Abbreviations list: See the notes in Table 2.

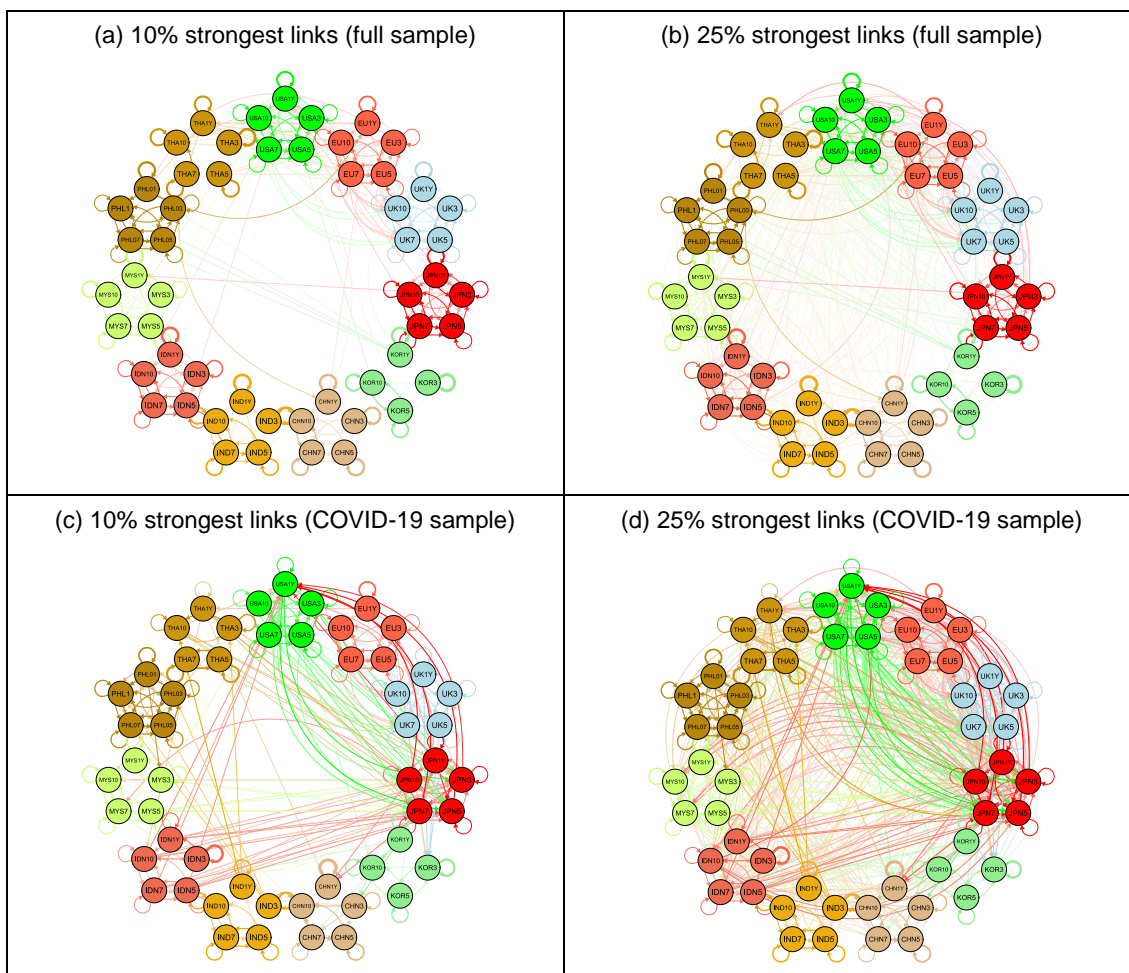
Notes: Long-run connectedness networks are estimated using the Baruník and Křehlík (2018) approach.

## 4.2 Volatility Connectedness

To provide a comprehensive understanding of the spillovers over the second order of returns, we estimate the interconnectedness among the underlying series for volatilities and long-run volatilities. **Figure 7** presents the volatility network connectedness among ASEAN-4, regional, and global bond markets. We estimate the volatilities based on

the ARMA(1,0)GARCH(1,1) process.<sup>2</sup> In terms of base-level volatility connectedness, following Diebold and Yilmaz (2014), we observe relatively strong interconnectedness among the three underlying bond markets. Specifically, we observe some connectedness for the PRC–Philippines, Japan–Malaysia, EU–Philippines, Republic of Korea–Philippines, and US–Indonesia pairs. Furthermore, we observe strong inter-country connectedness among global bond markets for both the 10% and the 25% threshold level. In terms of volatility connectedness for the COVID-19 sample, we report strong linkages among the three underlying bond markets. Specifically, ASEAN-4 markets are more strongly integrated with global and regional markets. For instance, the Japan–Indonesia, Japan–Malaysia, and India–Philippines pairs exhibit strong interconnectedness with each other over the 10% and 25% strongest links. Overall, these findings indicate that the uncertainty diversification potential relatively deteriorates; however, it persists for the COVID-19 sample.

