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Dynamic Interlinkages between the Twitter Uncertainty Index and the Green Bond Market: Evidence from the Covid-19 Pandemic and the Russian-Ukrainian Conflict

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Abstract
This study examines the time-varying connectedness between green bonds, Twitter-based uncertainty indices, and the S&P 500 Composite Index. We implement the time- and frequency-based connectedness methodologies and employ data between April 1, 2014 and April 21, 2023. Our findings suggest that (i) connectedness indices robustly capture prominent incidents during the episode; (ii) Twitter-based uncertainty indices are the highest transmitters of return shocks; (iii) net return spillovers transmitted by the S&P 500 Index sharply increased in 2020:1–2020:3, stemmed by the stock market crash in February 2020; and (iv) Twitter-based uncertainty indices showed significant net spillovers in July and November 2021.

Keywords Green bonds, twitter · Based uncertainty measures, frequency · Based connectedness network, TVP · VAR

JEL Classification G15 · G12 · D81

1 Introduction

In recent decades, the excessive use of fossil fuels due to the increase in population and development of industry has threatened climate change worldwide. This lead to threat, phenomena such as global warming, the melting of polar ice, and the perforation of layers of ozone, desertification, deforestation, drought, and floods have occurred. Chan (2018) addressed climate change as the last century's most significant threat to the living on Earth. Various global and national efforts (e.g.

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Kyoto Protocol in 1997, the Paris Agreement in 2015, and the COP26 in 2021) have not resolved this threat in recent decades. Following a temporary reduction in this threat during the outbreak of the coronavirus pandemic (Nicolini et al., 2022), there has been a resurgence in the threat of climate change since the end of 2021. This resurgence is attributed to the resumption of economic activities by countries and a rise in the demand for nonrenewable energies. According to the BP, the CO2 emissions from anthropogenic fossils reached more than 37.8 Gt of CO2 in 2021 (5.3% increase compared to 2020). In addition, due to tourism recovery, compared with that in the 2021 volume, the increase in CO2 emissions is predicted to increase by 1% (the 2022 Global Carbon Budget).

One of the significant problems in countries' failure to advance the goals of combating climate change is the need for sufficient capital to implement environmentally friendly projects. Metawa et al. (2022) argued that green policies could be successful only in countries with sufficient capital to run sustainable investments. Therefore, countries must find ways and instruments to attract capital for sustainable investment. Wang et al., (2022a, 2022b) suggested that combating environmental pollution requires suitable green projects related to green energy deployment, green technological transfer, and lowering energy intensity. However, governments do not have extra budget revenues to carry out all prioritized sustainable projects. To solve the problem of a lack of capital for providing green investments, the concept of green finance has been developed in the last decade. Green finance comprises a group of financing instruments with a specific "green" preference (Huang et al., 2022) and environmental benefits (Taghizadeh-Hesary et al., 2023). One of the most popular instruments for green finance is the "green bond" issued to support climate-related projects.

Green bonds are debt securities holding the potential to attract capital capital from the private sector. It provides some stimulation, such as tax exemptions, to make this financing instrument more attractive for foreign investors and private contributions. Teti et al. (2022) mentioned that green bonds could solve the capital problem for sustainable projects in other countries. Historically, the first green bond was issued in 2007 by the European Investment Bank and reached a record of 255 billion US dollars in 2019, doubling to 522.7 billion US dollars at the end of 2021 (Climate Bonds Initiative, 2022). Between 2014 and 2021, the United States (USD 303.9 billion), China (USD 199.1 billion), and France (USD 167.2 billion) emerged as notable global issuers of green bonds.

Despite the advantages of green bonds, their market needs critical success factors to become efficient (Liu, 2022; Zhao et al., 2022). Uncertainty is one of the most important influencing factors in developing the green bond market. The economic literature defines uncertainty as an unprecedented and uncontrollable event that affects economic markets. In this context, a precursor study described economic uncertainty as "unforeseen alterations -for instance shifts in fiscal, monetary policies, or any other government policies-, affect the economic ecosystem and and have an impact on corporations (Abel, 1983). Increased economic uncertainty causes agents to postpone decision-making processes to wait for more information, and this caution makes them less sensitive to changes in interest rates (Bernanke, 1983; Bloom, 2007; Dixit & Pindyck, 1994).

According to Moore (2017), economic uncertainty is related to the certainty—or lack thereof—of future economic activity. It includes both "Knightian uncertainty" and "risk." Based on Knight, knowledge is the key to differentiating between risk and uncertainty. Risk refers to conditions in which probabilities are observable, while uncertainty pertains to circumstances in which the data seems too unclear to be represented by probabilities (Schinckus, 2009).

