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Carbon disclosure, carbon performance and financial performance: International evidence

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ABSTRACT

This study examines how carbon performance affects carbon disclosure and how carbon disclosure affects financial performance. With a sample of global firms, the study analyses how relationships between carbon disclosure, carbon performance and financial performance vary in institutional contexts. Our results show that carbon disclosure positively affects carbon performance, consistent with the signalling theory. We find that carbon disclosure negatively (positively) affects financial performance in the short-term (long-term). Our findings have significant implications for investors as some firms use carbon disclosure as part of impression management. Our results help regulators to monitor carbon disclosure and assist investors with investment decisions.

1. Introduction

Greenhouse gas (GHG) emissions have become one of the primary threats to the existence of life on earth. The excessive GHGs in the earth's atmosphere lead to undesirable consequences in the ecosystem, creating global warming or climate change (Liu et al., 2015; United Nations [UN], 1992). McKinsey & Company (2020, p. 22) reports that "the global socio-economic impacts of climate change could be substantial as a changing climate affects human beings, as well as physical and natural capital". The consequences of climate change could be worker productivity losses, leading to adverse effects on global gross domestic product (GDP) growth (McKinsey & Company, 2020). Firms have always played a major role in creating climate change problems as they are among the largest emitters of GHG (Heede, 2014; Hoffmann & Busch, 2008; Levin, Cashore, Bernstein, & Auld, 2012; Wijen, 2014). In recent times, stakeholders, such as shareholders, consumers and regulatory authorities, have started exerting pressure on corporations to decrease their GHG emissions (Comyns, 2016; Daddi, Todaro, De Giacomo, & Frey, 2018; Helfaya, Whittington, & Alawattage, 2019; Jeswani, Wehrmeyer, & Mulugetta, 2008; Liesen, Hoepner, Patten, & Figge, 2015; Weinhofer & Hoffmann, 2010). As a consequence, firms are now likely to play a vital role in reducing their GHG emissions and contributing to stabilising climate change (Luo, 2019). In recent years, firms have been asked to disseminate information about climate change-related activities, also referred to as carbon disclosures, to satisfy the concerns of relevant stakeholders (Li, Huang, Ren, Chen, & Ning, 2018; Meng, Zeng, Shi, Qi, & Zhang, 2014). For example, since 2002, the Carbon Disclosure Project (CDP), comprising 525 institutional investors with total assets of USD 96 trillion, has asked the largest firms to disseminate reports on their carbon disclosures, risks, opportunities and strategies (see <www.cdp.net>). Mandatory initiatives that are also aimed at increasing transparency and/or improving emissions management have been the focus of many countries. Mandatory carbon reporting has been legislated in several countries including the United Kingdom (UK), some member states of the European Union (EU), Australia and Japan (see <www.carbonfootprint.com>). Carbon information disclosure is mandated by ISO 14064-1 (Peng, Sun, & Luo, 2015).

The study of carbon disclosure has been gaining increasing importance in recent years to help firms communicate their climate change activities to their stakeholders through environment disclosures (Hahn, Reimsbach, & Schiemann, 2015; Uyar, Karaman, & Kilic, 2020). These

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disclosures can help stakeholders, such as shareholders and creditors, to make better investment decisions. Carbon disclosure can also help stakeholders, such as regulatory agencies, institutional investors and the public, to better monitor and regulate a firm's carbon emissions, which is likely to contribute to its improved carbon performance. Improved carbon performance can, in turn, affect the firm's financial performance (Shen, Ma, & Wang, 2019). Therefore, it is evident that carbon disclosure and carbon performance that fall under the broad categories of environmental disclosure and environmental performance are important areas of study that deserve to be well researched.

Despite the importance of the relationship between carbon disclosure and carbon performance, few studies have investigated this topic, and the findings of those studies have been inconclusive (Clarkson, Overell, & Chapple, 2011; Freedman & Stagliano, 2008; He, Tang, & Wang, 2013; Luo, 2019; Peng et al., 2015). Our study extends the literature by re-examining the relationships between carbon disclosure and carbon performance, and between carbon disclosure and financial performance in a sample from the world's 500 largest firms. To assess these relationships, we test two conflicting predictions for the level of voluntary carbon disclosure using economic-based theories and socio-political theories.

Our study contributes to the literature in several ways. It extends the exploration of this contemporary issue by examining the relationships between carbon disclosure, carbon performance and financial performance. Although both accounting- and market-based measures offer complimentary assessments of performance, limited research, to date, has used both measures to test hypotheses exploring the relationship between carbon disclosure and financial performance. Most studies (e.g. Clarkson et al., 2011; Clarkson, Fang, Li, & Richardson, 2013; Clarkson, Li, Richardson, & Vasvari, 2008; Griffin & Mahon, 1997; Hassan & Romilly, 2018; Lin, Law, Ho, & Sambasivan, 2019) have examined social and/or environmental performance and social and/or environmental disclosure. Shen et al. (2019) argued that the relationship between environmental performance and financial performance plays a crucial role in exploring the internalisation of corporate environmental responsibility. A handful of studies have addressed the relationship between carbon/GHG emissions and firm performance. However, these studies are based either on a sample from a single country (Alsaifi, Elnahass, & Salama, 2020; He et al., 2013; Tang & Demeritt, 2018) or a sample from major industrialised countries (Lartey et al., 2020). He et al. (2013) examined the relationship between carbon disclosure, carbon performance, and S&P 500 firms' financial performance.[1] Our study complimented He et al. (2013) in several ways. Our study focused on the carbon disclosure, carbon performance, and financial performance for a sample of 25 advanced and emerging countries while He et al. (2013) focused on the US firms. Consistent with the voluntary disclosure theory, our study found a positive relationship between carbon disclosure and carbon performance. In contrast, He et al. (2013) found a negative relationship between carbon disclosure and carbon performance conforming to the legitimacy theory. However, our finding that a positive relationship between carbon disclosure and financial performance in the long-term is similar to that of He et al. (2013).[2] Our study also contributes to the literature by examining the relationship between carbon disclosure and financial performance in the short- and long-term.

The findings of our research are notable for several reasons. Firstly, our study found that carbon performance positively affects carbon disclosure. This implies that if a firm's carbon performance improves, it will make more carbon disclosure. Secondly, carbon disclosure negatively affects a firm's financial performance in the short-term. Thirdly, carbon disclosure positively affects a firm's financial performance in the long-term. Our results remain robust even after conducting various robustness tests. Furthermore, to eliminate any concerns about possible simultaneity bias and reverse causality, we added additional variables to our model and perform a two-stage least squares (2SLS) regression analysis with instrumental variables to address endogeneity issues. Different stakeholders of firms can use our findings to understand better the relationships between carbon disclosure, carbon performance and financial performance. Our findings are of significant importance to investors as firms sometimes use carbon disclosures as part of impression management.

The remainder of the paper is structured as follows. Section 2 presents the literature review on relationships between carbon disclosure, carbon performance and financial performance and develops the hypotheses. Section 3 provides the data and empirical strategy, while Section 4 presents the analysis and results. Section 5 describes the additional analyses conducted to check robustness and endogeneity, while Section 6 provides conclusions and implications.

2. Literature review and hypotheses development

Previous studies investigating the relationship between environmental/carbon disclosure and environmental/carbon performance have produced conflicting results (Bewley & Li, 2000; Cho & Patten, 2007; Clarkson et al., 2011; Deegan & Gordon, 1996; Farag, Meng, & Mallin, 2015; Freedman & Jaggi, 1982; Freedman & Wasley, 1990; Luo, 2019; Patten, 1992, 2002; Xie, Nozawa, Yagi, Fujii, & Managi, 2019). They have generally been based on two theoretical framework streams to predict the relationship between environmental/carbon disclosure and environmental/carbon performance. One stream is legitimacy theory and stakeholder theory, while the other stream is signalling theory and voluntary disclosure theory. Stakeholder theory and legitimacy theory suggest a negative relationship, while voluntary disclosure theory and signalling theory propose a positive relationship.

Suchman (1995, p. 574) provided an "inclusive, broad-based definition" of legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions". Prior to Suchman (1995), Maurer (1971, p. 361) asserted that "legitimation is the process whereby an organisation justifies to a peer or subordinate system its right to exist". Legitimacy theory suggests that firms with inferior environmental/carbon performance would make soft and unverifiable qualitative disclosure about their performance to maintain legitimacy and to satisfy the expectations of various stakeholders (O'Donovan, 2002; Sethi, 1978). When the legitimacy of a firm is at risk, stakeholders may consider "its performance as non-sustainable" (Davis, 1973; Hummel & Schlick, 2016, p. 458). Legitimacy theory also suggests that firms are likely to function inside the boundary of social values for their sustained existence (Deegan & Rankin, 1997). In other words, legitimacy can be described as an implicit contract between society and the firm which leads to increased disclosure to meet the expectations of stakeholders (Cormier, Magnan, & Van Velthoven, 2005; Solomon & Lewis, 2002). Firms must act appropriately to reduce the gap between their values and their stakeholders' values (Ashforth & Gibbs, 1990; Gray, Kouhy, & Lavers, 1995; Sethi, 1979). This also highlights the application of stakeholder theory which suggests that managers are primarily responsible for satisfying stakeholder expectations and demands (Ansoff, 1965). They are also responsible for balancing conflicts with stakeholders to achieve a firm's long-term success. As climate change is "among the most challenging ethical issues facing contemporary business and society" (Dahlmann, Branicki, & Brammer, 2019, p. 1), firms with high carbon emissions and those without effective reduction policies are regarded as socially irresponsible (Luo, 2019). These firms may be penalised by society if they do not adopt responsive strategies to combat climate change (Bansal & Clelland, 2004; Pfeffer & Salancik, 2003). Hence, the affected firms adopt strategies to offset

[1] He et al. (2013) used the cost of capital as a measure of financial performance.

