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Research article

Voluntary carbon information disclosures, corporate-level environmental sustainability efforts, and market value

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Abstract: Based on global 500 companies, this study examines whether the market incorporates the corporations' voluntary carbon emissions disclosures as part of their environmental sustainability efforts, thus increasing their market value. Proxies used to measure the corporations' ecological sustainability efforts include the choice of voluntary carbon disclosures, carbon emissions amounts, carbon intensity, and carbon disclosure quality. During the study period, those companies that chose to disclose their carbon information to the Carbon Disclosure Project (CDP), saw the market value their efforts towards environmental sustainability by increasing their market value. This study also compared the market value of disclosing and non-disclosing firms and found that non-disclosing companies had higher market value than did disclosing firms. However, this relationship was statistically insignificant. This study uses the more extensive data set, extended period, and more robust econometric approach (Difference GMM) and extends the boundaries of accounting research to incorporate environmental-related disclosures. Therefore, this most recent study can provide new insights to researchers, investors, and policymakers in the present context of environmental sustainability and business sustainability.

Keywords: voluntary carbon disclosures; environmental sustainability; market value; difference GMM; CDP

JEL Codes: G30, M50, Q51, Q56

1. Introduction

One of the pressing issues of the 21st century is climate change. The late 1700s Industrial Revolution shaped today's social and economic arrangements (Bebbington & Larrinaga-Gonza'lez, 2008) and is the main culprit behind today's climate crisis through the introduction of fossil fuels (coal, gas, oil, and peat) for the mechanization of production. This use created emissions of greenhouse gases (GHGs) causing environmental consequences to humanity for sustainable development (Kanwal and Khan, 2021). Between 1854 and 2015, corporations produced 52% of GHGs emissions (Griffin, 2017). The C-based gases (CO_2—Carbon Dioxide and CH_4—Methane) are the first and second most important anthropogenic GHGs, respectively leading to climate change. CO_2 emissions are the most important GHG (in terms of warming impacts) relative to others[1]. In simple terms, industrialization causes pollution and GHGs, which affects climate. Rising GHGs levels have serious repercussions, including global warming and sea-level rise (NASA). Therefore, the need of the hour is to take preventive steps at all levels, i.e., from individuals to corporations and from corporations to the international level. Immediate actions can help reduce CO_2 emissions at all levels. A first action is ground-level carbon accounting (carbon disclosures and carbon management) at the corporation level. Second is increased research in this area to explore whether these efforts offer pay back for the companies. This study focuses on global 500 companies (the Carbon Disclosure Project sample list, 2010) to examine whether the market positively perceives corporate-level voluntary carbon information disclosures as a step towards environmental sustainability.

Scientific consensus commonly suggests that national/international emissions targets must ensure mean global temperature rises this century remain below the recommended 2 ^{o}C above pre-industrial levels. Carbon management can help achieve environmental sustainability at the corporate level and at the city or provincial level. Also, the increased number of carbon disclosures to the CDP has made carbon management a necessary step for businesses to survive in the future. There are many reasons to disclose and reduce carbon emissions, such as (potential) environmental regulations, competition, investors and societal pressures, customers' awareness, the company's image, cost efficiency, among others. Among these many factors, the driving forces encouraging environmental-related disclosure behavior (to the CDP in the context of global 500 companies) are social and legal influences (i.e., the attitude of the general public and the government) (Luo et al., 2012). The CDP, on behalf of institutional investors such as Barclays Group and Merrill Lynch (Kim & Lyon, 2011), issues a questionnaire every year to the world's largest 500 companies to provide the companies' environment-related information such as their GHGs, risks, opportunities, and management strategies. CDP participation increases the shareholders' value in the face of the likelihood of climate change regulations. However, institutional investors' activism can interfere in management decisions in such an environment-cautious environment (Kim & Lyon, 2011).

[1]Other gases include methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

Moreover, the firms face financial consequences for their carbon disclosure and performance (Velte et al., 2020). These carbon disclosures minimize information asymmetry and increase financial performance (Velte et al., 2020) due to the value relevance content of non-financial environment-related variables (Matsumura et al., 2014), such as carbon emissions and disclosure performance. If the investors perceive carbon information as relevant and reliably measured, it will have significant market-value implications (Barth et al., 2001; Matsumura et al., 2014). This study shows that non-financial environmental-related performance metrics (carbon emissions, carbon disclosure quality, and carbon intensity) contain value-relevant content to help market participants make informed decisions. In most international business contexts, carbon disclosures and carbon performance measurements are voluntary, and many standards exist (Velte et al., 2020), so the extent and quality of the disclosure are up to managerial discretion. However, market participants require standardized disclosure reports because of the value relevance content of carbon-related variables due to climate change and global warming crises. Environmental sustainability standards can guide companies to report high-quality environmental-related information transparently and reliably to reduce information asymmetry. Considering the value relevance substance of climate-related variables, we recommend creating environmental sustainability standards similar to international financial reporting standards (IFRS) and the US generally accepted accounting principles (US GAAP). This study provides insights to standards setters regarding the necessity of these standards. Moreover, we recommend prioritizing environmental sustainability efforts. Policymakers need to bring mandatory environmental-related disclosures into force to make corporations environmentally responsible, specifically heavily polluting companies.

This study posits the choice of voluntary disclosures as the first step to environmental sustainability. Therefore, this paper first explores how the market reacts to the firms that either chose to disclose voluntarily or to not disclose their carbon emissions data to the CDP. The sample includes all companies that the CDP approached. Secondly, this study looks at how the market responds to carbon disclosure information among the firms that responded to the CDP's request and agreed to disclose their carbon emissions data. There is rarely a study that considers the nature of disclosures, whether core or comprehensive, qualitative or quantitative, or both. This research addresses the literature gaps by considering carbon emissions disclosures and their quality while assessing their impact on the firm's value across a broader set of companies over a longer time frame.

Various studies tested the impact of environmentally related variables on the firms' market value (Barth & McNichols, 1994; Campbell et al., 2003; Johnston et al., 2008; Matsumura et al., 2014; Clarkson et al., 2015; Utomo et al., 2020). This study is in the realm of voluntary disclosures, similar to Matsumura et al. (2014). In addition, this study provides an extended model with different dimensions of carbon information disclosures, including carbon emissions amounts (Matsumura et al., 2014), carbon intensity, and carbon disclosure quality. Moreover, these dimensions represent proxies for corporate-level environmental sustainability efforts.

In the rest of the paper, section 2 discusses voluntary carbon disclosures. Section 3 reviews the relevant literature on carbon information disclosures and firm value and develops hypotheses. Section 4 describes the sample, databases, and methodology. Section 5 reports and analyses the empirical results, and section 6 summarizes the findings. Section 7 discusses how this study differentiates from prior studies and its contributions. Finally, section 8 concludes the paper with its key findings, implications of the work, and grounds for future research.

2. Voluntary carbon information disclosures

Corporate-level carbon disclosures are rapidly growing (Qian & Schaltegger, 2017)[2], increasing by more than more than 11% between 2017 and 2018[3], around 37% between 2018 and 2020, and by about 52% between 2017 and 2020. The number of companies disclosing to the CDP increased by more than 70% between signing the Paris Agreement and 2020[4]. There are many benefits derived from the recording and subsequent disclosure of company GHG emissions, such as better corporate performance, the development of climate-friendly products, improved company image, or improved management of emissions (Hahn et al., 2015). The literature mentions two types of disclosure regimes related to the natural environment—mandatory and voluntary disclosures. Mandatory disclosure includes national or international regulations such as the Kyoto Protocol, the Securities and Exchange Commission (SEC), and Emissions Trading Schemes (ETS, for example, European Union Emissions Trading Scheme—EU ETS). Under mandatory regimes, the EU ETS is working well; the EU has reduced its carbon emissions as per Kyoto protocol targets. In the US, all facilities emitting at least 25,000 metric tons of CO_2 are required to disclose their emissions, and, in the UK, all listed companies need to report their scope 1 and scope 2 emissions as of 2013 under EU ETS (Hahn et al., 2015)[5]. Mandatory environmental disclosures require government intervention in terms of environmental policy and regulations at the corporation level. Due to a lack of political and governmental interests, mandatory disclosures are limited to only environmentally conscious countries such as the UK and other European Union (EU) countries. The best example is the UK-based publicly listed companies. These companies disclose their carbon-related information in their director's annual reports (Defra, 2014). However, organizations such as CDP, environment-friendly businesses and environmental scientists have started their own initiatives to mitigate the climate change problem in terms of carbon counting and reporting. This study focuses on voluntary carbon information disclosures as these disclosures are used widely in the present state of politics. However, little information is available on whether voluntary disclosures directly affect financial performance (Kim & Lyon, 2011).

