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Greenwashing, carbon emission, and ESG

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Abstract

Recent decades have seen an increasingly awareness of climate changes, putting a pressure on companies to do more to deal with carbon emission. One of the popular measures used in assessing how well a company commits to sustainable development and reduces carbon emissions is ESG ratings. Given the importance of both ESG ratings and carbon footprints on our society and the target of net zero by 2050, we explore the relation between carbon emission and the Refinitiv ESG scores for the US sample from 2005 to 2018. Our findings indicate that high ESG-rated or environment-rated firms do not have lower carbon emissions. It appears that these firms are not incentivized to do more for environment, as they have already been awarded with good publicity for being environmentally friendly. Finally, our findings also support the 'cheap talk' concept, greenwashing hypothesis and legitimacy theory. Companies are not genuinely committed to climate action.

KEYWORDS
carbon emission, ESG, greenwashing, legitimacy theory

1 | INTRODUCTION

Climate change and global warming are real threats to nature and human, as they lead to more frequent and larger scale of extreme weather disasters such as heatwaves, droughts, floods, bushfires and hurricanes. For example, the recent Cyclone Gabrielle hitting New Zealand in early 2023 causes devastating effects with thousands of missing people and an estimated loss of $8 billion.[1] Human's activities that cause global warming and climate change include burning fossil fuels, farming and destroying forests. Industrialization or modern society is built on fossil fuels, as they are abundant, easily acquired, widely used and less costly to produce. However, fossil fuels, with their depleting and finite supply, may not be a sustainable energy source, and even worse, they generate greenhouse gases.

Abbreviations: CDP, Carbon Disclosure Project; EBIT, earnings before interest and taxes; ESG, environmental, social and governance; FTSE, Financial Times Stock Exchange; MSCI, Morgan Stanley Capital International; OECD, Organisation for Economic Co-operation and Development; SG&A, selling, general and administrative expenses; US, United States.

[1]https://www.aljazeera.com/news/2023/2/20/cyclone-gabrielle-new-zealand-extends-state-of-emergency.

Relying heavily on cheap and abundant fossil fuels, modern society finds it incredibly costly to transition to greener energy. Recent decades have seen an increasing awareness of the consequences of climate change and global warming, with more people, including investors and governments, calling for real actions to fight against climate change. This puts pressure on companies to do more to deal with carbon emissions. To manage public interests regarding environmental concerns, some corporations voluntarily report their carbon performance. Given the public interests in environmental, social and governance (ESG) concerns, ESG ratings are made available by several agencies. Examples of agencies providing ESG ratings include Asset4 (or now Refinitiv), Sustainalytics, FTSE, MSCI, Inrate and Bloomberg. Research shows that ESG ratings affect how institutional investors with trillions of dollars in assets under management make investment decisions (Gibson Brandon et al., 2022).

While ESG ratings have been used as a tool in asset allocation by environmentally concerned investors, several recent studies have questioned the quality and reliability of these ratings (see, e.g., Berg et al., 2022; Christensen et al., 2022; Gibson Brandon et al., 2021). Recently, the integrity of the ESG ratings has also been questioned—whether firms with high ESG ratings actually do what they proclaim to do by being more socially and environmentally friendly and having good governance. For example, Cohen et al. (2020) document that the brownest firms, in fact, do more to reduce future carbon emissions. Relying on firm-level emission futures contracts, van Binsbergen and Brøgger (2022) document that firms with higher E ratings have higher, not lower, future emissions. These findings have implications to investors who rely on ESG ratings to make investment decisions. For example, Bams and van der Kroft (2022) report that investors allocating funds according to good ESG scores may incorrectly invest in firms with poorer sustainable performance.

In this paper, we investigate the relation between carbon emission and the Refinitiv ESG scores for the US sample from 2005 to 2018. According to the European Union's Joint Research Centre, the release of carbon emissions for the US is 4.535 Giga tonne. This is 12.6% of total global emission and made the United States the second highest carbon emissions country in the world.[2] As a key member of the United Nations (UN), the United States has to meet UN Sustainability Development Goals by 2030. In addition, Bolton and Kacperczyk (2021) show in their study that US investors care about carbon emissions by factoring in a premium to account for carbon risk. With the disclosure requirement on climate change being an ongoing development, our investigation is important to inform investors and policymakers in their decision-making.

The relationship between ESG ratings and carbon emissions is complex. There are arguments in favour of and against the proposition that high ESG ratings result in reduced carbon emissions. On the one hand, proponents of this idea argue that firms with high ESG ratings are more likely to prioritize sustainability and environmental stewardship as they are more likely to invest in renewable energy, implement environmentally friendly policies and engage in other initiatives to reduce their carbon footprint. Li and Xu (2024) find evidence consistent with this argument. Investigating Chinese listed companies between 2010 and 2020, they find that SynTao Green Finance ESG ratings significantly inhibit the firms' carbon emissions. They argue that good ESG ratings help to reduce financing constraints and agency problems in firms while poor ESG ratings. Analysts and media attention further reinforce this effect. The US economy is significantly different from the Chinese market. Hence, the findings of Li and Xu (2024) may not be generalizable to our US sample.

On the other hand, those against the idea argue that no clear causal relationship exists between ESG ratings and carbon emissions. Following this line of argument, firms with high ESG ratings produce higher carbon emissions. In addition, other factors may influence a firm's carbon emissions, such as industry type, regulatory environment and technological constraints. We contribute to this unresolved debate by investigating whether firms with high ESG or E ratings have more or less carbon emissions.

Using a deep learning algorithm, Bingler et al. (2024) found that voluntary climate-related is associated with more cheap talk in the MSCI World Index firms' annual reports. Higher emission growth is correlated with greater cheap talk. Investigating a cross country sample, Bui et al. (2022) find that the disciplinary power of climate change rating is limited as poorly performing firms tends to improve their disclosure metrics while not improving their emission intensity. While they investigated a cross-country sample, the CDP data period only covers 2011–2015 as CDP changed their rating system to a letter score from 2016. Using the Refinitiv ESG score allows us to have a longer time series for our analysis.