Long et al. (2022) discussed the importance of uncertainty in green bond markets. They believed that uncertainty has an impact on impacts the green bond market realated to its potential to increase or reduce risks. Economic policy uncertainty and price uncertainty are two crucial types of uncertainty leading to the inefficiency of green bond markets.

This paper investigates the relationships between issued green bonds, uncertainty, and green energy by employing daily data ranging from 1 April 2014 to 21 April 2023; these data are obtained from the S&P Green Bond Index (SPGBI), the S&P Global Clean Energy Index (SPGCEI), the Solactive Green Bond Index (SGBI), the S&P 500 Composite Index (SP500), the Twitter-based Economic Uncertainty Index (TEUI), and the Twitter-based Market Uncertainty Index (TMUI). Using a text mining technique, Baker et al. (2021) created TEU indicators starting in 2011 based on counts of tweets regarding the "economy" and "uncertainty." To assess market/economy risk, a number of studies have used Twitter-based uncertainty indices (Aharon et al., 2022; Aysan et al., 2023; Lang et al., 2021).

This research contributes to the body of existing literature in four ways. First, we utilize two novel methodologies and estimate the time-varying connectedness of returns in the time and frequency domains. Second, this study scrutinizes the COVID-19 pandemic and the RIU by examining the dynamic interdependencies between green bonds, Twitter uncertainty indexes, and geopolitical stress. Third, we focus on the time-varying connectedness of the indices mentioned above in the frequency domain, while most studies only focus on the time domain. Finally, we examine the transitory connectedness networks at two times with geopolitical turmoil.

The remaining sections of the document are arranged as follows: A brief survey of the literature is given in Sect. 2. The data and model specifications are covered in Sect. 3. The empirical findings are presented in the section that follows, and the research is concluded with some practical policies and recommendations for future study in the concluding section.

2 Literature Review

A relatively new instrument, the green bond market, has attracted the interest of investors and scholars, and the number of studies on this topic has recently increased. To our knowledge, Pham (2016) is the first study to examine spillovers in this market. Afterward, the market has attracted both investors and nations, and a body of literature in the field has proliferated (Ehlers and Packer 2017; Banga 2019; Broadstock & Cheng, 2019; Tu, Rasoulinezhad and Sarker 2020; Otek Ntsama et al., 2021; Cicchiello et al., 2022; Yadav et al., 2023). Another body of studies has examined investors' willingness to incur a premium for green bonds. (M. Baker et al. 2018; Zerbib 2019; Liaw, 2020; Facita et al. 2021; Baker et al., 2022; Dorfleitner et al., 2022). Another strand of literature has explored the links between green bonds and asset classes (Pham 2016; Wiśniewski & Zieliński, 2019; Broadstock & Cheng, 2019; Reboredo & Ugolini, 2020; Naeem et al., 2021; Karim et al., 2022). The relationship between green bonds and energy markets has been extensively investigated by more recent studies (Wang et al., 2022a, 2022b; Zhao et al., 2022; Tiwari et al., 2022; Ning et al., 2023; Yan et al., 2022; Taghizadeh-Hesary 2022). Moreover, the impact of policy uncertainty on the green bond market has also been covered by recent studies (Haq et al., 2021; Pham & Nguyen, 2022; Syed et al., 2022; Tian et al., 2022a; Wang et al., 2022a, 2022b).

Although the interconnectedness of green bonds with other financial assets has been analyzed in many respects in the extant literature, studies have yet to examine the relationships among green bonds, clean energy, and uncertainty. Therefore, we aim to focus on this subject and contribute to this research field. Studies have determined the significant effects of uncertainty measures such as the Twitter-based Economic Uncertainty Index and Twitter-based Market Uncertainty Index on financial markets (Baker et al., 2021). Recent studies have reported evidence of a significant relationship between the Twitter uncertainty index and stock volatility (Behera & Rath, 2022). Some studies show that the Twitter uncertainty index hurts cryptocurrency returns (Bashir & Kumar, 2022).

On the other hand, a number of academics have proposed a robust relationship between sectoral stocks and Twitter uncertainty indices (El Khoury & Alshater, 2022). Hence, assessing the impact of these uncertainty measures on the conduct of green bonds holds significant importance, especially considering the recent expansion of the green bond market.

Since this study focuses on employing green bonds as an uncertainty hedge, it also offers crucial results for portfolio diversification.

Among the studies investigating the relationship between green bonds and policy uncertainty, Pham and Nguyen (2022) reported evidence for the connectedness between bonds and uncertainty. Haq et al. (2021) revealed that green bonds serve as a hedge rather than a haven against economic policy uncertainty. Tian et al., (2022a, 2022b) argued that uncertainties comprehensively impact the green bond market. Syed et al. (2022) proposed that a positive shock in uncertainty harms green bonds, while a negative shock stemming from uncertainty enhances the performance of green bonds. Furthermore, these authors argued that the success of other asset classes, such as renewable energy, oil prices, and bitcoin, is reflected in green bonds and that they do not constitute a separate asset class.