[2] The terms environmental-related disclosures, carbon disclosures, and carbon information disclosures are used interchangeably.

[3] Sources: https://www.cdp.net/en/articles/companies/2017-the-year-in-climate-action.
https://www.cdp.net/en/articles/media/2018-a-new-chapter-for-climate-action.

[4] https://www.cdp.net/en/companies/companies-scores.

[5] There are three scopes of emissions—scope 1, 2, and 3. Scope 1 includes direct emissions from the GHG emissions sources that are owned and controlled by the reporting company, for example, the combustion of fuel in boilers or furnaces and generation of electricity, steam, or heat in equipment that are owned by the reporting organization. Scope 2 and 3 are indirect emissions from GHG sources that are owned and controlled by another company but are consumed by the reporting entity. Scope 2 includes purchased electricity, steam, heat, or cooling for the company's own use. Scope 3 includes indirect emissions other than scope 1 and 2 emissions (i.e., upstream, and downstream emissions), for example, business travel in non-company-owned vehicles. These scopes are differentiated to avoid double counting between organizations. GRI standard 305 deals with emissions to air and GRI Disclosure standards 305-1, 305–2, and 305–3 provide more specific guidance about scope 1, 2, and 3 emissions, respectively.

Voluntary carbon emissions disclosures can be a part of a company's corporate annual report, sustainability report, or 10K form (Kim and Lyon, 2011). The carbon emissions-related information in corporate reports is discretion-based. The CDP reports are more trustworthy than disclosures in the company's reports. These voluntary disclosures allow companies to engage with different stakeholders (such as investors and employees) more directly and can lead to internal management improvement; however, these disclosures have some limitations (Matisof et al., 2013). First, the complexity of, and changes to, the CDP survey have made it particularly difficult to assess CDP responses despite the rich information collected by the organization. Second, voluntary disclosure problems include the lack of uniformity, standardization, and comparability over time and across firms. However, the CDP must be acknowledged for improving its methodology and assessment techniques.

3. Literature review and hypothesis development

Disclosures provide many advantages, through increased transparency of information (reduced information asymmetry) between the shareholders (even other stakeholders) and the firm by mitigating the allocation of scarce resources in the capital markets (Healy & Palepu, 2001). Furthermore, the choice to voluntarily disclose carbon information can increase the firm's value, signaling to investors the company's efforts regarding its environmental responsibilities. In addition, transparent disclosures can help investors understand the potential future costs the firm may face pay for its carbon emissions (Matsumura et al., 2014).

Few studies on carbon information disclosures rely on theories (Hahn et al., 2015). Previous research has demonstrated wide variations in firms' strategic decision-making related to carbon disclosures (Matisof et al., 2013). Nonetheless, a significant number of articles do not explicitly state any theory, and scholars usually rely on previous empirical evidence to develop their hypotheses (Hahn et al., 2015). However, some researchers identify legitimacy, signaling, and institutional theories as promising anchors for future research (Hahn et al., 2015). Theories around institutional, economic, and managerial determinants of information disclosure can be used to explain variations in carbon disclosures (Matisof et al., 2013). Theoretical anchors can help explain the real intentions of organizations and investors toward environmental sustainability and the determinants of carbon disclosures. So far, there are three widely used theories in the literature concerning why companies disclose—sociopolitical theories, economics-based theories, and institutional theories (Hahn et al., 2015). The sociopolitical viewpoint is that disclosures are responses to social and political pressures from various stakeholders (Hahn & Lülfs, 2014). This group of theories includes a stakeholder and legitimacy approach as the basis of carbon emissions disclosures (Hahn et al., 2015). A stakeholder approach assesses actors (interested groups) that belong to a firm and their roles regarding management strategies, whereas a legitimacy approach considers impacts to the overall society (Cotter & Najah, 2011). An economics-based theory indicates that companies do a cost-benefit analysis, and if the benefits are more than costs, they will choose to disclose. In addition, companies only disclose with good news to report, and these disclosures imply that CDP participants are doing better jobs when compared to their counterparts (Kim & Lyon, 2011).

The institutional theory focuses upon pressures from institutional investors, CDP, government, and regulators to disclose. If companies just disclose under pressure to legitimize their environmentally negative actions, gain a reputation, etc. but do not improve their environmental performance, how can carbon disclosures help mitigate climate change? One research paper

discusses legitimacy and an "out in" management approach (Qian & Schaltegger, 2017). The legitimacy approach indicates that disclosure allows a company to stand out among its peers, but there is no focus on carbon emissions improvement. Thus, there is no incentive to improve (Qian & Schaltegger, 2017) as words speak louder than actions. A management-oriented approach is proactive and starts with unsustainability reporting (which means just reporting whatever a company's performance is), while the next step is sustainability reporting for improvement (based on the previous unsustainability reporting). The second approach is well accepted for reducing carbon emissions (Qian & Schaltegger, 2017). This study relies on a management-oriented approach, considering only those firms that extensively disclose (even with their poor and medium environmental performance) either by themselves (through their annual, sustainability, and other similar reports) or through CDP public disclosures, which really are intended to improve their environmental performance. However, there are mixed findings around who discloses the most carbon-related information. For instance, Hughes et al. (2001) found that high carbon emitters (i.e., poor environmental performers) report more emissions information (Hughes et al., 2001). In contrast, Luo and Tang (2014) found that good environmental performers disclose more carbon information (Luo & Tang, 2014). One explanation could be a legitimacy perspective, initially, if poor environmental performers declare the most; however, in subsequent years, an improvement in environmental performance could be because of a management-oriented perspective.

It has been proved that voluntary corporate social disclosures (corporate social reports—CSR) decrease the cost of capital for the firms with superior CSR performance when compared to their industry peers (Dhaliwal et al., 2011). Furthermore, Luo and Tang (2014) found a positive relationship between carbon disclosure and performance, indicating that companies with good carbon performance are more likely to disclose to distinguish themselves among others. Therefore, their performance can increase their firm value. Undoubtedly, when CDP and similar organizations ask the companies for their environmental-related data, it can pressure the firms to disclose their emissions and impose costs on them to measure and manage these emissions. However, there is an incentive for the firms as the voluntary disclosure can signal to the investors that firms can measure their emissions and manage their carbon emissions (Matsumura et al., 2014). That is, disclosure is the first step towards corporate-level environmental sustainability. Therefore, firms choosing to disclose their environmentally related information voluntarily should be advantaged over their competitors (similar firms in the market) and be seen positively as the market can reward the firms for their choice to disclose voluntarily. In that sense, it is hypothesized that:

H1: The choice to undertake carbon emissions disclosures promotes the firm's efforts toward environmental sustainability. Hence, it increases the firm's market value.