[2] He et al. (2013) found an inverse relationship between carbon disclsoure and cost of capital, which is synonymous to a postive relationship between carbon disclosure and firm value.

publicly available negative news to maintain legitimacy (Bebbington, Larrinaga-González, & Moneva-Abadía, 2008). One of the strategies to maintain legitimacy is voluntary carbon disclosure. Firms may use voluntary carbon disclosure to counter any threats to their legitimacy which can also help firms as an image management strategy to influence public perceptions (Bansal & Roth, 2000; Cho & Patten, 2007). Firms with inferior carbon performance prefer "low-quality information – that is superficial, incomplete, not easily subject to comparison or ambiguous – to obscure their poor true state while simultaneously maintaining legitimacy creating a proper sustainability image" (Hummel & Schlick, 2016, p. 459). Therefore, as suggested by legitimacy theory and stakeholder theory, firms with inferior carbon performance would make more carbon disclosures to satisfy important stakeholders and retain their legitimacy. Based on these theoretical frameworks, we can hypothesise the following:

H1. A negative relationship exists between carbon disclosure and carbon performance.

Dye (1985), Lang and Lundholm (1993), and Verrecchia (1983) were among many other researchers who formed the foundation of the application of voluntary disclosure theory to environmental disclosure. Verrecchia (1983, p. 182) demonstrated that "due to the existence of proprietary costs associated with information disclosure, traders are unable to interpret non-disclosure as unambiguously bad news". Dye (1985, p. 125) mentioned that "investors may be uncertain about the nature of the information a manager possesses" in the case of "non-disclosure". Lang and Lundholm (1993, p. 249) mentioned that "in the face of adverse selection … firms whose performance exceeds a certain threshold will disclose, while those below the threshold will not". Based on the findings of Dye (1985), Lang and Lundholm (1993), and Verrecchia (1983), Clarkson et al. (2008, p. 304) argued that firms with superior environmental performance demonstrate their "type" by releasing "objective environmental performance indicators" and firms with inferior environmental performance disclose less or remain silent on their environmental performance, "thus being placed in a pool of firms where investors and other users ascribe the average type to that pool."

Firms with superior environmental performance voluntarily disclose "non-financial information" to illustrate their performance (Clarkson et al., 2008). Firms with better environmental/carbon performance are likely to have a lower "cost of capital" (Dhaliwal, Li, Tsang, & Yang, 2011), increase their market value (Clarkson et al., 2013; de Villiers & Marques, 2016) and attract more analysts (Jo & Harjoto, 2014). Another dimension of voluntary disclosure is the truthfulness of disclosure, with Hummel and Schlick (2016, p. 458) arguing that "firms may provide high-quality information regarding topics that are favorable to themselves (superior performance) while disclosing only low-quality information on topics that may be detrimental to their interests (poor performance)". Hummel and Schlick (2016, p. 458) defined "high-quality disclosure" as "the complete disclosure of relevant and comparable numerical data that fulfil or exceed clearly defined quality requirements" while "low-quality disclosure" was defined as meaning "any other information that does not fulfill the criteria for high-quality disclosure, irrespective of its quantity". Hummel and Schlick (2016) argued that the premise of voluntary disclosure theory is "high-quality disclosure" to illustrate a firm's performance. Moreover, signalling theory suggests that firms with better environmental performance have "incentives to distinguish themselves from their poor counterparts to avoid [the] adverse selection issue" (Luo, 2019, p. 1239). Both the signalling theory and voluntary disclosure theory suggest a positive relationship between carbon disclosure and carbon performance. Therefore, Hypothesis 2 is presented below:

H2. A positive relationship exists between carbon disclosure and carbon performance.

Hypothesis 1 (H1) and Hypothesis 2 (H2) are based on two different aspects: "high-quality disclosure" (voluntary disclosure theory and signalling theory) and "low-quality disclosure" (legitimacy theory and stakeholder theory) of environmental disclosure. The disclosure behaviour of firms is motivated by incentives to increase market value (signalling theory and voluntary disclosure theory) and by efforts to have sustained legitimacy (stakeholder theory and legitimacy theory).

Extensive research has been conducted in academia to investigate the relationship between environmental performance and financial performance (Alsaifi et al., 2020; Barnett & Salomon, 2006; Bui, Moses, & Houqe, 2020; Griffin & Mahon, 1997; Hassan & Romilly, 2018; Lartey et al., 2020; Lin et al., 2019; Orlitzky, Schmidt, & Rynes, 2003; Porter & van der Linde, 1995; Tang & Demeritt, 2018; Velte, Stawinoga, & Lueg, 2020) as well as in the industry press (McKinsey & Company, 2020; Parlette, 2019; Tozzi, 2008). Although studies have had conflicting results, most studies have found a positive relationship between environmental disclosure and financial performance. The positive relationship has been labelled as the result of "innovation offsets" exceeding "the cost of compliance" (Porter & van der Linde, 1995, p.101), strong management capabilities (Aragón-Correa, 1998), firm legitimacy (Hart, 1995); and the desires of stakeholders (Freeman & Evan, 1990). However, following the "traditional economic trade-off argument" (Dixon-Fowler, Slater, Johnson, Ellstrand, & Romi, 2013, p. 355), some studies have suggested a negative relationship or no significant relationship (Freedman & Jaggi, 1986). The traditional economic trade-off argument suggested that the costs to firms outweighed their financial benefits from improving carbon performance (Friedman, 1970; Ruggiero & Lehkonen, 2017).

Our study applies two complementary financial performance measures to evaluate the relationship between carbon disclosure and financial performance. We examine how this relationship exists in the short-term and the long-term. The short-term financial performance measure accounts for current cash flows in the present market environment, while the long-term financial performance measure considers future profitability estimates given the possibility of proposed legislation to address climate change. The short-term financial performance measure evaluates current performance, while the long-term financial performance measure emphasises future performance (Peloza, 2009). Delmas, Nairn-Birch and Lim (2015, p. 378) argued that "[w]hen firms reduce GHG emissions, they, in essence, follow a pollution prevention strategy, as opposed to a strategy of pollution capture and remediation" with this strategy possibly resulting in cost savings from operational efficiency (Hart & Ahuja, 1996; Reinhardt, 1999). However, it is difficult for firms to benefit from these cost savings in the short-term, implying that the relationship between carbon disclosure and financial performance may become negative. Van der Laan, van Ees, and van Witteloostuijn (2008) found a negative relationship between negative corporate social performance for primary stakeholders (e.g., investors, consumers, employees) and short-term financial performance measured by return on assets (ROA). For example, they demonstrated that the ROA of an average firm would reduce from 8% to 0% when a firm does not meet consumers' demands. However, they did not find any demonstrable relationship between corporate social performance for secondary stakeholders (e.g., the community, diversity, the environment and human rights) and financial performance. Walker and Wan (2012, p. 227) found that 'green-washing' "measured as the difference between symbolic and substantive action" negatively affected financial performance. They argued that firms that talked about 'greenness' without the demonstration of actual green behaviours were negatively affected financially. Busch and Hoffmann (2011, pp.242–243) argued that "process-based Corporate Enivironment Performance (CEP)" as a "waste of resources", leading to a negative relationship between environment performance and financial performance. The process-based CEP fails to incorporate the actual outcome-based CEP and neglects "the measurement of concrete resource consumption and emission optimization" (Busch & Hoffmann, 2011, p.242). Busch and Hoffmann's (2011) process-based CEP can be considered as a green-washing technique.

Table 1
Distribution of sample firms by sector and country.

Country	GICS SECTOR									Total number of firms	% of Total
	Consumer discretionary	Consumer staples	Energy	Health Care	Industrials	IT	Materials	Telcom	Utilities		
Australia		2	1					1		4	2.14%
Belgium		1								1	0.53%
Brazil			1				1			2	1.07%
Canada			3		1		1	1		6	3.21%
Denmark				1	1					2	1.07%
Finland						1				1	0.53%
France	2	3		1	4		1	1		12	6.42%
Germany	3	1		1	2	1	2	1	1	12	6.42%
Hong Kong					1					1	0.53%
Ireland						1				1	0.53%
Israel				1						1	0.53%
Italy									1	1	0.53%
Japan	4	1		2	1	2		1		11	5.88%
Netherlands		1	1		2					4	2.14%
Norway			1					1		2	1.07%
Russia			1							1	0.53%
South Africa			1					1		2	1.07%
South Korea	1					1	1			3	1.60%
Spain	1		1						2	4	2.14%
Sweden	1				1	1		1		4	2.14%
Switzerland	1	1		2			2	1		7	3.74%
Taiwan						1				1	0.53%
Thailand			1							1	0.53%
UK	2	7	1	2	2		3	2	1	20	10.70%
USA	10	10	8	13	14	14	6	3	5	83	44.39%
Total	25	28	20	23	30	22	17	14	10	187	100.00%
% of Total	13.37%	14.97%	10.70%	12.30%	16.04%	11.76%	9.09%	7.49%	5.35%	100.00%	

Thus, we can hypothesise as below:

H3. A negative relationship exists between carbon disclosure and financial performance in the short-term.

It has been argued that firms with "climate-friendly practices" have been rewarded in many ways. For example, firms with climate-friendly practices are favourably evaluated by financial markets (Delmas, Etzion, & Nairn-Birch, 2013). This is evidenced by the HSBC Global Climate Change Benchmark Index, the Credit Suisse Global Warming Index and the ABN Amro Climate Change and Environment Index which appear to outperform major benchmark indices (Delmas et al., 2015). The performances of these indices highlight investors' perceptions of future market conditions for firms that "possess, or at least are developing, internal capabilities that will allow them to be more competitive in a business environment facing increased institutional pressure to comply with regulations, standards, and norms directed at mitigating climate change" (Delmas et al., 2015, p. 379). As increased carbon disclosure is likely to improve carbon performance, while increased carbon performance is likely to affect firm financial performance in the long-term positively, we hypothesise the following:

H4. A positive relationship exists between carbon disclosure and financial performance in the long-term.