These studies are notewothy since they have examined the characteristics of green bonds, including their performance and the relationships between green bonds and economic policy uncertainty and other financial assets.

Table 1 Summary statistics

Returns

	Mean	Variance	Skewness	Ex. Kurtosis	J-B
SPGBI	−0.003	0.083	−0.218***	8.962***	11,096.776***
SPGCEI	0.023	1.357	−0.157***	12.908***	22,978.402***
SGBI	0.003	0.054	0.102**	8.972***	11,100.192***
SP500	0.024	0.759	−0.265***	18.205***	45,719.733***
TEUI	0.062	1486.328	0.448***	3.823***	2124.794***
TMUI	0.048	1422.265	0.560***	5.291***	4032.350***

J-B-Jarque Bera, ***, **, and * denote 1%, 5%, and 10%, respectively

3 Data and Methodology

3.1 Data

In this study, we employed daily data ranging from 1 April 2014 to 21 April 2023, encompassing periods of geopolitical distress, such as the 2020 stock market crash, the COVID-19 pandemic, and the Russian-Ukrainian conflict. The dataset consists of the S&P Green Bond Index (SPGBI), the S&P Global Clean Energy Index (SPGCEI), the Solactive Green Bond Index (SGBI), the S&P 500 Composite Index (SP500), the Twitter-based Economic Uncertainty Index (TEUI), and the Twitter-based Market Uncertainty Index (TMUI). The S&P Green Bond Index is retrieved from https://www.spglobal.com/spdji, while the S&P Global Energy Index (SPGCEI), the Solactive Green Bond Index, and the S&P 500 Composite Index are sourced from the Refinitive Eikon. The Twitter-based market/economic uncertainty indices are collected from https://www.policyuncertainty.com. We used the return series in the empirical analysis and computed it as the first difference of the logarithmic prices. The summary statistics and plot of the return series are shown in Table 1 and Fig. 1, respectively.

The TEUI and the SPGBI provide the highest and the lowest average returns of 0.062% and -0.003%, respectively. Unsurprisingly, as gauged by the variability by the standard deviation, the former has the highest variability, while the latter has the second lowest variability, with 1486.328 and 0.083. It should be noted that the SPGBI provides negative average returns over the sample period. The returns for the SPGBI, SPGCEI, and SP500 exhibit a leftward-tailed distribution, while the rest have a rightward-tailed distribution. All the returns feature excess kurtosis, and high JB values indicate that the returns are nonnormally distributed (Fig. 2).

As indicated by Fig. 1, in addition to the Twitter-based indices, all the returns experienced significant fluctuations in March 2020, attributed to the impact of the COVID-19 pandemic. Twitter-based uncertainty indices sharply fluctuated in September–October 2014, July 2021 and November 2021 when global stock markets experienced sudden declines due to the fear of new COVID-19 variants[1].