**Figure 7: Volatility Connectedness Network among ASEAN-4, Regional, and Global Bond Markets**



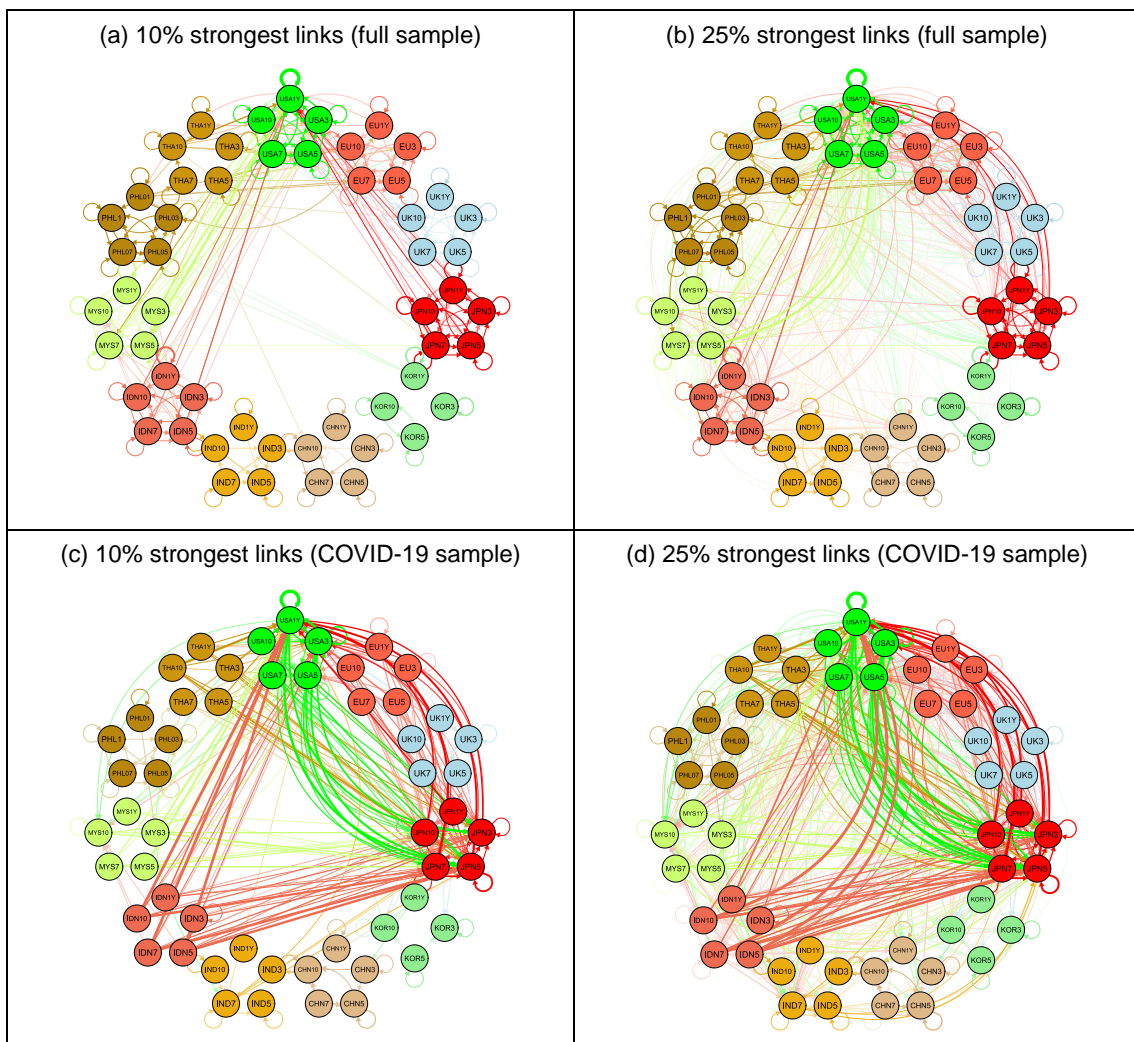
Abbreviations list: See the notes in Table 2.

Note: Volatility network connectedness is estimated utilizing Diebold and Yilmaz’s (2012) framework.

<sup>2</sup> The GARCH framework is selected based on the lowest Akaike Information Criterion (AIC) values from three different GARCH families: EGARCH, GJR-GARCH, and GARCH. For brevity, we chose not to report the results of the GARCH-type frameworks. However, these estimates are available from the corresponding author upon request.

In addition to the base-level volatility spillovers, we examine the long-run volatility network connectedness among the three underlying markets (**Figure 8**). The findings regarding the long-run volatility spillovers (Baruník and Křehlík 2018) corroborate the long-run return network connectedness findings. In terms of long-run uncertainty connectedness, we observe several strong links at the 10% and 25% threshold levels. Specifically, the US–Malaysia, Indonesia–US, Japan–US, EU–Philippines, and Republic of Korea–Philippines pairs exhibit the strongest linkage structure with each other. For the COVID-19 sample, we observe strong interconnectedness among ASEAN-4, regional, and global bond markets at the 10% and 25% threshold levels. This may be attributed to the long-run uncertainty caused by the COVID-19 pandemic, which resulted in increased connectedness among all the underlying markets.