There are a small number of studies that investigated carbon information disclosures. These studies examined the value relevance content of carbon emissions (or GHGs emissions or a firm's carbon intensity profile) (Chapple et al., 2013; Matsumura et al., 2014; Clarkson et al., 2015; Griffin et al., 2017; Utomo et al., 2020). The study by Chapple et al. (2013) is based on a tiny sample of 58 Australian firms expected to be affected by the proposed national emissions trading scheme (ETS). The study by Matsumura et al. (2014) is in the context of the United States for Standard and Poor's (S&P 500) firms. Clarkson et al. (2015) investigated GHG emissions' value relevance under the European Union Carbon Emissions Trading Scheme (EU ETS) with a sample size of 843 firm years. The findings are mixed because it is unclear how capital markets perceive the firm's responses to climate change and their carbon information disclosures (Lee et al., 2015). The studies, by Chapple et al. (2013)

and Clarkson et al. (2015), take place in a mandatory disclosure setup. Utomo et al. (2020) examined the relationship between environmental performance and firm value for the non-financial companies at the Indonesian Stock Exchange under the environmental performance assessment program held by the Life Environment and Forestry Ministry. The studies under voluntary disclosure regimes include Matsumura et al. (2014) and Griffin et al. (2017). Moreover, these studies are country and area specific.

Matsumura et al. (2014) find a positive association between carbon emissions and a firm's value. Based on 550 firm-year observations of S&P 500 firms (data from CDP) for 2006–2008, they show that a firm's value shrinks by $212,000 (on average) for every additional thousand metric tons of carbon emissions. The capital markets penalize all firms for their carbon emissions and add an additional penalty for not being transparent (Matsumura et al., 2014). A replicating study by Griffin et al. (2017) showed that the market imposes a penalty of $79 per ton of GHGs (for the median S&P 500 firm). Moreover, Konar and Cohen (2001) and Utomo et al. (2020) also relate the environmental performance with firms' market value and make it evident that environmental performance affects their value. The better the environment performance reputation, the higher the intangible assets (Konar and Cohen, 2001). Intangible assets include patents, trademarks, proprietary raw material sources, brand names, and a firm's goodwill (Konar and Cohen, 2001). Therefore, higher carbon emissions and equivalents denote a lower level of the company's environmental sustainability efforts. Based on these studies, it is hypothesized that:

H2(1): The higher carbon emissions and equivalents, the lower environmental sustainability efforts. Hence, it leads to a lower market value of the firm.

Various studies have used the carbon intensity as carbon performance measure either as the dependent or independent variable in their models (Kim et al., 2015; Brouwers et al., 2018; Qian & Schaltegger, 2017; Ganda and Milondzo., 2018). This indicator can provide further insights into environmental sustainability measured through carbon emissions amounts per dollar of sales. This measure is comparable across companies of different sizes (Cheema-Fox et al., 2021). Similar to carbon emissions levels, carbon emissions intensity can impact the firm's financial performance (Ganda and Milondzo, 2018). Therefore, it is hypothesized.

H2(2): The higher carbon intensity, the lower environmental sustainability efforts. Hence, it leads to a lower market value of the firm.

A meager disclosure or CDP participation (i.e., poor quality disclosures) cannot cause higher stock returns (Kim and Lyon, 2011), but good quality disclosures coupled with improved environmental performance might also play a role in increasing a company's stock prices. So far, several studies have used carbon disclosure quality to measure carbon performance and disclosure. either used it as a dependent or independent variables in these studies. Some of these papers include Giannarakis et al. (2016), Elsayih et al. (2018), Jaggi et al. (2018) and Krishnamurti and Velayutham (2018). Jaggi et al. (2018) use carbon disclosure quality as an independent variable to observe its effect on financial performance and find a positive impact on stock price and market to book value.

Moreover, another study examines the relationship between corporate-level environmental sustainability (CER) engagement and firm value in the context of Chinese firms (Li et al., 2020). This study finds that CER affects the firm's value negatively at the beginning when firms start to adopt environmental regulations; however, at a certain level, it starts to enhance company value. This finding also indicates that firms are less engaged initially, but over time, they could be more involved in their environmental sustainability responsibility, increasing the firm value. Furthermore, Assidy

(2020) establishes the positive association between a higher voluntary disclosure score and the firm's value for French firms. All of these studies are country specific.

Following prior studies, this study also predicts that higher carbon disclosure quality signals a higher level of the company's environmental sustainability efforts, thus increasing the firm's value. The lowest level indicates that the company just disclosed. The highest level denotes that the company has verified GHG emissions statements and has implemented emissions reduction strategies to reach company-wide goals. Therefore, carbon disclosure quality can increase firm value as the company approaches higher levels of quality disclosures. Thus, a positive reaction from investors can increase firm value and vice versa. Therefore, H3 is hypothesized as:

H3: The higher carbon disclosure quality, the higher environmental sustainability efforts. Hence, it leads to a higher firm's market value.

4. Sample, database, and methods

4.1. Sample selection and databases

This study focuses on the global 500 companies by market capitalization. The data collection process started with obtaining global 500 firms listed in the CDP's official sample 2010. The time frame of 2010–2018 was chosen because of carbon emission data's availability through the CDP from 2010, and the study's data was collected between late 2019 and early 2020. The CDP provides a unique and interesting database for studying environmental information with its two distinct features (Wegener et al., 2013). First, unlike annual reports, there is only climate-related information without any other confounding details. Second, it shows a unique mechanism for shareholders' activism through the CDP signatories.

The CDP began collecting voluntary carbon emissions data in 2003, but the regular data set is available from 2010 onward for empirical investigation. Two databases are used in this study—Capital IQ and CDP. Financial variables were collected from the Capital IQ and environment-related variables from the CDP. Financial variables used in this study include market capitalization (MktV), total assets (TA), total liabilities (TL), net income (NI), and total sales. Environment-related variables used are carbon emissions (scope 1 + scope 2), carbon disclosure quality levels, and response status.

The study started with 500 companies; by adjusting for companies' mergers/acquisitions and data points available, the sample was reduced to 468. Further, considering the required variables data availability to test H1, the selection was reduced to 455 firms. These 455 firms were tracked for the time frame of the study (2010–2018). Hypothesis 1 tested the connection between a firm's efforts towards environmental sustainability in terms of the decision to disclose carbon information (the first step towards sustainability) and the firm's value.

Table 1 presents the sector-wise sample distribution for the H1 regression. The financial/Real Estate sector dominates with 24.40%. Energy and Industrial Sectors score second and third place with 11.21% and 10.99%, respectively, followed by Consumer Staples with 8.13%. Other remaining sectors occupy from 7.25% to 7.91% portion of the sample.

Table 1. Sample distribution by sector for H1: 2010–2018.

Number	Sector	Observations	Percentage
1	Consumer Discretionary	324	7.91
2	Consumer Staples	333	8.13
3	Energy	459	11.21
4	Financials/Real Estate	999	24.40
5	Health Care	297	7.25
6	Industrials	450	10.99
7	Information Technology	297	7.25
8	Materials	324	7.91
9	Telecommunications	306	7.47
10	Utilities	306	7.47
Total		4,095	100.00

Table 2 reports the sample distribution by country for hypothesis H1 for the study period 2010–2018. There are forty-one countries in the sample. The top five countries in the sample are the United States (32.09%), Japan (9.01%), France (5.93%), the United Kingdom of Great Britain and Northern Ireland (5.93%), and Canada (5.05%). These five countries contribute over 50% of the sample with the US dominant. On the other hand, developing economies such as China and India only contribute 3.08% and 3.52%, respectively. In the remaining 36 countries, the proportion varies from 0.22% to 3.74%.

Table 3 displays the sample distribution by sector for H2 and H3. The financial industry ranks first with 24.30%. Industrials and Materials sectors occupy the second and third spots at 10.76% and 9.96%. With 9.56% and 9.16%, Consumers and Health Care stand fourth and fifth. The other five sectors range from 6.77% to 7.97% of the sample size.

