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Sustainability indices nexus: Green economy, ESG, environment and clean energy

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ABSTRACT

In this article, we examine the spillover effects and connectedness among four prominent sustainability-related indices. We analyze daily data spanning from August 8, 2014, to April 12, 2023, to explore the interrelationships among the Green Economy Index, the World Environmental, Social, and Governance Index, the Global Environment Index and the Global Clean Energy Index. Particularly, we observe a clustering characteristic where both the Green Economy Index and the World Environmental, Social, and Governance Index exhibit a net-contributing behavior, especially during and after the COVID-19 outbreak. Global Environment Index, on the other hand, exhibits a net-receiving role, which became strong during the COVID-19 outbreak. Further, the Global Clean Energy Index demonstrates a neutral role, although it shows a net-receiving trend after the year 2022. Finally, dynamic analysis confirms the evolving nature of these interconnectedness measures, highlighting their sensitivity to events and shifting economic conditions over time.

1. Introduction

Recently, there has been a big push worldwide to focus more on sustainable development and going green to narrow the economic gap, both locally and globally (Gunay, Muhammed, & Elkanj, 2022). This means that countries and organizations are now considering how their growth impacts the environment (Zilberman, 2014). Plus, as people become more aware, there is increasing pressure on companies and countries to commit to sustainability (Hakovirta, Kovanen, Martikainen, Manninen, & Harlin, 2022; Lin et al., 2023). With the United Nations' 2030 Agenda for Sustainable Development, the whole world is aiming for a more sustainable future (Jacob & Wilkens, 2021). Also, this focus on sustainability has made environmentally and socially responsible investors want to know about both financial and sustainability risks in their investments (Folqué, Escrig-Olmedo, & Corzo Santamaria, 2021).

In the literature, various terms, such as 'ESG', 'green' and 'clean' are employed to convey the concept of sustainable development, all sharing the idea that financing climate-neutral, energy-efficient, and resource-efficient technologies is essential for advancing environmental and sustainability goals (Aloui, Benkraiem, Guesmi, & Vigne, 2023;

Madaleno, Dogan, & Taskin, 2022; Wan, Yin, & Wu, 2024). In light of this context, a range of indices have emerged to capture the sustainability capabilities of businesses, extending their assessment beyond financial performance (Bax, Bonaccolto, & Paterlini, 2024; Chen & Lin, 2022; Lin & Liu, 2015). The basic premise is that the quantification of qualitative information can play a role in advancing sustainability and, consequently, enhancing efficiency. Nevertheless, there are costs associated with the comprehensive monitoring of all these indices. Thus, market participants should grasp the interconnections among these indices to formulate their strategies more effectively.

The green economy represents the fundamental concept for achieving sustainable economic development through the harmonized progress of both ecological and economic aspects (He, Zhang, Zhong, Wang, & Wang, 2019). It was introduced by the United Nations Environmental Programme in 2008, and since then, different measures have been developed to implement this concept (Ryszawska, 2015). In fact, as a concept, it includes various economic activities aimed at minimizing negative environmental impact and often includes broader sustainability aspects (Gunay et al., 2022). A prominent and well-established index that is created to track the performance of firms across diverse industries

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closely aligned with the sustainable development economic model is NASDAQ OMX Green Economy Index (GE Index) (Basse, Karmani, Rjiba, & Wegener, 2023; Gunay et al., 2022). Similarly, several sustainability indices have been constructed to evaluate companies with strong ESG. For instance, the MSCI World Environmental, Social, and Governance Leaders Index (ESG Index) is specifically crafted to showcase the performance of companies with elevated ESG ratings in comparison to their counterparts within the same sector (Lucey & Ren, 2023; Tanjung, 2021). The basic idea behind these indices is that companies focused on ESG practices tend to be more sustainable and create lasting value (Schoemaker & Schramade, 2019). Because of this, socially responsible investors prefer companies that do well in these areas. Therefore, based on this analysis, studying the interconnectedness between the GE Index and ESG Index is a topic worth exploring further.

In a similar vein, renewable sources and clean technology have attracted the attention of many stakeholders as they are standard means of addressing climate change - through the reduction of carbon emissions - and promoting environmental sustainability (Madaleno, Taskin, Dogan, & Tzeremes, 2023; Zhang, He, & Hamori, 2022). The signing of the Kyoto Protocol in 1997 and the Paris Agreement in 2015 represent pivotal milestones in global climate change efforts, exerting influence on financial markets through the green transition (Hanif, Teplova, Rodina, Alomari, & Mensi, 2023). In this context, the energy transition rationale supports the idea that carbon markets drive cost-effective emission reductions and low-carbon technology development, influencing renewable energy firms (Dogan, Luni, Majeed, & Tzeremes, 2023; Nie, Li, & Li, 2021). A well-known index representing global clean energy is the S&P Global Clean Energy Index (Demiralay, Gencer, & Bayraci, 2022). This index (CENE index) tracks the performance of the leading clean energy companies worldwide (Alkathery, Chaudhuri, & Nasir, 2023). In light of this, existing research indicates an association between the green and clean energy markets (Chatziantoniou, Abakah, Gabauer, & Tiwari, 2022; Ghosh, 2022). An index that has been constructed and serves as the benchmark for investors seeking firms that generate income through the efficient utilization of limited natural resources or the mitigation of environmental degradation are key objectives of the MSCI Global Environment Index (GENV index) (Chatziantoniou et al., 2022; Xiang, Asl, Isfahani, & Vasa, 2024). Therefore, empirically examining the interconnectedness between the CENE index and the GENV index is also a topic worth exploring further.

Considering that markets are dynamic and that the indices under analysis are influenced by these forces, our study builds on this foundation and examines the fundamental interconnections among these four indices. Despite their differences, as illustrated in Fig. 1, all these indices play a crucial role in the concept of sustainability. However, as previously mentioned, there are costs associated with the comprehensive monitoring of all these indices. Therefore, exploring their complex interactions provides an efficient way to understand the dynamic process and the underlying risks within this complex system (Inglesi-Lotz, Dogan, Nel, & Tzeremes, 2023). Connectedness, as an approach to “measure the degree of the inter-relations and the inter-dependencies between the components of a whole system concentrating this information in a single number or index”, makes it a broader concept than merely examining linear relationships between system variables (Maggi, Torrente, & Uberti, 2020, pp. 548–549). By understanding the contagion effect across these diverse indices, investors can better support their decision-making and construct diversified portfolios (see, Torrente & Uberti, 2021).