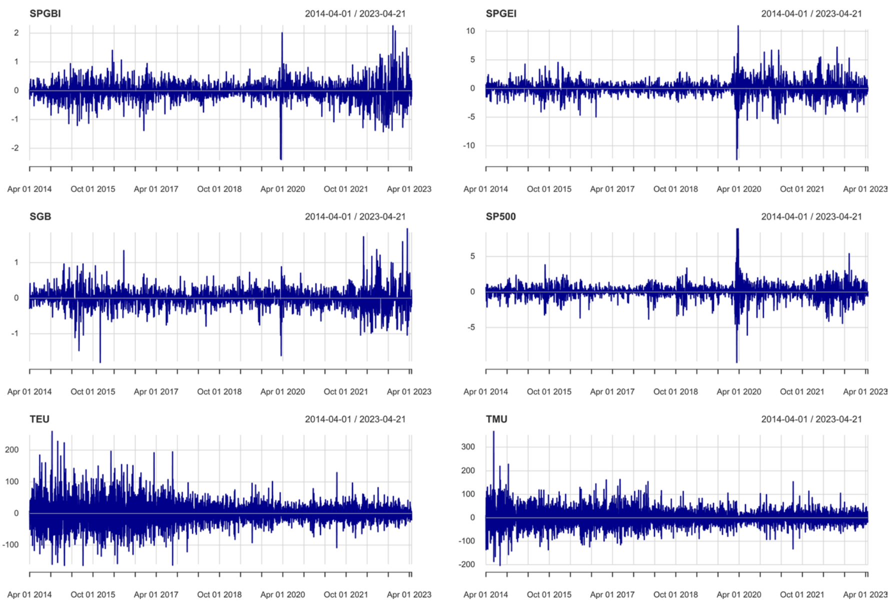

Fig. 1 Returns

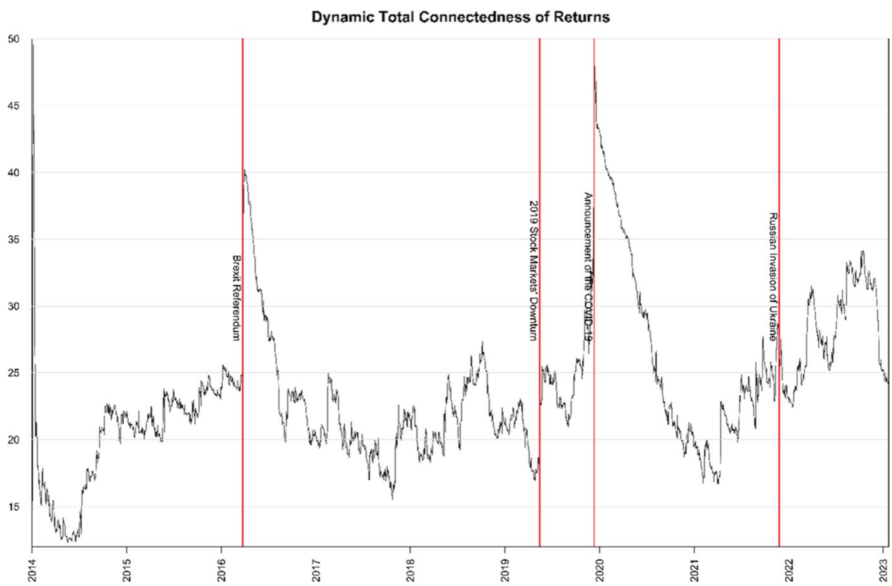

Fig. 2 TCI for returns

Moreover, all indices markedly oscillate around February–March 2022 following RIU on 24 February 2022.

3.2 Methodology

We employ TVP = VAR based on the connectedness methodologies of Antonakakis et al. (2020) and Barunik and Ellington (2020). Table 2 provides these approaches and their details in Appendices A.1 and A.2.

It's worth mentioning that the examination of frequency-dependent connectedness has been explored using alternative econometric methodologies, as evidenced by recent research in the literature (Yahya et al., 2019; Frimbong et al., 2021; Mensi et al., 2021; Boroumand & Porcher, 2023). These studies have employed methods such as the wavelet methodology. This approach is characterized by its concentration in both the time and frequency domains, allowing for the evaluation of the correlation between two time series throughout the observation period across different time intervals (e.g., short-term versus long-term). Conversely, Barunik and Ellington (2020) utilized the spectral decomposition of time-varying variance matrices in their methodology. The Bayesian structure of this framework incorporates prior shrinkage and imparts knowledge about estimation uncertainty through the posterior distribution of connectedness metrics. This stands in stark contrast to traditional studies that provide only single-point estimates and rely on bootstrapping for confidence intervals.

4 Empirical Findings

4.1 TVP-VAR interdependencies

We compute the time-varying interconnectedness of returns spanning from April 2014 to April 2023 and plot the TCI with well-known financial/geopolitical stress incidents in Fig. 3.[1]

The index oscillated between 12 and 63% and peaked on 29 June 2019, shortly after the Brexit referendum on June 23, 2016. The vote led to global stock market crashes, and investors lost more than the equivalent of 2 trillion USD on 24 June 2016, causing a loss of daily life.[2] The index gradually decreased until 10 September 2020, sharply increased in the last quarter of 2020, and reached its second maximum at 45.79% on 5 November 2020. This period coincides with global lockdowns. Afterward, the TCI decreased slightly and reached its trough on 9 September 2021, at 15.32%. The index markedly surged and reached 40% on 26 November 2021. The TCI exhibits significant spikes in February, June, and September 2022 due to the heightened geopolitical/financial stress triggered by incidents such as the RIU,

[1] Following Antonakakis et al. (2020), we use forecast horizons (H = 10), and decay factors κ_1= 0.99 and κ_2 = 0.96 in the TVP-VAR model settings.

