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RESEARCH

Is Quantile Connectedness Flexible or Uniform Under Catastrophic Tenure? Insights into ESG Investing and Financial Markets in the Quad Nations

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Abstract *This paper unfolds the quantile connectedness of the ESG investing index with the financial markets. The stock market is considered a representation of the broader financial markets. We use the FlexShares STOXX US ESG Select Index Fund (ESG) as a proxy for the ESG investing index. In contrast, the stock exchanges of each country, such as those in the USA, Japan, Australia, and India, are considered proxies for their respective stock markets. The daily observation of the examined markets extended from 31 December 2019 to 16 January 2023. Quantile vector autoregression (QVAR) is employed to investigate the connectedness at different quantiles. The dynamic linkages among the examined markets scatter at different quantiles, as they are not uniform. The low quantile is spotted with the highest connectedness, followed by the upper and middle quantiles. Additionally, the ESG investing index and the Japanese stock market dominate each quantile in terms of connectedness. This study offers valuable insights for investors, fund managers, and policy analysts.*

Keywords Quantile connectedness · ESG investing index · Financial markets · Quad nations

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Introduction

The global investment climate is shifting towards sustainable funds, reflecting the financial market origins of the concept of Environmental, Social, and Governance (ESG) investment (Agarwal, 2020; Mendiratta et al., 2023). The ESG investment has presented a new critical approach to analyse investment decisions under SDG-led business development (Patel & Deshmukh, 2025; Petrenko et al., 2024). In this regard, ESG investment is considered to have strategic importance in realising the United Nations (UN) Sustainable Development Goals (SDGs). Sustainable funds incorporate consistent information about material environmental, social, and economic factors to manage risk and opportunities while doing asset allocation. ESG investment and the SDGs can reinforce each other. This increasing transition in the financial ecosystem has also been spurred by the fact that sustainable funds have consistently shown lower downside risk than traditional funds, regardless of the investment class. It represents an array of investment options that encompass social, environmental, and governmental factors beneficial to both businesses and society. These are structured instruments for environmentally friendly projects and are considered ideal for diversification in the portfolios of environmentally concerned investors (Reboredo et al., 2020).

The rapid growth of green bonds has been considered a significant financial innovation, as it facilitates green

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investment in support of sustainable development (Litvinova et al., 2024; Mehedi et al., 2024; Singh et al., 2024). While the growing importance of ESG investing has garnered widespread attention from investors and policymakers, it is essential to examine the intricacies of its impact on financial returns. In addition, investors clarify an enigma by connecting ESG investing with the financial markets. The investigation into the connection between ESG investing and returns offers essential insights for investors to understand the level of risk associated with specific ESG investments. Additionally, it facilitates the identification of future investment opportunities (Arif et al., 2021). For instance, if ESG investments can withstand market uncertainties and realise diversification benefits, they may offer a strategic approach to enhance the portfolio stability of the investor. Many regional blocs have also recognised the urgent need to address climate change. A recent initiative in this direction is the 'Quad' forum's introduction of the Quad Climate Change Adaptation and Mitigation Package (Q-CHAMP), which focuses on both mitigation and adaptation ('Quad: Quad Recognises Urgent Need to Address Climate Change; Launches "Q-CHAMP"—The Economic Times', 2022). The Quadrilateral Security Dialogue (QSD), also known as the Quad, is a strategic forum comprising four major economies—India, Japan, Australia, and the USA—that was established in 2004 following the 2004 tsunami crisis. Although diplomatic and military arrangements began in 2007, the forum was institutionalised with the first Quad leaders' summit in 2021. The Quad Forum is committed not only to strengthening security cooperation in the Indo-Pacific region but also to enhancing climate resilience. At their first summit in 2021, the Quad leaders established a Climate Working Group to deepen cooperation on climate mitigation, adaptation, resilience, and climate finance, thereby aligning domestic, regional, and global actions to collectively address the climate crisis.

The financial markets of the Quad nations—namely the USA, Japan, Australia, and India—exert a significant influence on the global financial landscape. The USA is recognised as a global economic powerhouse, boasting one of the most advanced and influential financial markets worldwide. At the core of this realm lie institutions such as the New York Stock Exchange (NYSE) and NASDAQ, which accommodate a diverse portfolio of national and international investors, facilitating a wide range of financial activities. In Japan, the Tokyo Stock Exchange is home to some of the world's largest corporations, with indices such as the Nikkei 225 and the TOPIX serving as cornerstones for global trade and finance. India's financial sector, bolstered by liberalisation and reforms, is one of the fastest-growing globally, with the Bombay Stock Exchange (BSE) and the National Stock Exchange of India (NSE) acting as key barometers of market health. Meanwhile, Australia's well-developed financial market, centred on the Australian Securities Exchange, plays a significant role in the international financial framework.

Considering this discussion, the principle of flexible management systems provides a fundamental framework for analysing the evolving dynamics of ESG investment and the financial markets of the Quad nations. Recent research suggests that organisations and financial markets that adapt flexible systems are more resilient in navigating the challenges arising from rapid changes and uncertainties. The study highlights that integrating adaptive structures and dynamic feedback mechanisms is crucial for mitigating risk and achieving strategic responsiveness in this volatile financial environment. With respect to ESG investing, this flexibility enhances the decision-making process by integrating diverse information streams—from environmental, social, and governance indicators—thereby ensuring robust investment strategies amid market volatility. The continuous reassessment of risk and opportunity ensures that the investment decisions remain robust, sustainable, and aligned with long-term portfolio stability. ESG investment displaying strong resilience during financial distress presents a strong case for advocating and promoting sustainable investing (Sandberg et al., 2023). It aids in gaining insights to reveal patterns in investor behaviour across diverse market conditions and assess if ethical considerations take greater significance at specific time frames (Broadstock et al., 2021). Understanding the co-movement of environmentally friendly investments and financial returns is crucial in promoting sustainable investing and directing private investment towards building a climate-resilient financial sector.

Furthermore, ESG investment also signals an organisation's commitment to achieving sustainability in its business operations. Sustainable financing increases market transparency and adds benefits to society and all stakeholders (Wong, et al., 2021; Caroline, 2021). Given the existential threat posed by the climate crisis, the growing importance of realising sustainable development goals has led policymakers in both developed and developing countries to explore their nexus with production and operations management. Amid state initiatives to achieve the SDGs, financial markets can play a vital role in supporting the transition towards sustainable business operations by investing in ESG-aligned projects.

This paper addresses the following research questions:

1. Does ESG (Environmental, Social, and Governance) investing act as a receiver (contributor) to the financial markets of the Quad nations?

2. How does ESG investing influence market dynamics, investment flows, and overall economic growth within these countries?
3. Which quantile exhibits the highest (or lowest) connectedness between the ESG investing index and the stock markets in the examined nations?

Our study makes a significant contribution to the existing literature in three key ways. First, studies on the connection between ESG investing and other markets exist; however, research is sparse on the dynamic linkages between the ESG investing index and financial markets in the Quad nations, which provides a novel perspective. Second, analysing the connectedness of shocks between these markets offers valuable insights for domestic and international stakeholders in different quantiles, from the bearish to bullish natures of the market. Third, by capturing the period encompassing both the natural and manufactured outbreaks, this study offers insight to illuminate the dynamics of linkages in these two different precarious conditions. This study examines the connectedness using quantile vector autoregression, employing daily observations from 31 December 2019 to 16 January 2023. The result demonstrates that total connectedness is not uniform across quantiles; it is highest in the lower quantile, followed by the upper and middle quantiles. Additionally, the ESG investing index and the Japanese stock market consistently dominate in terms of connectedness across all quantiles.