This study makes significant contributions to the current body of literature. To the best of our knowledge, it is the first research that examines the spillover and connectedness among these four sustainability-related indices. Prior to this inquiry, Dogan et al. (2023) conducted a study focused on exploring the connectedness between global carbon and renewable energy sources. In a similar vein, Chatziantoniou et al. (2022) conducted a study that focused on four indices: the S&P Green Bond Index, the GENV Index, the Dow Jones Sustainability Index World

and the CENE Index. Additionally, Zhang et al. (2022) delved into the dynamic connectedness among several other sustainability-related indices. Through our rigorous analysis, we respond to the calls articulated in previous studies for more comprehensive investigations in this field, aimed at enhancing the body of knowledge related to sustainability investment. Second, our study applies the new Quantile Vector Autoregression (QVAR) framework that was proposed by Chatziantoniou, Gabauer, and Stenfors (2021). This methodology has been extensively employed by scholars to investigate dynamic, time-frequency, and nonlinear relationships across various disciplines (e.g., cryptocurrencies, insurance), market conditions, and time periods. The advantage of this methodology lies in the fact that the QVAR model diverges from the traditional conditional mean estimators, such as ordinary least squares (OLS), primarily because it handles VAR residuals differently (see Khalfaoui, Stef, Wissal, & Sami, 2022). This methodology serves three primary purposes: (i) capturing the directionality of interconnectedness transmission of indices movements; (ii) exploring whether these movements exhibit symmetry or asymmetry across different quantiles and identifying commonalities among quantiles of joint variable distributions across frequencies to reveal correlation patterns among covariates; (iii) determining the role of specific indices as either net transmitters or recipients of spillover shocks. Thirdly, in light of the robust connectedness observed among these four sustainability indices, our empirical findings hold significant implications for global investors when formulating investment portfolios.

The principal outcomes of this study can be outlined as follows: Firstly, it was observed that the ESG Index and the GE Index consistently exhibit a net-contributing behavior, while the GENV Index takes on a net-receiving role, particularly intensifying during the COVID-19 outbreak. Secondly, the dynamic connectedness analysis reveals that the GE Index consistently serves as a net information spillover contributor to all other indices. However, it is important to note that the ESG Index maintains a neutral net total degree of connectedness within the mid-range quantiles from 2018 to 2020. Thirdly, the results underscore that both the GENV and CENE indices consistently act as net information spillover recipients from all other indices.

The article is designed as follows: Section 2 shows extensive information on the dataset and methodology, while Section 3 provides the outcomes. Lastly, Section 4 offers our main conclusion and limitations-suggestions for the future agenda.

2. Dataset and methodology

The primary objective of our research is to investigate the interconnectedness among the GE Index, ESG Index, the GENV Index, and the CENE Index. To achieve this, we have implemented a quantile connectedness framework as proposed by Chatziantoniou et al. (2021).¹ All data were acquired from the Refinitiv database.² The dataset covers the period from August 8, 2014, to April 12, 2023, consisting of a total of 2078 daily observations. Moreover, our period covers the pre-COVID-19, during-COVID-19, and post-COVID-19 pandemic periods, as well as the Ukrainian-Russian war period. The methodological process employed is visualized in Fig. 2.

Briefly, the QVAR fashion is disclosed as follows:

$$\pi = e(l) + \sum_{j=1}^b \varnothing_j \pi_{l-1} + e(l) = e(l) + \sum_{j=1}^b \Delta_j \pi_{l-1} \quad (1)$$

¹ This methodology is employed in many studies (see Abakah, Adeabah, Tiwari, & Abdullah, 2023; Abdullah, Adeabah, Abakah, & Lee, 2023; Asadi, Tiwari, Gholami, Ghasemi, & Roubaud, 2023; Chang, Chang, Ling, & Yang, 2023; Ouyang & Zhou, 2023; Sheikh, Asadi, Roubaud, & Hammoudeh, 2024; Zhang, Gong, Yang, & Chen, 2023; Zhao & Park, 2024).