Based on almost 7,500 firm-year observations of the US firms, the Granger-causality tests show evidence against the idea that high ESG or E firms emit less carbon. Instead, our findings support the 'cheap talk' concept, greenwashing hypothesis and legitimacy theory such that ESG or E rating is a firm's publicity tool rather than a firm's commitment to do good for the environment. Additionally, our findings may align with regulatory capture and technological limitations hypotheses. Similar to the greenwashing hypothesis, the regulatory capture hypothesis suggests that firms having no real intention to reduce carbon emissions lobby regulators to intervene to set up a favourable ESG framework while continuing to pollute. Finally, consistent with the technological limitations hypothesis, it is possible that firms that are genuinely committed to ESG may still be producing high carbon emissions as they do not have the most advanced technologies for carbon emissions reductions.

We contribute to the existing literature by challenging the assumption that high ESG or E ratings always indicate superior environmental performance. Our findings imply that companies with high ESG or E ratings may not put in the effort to further improve their environmental performance. This typically happens due to the costs of implementing new technologies to reduce carbon emissions, reducing the competitiveness and viability of the firm in the global market. Furthermore, research and development to develop sustainable technologies may take a long time, and even if successful, a comparative advantage is not guaranteed (Holmstrom, 1989).

[2] https://worldpopulationreview.com/country-rankings/carbon-footprint-by-country.

This calls for the need for more comprehensive disclosure of environmental performance beyond the ESG or E ratings criteria. These measures could include carbon footprint assessments, life cycle assessments and other approaches that provide more detailed insights into a company's environmental impact, including green bonds, sustainability reporting and environmental audits. We also contribute to the development of ESG rating systems by highlighting the need for more stringent standards and a more thorough evaluation of companies' environmental impact. This study can also prompt policymakers to evaluate the effectiveness of current environmental regulations and enforcement mechanisms and consider additional measures, such as stricter regulations or stronger enforcement mechanisms, to address carbon emissions and other environmental concerns.

The remainder of this paper is organized as follows. Section 2 reviews related literature. Section 3 describes the data and method. Section 4 presents the empirical results. Section 5 concludes.

2 | LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 | Carbon emission

Carbon emissions, especially carbon dioxide (CO_2) emissions, are considered one of the most prominent climate change factors and are considered the prime cause of current environmental issues. Stakeholder and legitimacy theories are often utilized to explain how corporation deals with carbon emissions. According to stakeholder theory, managers should balance all stakeholders' interests to ensure that the company gets their support for long-term success (Roberts, 1992). Given carbon emissions lead to climate change and global warming risk, it is, therefore, in all stakeholders' interests to reduce carbon footprints. Examples of papers supporting stakeholder theory in this context include Huang and Kung (2010), Epstein and Roy (2001) and Pinzone et al. (2015). Liesen et al. (2015) and Huang and Kung (2010) suggest that firms utilize social and environmental disclosures to balance all stakeholders' interests. In a survey of greenhouse gas emissions from 431 European firms, Liesen et al. (2015) document that external stakeholders' pressure significantly affects greenhouse gas emissions, which influence managers' decision-making and disclosure of carbon information. Other studies supporting stakeholder theory suggest that the desire of stakeholders to safeguard the environment can act as a catalyst for firms to take proactive measures towards environmental protection (Epstein & Roy, 2001; Pinzone et al., 2015). Finally, in line with the stakeholder theory, the 2005 and 2008 KPMG international survey of corporate responsibility reporting suggests that firms rely on sustainability disclosure to communicate their actions in response to stakeholders' concerns on various sustainable issues (KPMG, 2005, 2008).

Another closely related theory is the legitimacy theory. A widely held assumption or conviction that an entity's activities are desirable, acceptable or appropriate within a socially built system of norms, values, beliefs and definitions is referred to as legitimacy, according to Suchman (1995) and Treepongkaruna et al. (2024). As such, carbon emission reduction is deemed to be desirable for a firm's sustainable development. According to Matsumura et al. (2014), there is a \$212,000 drop in firm value for every thousand more metric tons of carbon emissions. Moreover, Matsumura et al. (2014) discovered that the median value of businesses that publicly report their carbon emissions is around \$2.3 billion greater than the median value of businesses that do not publicly report. These findings illustrate that while the markets penalize all businesses for their carbon emissions, businesses that fail to declare their emissions are subject to an additional penalty. The findings support the claim that corporate valuations in the capital markets consider both carbon emissions and the voluntary disclosure of this information, thus supporting the aforementioned legitimacy theory.

2.2 | ESG and carbon emission

According to the OECD's (2021) report titled 'ESG Investing and Climate Transition: Market Practices, Issues and Policy Considerations', there is a growing trend of investors using the environmental component of ESG ratings to factor carbon transitions into their investment decisions. The report further notes that although ESG rating and investing has the potential to reveal important information about a company's climate risks and opportunities, there are still significant challenges for relying on such information for investment purpose. These challenges include the lack of uniformity in ESG criteria and rating methods among the rating agencies.

The existing empirical literature documents two opposing views on the relation between ESG and carbon emission. Example of studies supporting stakeholder theory and a positive relation between ESG and carbon emission includes Luo et al. (2012), Clarkson et al. (2013), Li et al. (2017), Plumlee et al. (2015), Schiemann and Sakhel (2019) and Cao and Rees (2020). For example, shareholders and debtholders, who are two common sources of funding, tend to favour companies that have superior carbon performance and lower carbon emissions (see Albarrak et al., 2019; Cheng et al., 2014; Choi et al., 2021; Choi & Luo, 2021; Griffin et al., 2017; Jung et al., 2018; Matsumura et al., 2014; and Shen et al., 2022). Consistent with the stakeholder theory, it is also suggested that firms make corporate social responsibility disclosures in response to stakeholders' demands, which improves the firms' reputation and, subsequently, better performance (Tsang et al., 2023). More recently, Bui et al. (2022) proposed that there is disciplinary power in ratings such that rated firms should improve their future disclosure scores. Hence, greater ESG ratings, which is based on disclosure, are expected to lead to a change in carbon emissions. On the contrary, another strand of research finds an insignificant or negative relation between ESG and carbon emission and supports legitimacy theory, along with 'cheap talk' or 'greenwashing' hypotheses. These studies include Diouf and Boiral (2017), Wedari et al. (2021), Christensen et al. (2021), Khan et al. (2022), Adu et al. (2022), van Binsbergen and Brøgger (2022) and Raghunandan and Rajgopal (2022). According to Diouf and Boiral (2017), managers may choose to engage in symbolic ESG reporting or selectively disclose only those ESG metrics that present the company in a positive light in order to justify their corporate decisions. However, Adu et al. (2022) argue that the use of symbolic ESG reporting can reduce transparency and hinder stakeholders from utilizing it for efficient benchmarking. As a result, it may not be possible for ESG reporting to have a tangible impact on carbon mitigation. Additionally, Raghunandan and Rajgopal (2022) examine whether ESG mutual funds actually invest in firms with stakeholder-friendly track records. They report that ESG scores actually indicate the quantity of voluntary ESG-related disclosures rather than compliance records or actual levels of carbon emissions by firms. Hence, it appears that socially responsible funds advocating to do more for stakeholders' concerns do not actually do so.