[2] https://www.cnbc.com/2016/06/26/brexit-cost-investors-2-trillion-the-worst-one-day-drop-ever.html

Table 2 Empirical approach

	Antonakakis et al. (2020)	Barunik and Ellington (2020)
Total Connectedness index (TCI)	$C_t(H) = \frac{\sum_{i,j=1,i\neq j}^{n}\widetilde{\Phi}_{ij,t}(H)}{\sum_{i,j=1}^{n}\widetilde{\Phi}_{ij,t}(H)} = \frac{\sum_{i,j=1,i\neq j}^{n}\widetilde{\Phi}_{ij,t}(H)}{n} \times 100$	
Local network connectedness		$C(\eta,d) = 100 \times \sum_{i,j=1 i\neq j}^{M}\left[\widetilde{\theta}(\eta,d)\right]_{j,k} / \sum_{\mathrm{i},j=1}^{N}\left[\widetilde{\theta}(\mu)\right]_{i,j}$
Total directional connectedness TO others	$C_{i\rightarrow j,t}(H) = \frac{\sum_{j=1,i\neq j}^{n}\widetilde{\Phi}_{ji,t}(H)}{\sum_{j=1}^{n}\widetilde{\Phi}_{ji,t}(H)} \times 100$	$C_{j\rightarrow\bullet}(\eta,d) = 100 \times \sum_{i=1 i\neq j}^{M}\left[\widetilde{\theta}(\eta,d)\right]_{i,j} / \sum_{i,j=1}^{M}\left[\widetilde{\theta}(\eta)\right]_{i,j}$
Total directional connectedness FROM others	$C_{i\leftarrow j,t}(H) = \frac{\sum_{j=1,i\neq j}^{n}\widetilde{\Phi}_{ij,t}(H)}{\sum_{i=1}^{n}\widetilde{\Phi}_{ij,t}(H)} \times 100$	$C_{j\leftarrow\bullet}(\eta,d) = 100 \times \sum_{i=1 i\neq j}^{M}\left[\widetilde{\theta}(\eta,d)\right]_{j,i} / \sum_{j,i=1}^{M}\left[\widetilde{\theta}(\eta)\right]_{j,i}$
NET total directional connectedness	$C_{i,t}(H) = C_{i\rightarrow j,t}(H) - C_{i\leftarrow j,t}(H)$	

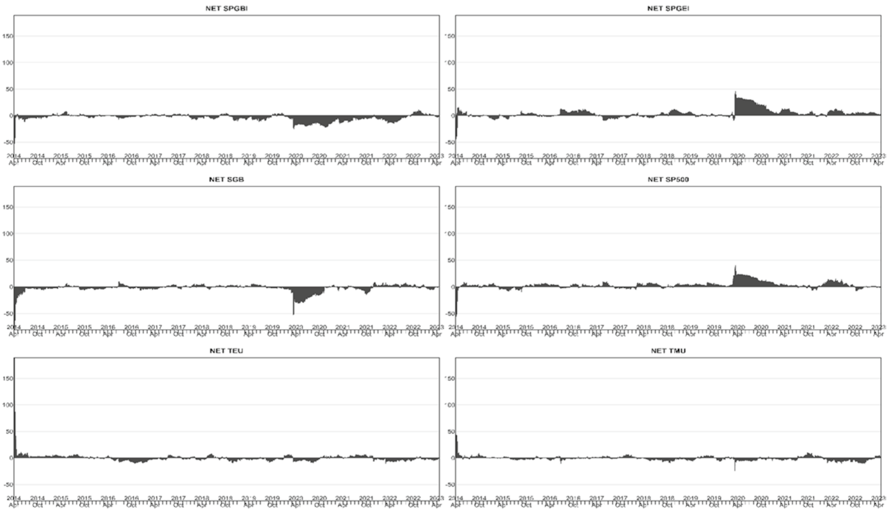

Fig. 3 Net directional connectedness for returns

Table 3 Average connectedness table for returns

	SPGBI	SPGEI	SGB	SP500	TEU	TMU	FROM
SPGBI	70.47	7.22	12.36	5.9	2.14	1.9	29.53
SPGEI	5.51	64.59	4.11	20.86	1.95	2.98	35.41
SGB	12.83	5.22	73.63	4.44	1.85	2.03	26.37
SP500	4.65	20.62	3.88	65.3	1.95	3.61	34.7
TEU	2.14	2.26	2.49	2.41	82.46	8.25	17.54
TMU	2.25	3.56	2.14	4.43	8.17	79.46	20.54
TO	27.38	38.88	24.98	38.04	16.05	18.77	164.1
NET	−2.15	3.47	−1.39	3.34	−1.49	−1.77	TCI = 27.35

economic slowdowns, and supply chain problems. Table 3 showcases the findings of average connectedness for the returns.

Possessing a shared feature, all returns contribute to their shocks to a greater extent than others. The S&P Green Bond Index is the largest transmitter/receiving of return shocks (38.88%, 35.41%), followed by the S&P 500 index (38.04%, 34.7%). These findings pinpoint the strengthening of uncertainties stemming from the stock market and are in line with the findings of previous studies (Balcilar and Ozdemir, 2021; Wei et al., 2023). SPGEI and SP500 are the net recipients of the shocks, while the rest are the net transmitters.