**Figure 8: Long-Run Volatility Connectedness Network among ASEAN-4, Regional, and Global Bond Markets**

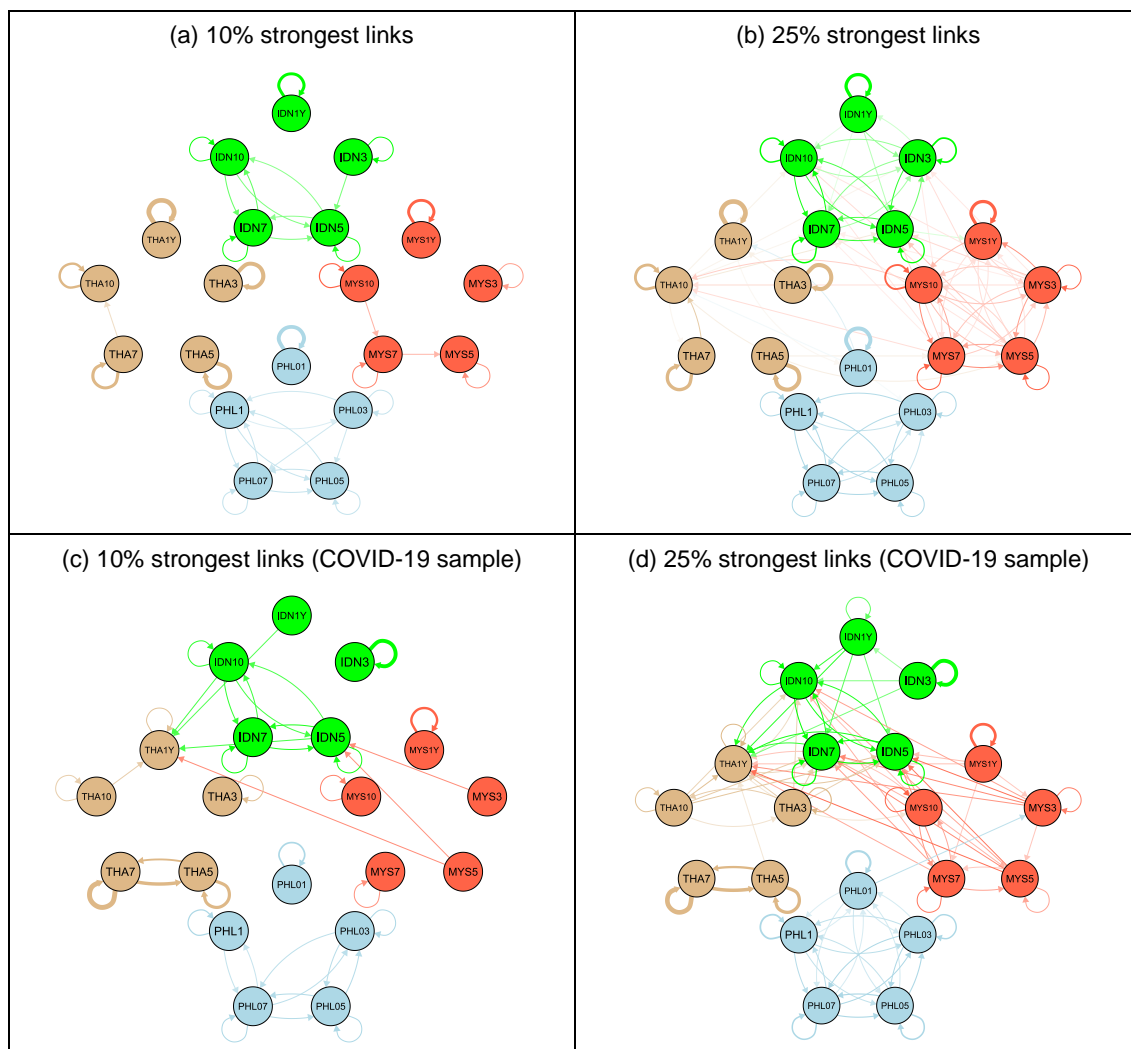


Abbreviations list: See the notes in Table 2.

Note: Long-run connectedness networks are estimated using the Baruník and Křehlík (2018) approach.

To provide a more comprehensive overview of the uncertainty connectedness among markets, we estimate the Baruník and Křehlík (2018) and Diebold and Yilmaz (2014) spillover frameworks for the long-run and base-level uncertainty among the underlying ASEAN-4 bond markets (**Figures 9 and 10**). In terms of the 10% strongest links for volatility network connectedness at the base level, we report Malaysia and Indonesia as the primary transmitters of uncertainties to the 1-year bond maturity issued by Thailand. Similarly, for the COVID-19 sample over the long-run horizon, we report Malaysia and Indonesia as the transmitters of spillovers to Thailand for bond maturities of 1 and 3 years. Furthermore, our findings indicate no linkages between the Philippines and other ASEAN-4 markets. This is significant as the Philippines can therefore serve as a market for investors' portfolio diversification.