2.3 | Hypotheses development

As previously noted, two contrasting pieces of evidence on the relation between ESG and carbon emission exist. We, therefore, develop the following hypotheses consistent with both positive and negative views of the effect of ESG on carbon emissions. First, consistent with *legitimacy theory* (Suchman, 1995), we propose the *cheap talk* or *greenwashing* hypothesis (Diouf & Boiral, 2017; Wedari et al., 2021) that predicts a negative relation between ESG ratings and carbon emissions. This hypothesis suggests that companies may engage in deceptive practices by presenting themselves as more environmentally friendly than they are. This is done to attract consumers who are becoming more environmentally conscious and to improve their public image. Cho and Patten (2007) find that firms with low performance provide more environmental disclosures to legitimize and offset their poor performance, which provides support to the legitimacy theory. A closely related theory is the 'agency theory' where self-interested managers may bias their disclosure to be environmentally friendlier than they really are (Tsang et al., 2023). 'Greenwashing' or 'cheap talk' involves promoting a company's environmental initiatives through advertising or other public relations efforts without making significant changes to reduce their environmental impact. This practice has become more prevalent as companies face increasing pressure to appear environmentally responsible. However, critics argue that such practice is a form of deception that can mislead consumers, undermining the efforts of companies genuinely committed to sustainability. Another hypothesis predicting a negative relation between ESG and carbon emission is *technological limitation* hypothesis. Under this hypothesis, companies may genuinely have intentional to reduce carbon footprints but do not have sufficient fund or know-how to do so.

A competing hypothesis is the *shared valued* hypothesis (Porter & Kramer, 2011), predicting a positive relation between ESG and carbon emission. Consistent with stakeholder theory, it is in the best interests of all stakeholders to reduce carbon emissions, which in turn leads to long-run corporate sustainability. The stakeholder theory also suggests that firms will improve environmental disclosure according to stakeholders' demands to improve their reputation and ESG ratings have disciplinary power (Bui et al., 2022). The *shared value* hypothesis suggests that companies prioritizing ESG factors, including environmental sustainability, can also generate long-term value for their shareholders. This value creation can occur through improved efficiency, cost savings and increased brand reputation, among other benefits. According to this hypothesis, companies that manage their environmental impact more effectively will likely succeed in the long run. In the case of carbon emissions, companies that reduce their emissions may also benefit from increased efficiency and reduced costs. For example, companies that actively address climate change and reduce their carbon footprint may attract customers who prioritize sustainability and benefit from increased brand loyalty and reputation. As such, this hypothesis suggests that companies that focus on environmental sustainability are not only benefiting the environment but also creating value for their shareholders and stakeholders.

3 | DATA AND METHOD

We obtain the data from several sources. Following Bolton and Kacperczyk (2021), we collect the data on carbon emissions of companies from S&P Trucost. Compustat provides accounting data for estimating firm-level control variables, while Refinitiv supplies ESG score and the various first-level constituents of the environmental pillar score.[3] The sample period of our study covers from 2005 to 2018.[4] To examine the relation between carbon emission intensity and ESG ratings, we employ the following Granger causality models[5]:

$$Carbon_{it} = \alpha_0 + \alpha_1 Environment_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{1}$$

$$Environment_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 Environment_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{2}$$

where *Carbon* is defined as the natural logarithm of carbon intensity, *Environment* is the ESG score (or E-score) from Refinitiv and *Control* is the list of control variables. Our carbon intensity measure is the amount of carbon emissions (measured in units of tons of CO_2 and CO_2 equivalent) and scaled by revenues and normalized using the natural logarithmic scale by company *i* in year *t*. The Greenhouse Gas (GHG) Protocol Corporate Standard categorizes a company's carbon

[3]The detailed specifications of the Refinitiv ESG scores and its constituents are available at https://www.lseg.com/content/dam/marketing/en_us/documents/methodology/refinitiv-esg-scores-methodology.pdf.

[4]We restricted our sample to 2005–2018 to prevent confounding effect from the Covid pandemic period. Our sample period also encompasses the post 2015 Paris Agreement period.

[5]Our panel unit root tests based on Levin et al. (2002) and Im et al. (2003) suggest that panels (of our variables of interests, including *Carbon*, *ESG* and *E* scores) are stationary with optimal lag lengths 1.42 lags average (chosen by BIC) and 1.51 lags average (chosen by AIC). Further, based on Dumitrescu and Hurlin (2012) Granger non-causality test results, we find optimal lag length of 1. As such, we include only one lag in our model specification below. See the appendix for more details.

emissions into one of the following 'scopes': direct emissions from owned or controlled sources (Scope 1); indirect emissions from the generation of purchased energy such as heat, steam and electricity (Scope 2); and other indirect emissions caused by the operations and productions of the company but occur from sources not owned or controlled by the company, including the production of purchased materials, product use and waste disposal (Scope 3). Because we focus on analyzing the relation between ESG- or E-performance and the company's carbon emissions, we employ only Scope 1, scaled by company revenues. We also run an alternative regression specification where *Environment* represents the E-score (Environmental score), and the three first-level constituents of the environmental pillar score (viz., environmental innovation score, emission score and resource use score, respectively) in place of the ESG score to focus more specifically on the Environmental pillar of the ESG.