Next, we estimate the net return spillovers and plot the results in Fig. 3.

The time trends of the net directional connectedness of returns reveal that the SPGEI and SP500 are the net recipients of return shocks most of the time of the study period. This finding underlines the adverse effects of market sentiment on the

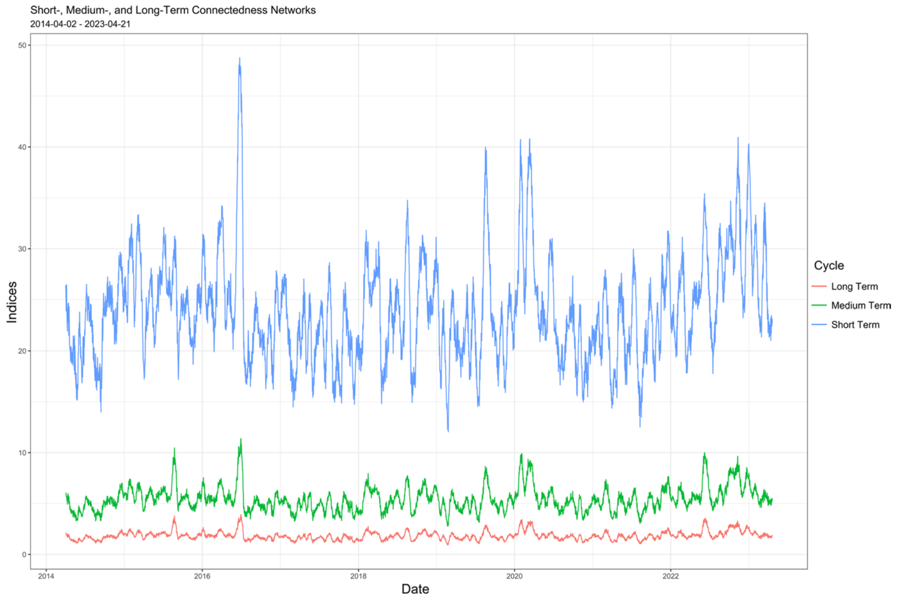

Fig. 4 Frequency-based connectedness networks for returns

green bond market, particularly during the first COVID-19 wave. Conversely, other indices continuously shift between the role of transmitter/recepient of shocks over the period. Moreover, SGB, TEU, and TMU received notable shocks approximately 2020:3, coinciding with the proclamation of the pandemic. The S&P 500 composite index propagates a noteworthy amount of spillover between 2020:1 and 2020:3, probably due to the outbreak of the pandemic and the stock market crash in February 2020. Similarly, the net spillovers conveyed by the TMU surged in November 2021, aligning with the global dissemination of the delta variant and intensifying adverse market sentiments accordingly. Furthermore, the net spillovers propagated by the TMU increased on 2022 March following the RIU on 24 February 2022. Overall, both the TEU and the TMU are the net receivers of shocks in the second half of 2022.

4.2 Frequency-Based Interlinkages

Continuing our analysis of the frequency-based connectedness networks, we compute the transitory, medium-, and persistent (1 to 5 days, 5 to 20 days, and more than 20 days, respectively) interdependencies of the returns and display them in Fig. 4.

As shown in Fig. 4 and in line with previous studies (Alshater et al., 2024; Umar et al., 2022a, 2022b), the short-term (transitory) interconnectedness is greater than the long-term (persistent) linkages. Furthermore, corroborating our time connectedness findings, all frequency-based connectedness network indices hit their apex in June 2016 (24, 30, and 30 June 2016 for the short, medium, and long-term,