3. Data and empirical strategy

3.1. Data

In the current study, carbon disclosure and performance scores are obtained from the Carbon Disclosure Project (CDP) from 2011 to 2015 as it is "the most comprehensive database of carbon and climate change-related information" (Griffin, Lont, & Sun, 2017). The CDP has climate change-related information from over 8400 firms worldwide. The Financial Times (FT) Global 500 (G500) firms are chosen for their size and the impact they may have on countries in which they operate (Jose & Lee, 2007). Another reason for choosing these firms is due to their public visibility and their principal role in responding to the climate change issue (Qian & Schaltegger, 2017). Data to measure financial performance and control variables are obtained from the DataStream database. Financial firms are excluded from the sample, as their businesses do not involve substantial carbon emissions (see Luo, 2019). Firms are also excluded if their carbon disclosure scores and/or carbon performance scores were missing in any of the years from 2011 to 2015: following these exclusions, the final sample is 187 firms. Table 1 shows the distribution of sample firms, with the industry sector classified following the Global Industry Classification Standard (GICS) as at 31 December 2015. The industrial sector comprises the highest number of firms, with 16.04% of the sample, followed by the consumer staples sector (14.97%) and the consumer discretionary sector (13.37%). The utilities sector has the lowest number of firms, accounting for 5.35% of the sample. The United States of America (USA) has the highest number of firms, accounting for 44.39% of the sample, followed by the UK (10.70%).

3.2. Measures

3.2.1. Measures for carbon disclosure and carbon performance

Our study uses carbon disclosure scores and carbon performance scores from the CDP as proxies for carbon disclosure and carbon performance, respectively. Disclosure scores indicate the level of detail and comprehensiveness in disclosures, while performance scores show the level of action taken on climate change by participating firms. Several studies (Luo, 2019; Qian & Schaltegger, 2017) have used CDP data as a measure for carbon disclosure and carbon performance.

3.2.2. Financial performance

Either accounting- or market-based measures have been used in the literature to assess financial performance (Margolis, Elfenbein, & Walsh, 2007). Accounting measures are used to assess performance in the short-term with regard to firms' initiatives to reduce costs (Peloza, 2009). On the other hand, "market-based measures" evaluate investors' assessments of the long-term profitability of a firm in the context of "its current or recent management practices" (King & Lenox, 2002). Both

accounting- and market-based measures have been used to evaluate financial performance. However, limited research to date has used both measures to test hypotheses for the relationship between carbon disclosure and financial performance (Delmas et al., 2015). We use return on assets (ROA) as a short-term financial performance measure. The ROA measure considers current costs and relevant revenues disclosed in the financial statement, with pay-off to be immediate for investments to be profitable (Delmas et al., 2015). We use Tobin's Q, a market-based measure that includes intangible assets and investors' long-term perceptions about the sustainability of firms (Dowell, Hart, & Yeung, 2000; Konar & Cohen, 2001). Dowell et al. (2000) found a positive relationship between the market value of a firm measured by Tobin's Q and the level of the environmental standard it adopts. In particular, they showed that firms adopting a stringent global environmental standard have higher market values than those adopting less stringent or local environmental standards. Konar and Cohen (2001) found that poor environmental performance has a negative effect on the intangible asset value of a publicly traded firm. They used Tobin's Q to measure the tangible and intangible value of a firm. Alsaifi et al. (2020) showed a positive relationship between carbon disclosure and financial performance. Alsaifi et al. (2020) created a financial performance index from a number of financial performance variables including the price to book ratio, which is a proxy for Tobin's Q. Jaggi, Allini, Macchioni, and Zampella (2018) found a positive relationship between carbon disclosure and financial performance. Tobin's Q reflects how market participants view a firm as competitive in the business environment, including consideration of future legislation to address climate change, while ROA recognises a firm's carbon disclosure practices via its operational efficiency in generating revenues (Busch & Hoffmann, 2011).

3.2.3. Control variables

Firm age, firm size, capital intensity, leverage, earnings quality, stock liquidity and carbon intensity are used as control variables in our study due to their potential impact on carbon disclosures and performance. Most voluntary disclosure studies have employed firm size as one of their control variables (Clarkson et al., 2011; Luo, 2019). Two primary reasons explain the relationship between carbon disclosure and firm size. Firstly, larger firms have the physical and financial resources needed to disclose detailed and comprehensive non-financial information and, secondly, they are often subject to "a high degree of public scrutiny" (Liu & Anbumozhi, 2009; Stanny & Ely, 2008). Firms that are highly leveraged often institute accounting and financial strategies that enable them to make thorough disclosures of their financial or non-financial (environment/social) information. Unless they do so, creditors may impose restrictions which would increase their agency cost (Clarkson et al., 2008). They also try to keep certain "stakeholders (investors, creditors) informed to avoid debt-covenants' breaches" (Freedman & Jaggi, 2005). Therefore, we can expect that highly leveraged firms would provide comprehensive carbon disclosure. Firms with larger capital spending are likely to have cleaner and newer technologies which should help them to improve their carbon performance. They would therefore like to disclose information about these technologies to let stakeholders know about them (Clarkson et al., 2008). Hence, firms with higher capital intensity are likely to provide higher carbon disclosures. de Villiers, Naiker, and van Staden (2011) and Huergo and Jaumandreu (2004) suggested that older firms are expected to be involved in environmental activities as they have adequate resources to do so at a relatively lower cost. Hence, firm age is used as a control variable.

Earnings quality encourages firms to make more voluntary disclosures (Francis, Nanda, & Olsson, 2008). Therefore, earnings quality is added as one of the control variables. Following Francis et al. (2008), we define earnings quality as the standard deviation of the firm's earnings over a 10-year period. Francis et al. (2008) demonstrated that the four measures of earnings quality (i.e., accruals quality, earning variability, absolute abnormal accruals and a common factor derived from these three measures) are highly correlated. Accordingly, we use the measure of earning variability from Francis et al. (2008). We use a 10-year rolling period to calculate earnings quality to enhance the construct validity of the measure.

We use stock liquidity as an additional control variable. According to legitimacy and stakeholder theory, managers may disclose more in order to improve transparency. One way to improve transparency is to increase stock liquidity. Managers have incentives to increase stock liquidity in order to issue shares or sell shares obtained from options or other compensation plans. Dhaliwal et al. (2011) suggested that lower levels of stock liquidity in firms tend to influence their voluntary disclosures. Following Dhaliwal et al. (2011), we define stock liquidity as the ratio of the number of shares in the year to the total shares outstanding at the year's end. Capital intensity has often been used to assess both environmental and financial performance (King & Lenox, 2001). Clarkson et al. (2008) suggested that firms with larger capital spending may adopt cleaner and newer technologies, helping them

Table 2
Definition of variables.

Variables	Definition	Source
Carbon disclosure (CD)	The natural logarithm of the carbon disclosure score	CDP
Carbon performance (CP)	The natural logarithm of the numeric equivalent (midpoint of carbon performance score) of carbon performance band: 93 for A/A- (86 + 1)/2; 73 for B; 5.5 for C; 3.5 for D and 1 for E.[a]	CDP
High carbon performance (HICP)	A dummy variable equals 1 if carbon performance (CP) score of a firm is in quartile 4 and 0 otherwise.	CDP
Size	The natural logarithm of total assets	DataStream
Leverage (LEV)	Total debts divided by total assets	DataStream
Earnings Quality	The standard deviation of the firm's earnings over a 10-year period. Earnings defined as earnings before extraordinary items scaled by total assets.	DataStream
Stock liquidity	The ratio of number of shares traded in the year to the total shares outstanding at the year's end.	DataStream
Return on Assets (ROA)	Net income before extraordinary items/preferred dividends, divided by total assets.	DataStream
Tobin's Q (TOBINSQ)	The ratio of the market value of a firm's assets (as measured by the market value of its outstanding stock and debt) divided by the replacement cost of the firm's assets (book value).	DataStream
Age	The natural logarithm of the age of the firm	DataStream
Capital intensity (CAPIN)	The ratio of capital expenditures to total sales revenue	DataStream
Carbon intensity (CINT)	A dummy variable equals 1 if the firm is in materials, energy or utilities industries (carbon-intensive industries) and 0 otherwise.	DataStream
EPI	A change in the Environment Performance Index (EPI) score	http://epi.yale.edu/
ETS	A dummy variable equals 1 if the firm is within a country with an operating Emissions Trading Scheme (ETS) and 0 otherwise.	https://icapcarbonaction.com/en/ets-map
Shareholders	A dummy variable equals 1 if the firm is in a common-law country and 0 otherwise.	Porta, Lopez-de-Silanes, Shleifer and Vishny (1998)

[a] For the sake of simplicity, our study uses only the 2012–2015 scoring methodology, which is slightly different from the 2011 scoring methodology.

Table 3
Descriptive statistics and correlation matrix.