The remainder of this paper is structured as follows. Sect. "Literature Review" covers the relevant literature, Sect. "Data and Econometric Models" discusses the data and econometric models, Sect. "Results and Discussion" presents the empirical results, and Sect. "Conclusion and Policy Implications" concludes with a summary, policy implications, and suggestions for future research.

Literature Review

This section highlights the different strands of literature on Environmental, Social, and Governance (ESG) investments alongside other asset classes. The first strand throws light on micro-level studies investigating the impact of ESG disclosure on firm value. There are a large number of studies reflecting a positive relationship between enhanced ESG disclosure and firm value, emphasising that improved transparency in ESG practices can increase shareholders' interests (Bang et al., 2023; Barros et al., 2024; Tondon and Bansal et al., 2022; Dmuchowski et al., 2023; Bax, 2023; Hornuf & Yüksel, 2023; Sandberg et al., 2023; Pedersen et al., 2021; Gillan et al., 2021; Widyawati, 2020; Naffa & Fain, 2022; Teti et al., 2023; Wong et al., 2021). Initial research also stated that higher ESG ratings are related to enhanced dividend stability, increased shareholder returns, and ultimately, improved firm value (Jo & Harjoto, 2011; Li et al., 2018; Aouadi & Marsat, 2018; Brogi & Lagasio, 2019; Pavlopoulos and Iatridis, 2021; Qureshi et al., 2020; Okafor et al., 2021; Fatemi et al., 2018; Lee et al., 2013). For example, Barros et al. (2023) witnessed that firms with higher ESG ratings tend to deliver higher and more stable dividend payouts, which, in turn, positively impact firm value. Similarly, Dmuchowski et al. (2023) and Sandberg et al. (2023) observed a strong positive relationship between ESG ratings and firms' financial performance, particularly evident over the long term. Institutional investors and fund managers have increasingly incorporated ESG considerations into their investment strategies, recognising their role in mitigating risks and contributing to both sustainable financial returns and broader societal benefits (Broadstock et al., 2021; Gillan et al., 2021). On the contrary, some studies have witnessed a negative relationship between ESG disclosure and firm value, attributing this to the potential costs associated with implementing ESG initiatives (Buallay, 2019; Duque-Grisales & Aguilera-Caracuel, 2021; Moore, 2001). Some studies highlight no significant relationship between the two, indicating that the costs and benefits of ESG initiatives may counterbalance each other (Lahouel et al., 2019; McWilliams et al., 1999).

A second strand of studies compares the performance of ESG indices with conventional benchmark indices. Many studies have witnessed that ESG funds perform comparably to benchmark indices (Charlo et al., 2015, 2017; Fowler & Hope, 2007; Mensi et al., 2017; Santis et al., 2016; Fogaliano et al., 2013; La Torre et al., 2020; Tularam et al., 2010; Kempf & Osthoff, 2007). In research, Derwall and Koedijk (2009) highlight similar performance between ESG bond funds and their benchmarks. Auer and Schuhmacher (2016) employed risk-adjusted performance measures, such as the Sharpe ratio, to demonstrate that portfolios comprising high and low ESG companies often exhibit comparable performance in the US and the Asia–Pacific region, with some underperformance observed in Europe. In contrast, some studies reflected that ESG funds may outperform conventional indices under certain conditions (Joliet & Titova, 2018; Oikonomou et al., 2018; Statman, 2000; Tripathi & Bhandari, 2016). On the other hand, existing studies also explore underperformance or merely similar performance, reinforcing the ongoing debate regarding the financial benefits of ESG investments (Bauer et al., 2005; Consolandi et al., 2009; Hartzmark & Sussman, 2019; Jawadi et al., 2019).

The third strand of literature reports the performance of ESG investments during periods of financial crisis. Many studies observe that ESG funds may serve as a haven

during bearish markets, primarily due to the development of moral capital among stakeholders (Bouslah et al., 2018; Flammer, 2015; Godfrey et al., 2009). For example, a study by Dottling and Kim (2022) during the COVID-19 pandemic highlights that ESG investments are sensitive to income shocks, while Rui et al. (2020) reflected that ESG stocks yield significantly higher returns during the same period. These findings support the notion that ESG funds can provide a risk reduction and effective hedging mechanism during times of heightened market uncertainty (Ameur et al., 2020; Nofsinger & Varma, 2014).

Moreover, recent studies have begun to investigate the dynamic connectedness between ESG investments and conventional financial markets, observing significant spillover effects (Zhang et al., 2023; Akhtaruzzaman et al., 2022; Hassan et al., 2022; Pedini & Severini, 2022; Umar et al., 2022; Umar & Gubareva, 2021; Lean & Pizzutilo, 2020; Ameur et al., 2020; Jawadi et al., 2019; Omura et al., 2020; Andersson et al., 2020). For instance, Andersson et al. (2020) investigated the relationship between conventional indices and ESG investments, while Nepal et al. (2024) and Liya et al. (2025) examined the connectedness among various asset classes, identifying causality and mixed patterns in both short- and long-run dynamics. Although much research has been conducted on ETFs, firm value, and market connectedness, very few studies have specifically investigated the stock markets of the Quad nations.

In addition to these strands, recent studies have begun to integrate the concepts from flexible management systems into the analysis of ESG investments. Recent studies have highlighted that adopting flexible and adaptive organisational structures enhances the integration of diverse information, ranging from environmental and social metrics to governance indicators, and supports more responsive investment strategies. Such flexible systems facilitate dynamic feedback mechanisms and adaptive decision-making processes that are vital in volatile financial environments for the investment and mitigation of risk. This integration helps realign investment strategies in response to market fluctuations, reinforcing the long-term stability and resilience of portfolios and complementing the emerging evidence on the ability of ESG investments to provide diversification and risk mitigation benefits.

Overall, the literature witnesses a multidimensional view of ESG investments, highlighting mixed findings regarding their impact on firm value, performance relative to benchmarks, and behaviour during crises. This research contributes to the literature by emphasising the dynamic connectedness among the Quad nations' financial markets, with a particular emphasis on the role of the ESG index in facilitating sustainable investment and risk management in an increasingly flexible and adaptive financial ecosystem.

Data and Econometric Models

Data and Preliminary Analysis

We unveil the dynamic connectedness of the ESG investing index with the financial markets of the Quad nations. In this paper, financial markets are represented by the stock markets of the Quad nations. Table 1 summarises the proxies of our examined markets, where the ESG investing index is measured by the FlexShares STOXX US ESG Select Index Fund (ESG), and one stock exchange is selected from each examined country. Furthermore, a daily observation of the examined markets is considered to extend from 31 December 2019 to 16 January 2023. The primary reason for thinking this tenure is that it encompasses both catastrophic events, such as COVID-19 and the Russia–Ukraine conflict (Goodell et al., 2022). The concise description of the constituent variables is furnished below:

Figure 1 graphically represents the raw series, which exhibits a stochastic trend. We observe a similar trend in the ESG investing index and the stock markets of the Quad nations, except for the Australian market (AUS). To eliminate the stochastic trend from the examined markets, the raw series is transformed into a log return and displayed in Fig. 2. The log return of each examined market exhibits mean reversion and volatility clustering, which is consistent with Sharma et al. (2023).

Before the empirical computation of connectedness, the pattern of each examined market is encapsulated in Table 2. Referring to this table, we note that the average return of each market is positive except for the Australian stock market (AUS). The variance of these returns is not significant; however, the ESG stock and the US market have comparatively high variance. Considering the distribution pattern, it is observed that the Australian and Japanese markets are positively skewed, while the rest of the examined markets are negatively skewed. Each series exhibits a leptokurtic distribution, as its kurtosis value exceeds 3.