Following Tanthanongsakkun et al. (2022) and Rehman et al. (2024), we include the following control variables that may be related to carbon emissions. These include firm size (natural logarithm of total assets), profitability (earnings before interests and taxes scaled by total assets), leverage (total debt divided by total assets), investments (capital expenditures divided by total assets), intangible assets (research and development divided by total assets and advertising expense divided by total assets), discretionary spending (SG&A expense divided by total assets), cash holdings (cash holdings divided by total assets) and dividend payouts (total dividends divided by total assets). Further, we account for corporate governance by including two popular proxies of board quality being the proportion of independent board members and the natural log of board size (Adams & Ferreira, 2009; Campbell & Mínguez-Vera, 2008; Nguyen & Nielsen, 2010; Tanthanongsakkun et al., 2022).

TABLE 1 Summary statistics.

Panel A: key variables of interests						
	N	Mean	SD	p50	p25	p75
Full sample						
Carbon	7,463	3.275504	2.102561	2.985906	2.033255	4.228223
ESG	7,468	45.63837	19.79361	44.22	29.96	61.035
Environment	7,464	35.59833	28.44181	33.45	7.715	59.92
High score						
Carbon	3,825	3.336739	2.297373	2.934115	1.857906	4.678478
ESG	3,827	60.95562	13.28604	60.54	50.85	70.62
Environment	3,819	58.53617	18.78613	59.38	45.52	73.24
Low score						
Carbon	3,638	3.211122	1.874208	3.035141	2.116898	3.954602
ESG	3,641	29.53865	10.59337	29.66	22.09	36.69
Environment	3,645	11.56552	12.562	7.62	0	20.56
Panel B: Control variables						
	N	Mean	SD	p50	p25	p75
Size	5,170	8.979407	1.216066	8.834919	8.075	9.780076
Leverage	5,170	0.2465238	0.1617944	0.2386899	0.1319929	0.3432955
Profitability	5,170	0.1133252	0.1044071	0.1043571	0.0662328	0.1538474
Capital investment	5,170	0.0522085	0.0511577	0.0375131	0.0205534	0.0656311
R&D intensity	5,170	0.0242038	0.0469659	0	0	0.0278399
Advertising intensity	5,170	0.0135959	0.0343863	0	0	0.0117847
Dividends	5,170	0.0196872	0.0272191	0.0136504	0	0.0271259
Cash holdings	5,170	0.1311799	0.1339476	0.0865021	0.0314319	0.1880302
Discretionary spending	5,170	0.1885897	0.1776072	0.145811	0.0523552	0.2730442
% Ind director	5,170	80.07027	11.03733	81.81818	75	88.88889
Bsize	5,170	2.394636	0.1793198	2.397895	2.302585	2.484907

Note: This table reports descriptive statistics for all variables. Carbon is the natural logarithm of carbon intensity (Scope 1), which is direct measure of carbon emission, scaled by firm's revenue. ESG and environment are the Refinitiv scores. Control variables include firm size (Ln of total assets), profitability (EBIT/total assets), leverage (total debt/total assets), investments (capital expenditures/total assets), intangible assets (research and development/total assets and advertising expense/total assets), discretionary spending (SG&A expense/total assets), cash holdings (cash holdings/total assets), dividend payouts (total dividends/total assets), proportion of board independence and natural log of board size.

Table 1 reports descriptive statistics for all variables included in this study. On average, firms in our sample emit carbon dioxide (CO_2) of about 26 tons per million dollars of revenues have an average ESG score of 45.6 and an environment score of 35.6. We further split the sample into two subsamples: firms with ESG (or Environment) scores above the median (Hi-score sample) and firms with ESG (or Environment) scores below the median (Low-score sample). The hi-score (Low-score) sample, on average, emits carbon dioxide (CO_2) of

TABLE 2 Granger causality between carbon emission and ESG combined score.

Variables	Full sample (1) Carbon	(2) ESG	Above median (3) Hi-carbon	(4) Hi-ESG	Below median (5) Low-carbon	(6) Low-ESG
ESG[−1]	−0.001	0.671	−0.000	0.385	−0.001	0.297
	(−1.183)	(39.171)	(−0.329)	(16.676)	(−1.086)	(15.402)
Carbon[−1]	0.828	−0.080	0.794	−0.081	0.685	−0.079
	(18.838)	(−0.386)	(31.480)	(−0.289)	(5.630)	(−0.377)
Size	−0.025*	1.736	0.000	1.043	−0.052**	0.822
	(−1.894)	(6.851)	(0.018)	(2.822)	(−1.990)	(3.523)
Leverage	0.096	−2.126	−0.045	3.339	0.112	−1.439
	(1.533)	(−1.578)	(−0.435)	(1.506)	(1.289)	(−1.314)
Profitability	−0.121	3.652**	−0.188	8.854	−0.194**	−0.432
	(−1.231)	(2.385)	(−0.974)	(4.569)	(−1.968)	(−0.335)
Capital investment	−0.549**	−1.719	−0.651	5.560	−0.217	0.605
	(−2.482)	(−0.376)	(−1.237)	(0.671)	(−0.760)	(0.151)
R&D intensity	0.058	5.793	−0.531	15.831	0.622	−2.428
	(0.207)	(0.989)	(−1.031)	(1.605)	(1.447)	(−0.511)
Advertising intensity	0.486	−3.007	0.193	−14.192	1.093*	−4.664
	(1.471)	(−0.372)	(0.336)	(−1.359)	(1.746)	(−0.787)
Dividends	0.103	14.724*	−0.169	18.924	0.231	6.598
	(0.356)	(1.715)	(−0.490)	(1.481)	(0.523)	(0.834)
Cash holdings	−0.333	−0.159	−0.436**	1.426	−0.338**	−1.019
	(−3.194)	(−0.080)	(−2.538)	(0.464)	(−2.455)	(−0.566)
Discretionary spending	−0.092	0.260	0.012	−2.294	−0.353	1.743
	(−0.920)	(0.114)	(0.068)	(−0.645)	(−1.532)	(0.928)
% Ind director	0.001	0.062	−0.000	0.022	0.003	0.035*
	(0.987)	(3.461)	(−0.241)	(0.758)	(1.431)	(1.954)
Bsize	−0.076	3.506	−0.170*	0.513	−0.005	−0.320
	(−1.296)	(2.912)	(−1.734)	(0.281)	(−0.066)	(−0.302)
Constant	1.561	−4.953	2.018	28.879	1.062	10.272
	(4.418)	(−1.394)	(6.438)	(5.415)	(2.660)	(3.414)
Observations	4,637	4,640	2,508	2,509	2,129	2,131
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered firm	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within model	0.439	0.321	0.441	0.258	0.364	0.397
R-squared overall model	0.963	0.740	0.967	0.561	0.960	0.620
R-squared between model	0.992	0.947	0.986	0.860	0.981	0.757