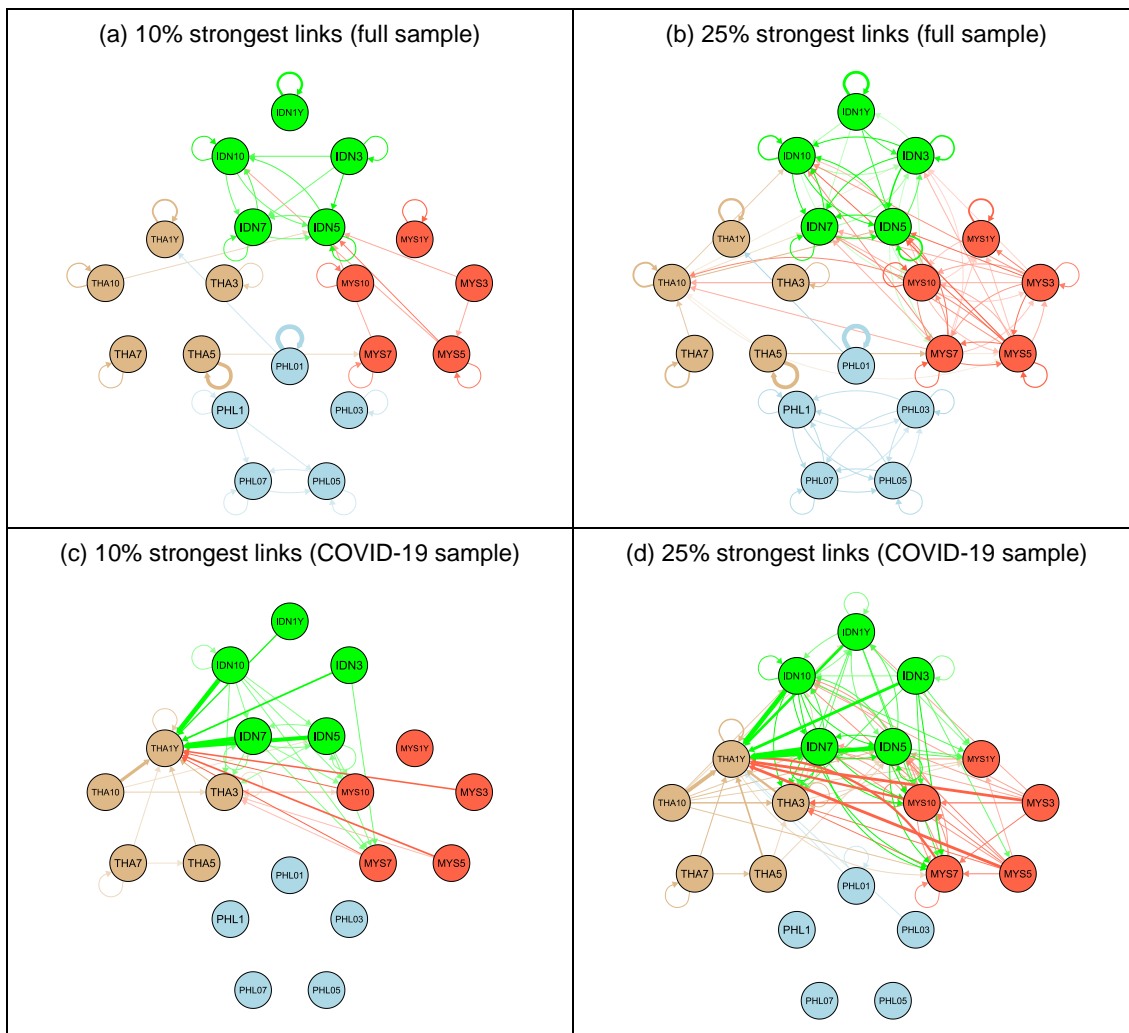
**Figure 9: Volatility Connectedness Network among ASEAN-4 Bond Markets**



Abbreviations list: See the notes in Table 2.

Note: The volatility connectedness network is estimated using Diebold and Yilmaz's (2012) framework.

**Figure 10: Long-Run Volatility Connectedness Network among ASEAN-4, Regional, and Global Bond Markets**



Abbreviations list: See the notes in Table 2.