Furthermore, the Jarque–Bera (JB) test indicates that there is no normality in each series, as evidenced by its significant value; the kurtosis values also verify this. For the unit root test, the ERS test is employed, which confirms stationarity in each return series, as it yields a significant p-value. The statistically significant values of Q(10) and Q2(10) statistics from the Ljung–Box test, which measures autocorrelation in a time series up to a certain lag (lag 10 in this case), suggest evidence of autocorrelation in the ESG investing index, as well as in the Quad stock exchanges. It indicates that the values of ESG metrics are not random and independent and may have predictive power for future values.

Table 1 Data description. Source: Author

Examined Markets	Index	Code	Data Source
ESG Stock Fund	FlexShares STOXX US ESG Select Index Fund (ESG)	ESG	Bloomberg
Australian Stock Exchange	Australian Securities Exchange	AUS	
India Stock Exchange	National Stock Exchange of India	IND	
Japan Stock Exchange	Tokyo Stock Exchange	JPN	
United States Stock Exchange	New York Stock Exchange	USA	

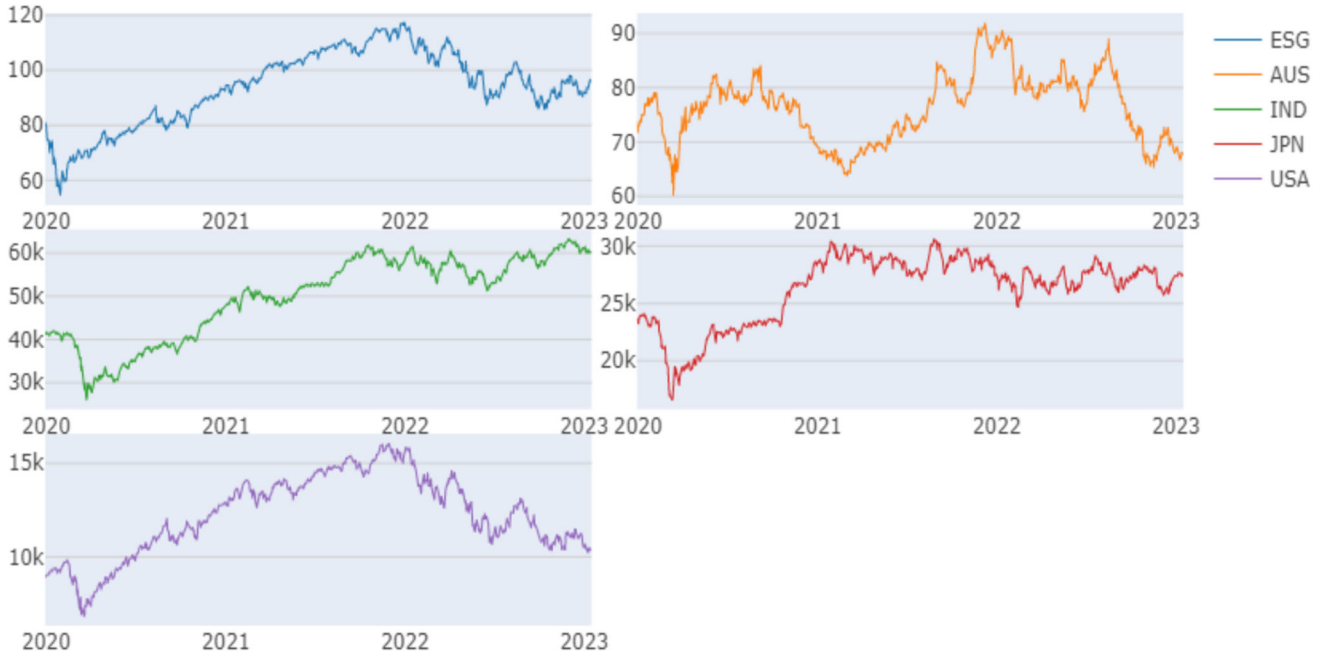

Fig. 1 Graphical display of raw series

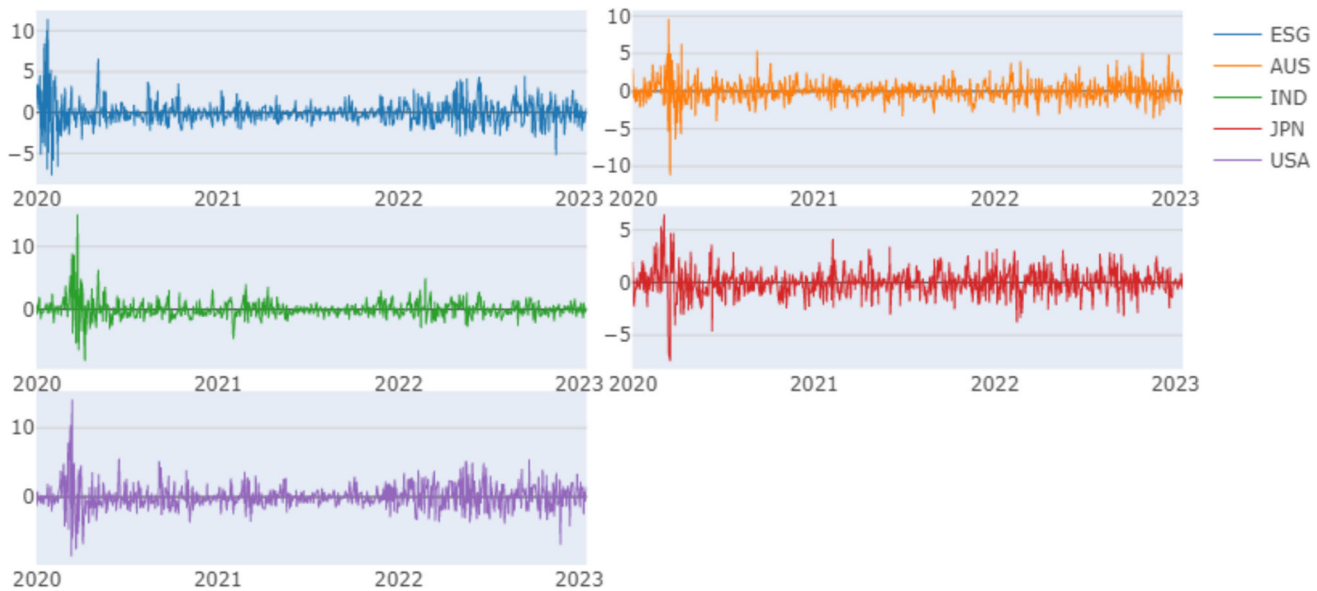

Fig. 2 Graphical display of the return series

Table 2 Summary statistics of constituent variables. Source: Author

	ESG	AUS	IND	JPN	USA
Mean	0.0002	-0.0001	0.0005	0.0002	0.0002
Variance	0.0003	0.0002	0.0002	0.0002	0.0003
Skewness	-0.6891***	0.2582***	-1.6059***	0.0812	-0.5888***
Ex. Kurtosis	7.7133***	8.3956***	17.5501***	3.1336***	5.7687***
JB	1944.1844***	2240.5174***	10,080.1835***	311.7745***	1097.7325***
ERS	-9.7346***	-2.1562*	-6.2042***	-3.8021***	-11.3805***
Q(10)	85.9131***	74.7384***	32.4800***	11.4116**	67.4565***
Q2(10)	613.4162***	281.5136***	288.0417***	251.9522***	459.4756***

* and *** indicate the significance level at 5% and 0.1%, respectively

In addition to the summary statistics for the pattern, we check the static correlation and overall distribution pattern displayed in Fig. 3. There is a positive correlation between ESG and the Indian market (0.011) and the Japanese market (0.101), while the Australian and US markets are associated negatively. Interestingly, the US and Indian markets are correlated positively and significantly with each other. An intriguing observation is evident from this graphical display, as there is a degree of association among the examined markets. With the advent of a distribution pattern, we observe that each series exhibits asymmetry and is not normally distributed.