Note: The Granger causality framework is employed to explore the causal relationship between carbon emission and the Refinitiv's ESG combined score (*ESG*). The following models are estimated with and without controls (Equations (3) and (4)). The sample period covers 2005–2018. A firm is classified as high (low) environment if the firm's environmental score is above (below) yearly median environmental score. Standard errors clustered by firm are reported in parentheses. *, ** and *** represent statistical significance at 10%, 5% and 1%, respectively. Robust z-statistics in parentheses.

about 28 (25) tons per million dollars of revenue. The Refinitiv's ESG (Environment) scores are 61 (59) for the Hi-score sample and 30 (12) for the Low-score sample, respectively. Firms in our sample have average leverage of 25%, have low intangible assets, hardly spend on capital investments, hold low cash and pay little dividends. Interestingly, in our average firm, 80% of board members are independent directors.

TABLE 3 Granger causality between carbon emission and environmental score.

	Full sample		Above median		Below median	
	(1) Carbon	(2) Escore	(3) Hi-carbon	(4) Hi-escore	(5) Low-carbon	(6) Low-escore
Escore[−1]	−0.000	0.827***	0.001**	0.583***	−0.003*	0.648***
	(−0.265)	(73.596)	(2.351)	(28.693)	(−1.836)	(25.485)
Carbon[−1]	0.829***	−0.272	0.861***	−0.008	0.633***	0.242
	(18.830)	(−1.324)	(45.981)	(−0.022)	(4.971)	(1.229)
Size	−0.027**	2.636***	−0.007	2.211***	−0.070**	1.565***
	(−2.045)	(10.427)	(−0.506)	(5.390)	(−2.342)	(4.906)
Leverage	0.096	−2.372*	0.041	−1.778	0.100	−0.781
	(1.539)	(−1.847)	(0.416)	(−0.764)	(1.123)	(−0.793)
Profitability	−0.123	1.538	−0.170	1.870	−0.161*	1.359
	(−1.243)	(1.165)	(−0.834)	(0.843)	(−1.858)	(1.075)
Capital investment	−0.542**	10.685**	−0.625	18.936*	−0.064	6.768*
	(−2.454)	(2.237)	(−1.358)	(1.781)	(−0.247)	(1.765)
R&D intensity	0.058	3.880	−0.873	29.295	0.650*	−5.836
	(0.204)	(0.595)	(−1.423)	(1.591)	(1.847)	(−1.327)
Advertising intensity	0.497	−4.811	0.043	−3.135	0.574	−4.056
	(1.504)	(−0.746)	(0.110)	(−0.365)	(0.980)	(−0.645)
Dividends	0.087	13.801	0.163	27.314	−0.067	2.327
	(0.300)	(1.319)	(0.357)	(1.543)	(−0.210)	(0.497)
Cash holdings	−0.332***	−0.163	−0.453***	3.054	−0.306*	2.146
	(−3.165)	(−0.089)	(−2.859)	(0.816)	(−1.849)	(1.401)
Discretionary spending	−0.097	2.985	0.039	0.145	−0.360*	1.757
	(−0.971)	(1.445)	(0.242)	(0.032)	(−1.726)	(1.113)
% Ind director	0.001	0.007	−0.000	0.011	0.002	0.006
	(0.895)	(0.437)	(−0.299)	(0.360)	(1.290)	(0.427)
Bsize	−0.080	2.920**	−0.076	2.493	−0.055	−1.004
	(−1.364)	(2.453)	(−0.941)	(1.219)	(−0.571)	(−0.984)
Constant	1.561***	−18.780***	1.204***	−4.132	1.810***	−11.022***
	(4.469)	(−5.098)	(4.817)	(−0.680)	(3.517)	(−2.851)
Observations	4,633	4,636	2,531	2,532	2,102	2,104
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered firm	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within model	0.439	0.595	0.437	0.535	0.321	0.616
R-squared overall model	0.963	0.892	0.970	0.773	0.952	0.797
R-squared between model	0.992	0.981	0.995	0.938	0.977	0.909

Note: The Granger causality framework is employed to explore the causal relationship between carbon emission and the Refinitiv's environmental score (*Escore*). The following models are estimated with and without controls (Equations (5) and (6)). The sample period covers 2005–2018. A firm is classified as high (low) environment if the firm's environmental score is above (below) yearly median environmental score. Standard errors clustered by firm are reported in parentheses.

*Statistical significance at 10%.

**Statistical significance at 5%.

***Statistical significance at 1%.

4 | RESULTS

Our main research question is whether ESG rating influences firms to reduce carbon emissions. Hence, we focus on two Refinitiv scores being ESG and first-level constituents of the environmental pillar score, namely, the environmental innovation score, emission score and resource use score.

We conduct Dumitrescu and Hurlin (2012) Granger causality test for our panel sample. We find that ESG (or Environment) score does Granger-cause carbon intensity at one lag. Table 2 reports the

TABLE 4 Granger causality between carbon emission and environmental innovation score.