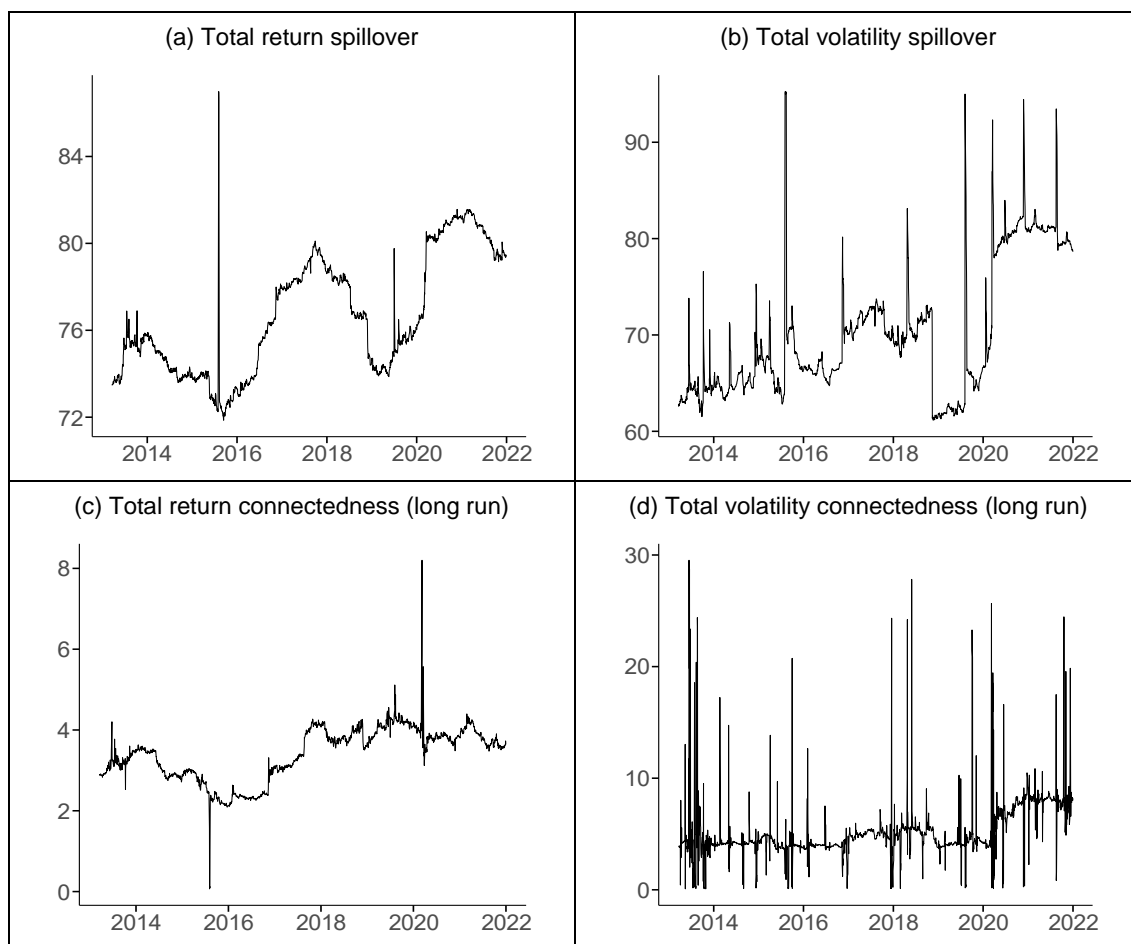
Note: Long-run connectedness networks are estimated using the Barunik and Křehlík (2018) approach.

### 4.3 Dynamic Spillovers

The static network return and volatility connectedness gives an overview of the spillover dynamics. However, the static analysis does not consider the dynamic nature of the connectedness (Badshah et al. 2018; Bekiros et al. 2017; Berger and Uddin 2016; Dahl et al. 2020; Lundgren et al. 2018; Yahya et al. 2019, 2020, 2021). Therefore, we provide an estimate of time-varying return and volatility connectedness at the time and frequency domain horizons (**Figure 11**). In terms of dynamic connectedness among the bond markets, we observe significant fluctuations in the total connectedness index for both returns and volatilities. Several key observations are found for the total return connectedness. First, the shale oil revolution and the PRC crisis between 2014 and 2016 (Yahya et al. 2021) led to a spike in the total connectedness index. Second, from 2016 to 2018, the price of crude oil remained relatively low, and emerging economies served as an avenue for international investors seeking portfolio diversification. These findings may be attributed to an increased reliance of ASEAN-4 and other developing economies on crude oil for economic growth

and development. For instance, the PRC and India are among the largest importers of oil, and therefore a decline in oil prices increases the connectedness among the underlying markets. Third, we report a downward movement in the total return connectedness between 2019 and 2020, a phase that has been characterized as an economic boom. Finally, between 2020 and 2022, we observe a significant increase in the total connectedness, which is attributed to COVID-19 and the OPEC–Russian Federation oil price war.