² <https://www.refinitiv.com/en/>

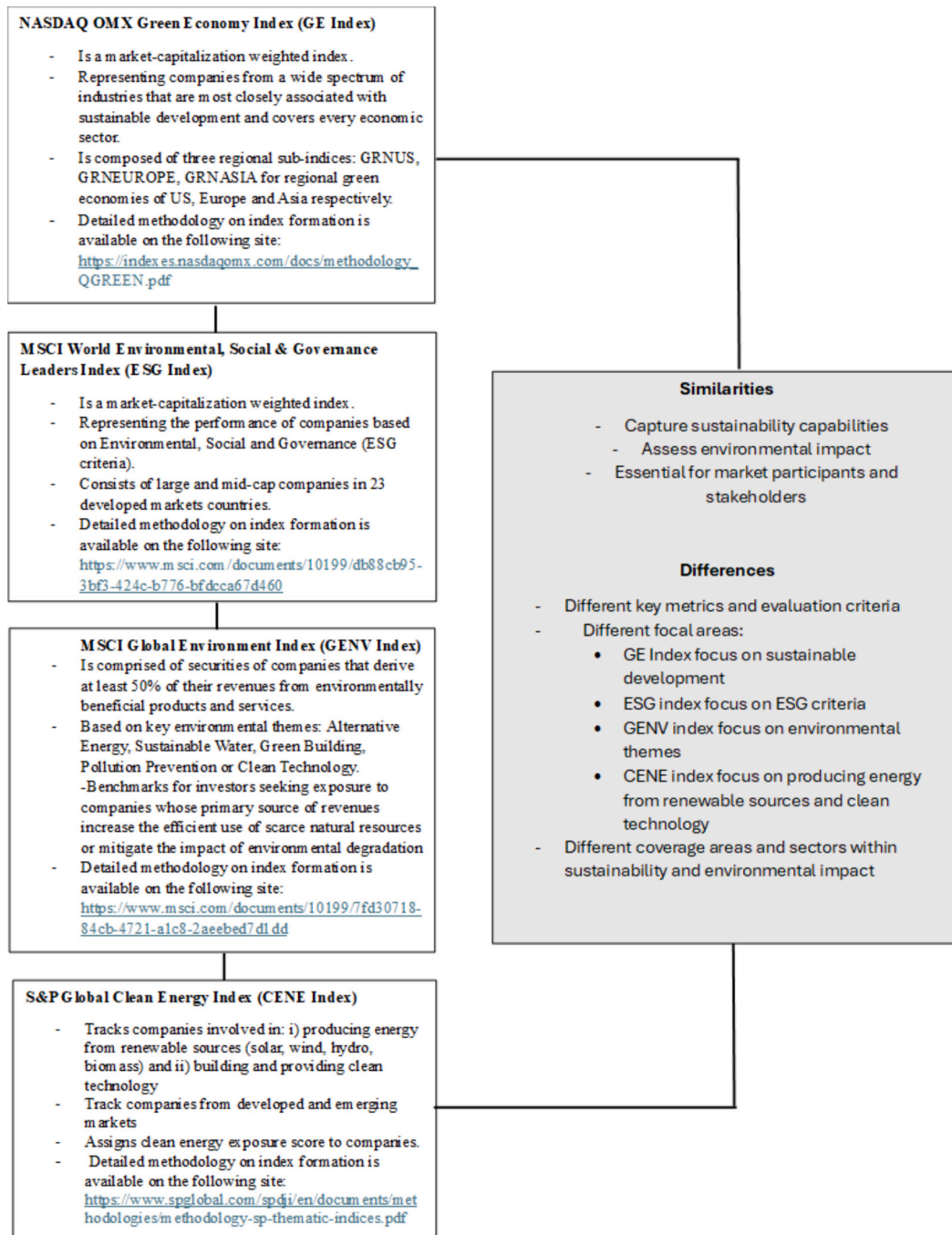


Fig. 1. Similarities-differences among the four sustainability indices.

while the GFEVDs with a future horizon H (10 in our case) is:

$$\psi_{ij}^g(W) = \frac{\sum(\tau)_{ii}^{-1} \sum_{h=0}^{W-1} (e_i' \Delta_h(l) \Sigma(l) e_j)^2}{\sum_{h=0}^{W-1} (e_i' \Delta_h(l) \Sigma(\tau) \Psi_h(l)' e_j)} \quad (2)$$

whereas the total connectedness TO covariates can be evaluated as:

$$C_{i-j}^g(W) = \sum_{j=1, i \neq j}^b \tilde{\psi}_{ji}^g(W) \quad (3)$$

On the reverse viewpoint, the total directional connectedness (TDC) FROM others is:

$$C_{i-j}^g(W) = \sum_{j=1, i \neq j}^b \tilde{\psi}_{ji}^g(W) \quad (4)$$

Thereby, the TDC TO others and the TDC FROM others that equals the net TDC.

$$C_i^g(W) = C_{i-j}^g(W) - C_{i-j}^g(W) \quad (5)$$

It should also be emphasized that the adjusted Total Connectedness Index (TCI) which also takes values from 0 to 1 is employed to capture market risk. The bigger the TCI values, the stronger the network inter-connectedness is revealed.

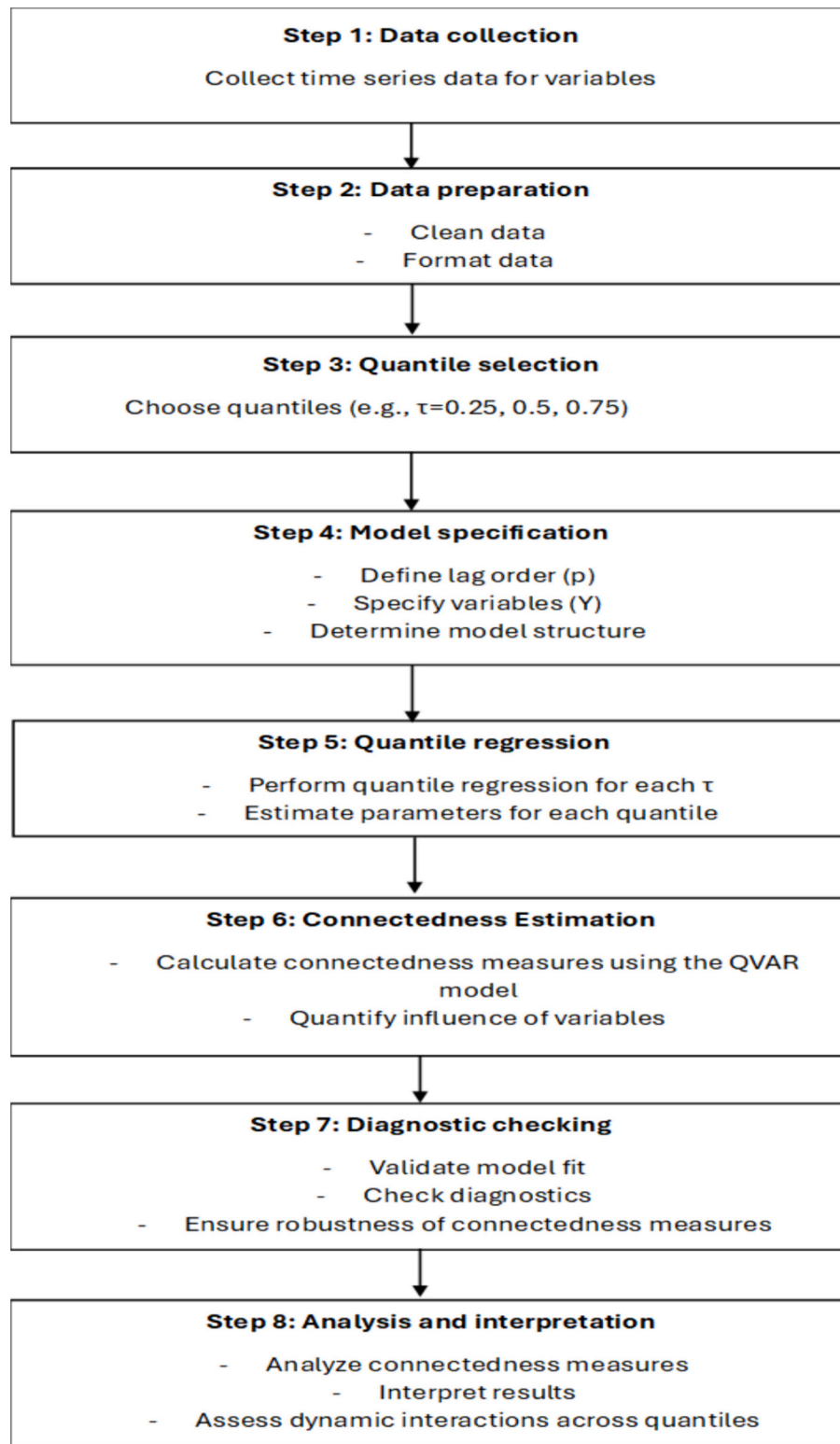


Fig. 2. Methodological process.