For hypotheses H2 and H3, the sample was further reduced to 251 firms (2259 firm-year observations) due to variable data points availability, specifically carbon emissions amounts. Carbon emissions levels are not available for the companies that did not respond to or declined to disclose to the CDP. H2 and H3 test the effect of climate-related information (carbon dioxide emissions and equivalents, CO_2e) reported in carbon disclosures, carbon intensity, and carbon disclosure quality on the firm's market value.

Table 4 reports the sample distribution by the country for hypotheses H2 and H3. There are 27 countries in the sample where the companies in the data set are situated. Rank-wise, the United States ranks first (36.3%) as most companies voluntarily reported to the CDP during the study period. The United Kingdom of Great Britain and Northern Island stands behind the US with an 8.8% proportion in the sample. Next to the rank-list are Japan and France with 7.2% each. In the sample, Canada and Japan are just behind with 4.4% and 4.0%, respectively. Other countries' proportion in the selection ranges from 0.4% to 3.6%. Thus, the top four countries in the sample contribute more than 50%. Nevertheless, there is no doubt that the US dominates the sample. The surprising fact is that none of the Chinese companies reported or disclosed their carbon emissions to the CDP during 2010–2018 except for two companies in the Hong Kong Special Administrative Region with a 0.8% proportion in the sample.

Table 2. Sample distribution BT country for H1: 2010–2018.

Number	Country	Observations	Percentage
1	Australia	99	2.42
2	Austria	9	0.22
3	Belgium	18	0.44
4	Brazil	72	1.76
5	Canada	207	5.05
6	Chile	9	0.22
7	China	126	3.08
8	China, Hong Kong Special Administrative Region	126	3.08
9	Columbia	9	0.22
10	Czechia	9	0.22
11	Denmark	27	0.66
12	Finland	18	0.44
13	France	243	5.93
14	Germany	153	3.74
15	Greece	9	0.22
16	India	144	3.52
17	Indonesia	9	0.22
18	Ireland	27	0.66
19	Israel	18	0.44
20	Italy	81	1.98
21	Japan	369	9.01
22	Luxembourg	18	0.44
23	Malaysia	9	0.22
24	Mexico	27	0.66
25	Netherlands	72	1.76
26	Norway	27	0.66
27	Peru	9	0.22
28	Poland	9	0.22
29	Portugal	18	0.44
30	Republic of Korea	54	1.32
31	Russian Federation	81	1.98
32	Singapore	45	1.10
33	South Africa	63	1.54
34	Spain	90	2.20
35	Sweden	45	1.10
36	Switzerland	117	2.86
37	Taiwan, Greater China	54	1.32
38	Thailand	9	0.22
39	Turkey	9	0.22
40	United Kingdom of Great Britain & Northern Ireland	243	5.93
41	United States of America	1314	32.09
	Total	4095	100.00

Table 3. Sample distribution by sector for H2 and H3: 2010–2018.

Number	Sector	Observations	Percentage
1	Consumer Discretionary	162	7.17
2	Consumer Staples	216	9.56
3	Energy	162	7.17
4	Financials/Real Estate	549	24.30
5	Health Care	207	9.16
6	Industrials	243	10.76
7	Information Technology	153	6.77
8	Materials	225	9.96
9	Telecommunications	162	7.17
10	Utilities	180	7.97
Total		2,259	100.00

Table 4. Sample Distribution by the Country for H2 and H3: 2010–2018.

Number	Country	Observations	Percentage
1	Australia	63	2.8
2	Belgium	18	0.8
3	Brazil	45	2.0
4	Canada	99	4.4
5	China, Hong Kong Special Administrative Region	18	0.8
6	Denmark	18	0.8
7	Finland	9	0.4
8	France	162	7.2
9	Germany	117	5.2
10	Greece	9	0.4
11	India	27	1.2
12	Ireland	27	1.2
13	Italy	54	2.4
14	Japan	162	7.2
15	Luxembourg	9	0.4
16	Netherlands	45	2.0
17	Norway	27	1.2
18	Portugal	9	0.4
19	Republic of Korea	45	2.0
20	Russian Federation	9	0.4
21	South Africa	54	2.4
22	Spain	81	3.6
23	Sweden	36	1.6
24	Switzerland	90	4.0
25	Taiwan, Greater China	9	0.4
26	United Kingdom of Great Britain and Northern Ireland	198	8.8
27	United States of America	819	36.3
Total		2259	100.0

4.2. Methods

The dependent variable for this study is the firm's value. Out of a few studies on carbon disclosures, most (Barth & McNichols, 1994; Campbell et al., 2003; Johnston et al., 2008; Matsumura et al., 2014; Clarkson et al., 2015) used market capitalization to measure the firm's value. The notion behind its use is that market capitalization is not subject to manipulation because the stock markets reflect the firm's value. This study agrees with this notion and uses market capitalization as the firm's value. Independent variables of interest include the choice to disclose carbon-related information voluntarily, carbon emissions, carbon intensity, and carbon disclosure quality. These different proxies are used to observe a firm's efforts toward environmental sustainability. If the company chooses to respond to the CDP's questionnaire, it signals that it is conscious of its environmental sustainability responsibility. The first step towards ecological sustainability is the decision to disclose and this is used to test hypothesis 1 (H1).

The second measure, carbon emissions amounts (levels), is used in the extant literature to measure a firm's environmental sustainability efforts (Matsumura et al., 2014; Griffin et al., 2017). A high level of carbon emissions indicates that the company is not keen on ecological sustainability. Hence, the market incorporates this information negatively, and the firm's market value decreases. However, this measure has one major drawback. For instance, as a company grows (in terms of production or sales), it seems obvious that carbon emissions would increase even if the company tried to reduce its carbon amounts using new technology. Another apparent reason is that larger firms can have higher carbon emissions. Therefore, the third measure—carbon intensity, is used to measure the firm's efforts towards environmental sustainability. Carbon intensity is a better measure than total carbon emissions amounts, and it is comparable across firms of various sizes (Cheema-Fox et al., 2021). Prior studies have also used carbon intensity to measure carbon performance and disclosure (Velte et al., 2020). The fourth crucial independent variable is carbon disclosure quality to observe the firm's efforts toward environmental sustainability. This variable is also used in the lietrature as carbon performnace measure and disclosure (Velte et al., 2020). If companies respond to the CDP yearly questionnaire, the disclosure quality can be assessed using the CDP disclosure score.

The CDP score's grade is based on comprehensive reporting using a 10-point criterion (Qian and Schaltegger, 2017). These criteria include (1) general risks and opportunities of climate change, (2) the effect of existing and future regulations, (3) physical risk of climate change, (4) innovations developed in response to climate change, (5) the management group or personnel responsible for climate change, (6) quantitative emissions levels, (7) emissions associated with products, services, and supply chains, (8) the emissions reduction strategy investment, (9) strategies for emissions trading, and (10) energy consumption and costs. This disclosure score ranges from 0 to 100. The carbon disclosure score assesses the quality and depth of a company's response to the annual CDP questionnaire. A high CDP disclosure score signals that a company thoroughly understands climate change's effect on its business and takes actions to achieve environmental sustainability with its sound internal management system of data related to GHGs emissions. In addition, this disclosure score can help demonstrate a company's progress on environmental performance over time. The CDPs scoring methodology assesses the level of detail and comprehensiveness in a response and the company's awareness of environmental issues, its management methods, and progress towards environmental stewardship (CDP, 2018).

Table 5. Carbon disclosure quality scales (1–5).

Number	Level	Climate Change	Score Band	Quality Indicators	Scale
1	Disclosure	0–44%	D-	Poor	1
		45–79%	D	Satisfactory	2
2	Awareness	0–44%	C-	Satisfactory	
		45–79%	C	Good	3
3	Management	0–44%	B-	Good	
		45–75%	B	Very good	4
4	Leadership	0–64%	A-	Very good	
		65–100%	A	Excellent	5

Note: This table presents the different levels of disclosures with their score bands. Information up to score bands is collected from the CDP (CDP, 2018).