**Figure 11: Dynamic Spillovers**

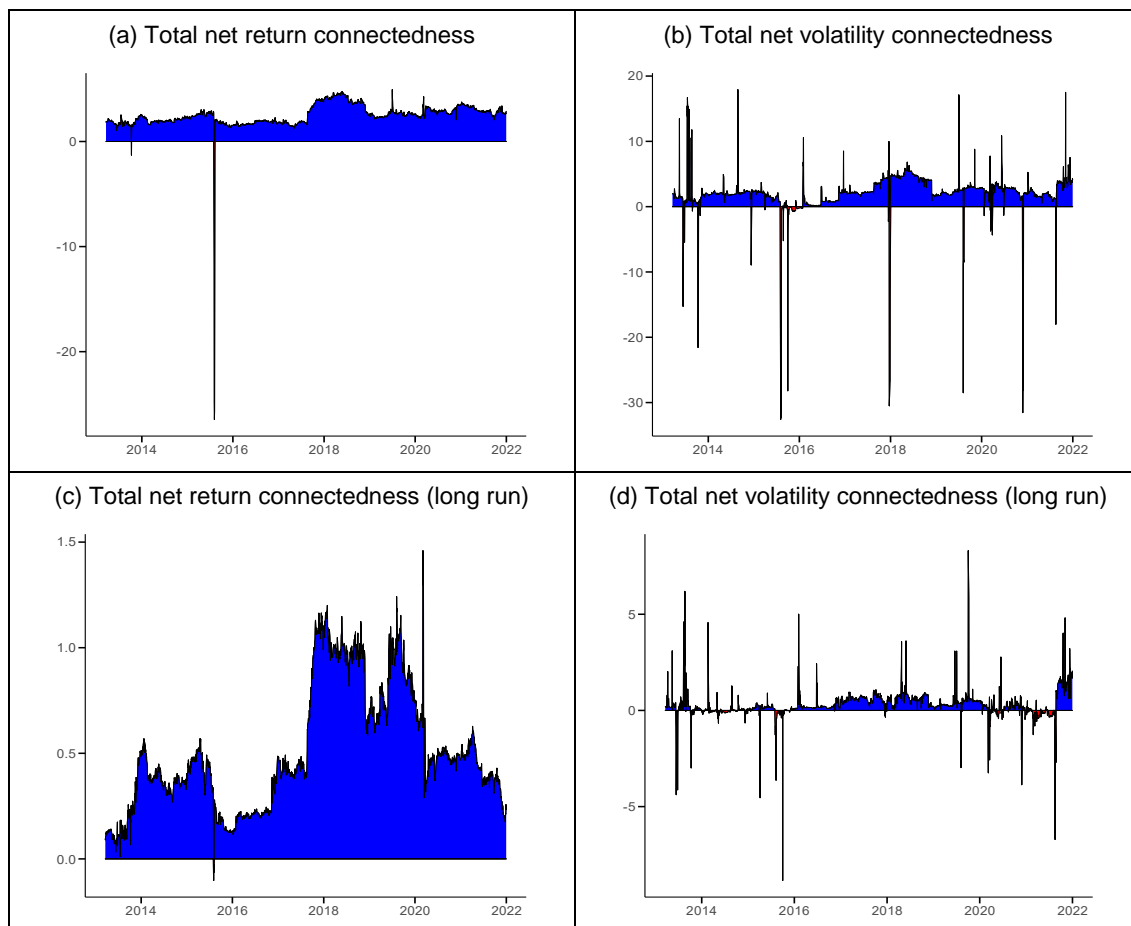


Note: The figure provides an overview of the development of time-varying spillovers over the time and frequency horizons of the series.

In addition to the total time-varying connectedness among the underlying bond markets, we examine the total time-varying net ASEAN-4 connectedness at both base-level and long-term horizons (**Figure 12**). In terms of total net return connectedness, we observe an overall positive net return connectedness among the ASEAN-4, with frequent periods of rising and falling trends. Notably, we observe an increase in net connectedness between 2017 and 2019. This concurs with the findings reported in the earlier analysis as it reflects the period corresponding to economic prosperity. A similar increase in connectedness is observed in terms of total net return connectedness over the long-term horizon. Specifically, we observe an increase in net connectedness between 2014 and 2016, corresponding to the shale oil revolution and the PRC crisis. Later, we identify a sudden increase in connectedness from mid-2017 to the end of 2020. The outbreak of the COVID-19 pandemic does not contribute to an

increase in the total net connectedness among ASEAN-4 bond markets. This reflects earlier findings of the disentanglement of ASEAN-4 bond markets and the potential to attain diversification during periods of economic turmoil.

**Figure 12: Time-Varying Net ASEAN-4 Spillovers**



#### 4.4 Determinants of Return and Volatility Spillovers

To examine further the determinants of risk spillovers in ASEAN-4 bond markets and identify the potential economic and financial fundamentals driving these spillovers, we utilize an ARDL model with fixed effects. This allows us to establish whether the determinants of the short- and long-term horizons under different maturities are different from one another. The dynamic panel model with country-specific fixed effects can be described as follows:

$$y_{i,t} = \sum_{k=1}^2 y_{i,t-k} + \sum_{k=1}^2 x_{i,t-k} + v_i + \varepsilon_{i,t}$$

Here, the response variable is a vector  $y_{i,t} = \{From1Y, From10Y, To10Y, To1Y, Net10Y, Net10Y\}$  corresponding to the different from, to, and net connectedness calculated following Baruník and Křehlík (2018) and Diebold and Yilmaz (2012, 2014). Thus, we estimate six different dynamic panel model settings for each setting. We use the potential drivers of DY spillovers



$x = \{IPI, Infl, stocks, VIX, EMVIX, USEPU, OVX, GVZ\}$ . IPI, inflation, and stocks capture local market factors that potentially drive spillovers; EMVIX captures regional uncertainty in financial markets; and VIX, USEPU, OVX, and GVZ are included to explain global market factors for the spillovers. Lastly,  $v_i$  is the country within fixed effects.