$$TCI(W) = \frac{\sum_{i,j=1, i \neq j}^b \tilde{\psi}_{ij}^g(W)}{b-1} \quad (6)$$

3. Empirical findings

This section is designed as follows: Firstly, we show an overview of

the descriptive statistics of our dataset. Then, we proceed to a detailed examination of spillover connectedness, specifically focusing on three quantiles, namely the lower (5th), middle (50th), and upper (95th) percentiles. Lastly, we elucidate the dynamics of connectedness within the dataset. Fig. 3 depicts their returns in the form of logarithmic differences.

Table 1 presents a summary of the investigated indices, offering

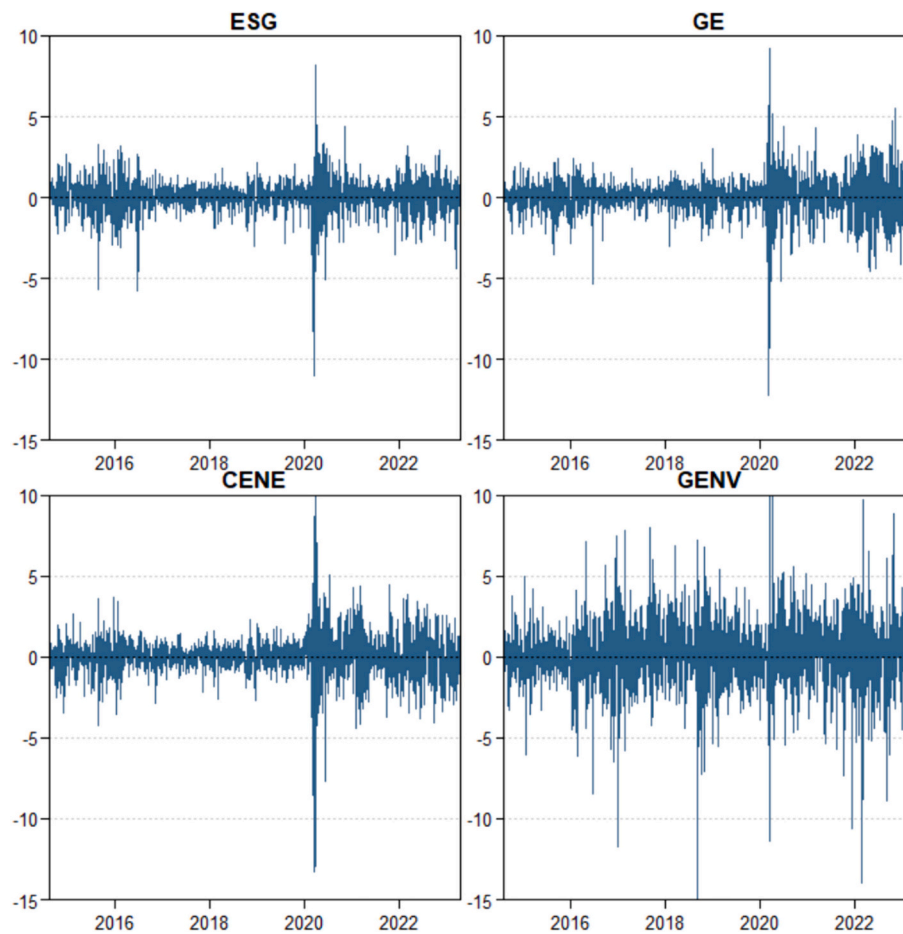


Fig. 3. Returns graph.

Table 1
Descriptive statistics and preliminary tests.

	ESG	GE	CENE	GENV
Mean	0.021	0.033	0.007	0.098
Variance	1.074	1.451	1.745	4.481
Skewness	-1.143***	-0.775***	-0.938***	-0.525***
Kurtosis	13.063***	11.262***	16.546***	5.317***
JB	15,189.279***	11,161.708***	23,951.663***	2536.997***
ERS	-6.776***	-7.709***	-19.945***	-10.974***
Q(20)	51.520***	95.009***	63.525***	15.279
Q2(20)	864.145***	1516.413***	2584.924***	256.821***

Notes: ***, ** and * show significance at 1 %, 5 % and 10 %, respectively.

valuable insights of relevance to market participants. All indices exhibit positive values, with GENV registering the highest, followed by GE and ESG, while CENE records the lowest value. Additionally, it is noteworthy that all indices demonstrate leptokurtic distributions alongside negatively skewed characteristics (Anscombe & Glynn, 1983; D’Agostino, 1970). The non-normality of these distributions is underscored by the outcomes of the Jarque and Bera (1980) test.

Furthermore, our analysis indicates that all indices demonstrate stationarity, as substantiated by the outcomes of the ERS unit root test (Elliott, Rothenberg, & Stock, 1996). However, this is essential to emphasize that the null hypothesis pertaining to a sufficiently fitted ARCH procedure is rejected, as per the findings of the Fisher and Gallagher (2012) weighted portmanteau test.

Regarding spillover connectedness, Tables 2–4 present the outcomes, categorized into lower (5th), middle (50th), and upper (95th) quantiles for joint distributions. In summary, the main results are as follows: (i)

Table 2
Spillover connectedness (5th quantile).

	ESG	GE	CENE	GENV	FROM
ESG	30.87	28.19	22.68	18.26	69.13
GE	27.18	32.17	23.48	17.17	67.83
CENE	23.85	26.09	32.59	17.47	67.41
GENV	21.49	21.83	20.39	36.29	63.71
TO	72.53	76.12	66.54	52.90	268.08
NET	3.40	8.28	-0.87	-10.82	TCI = 67.01

Table 3
Spillover connectedness (50th quantile).