Model and Method

To analyse the connection between ESG investing and stock markets, we employ Diebold and Yilmaz (2012) and the quantile vector autoregression (VAR) developed by

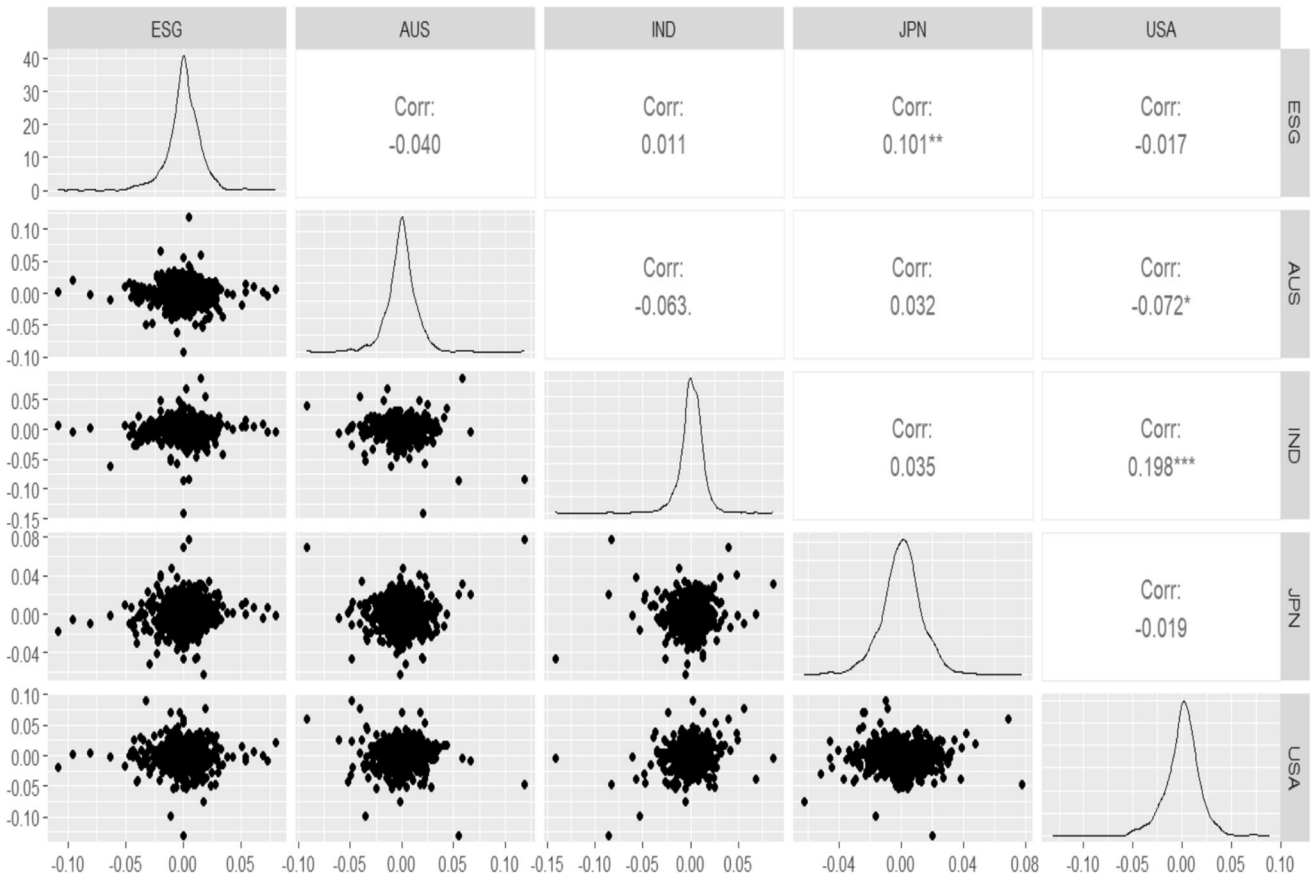

Fig. 3 Overall distribution pattern and static correlation

Ando et al. (2018). The Diebold and Yilmaz (2012) model encompasses the importance of capturing the connectedness among constituent variables to measure their behaviour, which is based on the variance decomposition from the vector autoregression model. The variance decomposition enables the analysis of how shocks in one variable affect the variance of the forecast error in another variable. This understanding is crucial for evaluating the degree of interdependence or connectedness between different variables within the system.

As a first step, a vector autoregressive model is determined, followed by a forecast for the H time period. Finally, the error variance of each variable is decomposed into shocks to one or all variables for the *t* time period. - Using the N × N matrix, the baseline model is represented as follows:

$$\varnothing(H) = [\varnothing_{ij}(H)]_{ij=1\ldots,N} \tag{1}$$

In Eq. (1), each entry measures the impact of shock (variable j) on the forecast error variance (variable i) of the time-varying covariance matrix. Since the connectedness approach assesses the directional impact between variables, the cross-impact of shocks (variable *j)* to the forecast error variance (variable *i*) is captured by off-diagonal elements. In contrast, the impact of shocks (variable *j)* on its own forecast error variance (variable *i*) is captured by the main diagonal elements. The combined connectedness approach is appended as follows:

$$TS(H) = \frac{\sum_{ij=1,i\neq j}^{N} \varnothing_{ij}(H)}{\sum_{ij=1}^{N} \varnothing_{ij}(H)} \times 100 = \frac{\sum_{ij=1,i\neq j}^{N} \varnothing_{ij}(H)}{N} \times 100 \tag{2}$$

Building on the methodologies proposed by Diebold and Yilmaz, the total risk spillover effect measured through variance decomposition is expressed as:

$$TCI \frac{\sum_{ij=1,i\neq j}^{N} \widetilde{\Theta}_{ij}^{g}(H)}{N-1} \tag{3}$$

To quantify the impact and direction of spillover effects between Market j and Market i, the directional spillover is represented as follows:

$$TO_{j,t} = \sum_{i=1,i\neq j}^{N} \widetilde{\Theta}_{ij,t}^{g}(H) \tag{4}$$

$$FROM_{j,t} = \sum_{i=1,i\neq j}^{N} \widetilde{\Theta}_{ji,t}^{g}(H) \tag{5}$$

where $TO_{j,t}$ index measures the combined impact that variable j exerts on all other variables, whereas $FROM_{j,t}$ index measures the impact of all other variables on variable j.

$$NET_{j,t} = TO_{j,t} - FROM_{j,t} \tag{6}$$

$NET_{j,t}$ spillover is computed by subtracting the recipient of the shock from the contributed shock, where a positive net value implies the shock (risks) transmitted by the variable *j* to the system. In contrast, a negative net value indicates that variable *j* receives shocks (or risk) from other markets within the system.

$$NPDC_{ij,t} = \widetilde{\Theta}_{ij,t}^{g}(H) - \widetilde{\Theta}_{ji,t}^{g}(H) \tag{7}$$