**Table 4: Short-Run Dynamic Panel**

	FROM_1Y (1)	FROM_10Y (2)	TO_1Y (3)	TO_10Y (4)	NET_1Y (5)	NET_10Y (6)
$Y_{t-1}$	0.210*** (0.054)	0.136*** (0.051)	0.336*** (0.050)	0.327*** (0.049)	0.181*** (0.050)	0.276*** (0.049)
$Y_{t-2}$	-0.074 (0.054)	-0.151*** (0.049)	-0.235*** (0.050)	-0.224*** (0.049)	-0.307*** (0.049)	-0.135*** (0.049)
$IPI_{t-1}$	0.026 (0.028)	0.016 (0.017)	0.035 (0.036)	-0.019 (0.051)	0.011 (0.034)	-0.035 (0.050)
$IPI_{t-2}$	-0.026 (0.027)	0.004 (0.017)	0.005 (0.035)	-0.020 (0.050)	0.035 (0.033)	-0.024 (0.048)
$Infl_{t-1}$	0.908 (0.849)	0.838 (0.516)	1.152 (1.076)	3.166** (1.537)	0.311 (1.021)	2.263 (1.494)
$Infl_{t-2}$	-0.101 (0.842)	0.051 (0.514)	-0.782 (1.066)	-2.601* (1.526)	-0.774 (1.012)	-2.484* (1.479)
$Stocks_{t-1}$	0.092 (0.082)	0.072 (0.050)	0.068 (0.103)	0.074 (0.148)	-0.013 (0.098)	0.027 (0.143)
$Stocks_{t-2}$	-0.121 (0.087)	-0.005 (0.053)	-0.015 (0.110)	-0.119 (0.158)	0.120 (0.105)	-0.111 (0.153)
$VIX_{t-1}$	0.263 (0.178)	0.081 (0.105)	-0.367* (0.217)	0.710** (0.312)	-0.486** (0.211)	0.741** (0.303)
$VIX_{t-2}$	0.138 (0.178)	0.077 (0.108)	0.383* (0.225)	-0.205 (0.320)	0.040 (0.214)	-0.241 (0.313)
$EMVIX_{t-1}$	-0.371** (0.188)	-0.345*** (0.110)	0.101 (0.229)	-0.636* (0.329)	0.324 (0.222)	-0.385 (0.319)
$EMVIX_{t-2}$	0.287 (0.185)	0.023 (0.113)	-0.251 (0.234)	0.219 (0.335)	-0.402* (0.224)	0.131 (0.325)
$USEPU_{t-1}$	0.025*** (0.008)	0.006 (0.005)	0.011 (0.010)	-0.031** (0.015)	-0.015 (0.010)	-0.034** (0.014)
$USEPU_{t-2}$	-0.026*** (0.008)	-0.026*** (0.005)	-0.014 (0.010)	0.025* (0.014)	0.005 (0.010)	0.048*** (0.014)
$OVX_{t-1}$	0.027 (0.035)	0.119*** (0.022)	0.013 (0.044)	0.067 (0.063)	0.000 (0.042)	-0.044 (0.061)
$OVX_{t-2}$	0.009 (0.035)	0.071*** (0.022)	0.031 (0.043)	-0.093 (0.062)	0.031 (0.041)	-0.142** (0.060)
$GVZ_{t-1}$	-0.067 (0.119)	-0.186** (0.076)	0.339** (0.150)	0.405* (0.215)	0.347** (0.143)	0.508** (0.211)
$GVZ_{t-2}$	-0.596*** (0.122)	-0.422*** (0.080)	-0.216 (0.154)	-0.630*** (0.219)	0.494*** (0.146)	-0.227 (0.216)
Observations	412	412	412	412	412	412
Adjusted R <sup>2</sup>	0.298	0.416	0.122	0.158	0.255	0.135

Notes: Here, the response variable is a vector  $y_{i,t} = \{From1Y, From10Y, To10Y, To1Y, Net10Y, Net10Y\}$  corresponding to the different from, to, and net connectedness calculated in accordance with Baruník and Křehlík (2018) and Diebold and Yilmaz (2012, 2014). Thus, we estimate six different dynamic panel model settings for each setting. We use the potential drivers of DY spillover  $x = \{IPI, Infl, stocks, VIX, EMVIX, USEPU, OVX, GVZ\}$ . IPI, inflation, and stocks capture local market factors that potentially drive spillovers; EMVIX captures regional uncertainty in financial markets; and VIX, USEPU, OVX, and GVZ are included to explain the global market factors for the spillovers. Lastly,  $v_i$  is the country within fixed effects.

\*\*\*, \*\*, and \* denote significance at the 1%, 5%, and 10% levels, respectively.

In terms of both short- and long-run dynamics, our findings suggest that the previous-period return exhibits a positive and statistically significant impact on all the underlying measures. For the two-period prior return,  $Y_{t-2}$ , we report negative and statistically significant coefficients for all the underlying variables except for the From\_1Y bond maturity in the short-run dynamics. In general, our findings indicate that financial market uncertainties act as the driving force for the short-run dynamic spillovers among the assets. Notably, VIX, USEPU, and GVZ contribute significantly to various measures of spillovers. These findings are in line with the earlier studies (see, e.g., Bernal et al. 2016; Bhattacharyay 2013; Boubaker et al. 2019; Dewachter et al. 2015) as they reported an asymmetric impact of returns on various bond maturities.