	ESG	GE	CENE	GENV	FROM
ESG	56.50	31.69	11.05	0.76	43.50
GE	28.83	55.11	15.40	0.67	44.89
CENE	14.52	23.39	61.15	0.93	38.85
GENV	5.52	5.28	2.89	86.31	13.69
TO	48.87	60.37	29.33	2.37	140.93
NET	5.37	15.47	-9.52	-11.32	TCI = 35.22

Spillover connectedness from (to) other indices appears notably substantial across all quantiles. At the lower quantile, contributions from (to) range from 63.71 % (52.90 %) to 69.13 % (76.12 %). In the middle quantile, contributions from (to) others vary between 13.69 % (2.37 %) and 44.89 % (60.37 %). In the upper quantile, contributions from (to) others lie among 61.08 % (48.82 %) and 67.19 % (74.16 %). (ii) Particularly, at the intermediate quantile, contributions from (to) other indices are notably lower compared to the other two quantiles. (iii) GE

Table 4
Spillover connectedness (95th quantile).

	ESG	GE	CENE	GENV	FROM
ESG	33.22	27.83	22.58	16.36	66.78
GE	27.48	32.81	23.76	15.95	67.19
CENE	23.69	26.06	33.75	16.51	66.25
GENV	20.42	20.27	20.39	38.92	61.08
TO	71.59	74.16	66.73	48.82	261.3
NET	4.81	6.97	0.48	-12.26	TCI = 65.31

Index emerges as the primary transmitter of information spillovers to other indices across all quantiles, accounting for 76.12 % (5th quantile), 60.37 % (50th quantile) and 74.16 % (95th quantile). ESG Index follows with respective figures of 72.53 % (5th-lowest quantile), 48.87 % (50th-middle quantile), and 71.59 % (95th-highest quantile). (iv) GE and ESG indices are the most significant recipients of information spillovers from other indices at all quantiles. Specifically, the GE Index received 67.83 % (5th quantile), 44.89 % (50th quantile), and 67.19 % (95th quantile), while the ESG Index received 69.13 %, 43.50 %, and 66.78 % at the corresponding quantiles. Notably, bidirectional information spillovers are observed between GE (ESG) Index and other indices. (v) Across all quantiles, the GENV Index emerges as the smallest contributor to spillovers to other indices, with values of 52.90 % (lower quantile), 2.37 % (middle quantile), and 48.82 % (upper quantile). (vi) At the lower quantile, all indices receive heightened information spillovers, with the majority (3 out of 4) contributing to increased information spillovers. This phenomenon may be found in the exogenous shock resulting from COVID-19, which significantly impacted the global economy and transmission mechanisms (Shaik & Rehman, 2023; Umar, Gubareva,

Tran, & Teplova, 2021; Zhang et al., 2022).

While it is evident that all indices participate both as contributors and recipients of information spillovers, it is noteworthy to identify the indices that exhibit a stronger tendency in either transferring or receiving information. Specifically, as elucidated in Tables 2–4, the GE Index emerges as the most significant net contributor across all quantiles, yielding a net of 8.28 % (lower quantile), 15.47 % (middle quantile), and 6.97 % (upper quantile). In parallel, GENV stands out as the primary net recipient across all quantiles, receiving -10.82 % (5th quantile), -11.32 % (50th quantile), and -12.26 % (95th quantile).

Furthermore, we proceed to analyze the dynamic net pairwise connectedness (DNPC) among indices for three quantiles (5th, 50th, and 95th), as visually represented in Figs. 4–6. Significantly, in instances where the upper part of each graph is filled, it indicates that the one index is the contributor, acting as the source of effects. Conversely, when the lower part is filled, the other index functions as the contributor of impacts. As observed across all quantiles, GE consistently acts as a net contributor to other indices throughout the entire examination period, while GENV consistently serves as a recipient of impact. This means that governments should capitalize on the momentum by reinforcing and expanding policies that encourage green investments. Policymakers could further incentivize private sector participation in renewable energy projects and sustainable infrastructure development through targeted tax breaks, grants, and subsidies. Furthermore, establishing dedicated GE funds or institutions can serve as conduits for channeling funds towards environmentally beneficial projects, fostering economic growth while advancing sustainability (Han & Li, 2022; He et al., 2019). Importantly, it is worth mentioning that within the extreme lower quantile, the GENV index briefly supposes the role of a transmitter of impact on the ESG index, albeit for a brief period following the year