$NPDC_{ij,t} > 0$ signifies the dominance exerted by variable *i* over variable *j* and vice versa**.** For the accurate computation of the quantile connectedness metrics in accordance with Ando et al. (2018), it is essential to outline an infinite-order VMA representation within the Quantile Vector Autoregressive (QVAR), which is expressed as follows:

$$y_t = \mu(q) + \sum_{j}^{p} \phi_j(q) y_{t-j} + u_t(q) = \mu(q) + \sum_{i=0}^{\infty} \Omega_i + (q) u_{t-i} \tag{8}$$

In Eq. (8), quantile (q) ranges between 0 and 1. Further, the generalised forecast error variance decomposition (GFEVD) with a time period for forecasting (H) is represented as below:

$$\Theta_{ij}^{g}(H) = \frac{\sum (q)_{jj}^{-1} \sum_{h=0}^{H-1} (\acute{e}_i \Omega_h(q) \sum(q) e_j)^2}{\sum_{h=0}^{H-1} (\acute{e}_i \Omega_h(q) \sum(\urcorner) \Omega_h(q) \prime e_i} \tag{9}$$

where e_i depicts a vector with unity on the ith position. Each element is normalised, and the decomposition matrix is specified as:

$$\widetilde{\Theta}_{ij}^{g}(H) = \frac{\Theta_{ij}^{g}(H)}{\sum_{j=1}^{k} \Theta_{ij}^{g}(H)} with \sum_{j=1}^{N} \widetilde{\Theta}_{ij}^{g} = 1 and \sum_{ij=1}^{N} \widetilde{\Theta}_{ij}^{g}(H) = 1 \tag{10}$$

Results and Discussion

This section presents results derived from the models employed in this manuscript, along with robustness testing.

Diebold & Yilmaz (2012) Model for directional connectedness

This section discusses the findings obtained to analyse the dynamic linkages between the ESG investing index and stock markets in QUAD nations. We report the results obtained from the Diebold and Yılmaz (2012) model, followed by Quantile VAR. Referring to Table 2, "FROM" denotes the recipient of the shock, while "To" indicates the

contribution/transmission of shock to the examined markets. In a similar realm, the diagonal of the matrix represents self-connectedness. The diagonal element estimates suggest that 93.62% of the volatility evolution in the ESG index is attributed to within-market behaviour, and 6.38% is attributed to the market's connection network.

Furthermore, 84.54% of the shock evolution in the Australian market, 75.08% in the Indian market, 92.45% in the Japanese market, and 73.59% in the US market are observed within the market ecosystem. On this note, it is deduced that the investigated markets are influenced by self-spillover to a great extent. Regarding the recipient of the shock, we note that the US stock exchange received the highest shock (5.28%) among the examined markets, followed by the Indian stock market (4.98%). In contrast, the ESG indices received the least shock (1.28%). Focusing on the extent of shocks transmitted from a particular asset to the broader system, it is witnessed that the highest volatility spillover is from the ESG index (5.55%) to other markets, followed by the US stock market (4.58%), Japanese stock market (2.97%), the Indian stock market (1.64%), and Australian stock market (1.40%). Assessing the results of contributions to and from, it is noted that higher shocks are transferred from the ESG index to the system as compared to what is received from other QUAD stock markets' indexes. The positive NET figure denotes the net transmitter, while a negative signifies the net receiver of the shock. To be precise, ESG and Japanese markets are net transmitters of the shocks, with 4.28% and 1.46% shocks, respectively.

In contrast, the Australian market (-4.11%), the Indian market (-6.55%), and the US market (-31.44%) are net receivers of shocks. The cumulative index (total connectedness index) of 16.14% derived from Diebold and Yilmaz's (2012) model suggests a slight connection between the ESG index and the QUAD stock markets' index in terms of shock transmission/dynamic linkage among the markets. The Quantile VAR model is used in the next section to analyse the magnitude of connectedness at different quantiles (Table 3).

Quantile Spillover Between the ESG Investing Index and the Financial Markets of QUAD

The Diebold & Yilmaz (2012) model is one of the popular models to analyse the interconnectedness across financial assets in economic and finance literature (Choi, 2022). This model provides average connectedness among examined markets irrespective of bear, tranquil, and bullish markets. To overcome this, we employ Quantile Vector Autoregression (QVAR), which is presented in Table 4. Regarding this table, panels 4A, 4B, and 4C provide connectedness at the lower (0.05), middle (0.5), and upper quantiles (0.95). Turning to the stressful market condition (q = 0.05) displayed in panel 4A, it is noted that the US and Japanese markets receive shocks with 77.58% and 73.57%, respectively.

In contrast, the ESG investing index is reported as the least recipient (71.15%) of the shock from constituent markets. An intriguing observation is noted regarding the transmission of the shock, as ESG investing is identified as the highest transmitter (86.13%), followed by the Indian market (75.34%). Further, the US market is found to be the least transmitter (67.73%) to the network connection. In the quest to unravel net connectedness, notably, the ESG investing index and the Indian market dominate the network connection, as these markets act as net transmitters with 14.98% and 2.55%, respectively. To be precise, the ESG index emerges as a central transmitter comparatively. It is noteworthy to mention that the examined markets are more connected during stressful market conditions, as indicated by the high average total connectedness, as shown in Table 3. On this note, the ESG investing index and Indian markets ought to be given priority by investors and portfolio managers for diversification opportunities.

Further, the quantile connectedness of q = 0.50 (the tranquil period) is furnished in panel 4B of Table 4. Referring to panel 4B, we note that the US stock market is the most vulnerable to shock, with 57.21%, followed by the Indian stock market with 35.97%. The ESG investing index is found to be the least affected by the shock (29.13%)

Table 3 Directional connectedness employing Diebold & Yilmaz (2012) model. Source: Author

	ESG	AUS	IND	JPN	USA	FROM
ESG	93.62	1.83	1.23	1.89	1.43	1.28
AUS	2.95	84.54	2.34	0.98	9.19	3.09
IND	4.57	2.19	75.08	7.72	10.45	4.98
JPN	3.63	0.86	1.22	92.45	1.83	1.51
USA	16.63	2.13	3.39	4.26	73.59	5.28
TO	5.55	1.40	1.64	2.97	4.58	TCI = 16.14
NET	4.28	-1.69	-3.35	1.46	-0.70	

Table 4 Spillover at various quantiles. Source: Author

	ESG	AUS	IND	JPN	USA	FROM
A: Lower quantile directional connectedness (Alpha = 0.05)						
ESG	28.85	16.52	19.11	17.5	18.02	71.15
AUS	20.32	27.71	17.74	17.87	16.36	72.29
IND	21.11	17.68	27.21	17.35	16.65	72.79
JPN	20.5	17.47	18.9	26.43	16.7	73.57
USA	24.2	16.45	19.58	17.34	22.42	77.58
TO	86.13	68.11	75.34	70.06	67.73	73.47
NET	14.98	-4.17	2.55	-3.51	-9.84	
B: Middle quantile directional connectedness (Alpha = 0.5)						
ESG	70.87	7.3	8.55	8.1	5.19	29.13
AUS	11.96	66.76	7.36	7.29	6.63	33.24
IND	14.02	6.47	64.03	7.89	7.6	35.97
JPN	10.78	7.56	6.54	69.45	5.66	30.55
USA	34.55	6.07	10.18	6.41	42.79	57.21
TO	71.32	27.4	32.63	29.69	25.08	37.22
NET	42.19	-5.84	-3.35	-0.86	-32.13	
C: Upper quantile directional connectedness (Alpha = 0.95)						
ESG	35.02	15.67	16.24	17.69	15.38	64.98
AUS	17.1	31.69	17.84	17.16	16.21	68.31
IND	16.68	17.03	33.64	16.8	15.84	66.36
JPN	17.51	17.78	16.9	31.1	16.72	68.9
USA	23.9	15.31	16.9	16.63	27.27	72.73
TO	75.19	65.79	67.88	68.28	64.15	68.26
NET	10.21	-2.52	1.51	-0.62	-8.57	

from the network connection. Surprisingly, ESG emerges as the most significant contributor (71.32%) to the constituent markets, followed by the Indian market (32.63%), while the US market is spotted as the least transmitter (25.08%) of the shock. Based on this evidence, it is observed that the magnitude of the total connectedness index (TCI) in the middle quantile is less than the lower and upper quantiles. Considering the net connectedness, it is worth noting that ESG investing dominates the rest of the financial markets of QUAD nations, as it transmitted more shocks to the markets than it received. Next, the directional connectedness at the right tail (q = 0.95) is documented, revealing that the US market is the largest recipient, followed by the ESG investing index.