**Table 5: Long-Run Panel Dynamics**

	FROM_LR_1Y (1)	FROM_LR_10Y (2)	TO_LR_1Y (3)	TO_LR_10Y (4)	NET_LR_1Y (5)	NET_LR_10Y (6)
$Y_{t-1}$	0.149*** (0.053)	0.150*** (0.049)	0.357*** (0.050)	0.215*** (0.050)	0.174*** (0.052)	0.162*** (0.050)
$Y_{t-2}$	-0.119** (0.054)	-0.329*** (0.049)	-0.250*** (0.050)	-0.138*** (0.050)	-0.244*** (0.051)	-0.053 (0.050)
$IPI_{t-1}$	0.028 (0.026)	0.014 (0.022)	0.035 (0.030)	-0.021 (0.059)	0.007 (0.033)	-0.031 (0.054)
$IPI_{t-2}$	-0.025 (0.025)	-0.012 (0.022)	-0.007 (0.029)	-0.019 (0.058)	0.031 (0.032)	-0.009 (0.053)
$Infl_{t-1}$	0.215 (0.771)	0.011 (0.666)	1.098 (0.894)	2.488 (1.786)	1.136 (1.002)	2.127 (1.632)
$Infl_{t-2}$	-0.113 (0.765)	-0.373 (0.661)	-0.618 (0.886)	-2.937* (1.771)	-0.161 (0.994)	-2.457 (1.616)
$Stocks_{t-1}$	0.018 (0.074)	0.103 (0.064)	0.042 (0.086)	0.109 (0.172)	0.009 (0.096)	0.021 (0.156)
$Stocks_{t-2}$	-0.090 (0.079)	-0.052 (0.069)	-0.001 (0.091)	-0.035 (0.183)	0.106 (0.103)	-0.009 (0.167)
$VIX_{t-1}$	0.482*** (0.163)	0.162 (0.139)	-0.211 (0.180)	0.886** (0.363)	-0.553*** (0.208)	0.588* (0.329)
$VIX_{t-2}$	0.200 (0.161)	0.395*** (0.139)	0.327* (0.186)	-0.095 (0.373)	-0.191 (0.210)	-0.145 (0.341)
$EMVIX_{t-1}$	-0.551*** (0.172)	-0.500*** (0.146)	-0.015 (0.190)	-0.856** (0.382)	0.459** (0.218)	-0.285 (0.347)
$EMVIX_{t-2}$	0.251 (0.170)	-0.080 (0.146)	-0.176 (0.194)	0.136 (0.391)	-0.266 (0.220)	0.013 (0.355)
$USEPU_{t-1}$	0.015** (0.007)	-0.001 (0.006)	0.006 (0.009)	-0.038** (0.017)	-0.010 (0.010)	-0.033** (0.015)
$USEPU_{t-2}$	-0.014* (0.007)	-0.025*** (0.006)	-0.014* (0.008)	0.016 (0.017)	0.004 (0.009)	0.041*** (0.015)
$OVX_{t-1}$	0.006 (0.032)	0.096*** (0.028)	0.014 (0.037)	0.089 (0.074)	0.025 (0.041)	-0.030 (0.067)
$OVX_{t-2}$	-0.046 (0.031)	-0.018 (0.028)	0.014 (0.036)	-0.122* (0.072)	0.084** (0.040)	-0.119* (0.066)
$GVZ_{t-1}$	0.108 (0.108)	0.150 (0.094)	0.357*** (0.125)	0.472* (0.250)	0.104 (0.141)	0.409* (0.229)
$GVZ_{t-2}$	-0.344*** (0.110)	-0.335*** (0.099)	-0.108 (0.128)	-0.340 (0.255)	0.295** (0.142)	-0.100 (0.234)
Observations	412	412	412	412	412	412
Adjusted R <sup>2</sup>	0.231	0.309	0.145	0.071	0.180	0.045

Note: See the notes in Table 4. \*\*\*, \*\*, and \* reflect significance at the 1%, 5%, and 10% levels, respectively.

## 5. CONCLUSION

Over the past two decades, ASEAN financial markets have become increasingly integrated into regional and global markets. Despite significant research into ASEAN financial markets, the strength and direction of bond market connectedness between ASEAN-4 and major global and regional bond markets remain relatively little explored. In this study, we aim to fill this gap by deriving a risk spillover measure based on the attributes of static and dynamic spillover models and empirically examining its role in receiving or transmitting shocks, relying on different information connectedness or contagion channels. Specifically, our objective is to investigate the connectedness dynamics empirically using various government bond yields in ASEAN-4 markets, major regional markets, and major global markets. Specifically, we aim to examine the risk spillovers in ASEAN bond markets and identify the potential economic and financial fundamentals driving the uncertainty spillovers in ASEAN-4 bond markets.

Our empirical findings have two important fronts. We provide empirically documented evidence of a novel complex network pattern of heterogeneity in the US (global) and Japan (regional) spillover effects across ASEAN-4 markets. We identify low-level integration between ASEAN-4 bond markets and find that market integration is more strongly linked with global markets than regional markets. We report that the time-varying return and volatility spillovers exhibit crisis jumps. Finally, differential macroeconomic fundamental responses among ASEAN-4 markets can rationalize the heterogeneity observed in the cross-border transmission of the US and Japan uncertainty shocks to these markets.

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