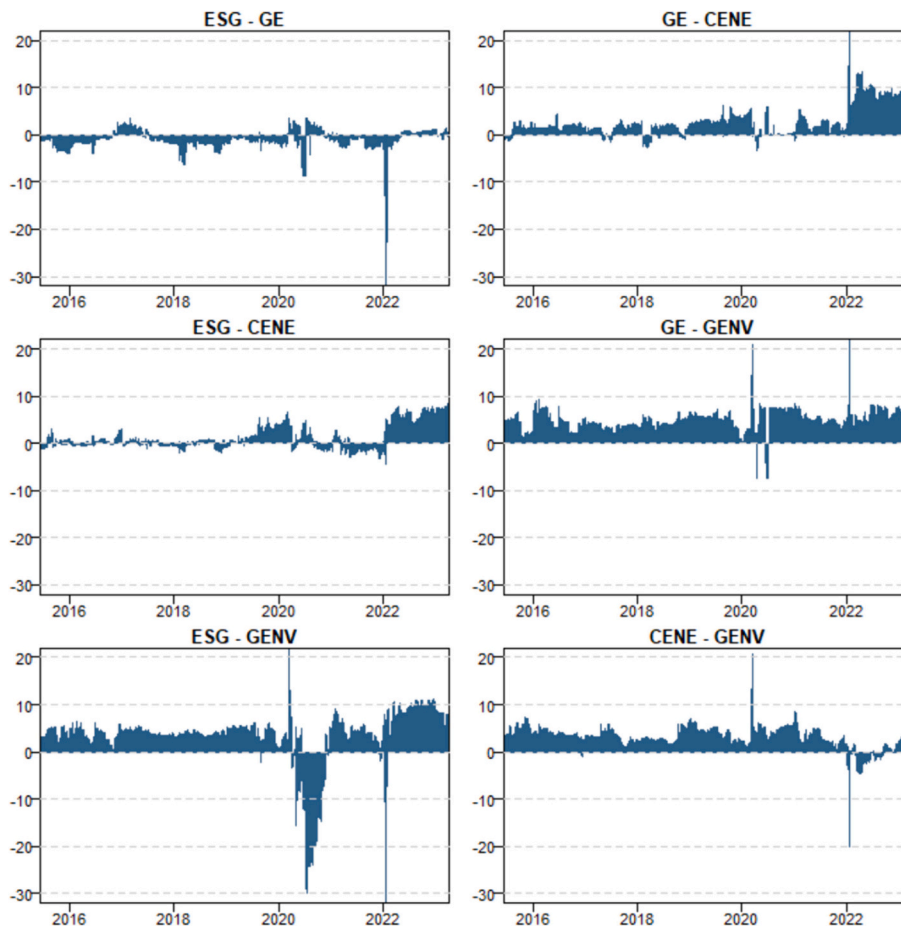


Fig. 4. 5th quantile- DNPC.

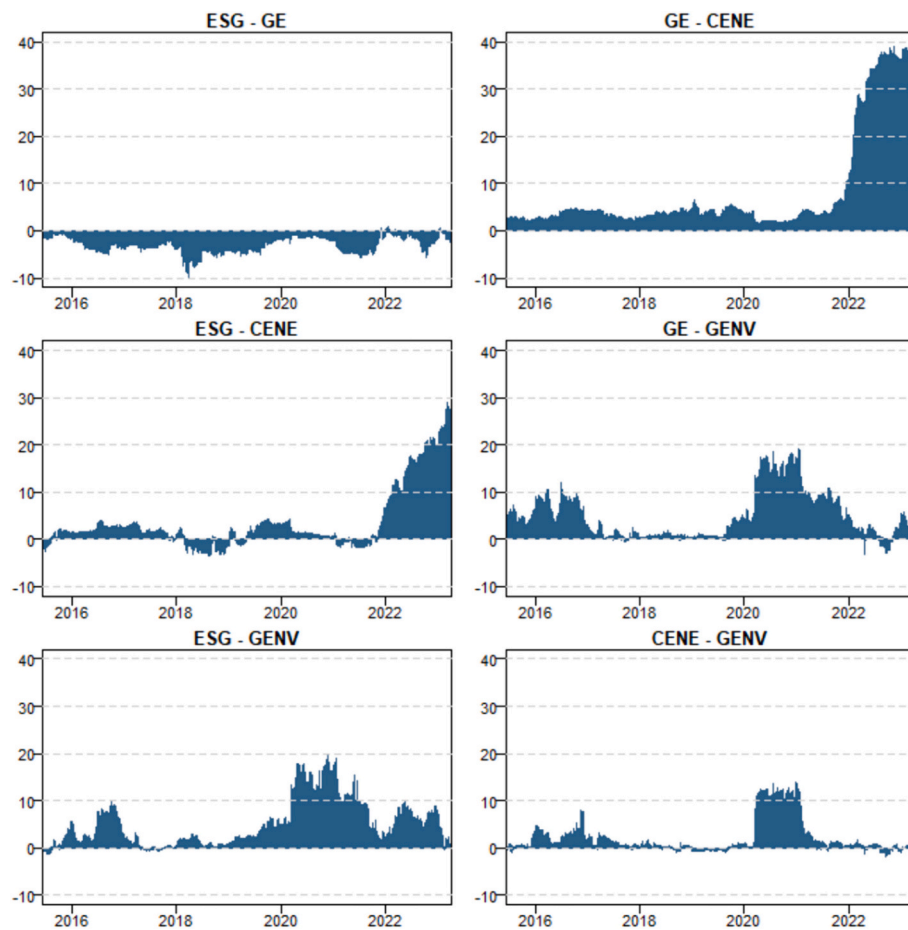


Fig. 5. 50th quantile- DNPC.

2020. Additionally, this aligns with the findings of He et al. (2019), which mention that the green economy represents a fundamental concept for achieving sustainable economic development through the harmonized progress of both ecological and economic aspects.

To present a thorough understanding of the dynamic spillover connectedness across all indices, we employed a 200-day rolling-window QVAR fashion³The outcomes of this investigation are visually represented in Fig. 7 in the form of a heatmap visualization. Specifically, the vertical axis on the heatmap corresponds to the quantiles, while the color line indicates the magnitude of TCI. Consequently, warmer shades on the heatmap signify an increased degree of connectedness.

Overall, the heatmap clearly illustrates that spillover connectedness remains relatively low within the 40 % to 60 % quantile range, both before the year 2020 and after 2021. Furthermore, it is evident that a high degree of connectedness prevails in the lowest (below 20 %) and upper (above 80 %) quantiles throughout the entire examined period. Additionally, during the period spanning from 2020 to 2021, there is a significant surge in the degree of connectedness across all quantiles.

To provide a detailed examination of this aspect, we directed our attention towards the net total directional connectedness exhibited by each index across the time-quantile domain. These findings are visually presented in Fig. 7, where an index is identified as a net spillover contributor when the shading is warmer and as a net spillover recipient when the shading is cooler.

Firstly, as depicted in Fig. 8, it is apparent that the ESG and GE

³ We employed a 150-day rolling-window QVAR model for robustness, and the results are nearly identical, particularly for the 5th and 95th quantiles. They are available upon request.

indices consistently function as net information spillover contributors to all other indices. This corroborates our earlier analysis and underscores the notion that the net spillover effect structure may be influenced by various factors. Therefore, strengthening ESG disclosure requirements and standardizing reporting frameworks can enhance transparency and promote investor confidence. Nevertheless, it is important that the net total degree of connectedness for the ESG Index remains neutral within the mid-range quantiles during the years 2018 to 2020. This suggests that policymakers should promote ESG standards as a market-based framework to enhance green innovation and sustainable development. Encouraging ESG adoption can alleviate financing constraints, mitigate agency problems, and increase R&D investment, driving substantive and 'source reduction' green innovations essential for sustainable growth (Nakajima et al., 2021).