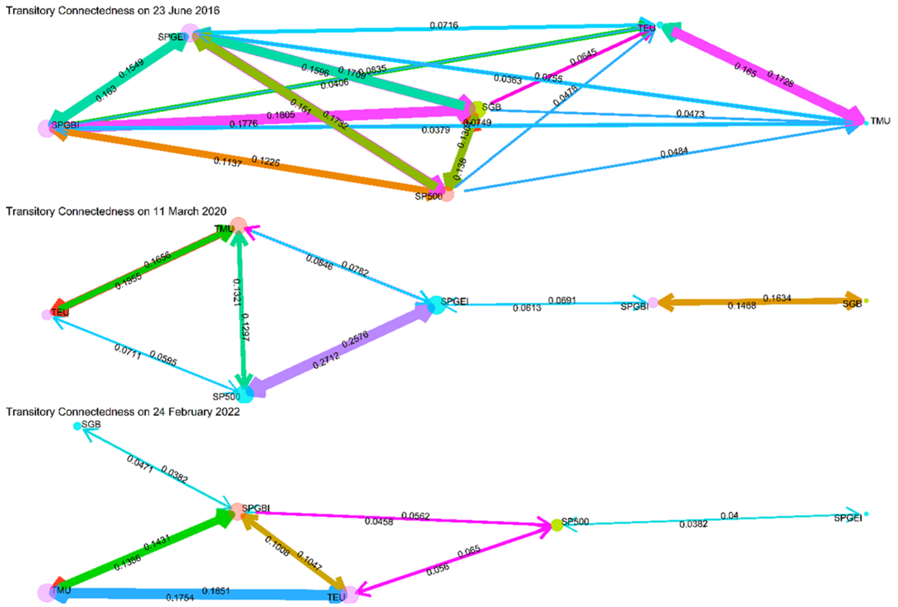

Fig. 5 Transitory network connectedness of returns

respectively) shortly after the Brexit referendum. Moreover, transitory connectedness markedly surges with heightened geopolitical risk, particularly in February 2020, July, and November 2021, February–March 2022, and August 2022 (Fig. 5).

Next, we focus on the transitory connectedness networks associated with the three geopolitical stress incidents[3] during the episodes.[4]

The network topologies of transitory connectedness indicate the following results. First, more pronounced interlinkages appear for the first connectedness network. Second, the TMU-TEU and SP500-SPGEI pairs have the highest interdependencies in the first and the second connectedness networks, respectively. Third, SGB, SP500, and TEU are the largest nodes in terms of cumulative transmission transmission (0.1072865, 0.101086, and 0.07699261, respectively).

4.3 Sensitivity Analysis

In accordance with Nham's (2022) study, we performed a diagnostic check of our connectedness outcomes. This involves configuring diverse forecast horizons and

[3] We estimate transitory connectedness networks on 23 June 2016 (Brexit), 11 March 2020 (announcement of the pandemic), and 24 February 2022 (start date of Russian invasion on Ukraine), respectively.

[4] The arrows depict the orientation of the connection, while the lines' hue and thickness signify the extent of the connection. Additionally, the node sizes reflect the cumulative transmission of shocks (TO) associated with each node.

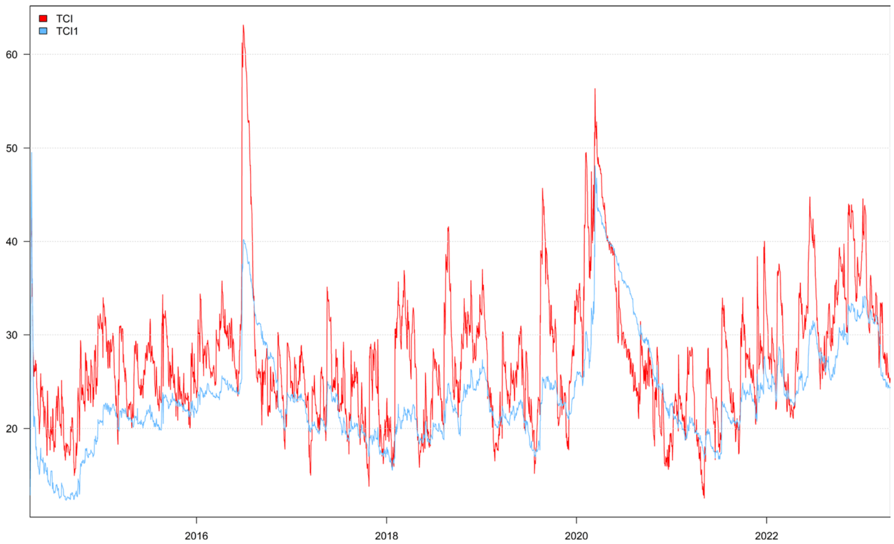

Fig. 6 Diagnostic check

decay factors (κ_1 and κ_2)[5] within our TVP-VAR connectedness model. We then illustrate the TCIs[6] computed using these settings alongside our initial TCIs in Fig. 6.

TCIs computed using different model parameters exhibited comparable trends and reached peaks within the same time intervals throughout the study period. This underscores the precision of our findings when employing alternative model configurations.

5 Discussion

Considering these main results, several significant findings stand out from this study. First, the TCI shows considerable fluctuations, ranging from 12 to 63%, in reaction to major financial and geopolitical occurrences, highlighting the susceptibility of the green bond market to external shocks (Mensi et al., 2022). Furthermore, the examination identifies the S&P Green Bond and the S&P 500 indices as pivotal conveyors and recipients of return shocks, emphasizing their substantial influence over time and this is in line with Piñeiro-Chousa et al., (2022). Moreover, the study emphasizes that short-term connectedness is more conspicuous than medium- and long-term interconnectedness, providing valuable insights into the temporal dynamics of interrelationships among the scrutinized indices (Ghaemi Asl et al., 2024).