This study focuses on the global 500 companies that voluntarily report their environmental-related information to the CDP at the CDP's request on behalf of institutional investors. Therefore, the carbon disclosure index can be used to measure the level of carbon disclosure quality (Lee et al., 2015). The CDP disclosure score is intended to provide the level of disclosure in response to the CDP questionnaire. There are four levels of disclosures, from the lowest (disclosure) to the highest (leadership) level. Each question in the CDP questionnaire has points attached to the information provided and its relative importance to data users, i.e., every question is scored at the disclosure level. A company can attain level 2 (awareness) only after meeting the minimum threshold for level 1 (disclosure). Level 2 measures the comprehensiveness of a company's evaluation of how climate issues interconnect with its business, including the impacts of business activities on the environment, the impact of the environment on business activities, and its effect on people and ecosystems. Level 3 (management) indicates the actions taken by the company to address environmental issues. Level 3 is achievable only if a company fulfills the minimum threshold for level 2. Management points are awarded for answers that provide evidence of sound environmental management actions, as determined by the CDP and its partner organizations. Responses representing more advanced environmental stewardship have more points associated with them. According to the scoring category's weighting, the points achieved per scoring category at the management level are used to calculate the final leadership score. Level 4 (leadership) is the final and highest level. Only companies with high scores in all other levels can reach the leadership level. Their responses will have demonstrated a thorough understanding of risks and opportunities related to climate change, and they will have formulated and implemented strategies to mitigate or capitalize on these risks and opportunities. These companies have verified GHG emissions statements and have implemented emissions reduction strategies to reach company-wide goals. In a nutshell, these four levels indicate the quality of the different levels of disclosures. This study identifies these levels as poor, satisfactory, good, very good, and excellent. Companies' score-bands indicate the level of their carbon emissions disclosure (refer to Table 5). A "D-" indicates poor quality disclosures, "D" and "C-" are for satisfactory, "C" and "B-" for good, "B" and "A-" for very good, and A indicates the excellent quality of the disclosures.

4.3. Empirical models

This study uses the balance sheet valuation model commonly used in prior studies (Barth and McNichols, 1994; Campbell et al., 2003; Matsumura et al., 2014) to examine the relationship between the decision to voluntarily disclose carbon information and the firm's market value. Firm characteristics such as total assets and total liabilities are the control variables that can potentially impact the market value of its equity. In addition, NI is a proxy for the firm's income in the year t to control for potential correlated omitted variable bias throughout different models (Matsumura et al., 2014). Higher income can encourage firms to invest in measuring and reporting their GHG emissions. A firm's better performance would lead to a higher market value of equity and lower emissions (Matsumura et al., 2014).

H1

$$\text{logMktV}_{\text{it}} = \beta_0 + \phi\text{logMktV}_{\text{it}}\text{\_lag1} + \beta_1\text{CarbDisc}_{\text{it}} + \beta_2\text{logTA}_{\text{it}} + \beta_3\text{logTL}_{\text{it}} + \beta_4\text{NI} + \varepsilon_{\text{it}} \quad (1)$$

where $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 < 0$, and $\beta_4 > 0$

where for the firm i and year t,

MktV = Firm value, i.e., the market value of common equity in millions of dollars (number of shares outstanding multiplied by the price per share at the end of a calendar year).

CarbDisc = A binary variable; 1 for a firm's response and consent to publish carbon-related information on CDP's website and 0 otherwise.

TA = Accounting book values of total assets at the end of the fiscal year.

TL = Accounting book values of total liabilities at the end of the fiscal year.

NI = Net income/total sales at the end of the fiscal year.

Moreover, studies such as Johnston et al. (2008), Clarkson et al. (2015), and Griffin et al. (2017) used the Ohlson (1995) model as a standard approach to examine the value relevance of various accounting variables. The Ohlson model shows how accounting data and other information relate to firm value and states that the earnings and book value of equity should be included in a price association regression (Johnston et al., 2008). In addition to the balance sheet approach, the Ohlson (1995) model is employed to reconfirm the results and see any differences in the findings. Following Matsumura et al. (2014), NI is included to control for potential correlated omitted variable bias. The following model, H1a, is an alternative to model H1.

H1a
$$\text{logMktV}_{\text{it}} = \beta_0 + \phi\text{logMktV}_{\text{it}}\text{\_lag1} + \beta_1\text{CarDisc}_{\text{it}} + \beta_2 logBV_{\text{it}} + \beta_3\text{NI}_{\text{it}} + \varepsilon_{\text{it}} \quad (2)$$

where $\beta_1 > 0$, $\beta_2 > 0$, and $\beta_3 > 0$

BV = Book value of common equity.

Hypothesis 2 (H2) tests the effect of climate-related information (carbon dioxide emissions and equivalents, CO2e) reported in carbon disclosures on the firm's value. For H2, the balance sheet valuation model (Barth & McNichols, 1994; Campbell et al., 2003; Matsumura et al., 2014) with variable CO2e is used. Total assets and total liabilities are included as the control variables as per the balance sheet model. NI is included to control for potential omitted variable bias (Matsumura et al. 2014).

H2
$$\text{logMktV}_{\text{it}} = \beta_0 + \phi\text{logMktV\_lag1} + \beta_1\text{logCO2e}_{\text{it}} + \beta_2\text{logTA}_{\text{it}} + \beta_3\text{logTL}_{\text{it}} + \beta_4\text{NI} + \varepsilon_{\text{it}} \quad (3)$$

where $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$, and $\beta_4 > 0$.
$CO2e$ = Carbon emissions and equivalents in thousands of metric tonnes.
The model H2a uses the Ohlson regression approach and is an alternative model for H2.

$$\text{H2a} \qquad \text{logMktV}_{it} = \beta_0 + \phi\text{logMktV\_lag1} + \beta_1\text{logCO2e}_{it} + \beta_2\text{logBV}_{it} + \beta_3\text{NI} + \varepsilon_{it} \qquad (4)$$

where $\beta_1 < 0$, $\beta_2 > 0$, and $\beta_3 > 0$

Regression model H3 is an extended model including two more independent variables of interest (carbon intensity and carbon disclosure quality along with carbon emissions amounts) that were missed in similar studies such as Matsumura et al. (2014). Carbon intensity is a better measure than total carbon emissions amounts, and it is comparable across firms of various sizes (Cheema-Fox et al., 2021), so the model adds carbon intensity (CarInt) as another independent variable of interest. Prior research validates that the score of voluntary disclosure affects the firm's value (Jaggi et al., 2018; Assidi, 2020). Carbon disclosure quality is included in the model as it can impact the firm's value.

$$\text{H3} \qquad \text{logMktV}_{it} = \beta_0 + \phi\text{logMktV\_lag1} + \beta_1\text{CarDiscQual}_{it} + \beta_2\text{logTA}_{it} + \beta_3\text{logTL}_{it} + \beta_4\text{NI}_{it} + \beta_5\text{logCO2e}_{it} + \beta_6\text{CarInt}_{it} + \varepsilon_{it} \qquad (5)$$

where $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 < 0$, $\beta_4 > 0$, $\beta_5 < 0$, and $\beta_6 < 0$
CarDiscQual = Carbon disclosure quality scale ranges from 1 to 5 (i.e., from poor to excellent).
CarInt = Carbon intensity, calculated as carbon emissions divided by total sales.

5. Empirical findings

Table 6. Descriptive statistics for variables used in H1.

Variable	Obs	Mean	Std. Dev.	Min	Max
CarbDisc	4095	0.752	.432	0	1
logMkt	4095	4.579	.383	2.932	5.935
logTA	4095	4.862	.598	3.497	6.605
logTL	4095	4.64	.706	2.896	6.567
NI	4095	0.143	.592	−3.771	34.494
logBV	4054	9.852	1.001	3.664	12.762

Note: This table presents the descriptive statistics of variables used to test hypothesis 1 (H1).