On the other hand, the Japanese market is the largest transmitter, followed by the European market, while the ESG investing index is the least affected by the shock. With respect to net spillover, it is observed that the ESG investing index and Indian markets are net transmitters of the shock, with net spillovers of 10.21% and 1.51%, respectively. Furthermore, the Australian, Japanese, and US markets are net recipients of the shock. It implies that the ESG investing index and the Indian market dominate the examined markets.

Additionally, it is documented that the total connectedness during the bearish market is highest at 73.47%, compared to other periods. To be precise, the transmission of information in a stressful market is large. ESG regulations and central monetary policies may influence the interconnectedness among these markets. Since monetary policies set by central banks of respective countries affect liquidity, interest rate, and overall economic condition, which are the link pins to the financial markets. Regarding ESG regulation, companies should implement more comprehensive ESG practices if countries adopt ESG regulations. It can lead to higher investor confidence in ESG assets and, in turn, boost the growth of ESG indices.

Furthermore, fluctuations in interest rates and liquidity can affect the flow of foreign direct investment (FDI) and portfolio investments into ESG-compliant companies. Central bank policies influence the decisions of foreign investors and, consequently, the interconnectedness between ESG stocks and financial markets in these countries. Our findings corroborate those of Yunus et al. (2022),

who documented that interconnectedness is not uniform across different time periods. Notably, the ESG investing index consistently dominates in each quantile. Hence, stakeholders in the markets ought to be cautious about the connectedness when making investment decisions. Additionally, it demonstrates that the theories of market integration and asymmetries in connectedness are closely intertwined. Both reflect this, indicating sturdy integration at both upper and lower quantiles.

To refine the connectedness over the period, we display TCI, transmission, recipient, and net connection of the middle quantile. As evident from Fig. 4, the total connectedness (TCI) is not uniform over time. Additionally, the TCI during the initial phase of the COVID-19 pandemic was not large. However, it starts increasing at the beginning of the Russia–Ukraine invasion and remains approximately the same throughout the period. It suggests that the ESG investing index, along with QUAD markets, withstood the shock created by this unmitigated catastrophe (the Russia–Ukraine invasion), resulting in comparatively high linkages. Similarly, the transmission of the shock to examined markets is displayed graphically in Fig. 5. It is noted that the transmission of shock from the ESG investing is large. Surprisingly, the manufactured outbreak, similar to the Russia–Ukraine invasion, led to a rise in ESG. The US market has remained relatively unaffected by the limited transmission during the Russia–Ukraine invasion.

Furthermore, as illustrated in Fig. 6, we observe that the recipient of the shock is not a large ESG stock in the Australian, Indian, and Japanese markets, regardless of the examined period. However, the US market received more shocks after the COVID-19 period. The primary reason behind this high level of shock might be the fuelling of inflation due to the supply shock created by the Russia–Ukraine invasion. Net connectedness is displayed visually in Fig. 7. It is noteworthy to mention the interesting observation that although ESG is the net transmitter on average, it transmits more shocks in manufactured outbreaks.

Robust Testing

For the robust testing, we display the network connectedness in Fig. 8. It shows the connectedness at quantiles 0.05, 0.50, and 0.95, respectively, where the yellow-coloured circle signifies the net receipt of the shock, while the dark blue circle indicates the net transmission of the shock. Furthermore, the direction of spillover is represented by the arrow, while the size of the circle indicates the magnitude of the net receipt/transmission. The figures, from left to right, represent the low, medium, and upper quantiles. Regarding a low quantile, the Indian market and the ESG investing index are net transmitters of the shock. Since the circle of the ESG index is large, it is found to be a large transmitter of the shock. The upper quantile is in a similar line to the lower quantile in terms of net transmission of the shock. However, ESG investing is primarily focused on stocks that are net transmitters in the middle quantile.

Conclusion and Policy Implications

The ESG investment offers a new, critical approach to evaluating investment decisions within SDG-led business development. In this regard, ESG investment is considered of strategic importance in realising the UN-SDGs. Similarly, sustainable funds incorporate consistent information about environmental, social, and economic components to manage risk and opportunities while making asset allocation decisions. On the other hand, the QUAD nations, a grouping of four democracies comprising Australia, India, Japan, and the US, are a combination of developed and emerging nations. These nations have major stock exchanges in the world, which attract domestic and international investors who seek to be informed about the