Panel A: Descriptive statistics

	CD	CP	SIZE	LEV	ROA (%)	TOBINSQ	AGE	STOCK LIQUIDITY	EARNINGS QUALITY	EPI	ETS	SHAREHOLDER	CINT	CAPIN
Mean	85.745	66.402	10.679	24.918	10.398	1.571	3.959	1.184	0.032	0.538	0.487	0.620	0.251	0.098
Maximum	100.000	93.000	12.855	83.873	51.240	8.129	5.858	6.038	0.405	3.443	0	0	1.000	0.934
Minimum	50.000	10.000	8.725	0.000	−148.371	0.000	0.000	0.002	0.002	−1.596	1	1	0.000	0.002
Std. Dev.	12.902	21.071	0.766	13.355	9.828	1.052	0.850	0.861	0.029	0.704	0.500	0.486	0.434	0.110
Observations	935	935	935	935	935	935	935	935	935	935	935	935	935	935

Panel B: Pearson correlation coefficients

	CD	CP	SIZE	LEV	ROA	TOBINSQ	AGE	STOCK LIQUIDITY	EARNINGS QUALITY	EPI	ETS	SHAREHOLDER	CINT	CAPIN
CD	1.000													
CP	0.759***	1.000												
SIZE	0.191***	0.198***	1.000											
LEV	0.137***	0.069***	−0.001	1.000										
ROA	−0.073**	0.002	0.181***	−0.129***	1.000									
TOBINSQ	0.078**	0.001***	0.182***	−0.071*	0.558***	1.000								
AGE	0.800	0.096***	0.105***	0.104***	−0.039	−0.036	1.000							
STOCK LIQUIDITY	−0.178***	−0.230***	−0.280***	−0.051	−0.080**	0.036	−0.104***	1.000						
EARNINGS QUALITY	−0.086***	−0.135***	−0.083**	−0.110***	−0.271***	0.136***	−0.029	0.219***	1.000					
EPI	−0.103***	0.004	−0.047*	−0.032	0.023***	−0.021	0.034	−0.122***	0.016	1.000				
ETS	0.143***	0.226***	−0.011	−0.060*	−0.112***	−0.173***	0.004	−0.517***	−0.074**	0.171***	1.000			
SHAREHOLDER	−0.110***	−0.145***	0.041	0.129***	0.095***	0.163***	0.026	0.384	0.087***	0.030	−0.654***	1.000		
CINT	−0.037	−0.078**	−0.117***	0.094***	−0.227***	−0.260***	0.038	0.012	0.080***	0.018	−0.017	−0.023	1.000	
CAPIN	−0.108***	−0.133***	−0.057**	0.075***	−0.294***	−0.202***	−0.046	0.010	0.180***	−0.021	−0.166***	0.049*	0.493***	1.000

Superscript asterisks *, ** and *** are significant at 10%, 5% an 1%, respectively.

achieve a higher level of environmental performance. Carbon intensity is used as a control variable as firms with higher carbon intensity relative to its peers are "are prone to report more carbon-related information to avoid the negative effect." (Luo, 2019, pp.1252–1253).

Following Luo et al. (2019), we use three measures to incorporate carbon-regulated institutional contexts: the presence of an Emissions Trading Scheme (ETS), of an Environment Performance Index (EPI) and of shareholder orientation. The existence of an Emissions Trading Scheme (ETS) demonstrates that a country/region is moving toward a "carbon-constrained economy" (Luo, 2019, p. 1243). An ETS requires the implementation of "carbon standards" for measuring "carbon performance, emission trading, reporting and verification" (Luo, 2019). To see whether a country with an ETS a different level of carbon performance to that of other countries has, a dummy variable for ETS is used (see Table 2 for the definition of an ETS dummy variable). Firms in countries with higher environmental performance scores are expected to have lower carbon emission levels and more carbon disclosure. A change in the EPI score is used to investigate firms' carbon disclosure and performance in countries with high EPI scores against those with low EPI scores. The literature shows that firms with a shareholder orientation appear to benefit shareholders from their social and environmental performance (Luo, 2019). On the other hand, firms in countries with a stakeholder orientation are likely to care about the environment and tend to follow relevant carbon-related regulations (Simnett, Vanstraelen, & Chua, 2009; Van der Laan Smith, Adhikari, & Tondkar, 2005). Firms in countries with civil (common) law are categorised as having a stakeholder (shareholder) orientation (Archambault & Archambault, 2003; del Carmen Briano-Turrent & Rodríguez-Ariza, 2016; Porta, Lopez-de-Silanes, Shleifer, & Vishny, 1998). The dummy variable for shareholder orientation is used to see whether firms with a shareholder orientation behave differently to those in a country with a stakeholder orientation.

3.2.4. Empirical models

Our empirical models to test the respective hypotheses are set out below:

Hypotheses 1 and 2:

$$CD_{i,t} = \alpha_0 + \alpha_1 CP_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \gamma_t + \delta_c + \delta_I + \varepsilon_{i,t} \quad (1)$$

Hypothesis 3:

$$ROA_{i,t} = \alpha_0 + \alpha_1 CD_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \gamma_t + \delta_c + \delta_I + \pi_{i.t} \quad (2)$$

Hypothesis 4:

$$TOBINSQ_{i,t} = \alpha_0 + \alpha_1 CD_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liquidity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \gamma_t + \delta_c + \delta_I + \vartheta_{i.t} \quad (3)$$

where $\varepsilon_{i.\,t}$, $\pi_{i.\,t}$ and $\vartheta_{i.\,t}$ is the error term at year t for each model. γ_t and δ_c are year and country effects, respectively to account for economic trends and time-invariant country characteristics that might influence carbon disclosures and financial performance. Skinner (1997) found that firms with a high legal risk appear to make more voluntary disclosures. Hence, δ_I is the industry fixed effect to account for the variation across industries. Table 2 provides the definitions of all variables.

4. Empirical results

4.1. Descriptive statistics

Table 3, Panel A presents the descriptive statistics of carbon disclosure, carbon performance, financial performance and dummy variables over the period 2011–2015. The mean carbon disclosure score is 85.745 out of 100 with a standard deviation (SD) of 12.902. The maximum carbon disclosure score is 100, while the minimum is 50. This indicates that the data disclosed by sample firms are of high quality and are useful. It also indicates that the sample firms are disclosing a good amount of data related to their activities to address climate change. Furthermore, the mean carbon disclosure score of all sectors increased significantly from 75.570 in 2011 to 95.310 in 2015. The one-way analysis of variance (ANOVA) test shows that a significant variation exists in mean carbon disclosure (CD) scores across the years (F-statistic = 88.120, p-value = 0.000). The mean carbon performance score is 66.402 out of 100 with an SD of 21.071. The minimum carbon performance score is 10, while the maximum is 93. Also, the mean carbon performance score of all sectors increased from 58.820 in 2011 to 68.360 in 2015.[3] The one-way ANOVA test shows that a significant variation exists in mean carbon performance scores across the years (F-statistic = 15.500, p-value = 0.000). This suggests a large variation in carbon performance among sample firms.

Return on assets (ROA) has a mean of 10.398% with an SD of 9.828%. The mean ROA is higher than that reported by Luo (2019) and Cotter and Najah (2012). The higher ROA in our study is reflective of the fact that other studies included the period of the Global Financial Crisis (GFC) in their samples. The mean Tobin's Q is 1.571, with an SD of 1.052. The mean leverage is 24.918%, which is similar to that of Luo (2019). The mean firm size is 10.679, which is consistent with Luo (2019). The mean stock liquidity is 1.184, which is lower than that of Dhaliwal et al. (2011).[4] This reflects that our sample consists of both the United States (US) and non-US countries, including emerging markets, while Dhaliwal et al. (2011) included only US firms. The mean earnings quality measured by earnings variability is 0.032. The mean result of earnings quality is consistent with that of Francis et al. (2008). The higher value of earnings variability indicates lower earnings quality. The average age of firms is 3.959. The average capital intensity is 0.098, which is similar to that of Luo (2019). One-quarter of sample firms are in a "carbon-intensive industry" (energy, materials or utilities industries). Approximately 49% (62%) of firm-year observations are from countries with an ETS (shareholder orientation). These results are consistent with those of Luo et al. (2019). The mean change in the EPI score is 0.538.

The correlation matrix of variables is presented in Table 3, Panel B. Carbon disclosure and carbon performance are highly correlated (correlation coefficient = 0.759, p-value = 0.000), suggesting that firms with a superior carbon disclosure have a higher level of carbon performance. Carbon disclosure (CD) increases as firm size increases (correlation coefficient = 0.191, p-value = 0.000), indicating that larger firms disseminate more comprehensive carbon disclosures. This finding is consistent with the literature which indicated that larger firms have a tendency to voluntarily disseminate carbon disclosures to legitimise their existence (Bansal & Roth, 2000; Cho & Patten, 2007; Deegan, 2002; Sethi, 1978). Consistent with the literature (Luo, 2019), the correlation coefficient between carbon disclosure and leverage is positive and significant (correlation coefficient = 0.137, p-value = 0.000). Firms in a country with an ETS are expected to have a higher level of carbon disclosure (correlation coefficient between carbon disclosure and ETS = 0.143, p-value = 0.000). Interestingly, Tobin's Q has a positive

[3] Yearly carbon disclosure and performance scores are not reported in this paper for reasons of brevity.

[4] Dhaliwal et al. (2011) report that the mean stock liquidity of US firms is 1.248.

Table 4
Level of carbon disclosure (CD) and carbon performance (CP) by country.