[5] We use forecast horizons (H = 30), and decay factors κ_1= 0.99 and κ_2 = 0.99 as alternative model settings..

[6] TC1: TCI estimations with lag 2, a 10-step ahead FEVD, decay factors κ_1= 0.99 and κ_2 = 0.96, TC11: TCI with lag 2, a 30-step ahead FEVD, and κ_1, κ_2= 0.99.

The findings of this study align with the outcomes of other studies indicating that the connectedness between uncertainty and green bonds is time-varying and state dependent (Pham & Nguyen, 2022; Tian et al., 2022b). Moreover, the uncertainty index's pass-through implications highlight the importance of green bonds as safe haven assets during times of uncertainty.

These revelations carry significant policy implications, suggesting that policymakers should diligently monitor spillover effects between the green bond market and uncertainty during significant financial and geopolitical events. Finally, our discovery of a more critical transitory connectedness indicates that investors, hedgers, and stakeholders should contemplate short-term asset allocation decisions.

For policymakers, the findings indicate the importance of implementing measures to stabilize financial markets in times of crisis. Implementing such policies will alleviate the influence of uncertainty on the performance of green bonds, thereby strengthening the ability of green bonds to hedge against uncertainty. This, consequently, will aid in boosting financial support for sustainable economic activities.

Based on our findings, we propose several implications for participants in the financial markets. Firstly, our insights into dynamic connectedness can assist portfolio managers, investors, and policymakers in formulating effective portfolio allocation strategies. For instance, the observation of SPGBI and SP emerging as net receivers during the COVID-19 pandemic underscores their potential as safe havens. Additionally, the frequency-based connectedness results offer valuable guidance for both long-term investors and short-term speculators in devising transaction strategies. Secondly, our findings hold promise for predicting financial crises as early risk indicators. For instance, analyzing the relationship between long-term connectedness and short- and medium-term connectedness can provide insights into whether the market is entering a bearish trend.

6 Conclusion

In the last decade, significant advancements have been made in the realm of green bonds, showcasing their advantages for stakeholders and countries alike. This is attributed to their substantial contribution in funding eco-friendly initiatives aimed at counteracting the adverse impacts of climate change. Nevertheless, research exploring the connections between this market and various financial and environmental factors remains relatively limited. This work scrutinizes the time-varying interconnectedness among green bonds, Twitter-based uncertainty indices, and the S&P 500 Composite index between April 2014 and April 2023 by employing two recently engineered approaches.

The interconnectedness measures, whether based on time or frequency, magnify in response to escalated geopolitical tension, which is evident during events such as the emergence of COVID-19, the stock market crash of 2020, and the RIU (Youssef et al., 2021; Nyakurukwa & Seetharam, 2023). Furthermore, our analysis indicates that the most significant conveyors of return shocks are the S&P Green Bond index and the S&P 500 indices.

The patterns in the net directional connectedness of returns indicate that the SPGEI and SP500 consistently experience the impact of return shocks for the majority of the study duration. This observation highlights the negative repercussions of market sentiments on the green bond market, especially during the initial phase of the COVID-19 pandemic. In contrast, various other indices alternate between acting as transmitters or recipients of shocks throughout the period. Notably, SGB, TEU, and TMU received a significant number of shocks approximately 2020:3, aligning with the declaration of the pandemic.

Utilizing the frequency-based interconnectedness methodology, the ensuing findings are: Firstly, in congruence with prior research, the temporary interdependencies surpass the enduring connections. Second, all frequency-based indicators peaked shortly following the announcement of the pandemic on March 11, 2020. Third, the uncertainty indices sourced from Twitter emerged as the most prominent hubs in the transient interconnection networks on June 23, 2016; March 11, 2020; and February 24, 2022. Additionally, the TEU-TMU pairings exhibited the strongest linkages within both networks. Finally, the directional propagation of effects exhibited a slightly decreased intensity in the second interconnection network.

While this work adds to the literature, it has several limitations that other researchers should take into account. First, this analysis exclusively looks at the interconnectedness between the green bond market and Twitter-based uncertainties. In terms of future research avenues, we propose several promising directions. Brown bonds and geopolitical stress may be examined in future investigations. Second, the green bond market and Twitter-based uncertainty connectedness in terms of returns are the only topics of this study. Volatility could also be the subject of future research.

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Declarations

Conflict of interest No potential competing interest was reported by the authors.

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