Table 6 reports the basic descriptive statistics for the variables used to test H1. The first variable is the choice of carbon disclosure (CarbDisc) to the CDP. On average, 75.2% of the time, the companies disclosed their carbon-related information to the CDP during 2010–2018. The market value (logMktV) varies from 2.93 to 5.93, with an average of 0.38. LogTA is 4.86 and is greater than logTL (4.64) by 0.22 points. The average logBV is 9.85 and ranges from 3.66 to 12.76.

Table 7 presents the correlation coefficients of the variables used to test hypothesis—H1. The firm's value (logMktV) positively correlates with the choice of disclosure (CarbDisc). It is highly significant, indicating that the firm's choice of disclosure increases the firm's value. Among the control variables, logTA and logTL are positively correlated with the disclosure choice and are

statistically significant at an alpha level of 1%. These correlations imply that larger companies (assets wise) possibly tend to disclose their carbon emissions information more when compared with smaller companies. Similarly, companies with high leverage (current liabilities + long-term debt) chose to disclose their environmentally related information to the CDP during the time of the study. LogBV is positively correlated with the disclosure choice (CarDisc) at a 1% significant level, indicating that companies with higher book value choose to respond to the CDP's questionnaire. In brief, the firms that chose to disclose to the CDP had a higher firm's market value, total assets, total liabilities, and the common stock's book value. NI is negatively connected with the firm's choice to disclose, and this relationship is highly significant. This finding shows that the companies which chose to disclose earned less net income than other companies that did not choose to disclose during the study period.

This study estimates the regression analysis using robust econometric approaches—Arellano-Bond generalized method of moments (Difference GMM) and the Bond-Blundell, an extended approach (System GMM)[6]. These robust econometric models resolve the endogeneity issue left unresolved in previous studies in the value relevance research of non-financial variables such as environment-related factors. Based on the rule provided by Bond et al. to choose the right econometric technique (Bond et al., 2001), the Difference GMM is found to be an appropriate econometric approach. Therefore, Table 8 reports the results using the Difference GMM. It is advised to estimate the dynamic model by Pooled OLS first and then by the Fixed Effect (FE) approach. The Pooled OLS estimate for the lagged dependent variable (as regressor) should be considered the upper limit estimate and corresponding FE as the lower limit estimate. If the difference GMM estimate lies below the corresponding FE estimate, it means the Difference GMM is downward biased because of weak instrumentation. This study has followed the process (results are not reported for Pooled OLS, FE, and the System GMM) to pick the suitable econometric method.

[6]The Arellano–Bond estimation (1991) first uses the difference of all regressors to remove heterogeneity and then uses second and higher-level lags of the dependent variables as instruments in a standard GMM framework to address reverse causality. System GMM corrects endogeneity by introducing more instruments to dramatically improve efficiency. It builds on a system of two equations, original and transformed equations. Instead of using first differences, the System GMM uses orthogonal deviations (it subtracts the average of all future available observations of a variable from the contemporaneous one), thereby minimizing data loss. Refer to Roodman (2009) to learn more about the GMM and System GMM (Roodman, 2009).

Table 7. Matrix of correlations for variables used in H1.

Variables	CarbDisc	logMktV	logTA	logTL	NI	logBV
CarbDisc	1.000					
logMktV	0.153***	1.000				
logTA	0.108***	0.414***	1.000			
logTL	0.137***	0.357***	0.974***	1.000		
NI	−0.057***	0.073***	0.034**	0.003	1.000	
logBV	0.064***	0.593***	0.774***	0.662***	0.053***	1.000

This table presents the correlation coefficient of variables used to test hypothesis 1 (H1). Note: ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 8 presents the results using the balance sheet model (Model H1) and the Ohlson model (Model H1a). The variable of interest—CarbDisc, has a negative sign opposite to the predicted one. It indicates that the choice of disclosing carbon emission voluntarily leads to a lower firm's market value than its counterparts. It seems that investors do not appreciate the company's efforts towards environmental sustainability. There can be several explanations for this. First, these voluntary disclosures might be perceived as substandard and not as effective as a mandatory disclosure. Second, investors may not see any strict environmental policy that could enforce rigorous penalties on the ecological polluters quickly, so they may see these disclosures as a waste of money and so do not value the company's sustainability efforts. Third, most investors may not believe in the climate change issue and so find these types of disclosures useless. However, this association is statistically insignificant. The Ohlson model also shows similar results as the balance sheet model that is the decision to disclose carbon information decreased the company's market value.

Control variables (logTA, logTL, and NI) have the same signs as predicted, similar to a prior study (Matsumura et al., 2014). Asset size and net income are directly related to the company's market value, indicating companies with higher assets and earnings have higher market value. However, these relationships are insignificant statistically. LogTL and the MktV are inversely associated, and this relationship is significant at 5%. This relationship indicates that the companies with lower leverage had higher market value during the study period. In the Ohlson model, log BV is positively associated with the firm's market value, but the relationship is statistically insignificant. The inclusion of the Ohlson model with the book value of the equity does not change any connection between the choice to disclose voluntarily and the firm's market value.

Table 9 provides the descriptive statistics of the variables used in hypotheses—H2 and H3. LogMktV is 4.63 on average, and it ranges from 2.93 to 5.90. Log emissions ($\log CO_2e$) vary from 2.56 to 8.29, with an average value of 6.13. The average logTA and logTL are 4.74 and 4.93. LogTA ranges from 3.50 to 6.45 and logTL from 3.07 to 6.43. The average logBV stands at 9.92. LogBV lies between 3.67 and 12.56. NI is around 12 cents per dollar of revenues, and it goes from −$3.77 to $4.41. The carbon disclosure quality scale (CarDiscQual) is 3.74 on average. It indicates that the sample companies have the disclosure quality between the CDP's score bands C (awareness, from 45%–75%) and B (management, from 45%–75%). It means that companies have moved to between the awareness and management level yet have not reached score band A (leadership level).

Table 10 describes the Pearson correlation coefficients for the variables to test the hypotheses—H2 and H3. The positive correlation coefficient is not as predicted between logMktV and logCO2e (11%); however, it is consistent with Matsumura et al.'s (2014) study. A positive correlation between logMktV and logCO2e begs the question: why do higher carbon emissions levels increase the market value of equity? It appears that investors ignore the magnitude of carbon emissions disclosed by firms. Instead, they value the company's choice to voluntary disclose to the CDP (Table 7–H1). An alternative explanation is that a positive relationship between the logMktV and logCO2e may be because of the firm size, the larger the firm with high market value, the higher the carbon emissions (Matsumura et al., 2014).

Table 8. Regression analysis for H1 using difference GMM.

Dependent Variable: logMktV	Hypothesized Sign	Model H1	Model H1a
Constant	+/−	NA	NA
$logMktV\_lag1$	+	0.780***	0.866***
		(6.64)	(2.82)
CarDisc	+	−0.00816	−0.0128
		(−1.04)	(−1.89)
logTA	+	0.185	
		(1.46)	
logTL	−	−0.113**	
		(−2.24)	
NI	+	0.00615	0.0063
		(0.94)	(1.06)
logBV	+		0.0193
			(0.36)
Year Dummies		Yes	Yes
Observations (n)		3185	3,146
Groups/Instruments		455/17	454/16
No of lags of endogenous variable(s) used for instrumentation		2	2
AR(2)		0.999	0.888
Hansen Statistics		0.125	0.110

Note: This table presents the regression analysis for H1 using Difference GMM.

Note: t statistics are in parentheses; ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. P-Values are reported for AR (2) and Hansen statistics.

Table 9. Descriptive statistics of variables used to test H2 & H3.