Country	N	%	CD				CP			
			Mean	Min	Max	SD	Mean	Min	Max	SD
Australia	20	2.140	83.25	66	98	9.940	66.500	31	73	12.260
Belgium	5	0.530	86.6	77	98	9.180	81.000	73	93	10.950
Brazil	10	1.070	89.4	80	100	7.600	59.800	51	73	11.360
Canada	30	3.210	81.27	59	100	13.060	58.530	31	93	20.770
Denmark	10	1.070	82.4	63	100	13.770	62.200	31	73	15.100
Finland	5	0.530	95.400	84	100	6.470	89.000	73	93	8.940
France	60	6.420	84.580	53	100	15.510	66.630	10	93	24.280
Germany	60	6.420	92.520	63	100	9.800	79.000	31	93	16.450
Hong Kong	5	0.530	87.000	71	97	9.700	55.400	51	73	9.840
Ireland	5	0.530	94.200	92	99	2.780	81.000	73	93	10.950
Israel	5	0.530	77.200	59	96	15.070	43.600	10	73	28.170
Italy	5	0.530	93.200	87	100	5.630	77.000	73	93	8.940
Japan	55	5.880	85.470	54	100	13.900	66.440	10	93	20.760
Netherlands	20	2.140	90.300	52	100	13.860	73.600	31	93	19.590
Norway	10	1.070	84.300	60	100	13.620	63.900	10	93	26.410
Russia	5	0.530	60.000	50	66	6.600	34.800	10	51	17.090
South Africa	10	1.070	84.700	69	99	10.380	55.600	31	93	19.210
South Korea	15	1.600	91.670	79	99	6.690	78.200	51	93	12.180
Spain	20	2.140	92.650	57	100	10.930	79.800	31	93	16.740
Sweden	20	2.140	82.950	57	99	12.460	65.300	31	93	21.670
Switzerland	35	3.740	90.600	66	100	8.300	74.890	31	93	16.580
Taiwan	5	0.530	88.200	76	97	8.700	73.000	73	73	0.000
Thailand	5	0.530	80.000	62	97	14.210	51.400	31	93	25.310
UK	100	10.700	86.960	53	100	10.990	70.700	10	93	19.000
US	415	44.390	84.470	50	100	13.260	63.130	10	93	21.460
Total	935	1.000	85.745	50	100	12.902	66.402	10	93	21.071

Notes: This table provides the summary statistics of carbon disclosure and carbon statistics. N is the number of firm-year observations.

Table 5
The effects of carbon performance (CP) on carbon disclosure (CD).

Variables	Dependent variable: CD
C	63.291***
	(3.76)
CP (−1)	0.282***
	(13.10)
SIZE (−1)	0.952**
	(2.05)
LEV (−1)	0.011*
	(1.69)
CAPIN (−1)	−7.323
	(−1.38)
Earnings Quality (−1)	22.950
	(1.54)
Stock Liquidity (−1)	0.211
	(0.30)
CINT (−1)	2.491
	(1.06)
AGE (−1)	−0.050
	(−0.11)
ETS (−1)	4.372
	(0.23)
EPI (−1)	−7.244
	(−0.39)
Shareholders (−1)	−8.472
	(−0.39)
Observations	935
R-squared	0.109
F-statistic	18.000***
Industry fixed	Yes
Country fixed	Yes
Year fixed	Yes
F-test (Ho: No variation due to the difference across panels)	1.851***

Notes: This table presents the results of carbon performance on carbon disclosure from Eq. (1).
t-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% an 1%, respectively.

correlation with carbon disclosure, while ROA has a negative correlation with carbon disclosure. This supports Hypothesis 3 (H3) that a negative relationship exists between carbon disclosure and financial performance in the short-term, and Hypothesis 4 (H4) that a positive relationship exists between carbon disclosure and financial performance in the long-term. Both stock liquidity and earnings quality are negatively correlated with carbon disclosure scores. However, we find insignificant correlations between carbon disclosure and age, and carbon disclosure and carbon intensity.

Table 4 provides the level of carbon disclosure (CD) and carbon performance (CP) by individual countries. Of the 25 countries, the USA has the largest scores followed the UK. Finland has the highest mean carbon disclosure score as well as the highest mean carbon performance score, while Russia has the lowest mean carbon disclosure score and the lowest carbon performance score. The one-way ANOVA indicates that significant variation exists between the mean carbon disclosure scores between countries and sectors.

To validate the data and models used in this study, diagnostic tests are performed for normality, endogeneity, multicollinearity and heteroscedasticity. Residual plots are investigated to check linearity and the presence of heteroscedasticity. To check for any visible non-linearity, the necessary transformation (usually the logarithmic transformation) of the dependent and primary explanatory variables is undertaken to establish linearity. In all these cases, logarithmic transformation is shown to be adequate for correcting non-linearity in the relationship. The normal residual plots for all the models do not show any major violations of the normality assumption, thus confirming that regression residuals are normally distributed for all models used in this study. The variance inflation factor (VIF) values for each variable are not more than 2, whereas it is VIF values of more than 2 that may create a multicollinearity issue (Dielman, 2001; Gujarati & Porter, 2003). Therefore, we can conclude that no multicollinearity is present in any of the models used in our study.

4.2. Carbon disclosure and carbon performance

Results in Table 5 indicate that a significant positive relationship

Table 6
Effects of carbon disclosure (CD) on financial performance.

Variables	Dependent variable	
	ROA	TOBIN'S Q
C	0.401	1.211
	(0.03)	(0.931)
CD (−1)	−0.042**	0.003**
	(−2.06)	(2.11)
SIZE (−1)	1.281	0.008
	(1.29)	(0.16)
LEV (−1)	0.044	0.004
	(1.21)	(1.32)
CAPIN (−1)	−31.405***	−0.671
	(−6.90)	(−1.60)
Earnings Quality (−1)	20.506	3.962***
	(1.61)	(3.46)
Stock Liquidity (−1)	−0.823	−0.083
	(−1.36)	(−1.45)
CINT (−1)	4.842**	−0.152
	(2.40)	(−0.85)
AGE (−1)	−0.675	−0.142
	(−1.52)	(−1.60)
EPI (−1)	1.562	−0.172
	(0.10)	(−0.12)
ETS (−1)	−5.311	0.031
	(−0.32)	(0.02)
Shareholders (−1)	8.213	1.750
	(0.42)	(0.556)
Observations	935	935
R-squared	0.041	0.042
F-statistic	5.722***	2.810***
Industry fixed	Yes	Yes
Country fixed	Yes	Yes
Year fixed	Yes	Yes
F-test (Ho: No variation due to the difference across panels)	1.591***	2.822***

Notes: This table presents the results for the relationship between carbon disclosure and financial performance from Eqs. ((2) and (3)). t-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

exists between carbon disclosure and carbon performance. This implies that firms with better carbon performance would make more carbon disclosures. This result supports Hypothesis 2 (H2), which proposes a positive relationship between these two variables. Firms with good carbon/environment performance are likely to make more disclosures to indicate their good quality to market participants. By doing so, they can differentiate themselves from firms with inferior performance and thereby avoid "adverse selection problems" (Al-Tuwaijri, Christensen, & Hughes, 2004; Peng et al., 2015). Given the sample firms are from the FT Global 500 firms, these results support the view that these firms release "high-quality disclosure" to increase the market value which conforms with voluntary disclosure theory and signalling theory.

This finding demonstrates that a positive relationship exists between firm size and carbon disclosure. This reinforces the view that larger firms are likely to provide comprehensive non-financial information such as carbon disclosure. The finding is supported by the literature (Clarkson et al., 2011; Luo, 2019). Also, consistent with the literature, the relationship between carbon disclosure and leverage appears to be positive. This implies that leveraged firms are expected to make more disclosures about their climate risk-mitigation strategies. This finding conforms with results from several studies (Freedman & Jaggi, 2005; Luo, 2019). Capital intensity demonstrates a negative relationship with carbon disclosure, although the relationship is not statistically significant. Luo (2019) found a negative relationship between capital spending and carbon disclosure. No significant relationship was found between carbon disclosure and earnings quality, stock liquidity, firm age and carbon intensity. Results show that firms in a country with a high EPI score are expected to decrease their level of carbon disclosure, although the relationship is not significant. This finding is consistent with that of Luo (2019). Results also demonstrate that the level of carbon disclosures by firms in a country with an ETS is not different from those in a country without an ETS.

4.3. Carbon disclosure and financial performance

Table 6 presents the study's results on the relationship between carbon disclosure and financial performance. The results demonstrate that carbon disclosure negatively affects a firm's ROA, thus signifying that firms do not have enough financial benefits to outweigh the cost of carbon disclosure in the short-term. This finding corroborates with that of Delmas et al. (2015) and supports Hypothesis 3 (H3). The result is consistent with Van der Laan et al. (2008) argument that a negative relationship exists between negative corporate social performance for primary stakeholders (e.g. investors, consumers, employees) and short-term financial performance. This result echoes the argument that green-washing negatively affects financial performance (see Walker & Wan, 2012). Du (2015) found a negative relationship between green-washing and financial performance. Busch and Hoffmann (2011, p.242) found a negative relationship between a process-based corporate environment performance (CEP) and financial performance, and argued that the process-based CEP neglects "the measurement of concrete resource consumption and emission optimization". This is consistent with the proposition of "low-hanging fruit" at the beginning of pollution prevention initiatives (Hart & Ahuja, 1996). On the other hand, results demonstrate that a significant positive relationship exists between Tobin's Q and carbon disclosure. This implies that firms gain in the long-term by providing "high-quality disclosure" and that investors perceive the carbon disclosure practices of the firm positively. This result corroborates with the literature (Delmas et al., 2013; Delmas et al., 2015) and supports Hypothesis 4 (H4). This result is supported by studies such as the work of Earnhart and Lizal (2006) who demonstrated that when a firm's financial performance improves, it can generate additional internal financial resources to improve its environmental performance.