	Full sample		Above median		Below median	
Variables	(1) Carbon	(2) E_innovation	(3) Hi-carbon	(4) Hi-E_innovation	(5) Low-carbon	(6) Low-E_innovation
E_innovation[−1]	0.000	0.761***	0.001	0.450***	−0.000	0.073***
	(0.309)	(51.888)	(1.236)	(19.204)	(−0.214)	(3.946)
Carbon[−1]	0.828***	−0.280	0.858***	−0.115	0.781***	0.086
	(18.774)	(−0.831)	(36.790)	(−0.159)	(8.554)	(1.125)
Size	−0.030**	2.283***	0.003	1.910**	−0.053**	0.233**
	(−2.272)	(6.517)	(0.148)	(2.480)	(−2.487)	(2.573)
Leverage	0.098	−3.610	0.209	3.642	−0.004	0.061
	(1.551)	(−1.790)	(1.948)	(0.636)	(−0.052)	(0.120)
Profitability	−0.124	2.234	−0.363	25.823**	−0.099	0.218
	(−1.253)	(1.190)	(−1.175)	(2.108)	(−0.954)	(0.863)
Capital investment	−0.544**	6.406	−0.574	25.620	−0.475	2.777
	(−2.464)	(0.784)	(−1.114)	(1.097)	(−1.810)	(1.585)
R&D intensity	0.060	−2.548	−0.495	15.942	0.066	−1.063
	(0.212)	(−0.264)	(−0.536)	(0.477)	(0.262)	(−0.709)
Advertising intensity	0.501	6.618	0.082	1.218	0.696	0.913
	(1.511)	(0.670)	(0.108)	(0.042)	(1.693)	(0.745)
Dividends	0.071	21.725	0.634	−3.180	−0.184	−0.623
	(0.246)	(1.826)	(0.938)	(−0.122)	(−0.558)	(−0.436)
Cash holdings	−0.333***	−2.367	−0.488**	−4.500	−0.238**	0.540
	(−3.171)	(−0.819)	(−2.390)	(−0.612)	(−2.188)	(0.730)
Discretionary spending	−0.103	1.190	−0.031	−3.293	−0.199	−0.531
	(−1.021)	(0.399)	(−0.120)	(−0.310)	(−1.239)	(−0.815)
% Ind director	0.001	−0.003	−0.001	−0.070	0.002	−0.004
	(0.890)	(−0.123)	(−0.613)	(−1.083)	(1.074)	(−0.787)
Bsize	−0.083	3.062	−0.159	3.877	0.017	0.071
	(−1.407)	(1.770)	(−1.565)	(0.985)	(0.221)	(0.181)
Constant	1.592***	−29.343***	0.718***	15.260	1.840***	−3.488**
	(4.447)	(−4.919)	(2.676)	(1.166)	(2.727)	(−2.502)
Observations	4,633	4,636	2,126	2,127	2,507	2,509
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered firm	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within model	0.439	0.404	0.376	0.127	0.402	0.208
R-squared overall model	0.963	0.777	0.964	0.594	0.966	0.502
R-squared between model	0.992	0.958	0.993	0.826	0.990	0.760

The Granger causality framework is employed to explore the causal relationship between carbon emission and the Refinitiv's environmental innovation score (*E_innovation*). The following models are estimated with and without controls (Equations (7) and (8)). The sample period covers 2005–2018. A firm is classified as high (low) environment if the firm's environmental score is above (below) yearly median environmental score. Standard errors clustered by firm are reported in parentheses. *, ** and *** represent statistical significance at 10%, 5% and 1%, respectively. Robust z-statistics in parentheses.

estimation results. The coefficient of lagged ESG score on carbon intensity does not reject the null hypothesis of Granger non-causality across all columns. These findings indicate that ESG score hardly has any impact on carbon emission.

$$Carbon_{it} = \alpha_0 + \alpha_1 ESG_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \quad (3)$$

$$ESG_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 ESG_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t. \quad (4)$$

TABLE 5 Granger causality between carbon emission and emission score.

	Full sample		Above median		Below median	
	(1) Carbon	(2) Emission	(3) Hi-carbon	(4) Hi-emission	(5) Low-carbon	(6) Low-emission
Emission[−1]	−0.000	0.792***	0.001**	0.516***	−0.000	0.466***
	(−0.651)	(66.879)	(2.077)	(28.685)	(−0.126)	(13.381)
Carbon[−1]	0.827***	−0.176	0.781***	0.076	0.800***	0.037
	(18.677)	(−0.653)	(32.227)	(0.188)	(7.472)	(0.083)
Size	−0.025**	3.378***	−0.003	2.798***	−0.046*	1.358***
	(−1.979)	(10.553)	(−0.149)	(5.568)	(−1.761)	(3.678)
Leverage	0.096	−1.543	0.042	−1.119	0.093	1.969
	(1.530)	(−0.906)	(0.350)	(−0.338)	(1.267)	(1.215)
Profitability	−0.124	1.563	−0.244	2.054	−0.071	−1.096
	(−1.255)	(0.755)	(−1.167)	(0.749)	(−0.995)	(−0.819)
Capital investment	−0.546**	13.943**	−0.699	−2.926	−0.088	7.260
	(−2.465)	(2.527)	(−1.642)	(−0.339)	(−0.302)	(1.466)
R&D intensity	0.062	5.659	−1.643**	34.403*	0.392	−3.092
	(0.221)	(0.738)	(−1.966)	(1.841)	(1.326)	(−0.458)
Advertising intensity	0.500	−3.927	0.438	7.752	0.600	−4.892
	(1.512)	(−0.439)	(0.754)	(0.818)	(1.344)	(−0.651)
Dividends	0.088	7.548	−0.086	6.361	0.428	0.201
	(0.302)	(0.637)	(−0.196)	(0.404)	(1.505)	(0.034)
Cash holdings	−0.329***	3.595	−0.644***	8.120**	−0.149	2.112
	(−3.138)	(1.482)	(−3.593)	(2.056)	(−1.242)	(1.029)
Discretionary spending	−0.096	3.567	0.248	−1.737	−0.286*	1.343
	(−0.953)	(1.259)	(1.240)	(−0.303)	(−1.717)	(0.503)
% Ind director	0.001	0.016	0.002	−0.035	0.001	0.001
	(0.903)	(0.764)	(1.082)	(−0.780)	(0.618)	(0.087)
Bsize	−0.078	3.322**	−0.095	2.616	−0.001	−2.401*
	(−1.332)	(2.075)	(−0.955)	(0.982)	(−0.015)	(−1.901)
Constant	1.563***	−25.538***	1.590***	7.283	1.828**	6.187
	(4.473)	(−5.427)	(5.132)	(0.919)	(2.155)	(1.037)
Observations	4,633	4,636	2,517	2,518	2,116	2,118
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered firm	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within model	0.439	0.525	0.401	0.377	0.327	0.482
R-squared overall model	0.963	0.877	0.968	0.728	0.957	0.700
R-squared between model	0.992	0.972	0.990	0.904	0.990	0.826