Secondly, both the GENV and CENE indices emerge as net information spillover recipients from all other indices, aligning with our earlier analysis and reinforcing the argument that implementing stricter regulations on carbon emissions and pollution can encourage industries to adopt cleaner technologies and practices, paving the way for a more sustainable future. Hence, investing in the R&D of green innovations can enhance the competitiveness of ESG firms while contributing to global sustainability goals. Furthermore, it is worth highlighting that the CENE Index only supposes the role of a transmitter of information during the years 2020–2021.

Thirdly, our findings are of particular significance to global investors looking to develop portfolio strategies, as the GE Index consistently exhibits a role as a net information spillover contributor to all other indices.

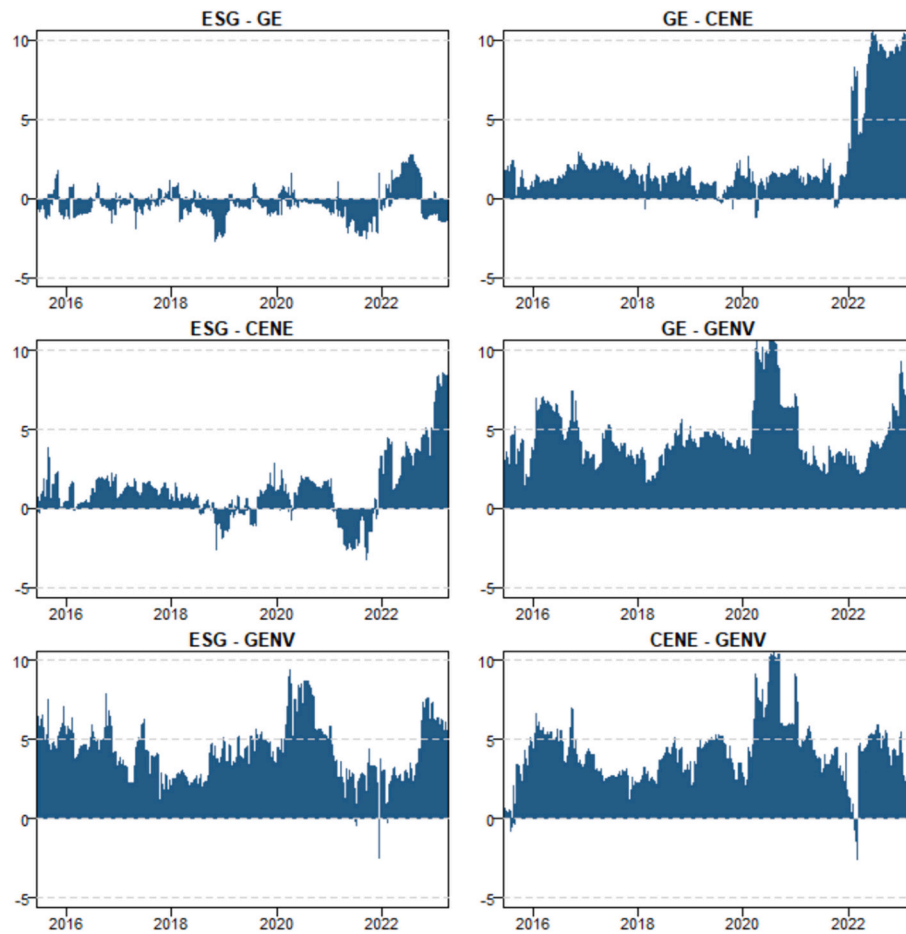


Fig. 6. 95th quantile- DNPC.

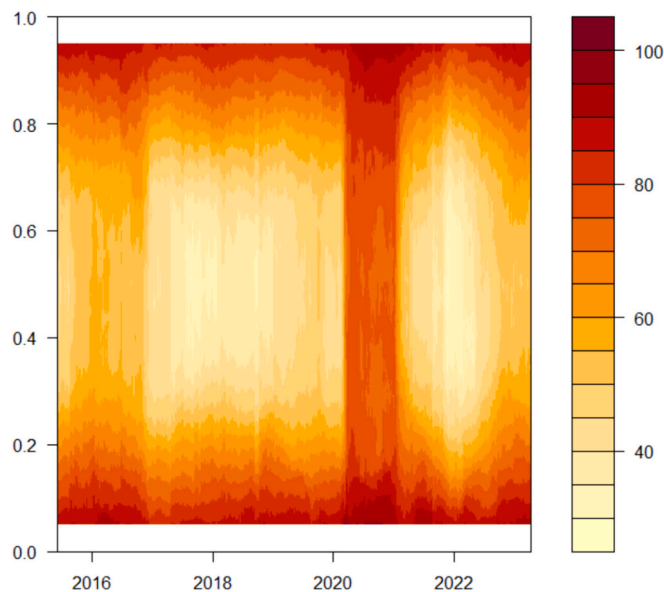


Fig. 7. Dynamic total connectedness.

4. Conclusions

Recently, there has been a growing global concern among market participants in the realm of sustainability indices. Within this context, the present study conducts a comprehensive examination of the time-

varying spillover effects and interconnectedness observed among four prominent sustainability indices: namely, the GE Index, the ESG Index, the GENV Index, and the CENE Index. To accomplish this analysis, we employ an innovative connectedness framework, as proposed by Chatziantoniou et al. (2021), and apply it to a rich dataset comprising daily observations spanning from August 8, 2014, to April 12, 2023.

The principal outcomes of this study can be outlined as follows: Firstly, it was observed that the GE and the ESG indices consistently exhibit a net-contributing behavior, while the GENV Index takes on a net-receiving role, particularly intensifying during the COVID-19 outbreak. Secondly, the dynamic connectedness analysis reveals that the GE Index consistently serves as a net information spillover contributor to all other indices. Although, it is interesting to note that the ESG Index maintains a neutral net total degree of connectedness within the mid-range quantiles from 2018 to 2020. Thirdly, the results underscore that both the GENV and CENE indices consistently act as net information spillover recipients from all other indices.