4.4. Carbon disclosure, carbon performance and financial performance

Our results show that carbon performance positively affects carbon disclosure, with carbon disclosure, in turn, positively affecting long-term financial performance which is consistent with signalling theory. Hence, a situation could emerge in which carbon performance plays a role in the relationship between carbon disclosure and financial performance. To examine the interaction between carbon disclosure, carbon performance and financial performance, we apply a three-stage least squares (3SLS) system of simultaneous equations as presented below. Eqs. (4)–(6) are for the relationships between carbon disclosure, carbon performance and financial performance in the short-term, while Eqs. (7)–(9) are for the relationships between carbon disclosure, carbon performance and financial performance in the long-term.

$$CD_{i,t} = \alpha_0 + \alpha_1 CP_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} ROA_{1,t-1} + \tau_{i,t} \quad (4)$$

$$CP_{i,t} = \alpha_0 + \alpha_1 CD_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} ROA_{1,t-1} + \varphi_{i,t} \quad (5)$$

$$ROA_{i,t} = \alpha_0 + \alpha_1 CP_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} CD_{1,t-1} + \omega_{i,t} \quad (6)$$

Table 7
Three-stage least squares (3SLS) estimates to examine the moderating role of carbon performance.

Variables	Equations for 3SLS					
	4	5	6	7	8	9
	CD	CP	ROA	CD	CP	TOBIN'S Q
C	−0.1552	142.381	12.158**	−10.091	^	1.388***
	(−0.02)	(1.44)	(2.22)	(−0.21)		(1.2e^+04)
CD (−1)		0.476*	0.030		0.700	0.003*
		(1.77)	(0.81)		(0.00)	(1.68)
CP (−1)	0.421**		−0.039*	0.215***		0.00001***
	(2.19)		(−1.70)	(7.65)		(17.36)
SIZE (−1)	−4.009	7.306	0.730*	−3.483	^	0.063***
	(−0.71)	(1.23)	(1.66)	(−1.56)		(7088.13)
LEV (−1)	0.045	−0.075	−0.010	0.310	0.007	−0.006**
	(0.32)	(−0.31)	(−0.43)	(1.41)	(0.00)	(−2.38)
CAPIN (−1)	124.364	−258.904	−25.102***	76.260	−10.023	−1.605***
	(0.72)	(−1.61)	(−7.49)	(1.37)	(−0.00)	(−4.59)
Earnings Quality (−1)	−57.068	101.383	10.524	−225.228	−16.369	4.289****
	(−0.59)	(0.77)	(0.94)	(−1.40)	(−0.00)	(3.59)
Stock Liquidity (−1)	10.101	−20.525*	−1.983***	6.267	−0.937	−0.126***
	(0.73)	(−1.65)	(−4.27)	(1.42)	(−0.00)	(−2.88)
CINT (−1)	9.320	−17.869	−1.692**	17.573	−2.121	−0.329***
	(0.77)	(−1.42)	(−2.05)	(1.43)	(0.00)	(−3.73)
AGE (−1)	3.430	−5.877	−0.663*	3.351*	1.567	−0.065*
	(0.69)	(−1.06)	(−1.78)	(1.76)	(0.00)	(−1.87)
EPI (−1)	−4.259	13.636*	1.038**	−2.455	4.308	0.070
	(−0.02)	(1.87)	(2.27)	(−0.72)	(0.00)	(1.45)
ETS (−1)	24.312	−47.158	−4.875***	22.833	3.089	−0.462***
	(0.72)	(−1.52)	(−5.21)	(1.55)	(0.00)	(−4.88)
Shareholders (−1)	−1.607	−2.509	−0.024	−9.216	−1.352	0.144
	(−0.33)	(−0.29)	(−0.03)	(−1.25)	(−0.00)	(1.58)
ROA	5.248	−9.831*				
	(0.77)	(−1.06)				
TOBIN'S Q				52.085	^	
				(1.54)		
Observations	935	935	935	935	935	935
RMSE	50.698	91.751	9.193	51.815	18.448	0.986
R-squared	−14.453	−18.065	0.140	−15.141	0.229	0.129
Chi-squared	14.540	13.690	145.73***	143.470***	0.000	5.04e+07***

Notes: This table presents the 3SLS results for the relationship between carbon disclosure, carbon performance and financial performance from Eqs. (4)–(6) for the relationships between carbon disclosure, carbon performance and financial performance in the short-term, while Eqs. (7)–(9) for the relationships between carbon disclosure, carbon performance and financial performance in the long-term. z-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively. ^ Co-efficient values are omitted by the three-stage least squares (3SLS) model.

$$CD_{i,t} = \alpha_0 + \alpha_1 CP_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\,Quality_{1,t-1} + \alpha_8 Stock\,Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} TOBINSQ_{1,t-1} + \tau_{i,t} \quad (7)$$

$$CP_{i,t} = \alpha_0 + \alpha_1 CD_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\,Quality_{1,t-1} + \alpha_8 Stock\,Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} TOBINSQ_{1,t-1} + \varphi_{i,t} \quad (8)$$

$$TOBINSQ_{i,t} = \alpha_0 + \alpha_1 CP_{1,t-1} + \alpha_2 SIZE_{1,t-1} + \alpha_3 LEV_{1,t-1} + \alpha_4 CAPIN_{1,t-1} + \alpha_5 AGE_{1,t-1} + \alpha_6 CINT_{1,t-1} + \alpha_7 Earning\ Quality_{1,t-1} + \alpha_8 Stock\ Liqudity_{1,t-1} + \alpha_9 Shareholders_{1,t-1} + \alpha_{10} ETS_{1,t-1} + \alpha_{10} EPI_{1,t-1} + \alpha_{11} CD_{1,t-1} + \omega_{i,t} \quad (9)$$

Results demonstrate that both carbon disclosure and carbon performance positively affect a firm's financial performance in the long-term (Table 7, Eq. [9]). Results from Eq. (6) show that carbon performance negatively affects a firm's financial performance in the short-term. However, the effect of carbon disclosure on a firm's financial performance in the short-term becomes insignificant due to the presence of carbon performance. To further analyse the moderating role of carbon performance in the relationship between carbon disclosure and financial performance, we use carbon performance as a moderator and include an interaction variable: carbon disclosure*carbon performance. Following He et al. (2013), we have also included an interaction variable: HIPC*carbon performance where HIPC is an indicator variable that equals one if firm's carbon performance scores are in quartile 4 and 0 otherwise (see Table 8). However, the results, as shown in Table 8, demonstrate that carbon performance does not appear to be moderating the relationship between carbon disclosure and financial performance in either the short-term or the long-term.

5. Robustness and endogeneity

To investigate robustness, we perform tests using several alternative

Table 8
Moderating role of carbon performance in the relationship between carbon disclosure and carbon performance.

Variables	Dependent variables			
	ROA [Eq. (1A)]	ROA [Eq. (1B)]	TOBIN'S Q [Eq. (2A)]	TOBIN'S Q [Eq. (2B)]
C	−0.679	−2.292	0.210	0.932
	(−0.09)	(−0.16)	(0.15)	(0.71)
CD (−1)	−0.008*	−0.016*	0.017**	0.008*
	(−1.72)	(−1.69)	(2.16)	(1.70)
CP (−1)	−0.060	−0.035	0.014	−0.003
	(−0.49)	(−1.12)	(1.26)	(−1.21)
CD (−1)* CP (−1)	0.000		−0.000	
	(0.23)		(−1.60)	
HICP		−3.065		−0.437
		(−0.68)		(−1.09)
HICP* CP (−1)		0.031		0.004
		(0.55)		(0.80)
SIZE (−1)	1.330**	1.330**	0.007	0.013
	(2.36)	(2.36)	(0.14)	(0.27)
LEV (−1)	0.034	0.033	0.003	0.003
	(1.13)	(1.11)	(1.23)	(1.20)
CAPIN (−1)	−31.055***	−31.268***	−0.678*	−0.674*
	(−6.80)	(−6.84)	(−1.66)	(1.65)
Earnings Quality (−1)	20.334	20.026	3.919	3.900
	(1.59)	(1.57)	(1.44)	(1.41)
Stock Liquidity (−1)	−0.902	−0.935	−0.090	−0.091*
	(−1.48)	(1.53)	(−1.55)	(−1.66)
CINT (−1)	4.721**	4.840**	0.134	0.165
	(2.34)	(2.39)	(0.74)	(0.91)
AGE (−1)	−0.647	−0.662	−0.143***	−0.142***
	(−1.47)	(−1.50)	(−3.62)	(−3.59)
EPI (−1)	1.964	1.989	−0.137	−0.167
	(0.12)	(0.12)	(−0.10)	(−0.12)
ETS (−1)	−5.593	−5.630	−0.005	0.030
	(−0.34)	(−0.34)	(−0.00)	(0.02)
Shareholders (−1)	8.407	8.539	1.045	0.976
	(0.43)	(0.44)	(0.60)	(0.56)
Observations	935	935	935	935
R-squared	0.040	0.044	0.031	0.0268
F-statistic	4.93***	4.62***	2.69***	2.49***
Industry fixed	Yes	Yes	Yes	Yes
Country fixed	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes
F-test (Ho: No variation due to the difference across panels)	1.580***	1.580***	2.830***	2.830***