The Granger causality framework is employed to explore the causal relationship between carbon emission and the Refinitiv's emission score (*Emission*). The following models are estimated with and without controls (Equations (7) and (8)). The sample period covers 2005–2018. A firm is classified as high (low) environment if the firm's environmental score is above (below) yearly median environmental score. Standard errors clustered by firm are reported in parentheses. *, ** and *** represent statistical significance at 10%, 5% and 1%, respectively. Robust z-statistics in parentheses.

Turning to the effect of environmental pillar score (*Escore*) on carbon emission reported in Table 3, Columns 1, 3 and 5, we find the coefficient of lagged *Escore* is only significant for Column 3. For the sub-sample of high environmental pillar score reported in Column 3, the coefficient for lagged Escore is positive and statistically significant at the 5% level. Given the standard deviation of the natural logarithm of carbon emission is 18.79 in the hi-*Escore* sample, an increase in an *Escore* increases carbon emission by 0.001 divided by 18.79, which is 0.005% or approximately 0.01 t per millions of revenues. Thus, it suggests that firms in high Escore samples increase

TABLE 6 Granger causality between carbon emission and resource use score.

	Full sample		Above median		Below median	
	(1) Carbon	(2) Resource	(3) Hi-carbon	(4) Hi- resource	(5) Low-carbon	(6) Low- resource
Resource[−1]	−0.000	0.791***	0.001**	0.439***	−0.003*	0.550***
	(−0.612)	(60.380)	(2.349)	(20.200)	(−1.904)	(14.819)
Carbon[−1]	0.827***	−0.421	0.844***	0.074	0.628***	−0.079
	(18.698)	(−1.621)	(42.280)	(0.170)	(4.629)	(−0.308)
Size	−0.025*	3.867***	−0.011	3.742***	−0.037	0.826**
	(−1.955)	(10.980)	(−0.729)	(6.790)	(−1.428)	(2.275)
Leverage	0.096	−4.217**	−0.056	0.309	0.109	1.488
	(1.540)	(−2.471)	(−0.551)	(0.096)	(1.167)	(1.167)
Profitability	−0.124	0.028	−0.199	1.581	−0.179**	−2.128
	(−1.247)	(0.016)	(−0.995)	(0.673)	(−2.001)	(−1.367)
Capital investment	−0.543**	14.849**	−0.565	37.525***	−0.104	0.514
	(−2.457)	(2.323)	(−1.077)	(2.620)	(−0.420)	(0.094)
R&D intensity	0.065	4.769	−0.803	32.993*	0.799**	−4.311
	(0.230)	(0.514)	(−1.363)	(1.753)	(2.261)	(−0.779)
Advertising intensity	0.493	−17.974**	−0.072	−20.905	0.652	−9.878
	(1.489)	(−2.229)	(−0.203)	(−1.338)	(0.971)	(−1.179)
Dividends	0.093	20.640*	−0.043	29.994*	0.119	0.842
	(0.322)	(1.754)	(−0.106)	(1.871)	(0.431)	(0.156)
Cash holdings	−0.330***	1.375	−0.512***	7.144*	−0.194	0.832
	(−3.159)	(0.559)	(−3.234)	(1.905)	(−1.190)	(0.414)
Discretionary spending	−0.094	7.919***	0.061	3.921	−0.280	2.219
	(−0.936)	(2.791)	(0.362)	(0.575)	(−1.270)	(0.950)
% Ind director	0.001	0.023	0.000	−0.006	0.002	0.026
	(0.904)	(0.887)	(0.301)	(−0.120)	(1.141)	(1.389)
Bsize	−0.079	3.963**	−0.057	3.162	−0.063	−0.519
	(−1.342)	(2.505)	(−0.673)	(1.272)	(−0.671)	(−0.364)
Constant	1.557***	−27.356***	1.324***	−3.383	3.106***	−13.772***
	(4.492)	(−5.416)	(4.719)	(−0.422)	(2.869)	(−2.775)
Observations	4,633	4,636	2,493	2,494	2,140	2,142
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Clustered firm	Yes	Yes	Yes	Yes	Yes	Yes
R-squared within model	0.439	0.521	0.409	0.372	0.433	0.584
R-squared overall model	0.963	0.865	0.966	0.706	0.957	0.738
R-squared between model	0.992	0.976	0.993	0.902	0.973	0.845

The Granger causality framework is employed to explore the causal relationship between carbon emission and the Refinitiv's resource use score (*resource*). The following models are estimated with and without controls (Equations (9) and (10)). The sample period covers 2005–2018. A firm is classified as high (low) environment if the firm's environmental score is above (below) yearly median environmental score. Standard errors clustered by firm are reported in parentheses. *, ** and *** represent statistical significance at 10%, 5% and 1%, respectively. Robust z-statistics in parentheses.

carbon emission by approximately 0.005%. In short, it appears that firms with high environmental pillar scores emit more carbon dioxide. On other hand, firms in a low Escore sample decrease carbon emissions, which is significant at the 10% level.

$$Carbon_{it} = \alpha_0 + \alpha_1 Escore_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{5}$$

$$Escore_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 Escore_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t. \tag{6}$$

As further analysis, we re-estimate Granger causality using first-level constituents of the environmental pillar score—environmental innovation score, emission score and resource use score, respectively. The environmental innovation score from Refinitiv is defined as 'reflecting a firm's capacity to reduce the environmental costs and burdens for its customers, thereby creating new market opportunities through new environmental technologies and processes or eco-designed products'. Table 4 shows that the lagged environmental innovation score (E_innovation) does not Granger-cause carbon emissions. The results could also have resulted from the environmental innovation score being directed towards a broader environmental issue encompassing carbon emissions. Yet the absence of a negative Granger causality supports the greenwashing hypothesis that the greater environmental innovation score does not lead to a reduction in carbon emissions.