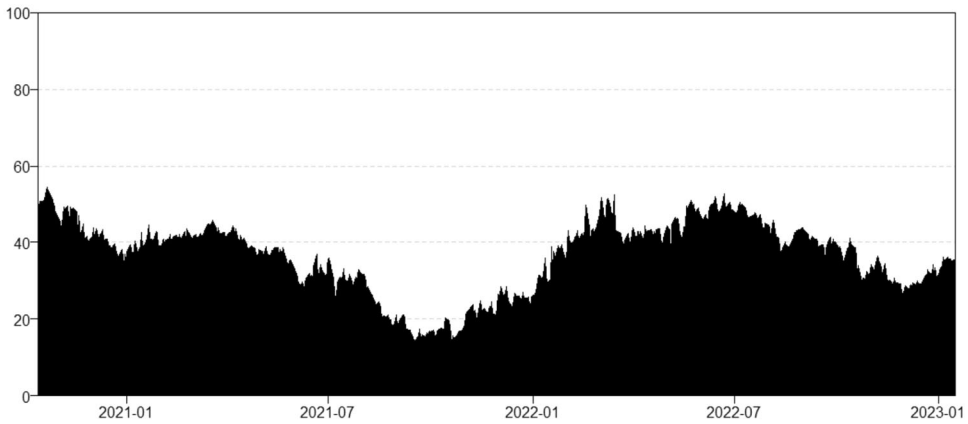

Fig. 4 Graphical depiction of total connectedness

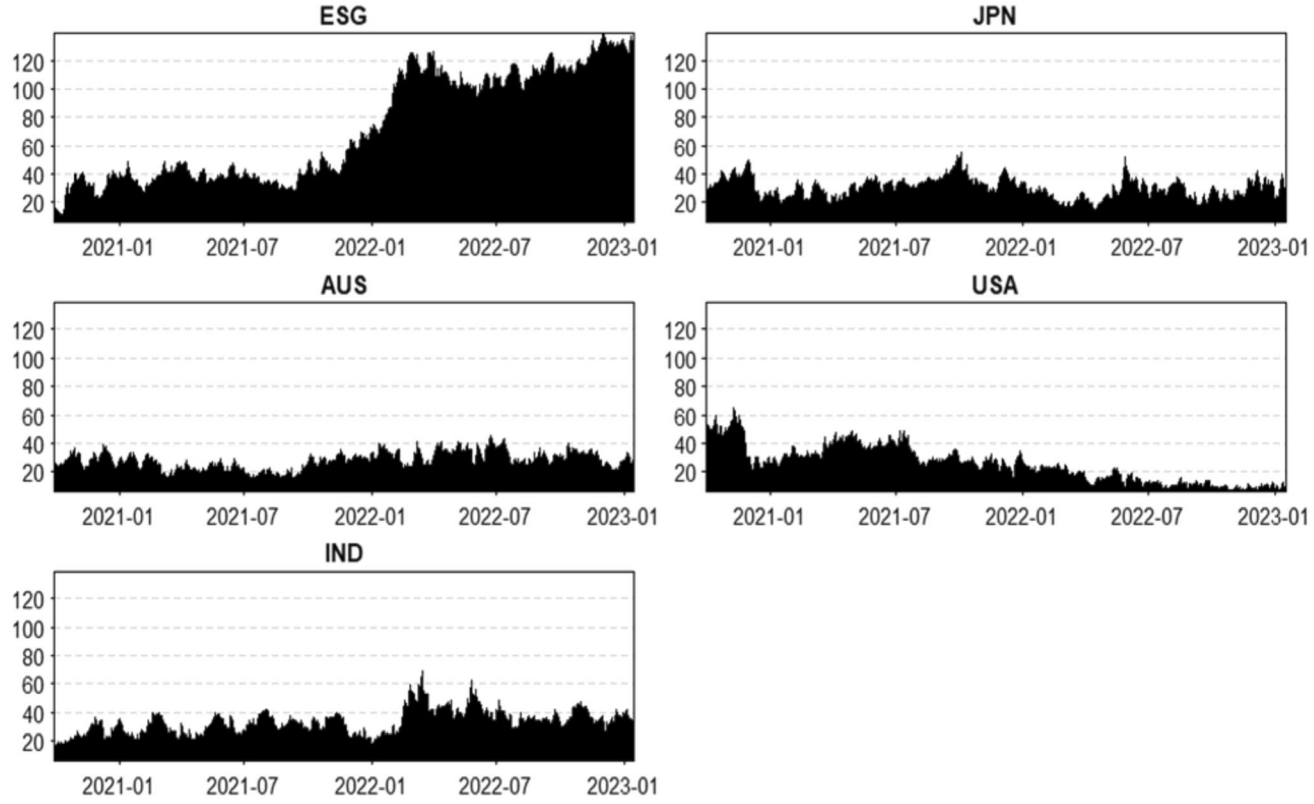

Fig. 5 Graphical depiction of transmission of shocks

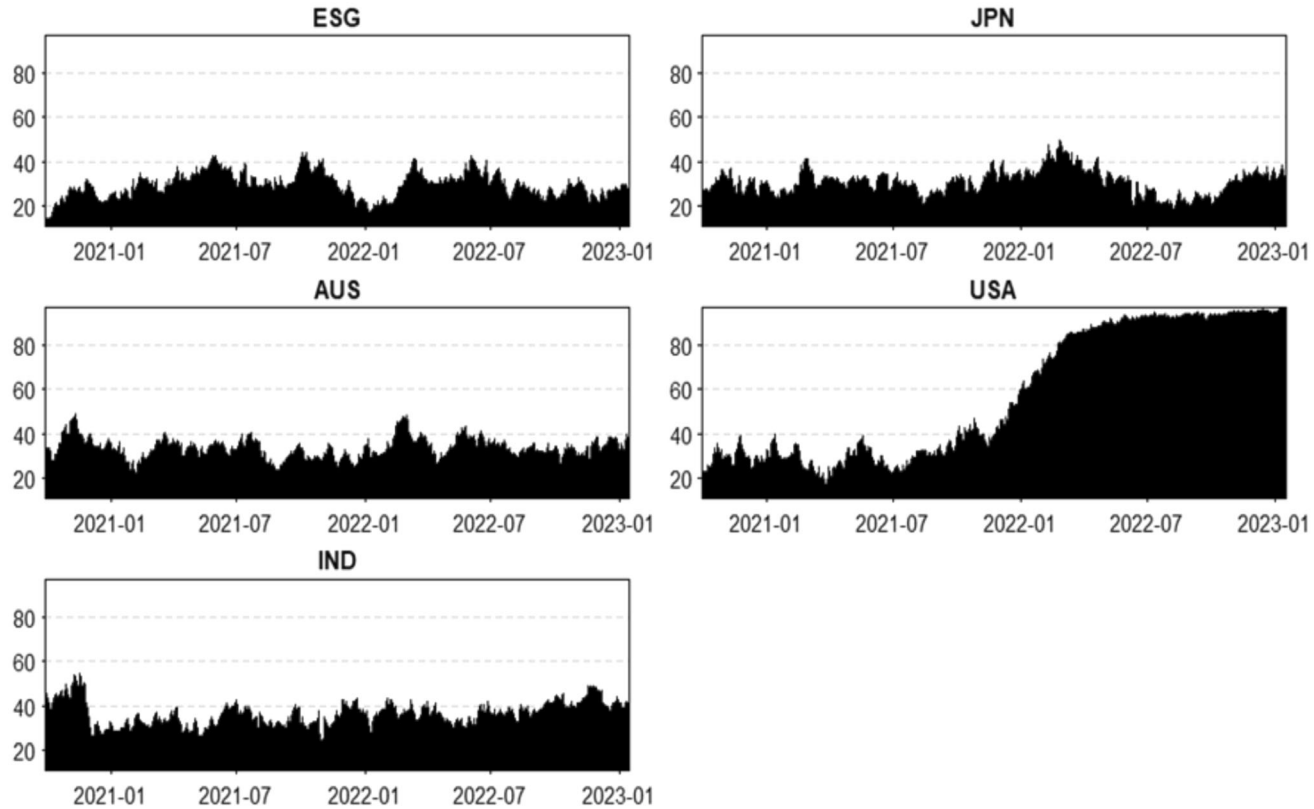

Fig. 6 Graphical depiction of the recipient of shocks

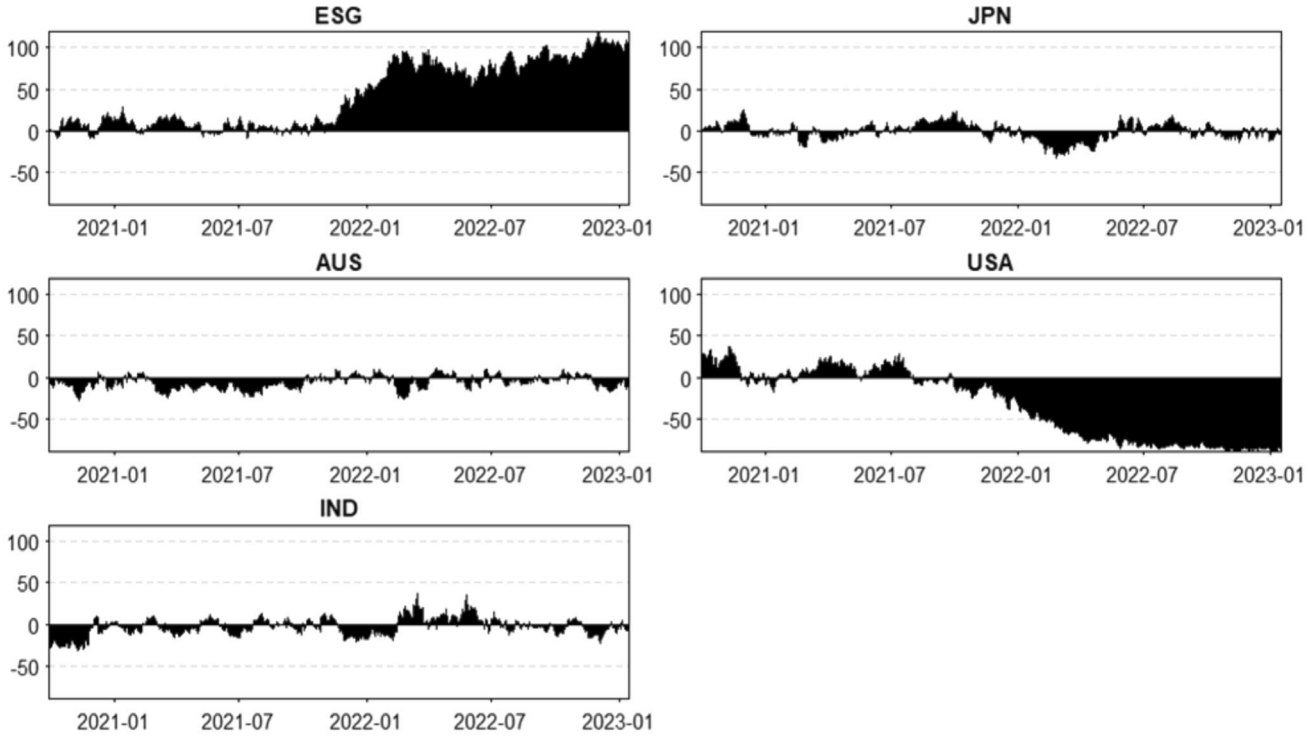

Fig. 7 Net connectedness among constituent markets

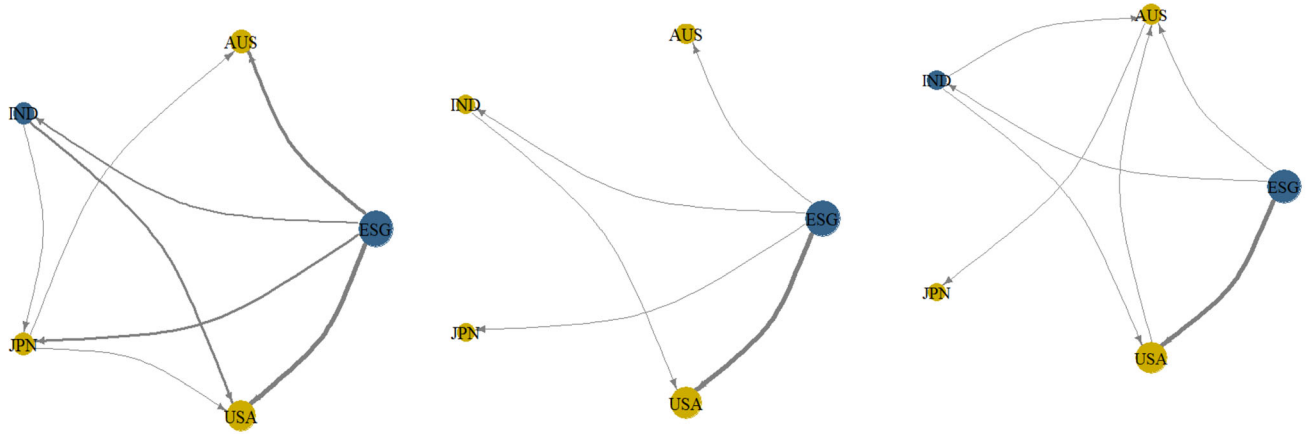

Fig. 8 Network connectedness at q = 0.05, q = 0.5, and q = 0.95, respectively

transmission of information, thereby mitigating risk associated with examined assets. In this regard, this study aims to quantify the connection between the ESG investing index and the financial markets of the QUAD nations.

We use the FlexShares STOXX US ESG Select Index Fund (ESG) to represent the ESG investing index, while one stock exchange of each Quad nation is considered to proxy the financial market. The QVAR is employed for empirical estimation based on daily observations collected from 31 December 2019 to 16 January 2023. The empirical results under lower quantiles reveal that the US stock market is the most resilient, and the ESG investing index is the least resilient to the shock. In contrast, the ESG investing index is the highest transmitter, and the US market is the least transmitter in the network connection. Additionally, the ESG investing index and the Indian stock market dominate the examined markets under stressful conditions. With the advent of a tranquil period, the US and ESG stocks are the least affected, while ESG emerges as the most significant contributor.

Furthermore, ESG investing dominates the financial markets of the QUAD nations, ranking in the middle quantile. Regarding the upper quantile, the US market is the largest recipient, while the ESG investing index is the

largest transmitter. Further, the ESG investing index and the Indian market are found to be net transmitters of the shock. In addition, the total connectedness is realised at its highest in the lower quantiles, followed by the upper and middle quantiles.

The findings offer policy implications threefold to various stakeholders of the markets. First, investors and portfolio managers seeking to mitigate risk should consider including ESG investing indices and the Japanese stock index in their portfolios, as they dominate the rest of the examined markets. Second, one should exercise caution when investing in these markets under stressful conditions, given the high level of interconnection during this period. Third, policy analysts must strategize a policy framework that considers the connectedness across different quantiles, as it is not homogeneous. Hence, the policy framework of lower quantiles does not work for tranquil and upper quantiles. This study is likely to have limitations, as it is based on the quantile connectedness of the ESG investing index with the financial markets of the Quad nations.