Notes: This table presents the results for the moderating effects of carbon performance on the relationship between carbon disclosure and financial performance in the short-term [Eqs. (1A and 1B)] and long-term [Eqs. (2A and 2B)]:

$$ROA_{i,\,t} = \alpha_0 + \alpha_1 CD_{1,\,t-1} + \beta_1 CP_{1,\,t-1} + \beta_2 CD_{1,\,t-1} * CP_{1,\,t-1} + \alpha_2 SIZE_{1,\,t-1} + \alpha_3 LEV_{1,\,t-1} + \alpha_4 CAPIN_{1,\,t-1} + \alpha_5 AGE_{1,\,t-1} + \alpha_6 CINT_{1,\,t-1} + \alpha_7 Earning\ Quality_{1,\,t-1} + \alpha_8 Stock\ Liqudity_{1,\,t-1} + \alpha_9 Shareholders_{1,\,t-1} + \alpha_{10} ETS_{1,\,t-1} + \alpha_{10} EPI_{1,\,t-1} + \pi_{i.\,t} \quad (1A)$$

$$ROA_{i,\,t} = \alpha_0 + \alpha_1 CD_{1,\,t-1} + \beta_1 CP_{1,\,t-1} + \beta_2 HICP + \beta_3 CP_{1,\,t-1} * HICP + \alpha_2 SIZE_{1,\,t-1} + \alpha_3 LEV_{1,\,t-1} + \alpha_4 CAPIN_{1,\,t-1} + \alpha_5 AGE_{1,\,t-1} + \alpha_6 CINT_{1,\,t-1} + \alpha_7 Earning\ Quality_{1,\,t-1} + \alpha_8 Stock\ Liqudity_{1,\,t-1} + \alpha_9 Shareholders_{1,\,t-1} + \alpha_{10} ETS_{1,\,t-1} + \alpha_{10} EPI_{1,\,t-1} + \pi_{i.\,t} \quad (1B)$$

$$TOBINSQ_{i,\,t} = \alpha_0 + \alpha_1 CD_{1,\,t-1} + \beta_1 CP_{1,\,t-1} + \beta_2 CD_{1,\,t-1} * CP_{1,\,t-1} + \alpha_2 SIZE_{1,\,t-1} + \alpha_3 LEV_{1,\,t-1} + \alpha_4 CAPIN_{1,\,t-1} + \alpha_5 AGE_{1,\,t-1} + \alpha_6 CINT_{1,\,t-1} + \alpha_7 Earning\ Quality_{1,\,t-1} + \alpha_8 Stock\ Liqudity_{1,\,t-1} + \alpha_9 Shareholders_{1,\,t-1} + \alpha_{10} ETS_{1,\,t-1} + \alpha_{10} EPI_{1,\,t-1} + \vartheta_{i.\,t} \quad (2A)$$

$$TOBINSQ_{i,\,t} = \alpha_0 + \alpha_1 CD_{1,\,t-1} + \beta_1 CP_{1,\,t-1} + + \beta_2 HICP + \beta_3 CP_{1,\,t-1} * HICP + \alpha_2 SIZE_{1,\,t-1} + \alpha_3 LEV_{1,\,t-1} + \alpha_4 CAPIN_{1,\,t-1} + \alpha_5 AGE_{1,\,t-1} + \alpha_6 CINT_{1,\,t-1} + \alpha_7 Earning\ Quality_{1,\,t-1} + \alpha_8 Stock\ Liqudity_{1,\,t-1} + \alpha_9 Shareholders_{1,\,t-1} + \alpha_{10} ETS_{1,\,t-1} + \alpha_{10} EPI_{1,\,t-1} + \vartheta_{i.\,t} \quad (2B)$$

Variables used in the above equations have been described in Table 1. t-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

Table 9
Two-stage least squares (2SLS) estimates for relationships between carbon disclosure and carbon performance and financial performance.

Variables	CD	ROA	Tobin's Q
Second-stage regression results			
C	70.391***	12.330**	1.812**
	(10.95)	(2.50)	(2.01)
CD (−1)		−0.020**	0.002**
		(−2.03)	(1.99)
CP (−1)	0.24***		
	(6.78)		
SIZE (−1)	0.191	0.590	0.080
	(0.10)	(1.56)	(0.29)
LEV (−1)	0.011	−0.010	−0.010**
	(0.09)	(−0.28)	(−2.45)
CAPIN (−1)	−9.030**	−24.760***	−1.700***
	(−2.08)	(−7.41)	(−4.31)
Earnings Quality (−1)	−2.881	12.560	4.313***
	(−0.11)	(1.10)	(3.59)
Stock Liquidity (−1)	−0.382	−1.930***	−0.131***
	(−0.56)	(−4.22)	(−2.46)
CINT (−1)	0.601	−1.651**	−0.332***
	(0.63)	(−1.96)	(−3.74)
AGE (−1)	−0.033	−0.701*	−0.063
	(−0.16)	(−1.81)	(−1.62)
ETS (−1)	−1.091	−5.162***	0.062
	(−1.11)	(−5.34)	(0.67)
EPI (−1)	0.860	1.053**	0.451***
	(1.59)	(2.03)	(2.71)
Shareholders (−1)	−1.831	−0.023	0.131
	(−1.61)	(−0.08)	(1.51)
Industry fixed	Yes	Yes	Yes
Country fixed	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes
Observations	935	935	935
R-squared	0.311	0.136	0.12
Chi-squared	83.902***	141.070***	130.80***
Wu–Hausman (*p*-value)[a]	1.991	0.397	(01.31
		(0.529)	
Durbin score (*p*-value)[a]		0.403	
		(0.525)	
Sargan test statistic (*p*-value)[b]	5.671*	0.192	9.87***
		(0.910)	
First-stage regression summary			
Instrumented variable	CP (−1)	CD (−1)	CD (−1)
F-test	81.140***	65.574***	65.574***
R-squared	0.311	0.271	0.271
Shea's partial R-squared	0.221	0.181	0.181
Cragg and Donald (1993) minimum eigenvalue statistic[c]	81.140***	65.574***	65.574***
Stock and Yogo (2005) Critical values: 2SLS relative bias			
5%	13.910	13.910	13.910
10%	9.080	9.080	9.080
20%	6.460	6.460	6.460
30%	5.390	5.390	5.390
Stock and Yogo (2005) Critical values: 2SLS size of normal 5% Wald test			
5%	22.300	22.300	22.300
10%	12.830	12.830	12.830
20%	9.540	9.540	9.540
30%	7.800	7.800	7.800

Notes: This table presents the results from both the first-stage regression summary and second-stage regression results in a two-stage least squares (2SLS) model. Variables used in the model have been described in Table 1 and Section 3.2.3. z-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

[a] Endogeneity test: Both Durbin and Wu–Hausman tests have the null hypothesis that variables are exogenous.

[b] Test of over-identifying restrictions: the Sargan test is with a null hypothesis that overidentifying restrictions are valid.

[c] Weak instrument test: Cragg and Donald (1993) minimum eigenvalue statistic is used to perform a weak instrument test with a null hypothesis that instruments are weak.

Table 10
Sub-sample analysis.

Variables	US			Non-US countries		
	1	2	3	4	5	6
	CD	ROA	TOBIN'S Q	CD	ROA	TOBIN'S Q
C	103.655***	−0.336	2.134***	80.381***	8.635**	0.843***
	(14.47)	(−0.02)	(2.93)	(8.11)	(2.17)	(3.38)
CP (−1)	0.077**			0.118***		
	(2.21)			(4.27)		
CD (−1)		−0.046**	0.002**		−0.068***	0.005***
		(−1.99)	(1.97)		(−3.95)	(4.40)
SIZE (−1)	−1.718	0.750	0.000	0.086	0.381	0.017
	(−1.49)	(0.67)	(0.00)	(0.10)	(1.09)	(0.77)
LEV (−1)	−0.035	0.062	−0.002	0.017	0.017	0.001
	(−0.58)	(1.06)	(−0.56)	(0.37)	(0.92)	(0.11)
CAPIN (−1)	9.069	−22.144	−0.594	−0.941	−0.834	−0.378*
	(1.11)	(−0.78)	(−1.50)	(−0.10)	(−0.23)	(−1.66)
Earnings Quality (−1)	−23.428	23.526	2.075	−16.064	−24.205**	−0.220
	(−1.22)	(1.27)	(1.26)	(−0.53)	(−2.00)	(−0.29)
Stock Liquidity (−1)	−1.675	−1.069	−0.232	−2.231	0.787	−0.053
	(−1.42)	(−0.93)	(−1.07)	(−1.55)	(1.38)	(−1.49)
CINT (−1)	−3.596	2.685	0.063	0.672	−0.425	0.047
	(−1.29)	(1.00)	(0.47)	(0.47)	(−0.75)	(1.33)
AGE (−1)	−0.371	0.011	0.007	−0.202	0.272	−0.032*
	(−0.32)	(0.01)	(0.12)	(−0.30)	(1.03)	(−1.93)
EPI (−1)	0.865	2.402	−0.156	0.417	0.165	0.012
	(0.74)	(1.24)	(−1.02)	(0.61)	(061)	(0.69)
ETS (−1)				−2.869	1.229	0.110
				(−0.74)	(0.80)	(1.14)
Shareholders (−1)				6.995	1.291	0.049
				(1.51)	(0.70)	(0.61)
Observations	415	415	415	520	520	520
F-statistic	1.830*	1.390	4.970***	2.290***	2.100**	3.150***
Industry fixed	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed	No	No	No	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes	Yes	Yes
F-test (Ho: No variation due to the difference across panels)	2.710***	2.030***	15.230***	3.240***	13.310***	74.410***

Notes: This table provides results from the sub-sample analysis of US firms (415 firm-year observations) and non-US firms (520 firm-year observations). t-statistics are provided in the parentheses.Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

models (see Table 7).[5,6] Firstly, we run an "instrumental variable two-stage least squares (IV-2SLS) model" to examine the endogenous relationship between variables in our study (Alsaifi et al., 2020; Jo & Harjoto, 2012). Results from the IV-2SLS model appear to be the same as those presented in Tables 5 and 6. The Wu–Hausman test shows that the instrumental variables are exogenous. The Sargan test shows that overidentifying restrictions are valid (i.e. the instruments are valid). Results from the first-stage summary show that all the instruments are jointly significant (*F*-stat = 65.5749 (*p*-value = 0.000)). With Shea's partial R-squared values ranging from 0.181 to 0.221 and Cragg and Donald's (1993) minimum eigenvalue statistics being more than Stock and Yogo's (2005) critical values, the instruments are shown to be not weak (see Table 9). Secondly, the generalized method of moments (GMM) model is used to deal with endogeneity. Endogeneity can cause incorrect and biased estimates which may provide incorrect conclusions (Ullah, Akhtar, & Zaefarian, 2018). By employing the GMM model, we can better control for "three sources of endogeneity, namely, unobserved heterogeneity, simultaneity and dynamic endogeneity" (Ullah et al., 2018, p. 69). The lags of "dependent variables are used as instruments" in the GMM estimation to control for endogeneity issues (Arellano & Bond, 1991). The results from the GMM models are qualitatively similar to those in the main findings (see Table 11). We also perform the Hansen (1982) J-statistic test to check the important assumption regarding the GMM model's validity that the instruments are not endogenous. We find an insignificant Hansen J-statistic for GMM models at the 5% significance level, implying that the instruments are valid (i.e. the model has no overidentifying restrictions). All alternative specifications, including two-stage least squares, three-stage least squares and the GMM, point to the same results, that is, that carbon performance positively affects carbon disclosure, demonstrating that signalling theory and carbon disclosure negatively (positively) affects financial performance in the short-term (long-term).