$$Carbon_{it} = \alpha_0 + \alpha_1 E\_innovation_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{7}$$

$$E\_innovation_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 E\_innovation_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t. \tag{8}$$

Table 5 reports the Granger-causality analysis between emission score and actual carbon emissions. The results show that the lagged emission score (Emission) positively Granger-causes carbon emission only in the high Emission score subsample at the 5% sample. However, in Column 4, lagged carbon emission does not Granger cause emission. This supports Berg et al. (2022) findings of low correlation of the variables across different data providers (carbon emission data from Trucost versus emission score from Refinitiv here). An alternative explanation could be that the emission score from Refinitiv consists of various sub-items other than carbon emission.

$$Carbon_{it} = \alpha_0 + \alpha_1 Emission_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{9}$$

$$Emission_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 Emission_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t. \tag{10}$$

In Table 6, we report the Granger-causality analysis between resource use score and actual carbon emissions. Refinitiv defines resource use score as 'a firm's performance and capacity to reduce the use of materials, energy or water, and to find more eco-efficient solutions by improving supply chain management'. The results show that lagged resource use score (Resource) positively Granger causes carbon emission only in the subsample of firms with high resource score. At first glance, this result seems to support the greenwashing hypothesis. However, an improvement in resource use score could happen gradually over time. For instance, eco-efficient solutions through supply chain management require several years of planning. Hence, an alternative interpretation is that improvement in resource use to reduce carbon emissions may take a longer time (beyond the scope of Granger causality set up of one year in this study) to be reflected in practice.

$$Carbon_{it} = \alpha_0 + \alpha_1 Resource_{it-1} + \alpha_2 Carbon_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t, \tag{11}$$

$$Resource_{it} = \alpha_0 + \alpha_1 Carbon_{it-1} + \alpha_2 Resource_{it-1} + \sum b_j Control_{it} + \sum FE + \varepsilon_t. \tag{12}$$

5 | CONCLUSION

Climate change is a pressing global issue needing urgent action. Carbon emissions reduction has been targeted as one way to reduce the speed of climate change. While governments worldwide collectively work towards meeting the goals of the Paris Agreement and the United Nation's Sustainable Development Goals (SDGs), social and environmental concern investors are also increasingly using ESG ratings to inform their investment decisions. This makes ESG investing a popular form of sustainable finance, which is in line with long-term societal values. However, recent studies raised concerns that some highly rated ESG firms or funds may not have the incentive to actively reducing their carbon emissions as they already have high ESG scores. It is, therefore, important to study the relationship between ESG scores and carbon emissions. Understanding the relationship between ESG and carbon emissions helps investors make informed decisions in investments and assists regulators in developing policies and regulations supporting carbon emission reduction.

Our findings are consistent with the legitimacy theory, as it indicates that high ESG ratings or the E pillar of the ESG scores do not translate to lower carbon emissions, supporting the 'cheap talk' or 'greenwashing' hypothesis. Firms with high ESG or E scores may not have the incentives to do more to produce less carbon emissions. Based on our findings, environmentally concerned investors should not rely on ESG ratings only in their investment decisions. Instead, they should choose to invest in firms that provide evidence of actions taken to reduce their carbon footprints. Our findings also affect how regulators set their policies towards a green economy. Regulators may wish to impose fines to discourage firms from 'greenwashing' behaviours. Further, regulators may also introduce policies such as tax reduction to encourage firms with limited technologies to do more to reduce carbon footprints.

Our results are based on the assumptions that the Refinitiv ESG (or E-score) scores are accurately capturing their environmental, social and governance (or environmental) effort. Nevertheless, Refinitiv ESG ratings have been extensively used in practice and in academic research (see, e.g., Demers et al., 2021; Danisman & Tarazi, 2024; Saharti et al., 2024). Due to the inconsistencies among the ESG ratings provided by various rating agencies (Berg et al., 2022), more work needs to be done to ensure comparability and more importantly that ESG ratings represent what they are supposed to score.

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APPENDIX: STATIONARY, GRANGER CAUSALITY AND OPTIMAL LAG LENGTH

Panel A of this table reports panel unit root tests based on Levin et al. (2002) and Im et al. (2003) with optimal lag length chosen based on both Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). For environmental score, there is not sufficient period for balanced panel estimation. Panel B reports Dumitrescu and Hurlin (2012) Granger non-causality test.

Panel A: Levin et al. (2002) and Im et al. (2003) tests

		Levin et al. (2002)			Im et al. (2003)	
		AIC	BIC		AIC	BIC
Carbon	Adjusted t^*	−26.9017	−27.1715	W-t-bar	−8.4316	−8.7856
	Average chosen lag	1.51	1.42			
ESG	Adjusted t^*	−21.9801	−22.9145	W-t-bar	−7.5699	−7.739
	Average chosen lag	1.76	1.53			
E	Adjusted t^*	−42.9797	−43.3621	W-t-bar	n/a	n/a
	Average chosen lag	1.97	1.78			

Panel B: Dumitrescu and Hurlin (2012) Granger non-causality test

Dumitrescu and Hurlin (2012) Granger non-causality test results Optimal number of lags (BIC): 1 (lags tested: 1 to 2) W-bar = 2.3861 Z-bar = 17.1172 (p value = .0000) Z-bar tilde = 9.1643 (p value = .0000)
H0: ESGscore does not Granger-cause lnCEI1
H1: ESGscore does Granger-cause lnCEI1 for at least one panel (TCUID)
Dumitrescu and Hurlin (2012) Granger non-causality test results Optimal number of lags (BIC): 1 (lags tested: 1 to 2) W-bar = 3.5873 Z-bar = 10.1861 (p value = .0000) Z-bar tilde = 5.0310 (p value = .0000)
H0: EnvironmentScore does not Granger-cause lnCEI1
H1: EnvironmentScore does Granger-cause lnCEI1 for at least one panel (TCUID)