The documents of this research bear significant implications for a range of market participants. Global investors can use these findings to make better investment plans. For example, high-frequency traders can create better algorithms that focus on the GE Index. Also, companies can use what they learn from this study to manage risks better. Banks might start using certain indices more when they decide on loans and investments. Plus, regulators who watch over financial markets can learn from these results to make better rules that keep the markets stable and fair. Our study is set to be a foundation for guiding future research in sustainable investment. In particular, upcoming studies could include a broader range of indices to give a more complete picture of this research area. Requiring companies to share their ESG information can boost

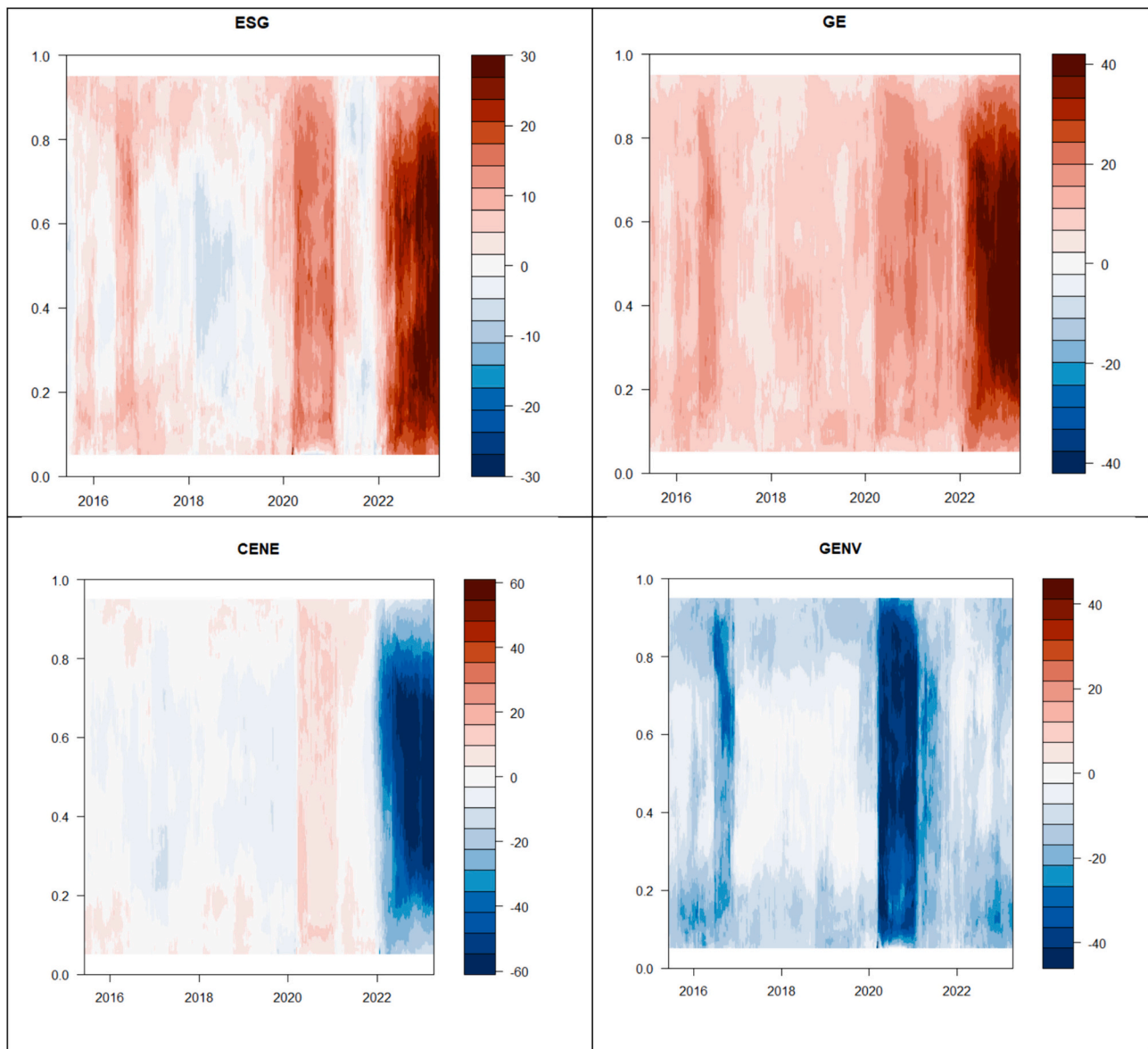


Fig. 8. Net total directional connectedness.

their green innovation and benefit the whole industry. It is important for regulators and market participants to push for mandatory ESG disclosures. Companies should regularly check and improve their practices to ensure they are both ethical and economically beneficial. The goal is to create sustainable, low-carbon businesses that contribute to high-quality development (Hunjra, Azam, Bruna, Verhoeven, & Al-Faryan, 2022). Green innovation needs outside help, too. Developing a strong green financial system is crucial to provide enough funding for green projects. Financial resources like green credit, bonds, and development funds should be used to support green innovation. Additionally, government and regulatory bodies must ensure transparent and accurate information disclosure to prevent companies from misleading investors with false ESG claims (Rudkin & Cai, 2023; Wang, Ma, Dong, & Zhang, 2023). Inside the company, leaders play a key role in driving green innovation. Executives should embrace sustainable development and recognize green opportunities, guiding their companies towards competitive advantages through green strategies. The media should also help by highlighting environmental issues and encouraging company leaders to improve their environmental practices (Moufty, Al-Najjar, & Ibrahim, 2024). Turning industrial companies into green businesses is a slow

process because they often have high pollution and energy use. These companies need to constantly work on green development, increase their social responsibility, and adopt energy-saving and pollution control measures. These efforts are essential for creating a modern, green, and low-carbon industry that supports sustainable development (Li, Lian, & Xu, 2023; Wang, Shahid, Binh An, Shahzad, & Abdul-Samad, 2022).

Also, using advanced models and more frequent data could make this research even stronger. Lastly, analyzing how GE, ESG, CENE, and GENV are connected in different economic regions such as Asia, Europe, and others would be very valuable. Looking into these improvements can give us a deeper understanding of sustainable investment dynamics.

A limitation of this research is the absence of variables representing the individual pillars of ESG as a global index. Specifically, the three pillars of ESG—Environmental, Social, and Governance—could provide more insightful information if, for example, the pillars showed contributor behavior (like the main variable) or acted as influencing factors in relation to the other covariates and over different periods. Therefore, this limitation could be addressed in future research. Additionally, future studies could employ more advanced quantile models.

Data availability

Data will be made available on request.

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