We also conduct a sub-sample analysis of US firms (415 firm-year observations) and non-US firms (520 firm-year observations). Results demonstrate that no difference exists between firms in the US and those in non-US countries in terms of the relationships between carbon disclosure and carbon performance, and between carbon disclosure and financial performance (Table 10).

As the sample included firms that had voluntarily contributed to the CDP from 2011 to 2015, the sample may become biased or non-random. This may have "self-selection bias" which could lead to incorrect inferences about the population. The Heckman (1979) two-stage model can be applied to address self-selection bias. Accordingly, we perform the Heckman two-stage model with the results presented in Table 12. In the Heckman model, the first stage is a disclosure choice model where the firm's voluntary carbon-disclosure decision to participate in the CDP

[5] We employ a Tobit regression model to control for "the censured nature of the dependent variable" (Alsaifi et al., 2020, p. 719). In our model, the carbon disclosure score is censored, and the score lies between 0 and 100. As a result, ordinary least squares (OLS) estimates may provide inconsistent results (Luo, 2019). However, we find qualitatively similar results from the Tobit model to those in the OLS model. Results are not reported for reasons of brevity and are available from the authors upon request.

[6] We also winsorise the variables, except for dummy variables, at the 1st and 99th percentile to remove the effect of outliers. From the findings from all alternative specifications, we find similar results for both relationships, namely, between carbon disclosure and carbon performance, and between carbon disclosure and financial performance. Results are not reported for reasons of brevity and are available from the authors upon request.

Table 11
GMM model to address endogeneity issues.

Variables	Dependent variable		
	CD	ROA	Tobin's Q
C	70.171***	15.231**	−0.688
	(11.23)	(2.51)	(−1.49)
CD (−1)		−0.045*	0.047**
		(−1.71)	(1.99)
CP (−1)	0.225***		
	(8.14)		
SIZE (−1)	0.254	0.660	−0.096
	(0.40)	(1.56)	(−1.18)
LEV (−1)	0.014	0.019	−0.012**
	(0.04)	(0.52)	(−1.98)
CAPIN (−1)	−8.955**	−20.236**	−0.882**
	(−1.98)	(−2.14)	(−4.88)
Earnings Quality (−1)	−3.218	16.632*	4.324***
	(−0.69)	(1.72)	(3.00)
Stock Liquidity (−1)	−0.446	−1.775***	−0.086
	(−0.60)	(−3.69)	(−1.25)
CINT (−1)	0.535	−1.775*	−0.370***
	(0.90)	(−1.82)	(−4.88)
AGE (−1)	0.045*	−0.612**	−0.072
	(1.65)	(−1.96)	(−1.39)
ETS (−1)	−0.933	−4.777***	−0.529***
	(−1.36)	(−5.14)	(−5.87)
EPI (−1)	0.863*	0.719*	0.149**
	(1.66)	(1.69)	(1.98)
Shareholders (−1)	−1.853*	−0.276	0.228**
	(1.68)	(−0.00)	(2.46)
Observations	935	935	935
Chi-squared	87.140***	120.970***	136.69***
Hansen J-test statistics (*p*-value)	2.495	16.679*	16.944
	(0.287)	(0.054)	(0.152)

Notes: This table provides the results from the GMM model to check the endogeneity. z-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

is modelled using a probit model. The second stage comprises the self-selection parameter (inverse Mills ratio) estimated from the first stage as an additional explanatory variable. The results in Table 12 are qualitatively similar to those in the main findings. Furthermore, the coefficients in the inverse Mills ratio (lambda) are not statistically significant, suggesting that the estimations for the sample firms do not suffer from self-selection bias. Luo (2019) applied the Heckman (1979) two-stage model for the CDP data and found no self-selection bias.

6. Conclusions

The existing research has produced conflicting results regarding the relationship between carbon performance and carbon disclosure. We revisit these relationships using a recent sample of global firms. We assess these relationships by testing competing predictions by socio-political and economic-based voluntary disclosure theories. Our results demonstrate that carbon disclosure positively affects carbon performance. This finding is supported by voluntary disclosure theory and signalling theory. The existing research also suggests a mixed relationship between carbon disclosure and financial performance. We find a negative relationship between carbon disclosure and financial performance in the short-term and a positive relationship in the long-term.

Our findings have important implications for regulators, policy-makers, investors and managers. Firstly, firms should understand the premise of comprehensive carbon disclosure to meet stakeholder demand. Firms could be penalised for non-disclosure or "low-quality disclosure". Secondly, results provide an opportunity for investors to assess whether they invest in firms with "high-quality disclosure" or "low-quality disclosure". This is very important for investors as some firms may be involved in carbon/GHG disclosure as part of impression management (Talbot & Boiral, 2018) or as green-washing (Walker & Wan, 2012). Our findings provide evidence that high-quality carbon disclosure leads to carbon performance and that this disclosure leads to long-term financial performance. Thirdly, regulators may consider the adverse impact of carbon disclosure on stakeholders and devise carbon disclosure policy to mitigate the climate change risk.

Our results provide an opening for several future research opportunities. For example, our study sample consists of only large firms. Future

Table 12
Heckman's two-stage model to examine the sample selection bias.

Variables	Dependent variable		
	CD	ROA	Tobin's Q
Second-stage regression			
C	−3.036	123.709	28.186
	(−0.03)	(1.15)	(1.31)
CD (−1)		−0.028*	0.013*
		(−1.72)	(1.69)
CP (−1)	0.293***		
	(5.76)		
SIZE (−1)	7.090	−9.434	−2.108
	(0.80)	(−1.06)	(−1.18)
LEV (−1)	−0.025	0.051	0.009
	(−0.20)	(0.40)	(0.34)
CAPIN (−1)	−14.169	0.315	1.097
	(−0.73)	(0.02)	(0.28)
Earnings Quality (−1)	−31.033	43.932	10.281
	(−0.52)	(0.73)	(0.85)
Stock Liquidity (−1)	0.029	−0.058	−0.012
	(0.33)	(−0.65)	(−0.68)
CINT (−1)	−7.680	5.653	1.219
	(−0.82)	(0.59)	(0.64)
AGE (−1)	−4.036	2.648	0.564
	(−1.18)	(0.76)	(0.81)
ETS (−1)	−7.600	5.803	1.209
	(−0.97)	(0.73)	(0.64)
EPI (−1)	−5.291	6.041	1.089
	(−0.96)	(1.07)	(0.96)
Shareholders (−1)	0.561	−1.929	−0.292
	(0.11)	(−0.38)	(−0.29)
First-stage: Discrete choice model			
C	4.845***	4.816***	4.816***
	(8.60)	(8.54)	(8.54)
SIZE (−1)	−0.299***	−0.298***	−0.298***
	(−10.33)	(−10.29)	(−10.29)
LEV (−1)	0.002	0.002	0.002
	(0.83)	(0.85)	(0.85)
CAPIN (−1)	0.387	0.394	0.394
	(1.03)	(1.05)	(1.05)
Earnings Quality (−1)	1.275	1.261	1.261
	(1.08)	(1.07)	(1.07)
Stock Liquidity (−1)	−0.002*	−0.002*	−0.002*
	(−1.71)	(−1.71)	(−1.71)
CINT (−1)	0.311***	0.311***	0.311***
	(2.94)	(2.95)	(2.95)
AGE (−1)	0.103**	0.104**	0.104**
	(2.22)	(2.24)	(2.24)
ETS (−1)	0.243***	0.244***	0.244***
	(2.62)	(2.63)	(2.63)
EPI (−1)	0.195***	0.196***	0.196***
	(3.81)	(3.84)	(3.84)
Shareholders (−1)	−0.106	−0.107	−0.107
	(−1.10)	(−1.11)	(−1.11)
Inverse Mills ratio (lambda (*p*-value))	−46.094	46.483	9.341
	(0.333)	(0.334)	(0.334)
Total observations (selected and non-selected)	1435	1435	1435
Selected observations	935	935	935
Non-selected observations	500	500	500

Notes: This table provides from the Heckman two-stage model. In the Heckman model, the first stage is a disclosure choice model where the firm's voluntary carbon-disclosure decision to participate in the CDP is modelled using a probit model. The second stage comprises the self-selection parameter (inverse Mills ratio) estimated from the first stage as an additional explanatory variable. z-statistics are provided in the parentheses. Superscript asterisks *, ** and *** are significant at 10%, 5% and 1%, respectively.

studies may try to investigate whether these results hold true for medium-sized and small firms. Researchers could also undertake in-depth analysis of firms' carbon disclosure practices in terms of hard disclosure and soft disclosure.

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