Furthermore, it can be explored in consideration of other economies, such as the G20, MINT, and MENA. This study utilises catastrophe periods (both manufactured and natural), which can be explored in conjunction with another manufactured outbreak period, such as the Israel–Hamas war. In addition, decomposed connectedness and quantile-on-quantile (direct and reverse) total connectedness may be employed to check both lagged and contemporaneous connectedness across different quantiles among the examined markets.

Author Contributions M.P.Y. led the data analysis and drafted the main manuscript text. S.V.K. contributed significantly to the literature review and the development of the methodology. V.S. assisted in preparing figures and revising the manuscript. V.R.S. provided critical feedback, supervised the research process, and contributed to the final editing. All authors reviewed and approved the final manuscript. A.P.S. oversaw the project, ensuring that the theoretical framework was aligned with flexible management theory, extensively proofread and edited the manuscript, and managed the submission and communication with the journal.

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Data Availability Data will be provided upon further request.

Declarations

Conflict of interests The authors declare no conflicts of interest related to this study. A Co-author, Adam P. Shore is serving as Associate Editor for the Journal.

Ethical Statement This study complies with the ethical guidelines set by the journal. The research did not involve human participants or animals. The authors declare no competing interests. The work is original, unpublished, and not under consideration elsewhere. Data is available upon reasonable request.

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Key Questions

(1) To what extent can ESG investments be considered more resilient than traditional assets during periods of financial crisis, and how might this be tested across other market contexts?
(2) What structural or behavioural factors could explain why the Japanese market and the ESG index act as primary transmitters of shocks within the Quad network?
(3) How can policymakers and regulators incorporate evidence of quantile-specific connectedness into frameworks that promote sustainable and stable financial systems?
(4) How might future studies investigate the relationship between investor sentiment, market conditions, and variations in connectedness across quantiles?
(5) What potential exists for coordinated ESG standards and disclosure practices across the Quad nations to strengthen financial integration and reduce systemic risk?

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