Variable	Obs	Mean	Std. Dev.	Min	Max
logMktV	2259	4.627	0.369	2.932	5.895
logTA	2259	4.932	0.614	3.497	6.452
logTL	2259	4.741	0.707	3.069	6.429
NI	2259	.123	0.228	−3.771	4.407
logCO_2e	2259	6.132	0.97	2.556	8.287
CarInt	2259	354.648	908.947	−162.13	9468.538
CarDiscQual	2259	3.744	0.969	1	5
logBV	2232	9.922	1.033	3.664	12.555

Note: This table presents the variables used to test H2 and H3.

LogTA (−0.190) and logTL (−0.219) are modestly negatively correlated with logCO2e and statistically significant. These correlation coefficients are different from a similar study with voluntary carbon disclosures (Matsumura et al., 2014). Larger firms (asset wise) might be more efficient in reducing their carbon amounts, so the higher liabilities are an indication to finance those assets used to control the companies' carbon emissions levels. NI and firm value are positively correlated and statistically significant at 1%. The higher the company's earnings, the higher its value.

Moreover, logBV has the same relation with logCO2e as the logMktV and logCO2e. Finally, a point to be noted is that logMktV is the market value of equity, and logBV is the book value of the equity.

Table 10. Matrix of correlations for the variables used to test H2 and H3.

Variables	logMktV	logTA	logTL	NI	logCO_2e	CarInt	CarDiscQual	logBV
logMktV	1.000							
logTA	0.368***	1.000						
logTL	0.325***	0.981***	1.000					
NI	0.187***	0.121***	0.110***	1.000				
logCO_2e	0.106***	−0.190***	−0.219***	0.200***	1.000			
CarInt	0.182***	−0.152***	−0.164***	−0.052**	0.537***	1.000		
CarDiscQual	0.189***	0.080***	0.101***	−0.032***	0.085***	−0.037*	1.000	
logBV	0.552***	0.733***	0.683***	0.083***	0.114***	−0.040*	0.072***	1.000

Note: This table presents the correlation coefficient of variables used to test hypotheses H2 and H3. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 11 reports the regression results for hypotheses 2 and 3, applying the models widely used in the previous studies related to the value relevance of environmentally related factors and the extended model solely used in this study. Model 1 (balance sheet model) shows that the lagged logMktV is statistically significant at 1%. After adjusting for the endogeneity issue, the selected Difference GMM model shows that logCO_2e and logMktV are inversely related as predicted but statistically insignificant. Alternative model 2 is based on the Ohlson model and has been used in

previous value-relevance studies (Johnston et al., 2008; Clarkson et al., 2015). This model shows the same relationship between the firm's market value and carbon emissions as in model 1, but statistically, this association is insignificant. Previous studies (Matsumura et al., 2014; Griffin et al., 2017) also offer the same relationship, but their results show this relationship as highly statistically significant. The possible reasons for the differences in outcomes are that the prior studies were country-specific, and the research was conducted just before the mandatory reporting of GHGs emissions in the US (Matsumura et al., 2014). The control variable—BV is not statistically significant, whereas NI has the same sign as predicted and is statistically significant at 10% (Model 1) and 5% (Model 2).

Table 11. Regression analysis for H2 and H3 using difference GMM.

		Prior Studies - Models		Extended Model
Dependent Variable: logMktV	Hypothesized Sign	Model 1	Model 2	Model 3
Constant	+/−	N/A	N/A	NA
logMktV_lag1	+	0.746***	0.575**	0.483***
		(4.68)	(2.95)	(16.68)
logCO2e	−	−0.0185	−0.0110	−0.0424*
		(−1.11)	(−0.75)	(−1.76)
CarDiscQual	+			0.132**
				(2.36)
CarInt	−			−0.0000346*
				(−1.93
logTA	+	0.197		0.647***
		(1.05)		(4.75)
logTL	−	−0.113		−0.327***
		(−1.29)		(−3.00)
NI	+	0.0598*	0.0889**	0.0633**
		(1.90)	(2.53)	(2.31)
logBV	+		0.0524	
			(1.53)	
Year Dummies		Yes	Yes	Yes
Observations (n)		1757	1732	1757
No. of lags of endogenous variable(s) used for instrumentation		3	3	2
Groups/Instruments		251/16	250/15	251/19
AR(2)		0.289	0.366	0.491
Hansen Statistic		0.193	0.442	0.321

Note: This table presents the findings using the Difference GMM econometric approach based on regression analysis. t statistics are in parentheses. ***Significant at 1% level. **Significant at 5% level. *Significant at 10% level. P-Values are reported for AR(2) and Hansen Statistic.

Moreover, the Matsumura et al's. study (2014) also separated the companies in the sample into two groups, companies with required disclosure by the EPA (the United States Environment Protection Agency), that is, mandatory disclosures in the future and firms exempted from disclosing their carbon emissions, that is, these companies voluntarily disclosed their environmental information. The coefficient for carbon emissions was negative and highly significant for the first set of companies (companies with required disclosures under EPA). However, this coefficient had the same negative sign for the firms not required to report, and it was insignificant statistically.

Model 3 is the extended model used in this study. Matsumura et al. (2014) have used the balance sheet model as their primary model, using total assets and total liabilities with earnings as control variables to see the value relevance impact of carbon emissions on the firm's market value. They also performed a sensitivity analysis using the Ohlson model. This study uses an extended model by adding two more crucial variables of interest (CarDiscQual and CarInt) that can play an essential role in determining a firm's value. Difference GMM results show the signs of variables of interest (CarDiscQual, logCO2e, and CarInt) and control variables (logTA, logTL, and NI) are the same as predicted.

There is a positive association between logMktV and CarDiscQual with a statistically significant level of 5%, indicating that the market values the company's disclosure quality. Assidy (2020) also found that a higher voluntary disclosure score increases the firm's value (in terms of Tobin's Q) for French firms from 2006 to 2016. The reason is that the company annual reports or the content of financial statements may not be enough for the investors to make the best and most wise investment decisions. Therefore, the voluntary disclosure scale (or score) can increase transparency by reducing information asymmetries between investors and management.

Moreover, logCO2e and CarInt are both negatively associated with logMktV and significant at 10%. These negative associations indicate that higher carbon emissions and carbon intensity lowers the market value during the study period. These findings confirmed that investors pay attention to the company's carbon emissions amounts (Matsumura et al., 2014), carbon intensity, and disclosure quality (Jaggi et al., 2018). It is worth mentioning that the more robust model (the Difference GMM) after resolving the endogeneity issue with the extended model also verifies the reverse relationship between the firm value and carbon emissions reported by a previous study (Matsumura et al., 2014). The results show that the market perceives carbon emissions as a future liability and punishes the firms with higher carbon emissions and higher carbon intensity. Moreover, the market values companies' higher-level sustainability efforts regarding higher disclosure quality.

Regression outcomes in table 11 are based on 251 corporations that chose to disclose their data to the CDP. Unfortunately, environmental data for the firms that declined to respond were not available. Therefore, nondisclosure firms were not included in the sample, leading to self-selection bias. A very relevant and similar study (Matsumura et al., 2014) had a full range of environmental data on all firms and could examine differences between disclosure and nondisclosure firms to address the impact of self-selection bias. However, due to the lack of ecological data for nondisclosure firms, we could not control the self-selection bias, which is a limitation of this study.

6. Summary of findings

The empirical findings do not support the H1 that the choice to disclose carbon-related data voluntarily increases the firm's value. Instead, the Difference GMM shows a negative relationship between the firm's value and its intention to unveil its environmental information, not as

hypothesized. Moreover, this association is insignificant. Thus, the regression results do not indicate any link between the firm's value and the choice of voluntary disclosure. The hypothesis—H2(1) is whether carbon emissions levels affect the firm's value. That is, the increase in emissions levels decreases the firm's value. Regression analysis showed the same signs as predicted, but it does not establish this relationship as statistically significant. Therefore, the Difference GMM (a suitable econometric technique for this study) rejected hypothesis H2(1). A similar study using the same balance sheet model (using total assets and total liabilities and earnings as control variables) showed that this relationship was highly significant statistically. Still, after resolving an endogeneity issue, this study does not confirm the results in the previous study (Matsumura et al., 2014).

An extended balance sheet model 3 with two more metrics (CarbDiscQual and CarInt) of corporate-level environmental sustainability confirms that carbon emissions levels (H2(1)) and carbon intensity (H2(2)) convey information to the market about the company's environmental sustainability efforts. Therefore, the market punishes the firms for increasing carbon emissions and carbon intensity levels. These relationships are significant at 10%. Moreover, this study proves that carbon disclosure quality (H3) plays a vital role in determining market-based firm value. Regression results using robust econometric techniques show the positive association between the carbon disclosure quality and market-based firm value, meaning that a higher disclosure quality leads to an increased firm's value.

7. Discussion

In the regime of voluntary carbon disclosures, this study investigated global 500 companies that reported their carbon-related information to the CDP during the period studied. This paper empirically examined the impact of corporate-level environmental sustainability efforts on firm value using different proxies such as the choice of voluntary carbon disclosures, carbon emissions levels (amounts), carbon intensity, and carbon disclosure quality, whereas previous similar studies (Matsumura et al., 2014) only used carbon emissions levels.

This study differentiates its work from the previous studies in several ways. First, the differentiation started with the data frame used. Previous studies considered the data until 2009 (Matsumura et al., 2014), but this study began in 2010. The next is in using a more robust econometric approach to resolve the endogeneity issue left unresolved in previous similar studies. Moreover, this study is more relevant and can provide new insights to researchers, stakeholders, and policymakers in the present context of environmental and business sustainability.

The first hypothesis tested whether the company's voluntary choice to disclose its carbon emissions is value-relevant to the investors. After resolving the endogeneity issue, the regression results showed a negative relationship between the firm's value and its choice to disclose its environmental information instead of the predicted positive association. Possible explanations could include that those investors might not trust these disclosures or foresee any regulatory intervention in their country. Otherwise, the voluntary disclosure reduces information asymmetry, increases transparency (Assidi, 2020), and shows the firm's efforts toward its business and environmental sustainability during the ongoing climate crisis. However, this negative association is not significant.

Prior literature highlighted some studies that used participation in the CDP as one of the variables required for their research (Ben-Amar et al., 2017; Li et al., 2018; Akbas and Canikli, 2019). But these studies have used disclosure choice as a dependent variable to explore the

determinants of voluntary disclosure choice. These studies are also country-specific, unlike our research. Therefore, no other similar study is available to compare with our findings.

The second and third hypotheses investigated whether the market incorporates the firms' carbon emissions information to value the firms using the balance sheet and Ohlson models used in previous value-relevance studies of environmentally related variables (Barth & McNichols, 1994; Johnston et al., 2008; Matsumura et al., 2014) and an extended model. Using the Difference GMM, regression results established the same relationship between the carbon emissions and the firm value as hypothesized using models from prior studies. But these findings are not found to be statistically significant. However, a similar study (Matsumura et al., 2014) using the same variables such as a measure for the firm's value (MktV), a variable of interest (carbon emissions amounts), and independent variables (total assets, total liabilities, net income) showed this relationship highly significant statistically. Still, this study does not confirm their results after resolving an endogeneity issue, perhaps due to the study time and country effects. This research is 2010–2018 based, and the previous study (Matsumura et al., 2014) is 2006–2009 based. In the beginning, the companies could be more environmentally conscious, and there could be regulatory fear in terms of environmentally sustainability policies. Therefore, investors paid attention and valued the firms accordingly as these regulations would affect all the firms. However, as time passed, no stringent regulation came into existence to keep the corporations on their toes for their negative environmental activities. Therefore, it seems that neither companies took environmentally sustainability seriously, nor did the investors. Moreover, even a significant proportion of the sample for this study contains US firms, around 32%. But this study is global 500 companies-centered, whereas Matsumura et al.'s (2014) analysis was the S&P 500 companies-focused.

This study also extends the previous value-relevance model used by Matsumura et al. (2014) in the context of voluntary carbon disclosures by adding two additional proxies (CarbDiscQual and CarInt) for corporate-level environmental sustainability. This extended model verifies the reverse relationship between the firm's value and carbon emissions levels reported by Matsumura et al. (2014). Carbon intensity also behaves oppositely to the firm's market value significantly at 10%. Lower carbon intensity means lower regulatory and reputational exposures and other climate-related risks from a climate change viewpoint (Cheema-Fox et al., 2021). Therefore, the market punishes the firms for increasing carbon emissions and carbon intensity levels. Regression results show the positive association between the carbon disclosure quality and market-based firm's value consistent with Assidy (2020), meaning that a higher disclosure quality leads to an increased firm's value.

This study contributes to the existing literature in several ways. The most obvious is that the investigation extends the financial accounting research boundaries by incorporating environmentally related disclosures and linking them to the firm's value and corporate-level environmental sustainability. Moreover, these disclosures could be part of the company's annual reports under a mandatory environmental regime and play a vital role in helping investors to make more sound investment decisions. The second contribution is that this study uses a more extensive data set (the global 500 largest companies) and an extended period (i.e., nine years from 2010 to 2018). Therefore, these findings are more recent and provide helpful information to the different stakeholders.

The third contribution is that this research adds three more environmental sustainability measures: the choice of disclosure (binary variable), carbon intensity, and carbon disclosure quality in addition to carbon emissions amounts in the value relevance model. The fourth is that this study uses the more robust econometric technique (Difference GMM) to resolve the endogeneity issue that

was left unaddressed in the previous similar studies. This approach also helps obtain unbiased estimates (Leszcensky and Wolbring, 2019). Finally, this study emphasizes the impact of carbon disclosures and related information and their link to firm value and environmental sustainability in carbon accounting. The notion behind this study is that corporation-level carbon disclosures can be a prerequisite to corporation-level environmental sustainability as these disclosures might serve as necessary and valuable environmentally related information not only for existing and potential investors but also for other interested stakeholders such as NGOs, governments, policymakers, accountants, standard setters, sustainability experts, and researchers in the field. This research is vital because studies confirm that markets react to carbon disclosures, although these disclosures are substandard. Markets penalize the companies for their poor environmental performance and punish them for not disclosing. Similar to Assidi's (2020) research, this study provides guidelines for investors and managers to increase the firm's value by using better quality carbon disclosures. This custom could be even more advantageous in a mandatory set-up.

8. Conclusions

This research paper has examined whether corporate-level environmental sustainability efforts affect the firm's market value in a voluntary ecological disclosure regime. We found that these disclosures have value-relevant content that helps investors make financial decisions. These findings are essential to the US and international regulators and standard setters in developing standards for measuring, assuring, and reporting on a firm's GHG statement. In addition, our results suggest that the capital market incorporates environmentally related information to help value the companies even in a voluntary disclosure setup. However, these voluntary disclosures are substandard because companies disclose at their discretion. There is a need for environmentally related sustainability standards that can guide managers for environmentally related statement preparation to disseminate this crucial information to all stakeholders to make informed investment decisions.

This study provides insights to standard setters about the importance of environmentally related disclosures. Even the international investors holding global investments are raising their demand for high quality, reliable and comparable reporting by corporations on climate and other environmental, social and governance (ESG) issues (IFRS Foundation)[7]. Clearer guidelines from regulators and standard setters can also meet the demands of users and preparers of GHGs-related disclosures. Consistent sustainability standards can help companies consistently prepare their sustainability reports, and investors and market participants to make more informed decisions. Therefore, we recommend environmental sustainability standards similar to international financial reporting standards (IFRS) and the US generally accepted accounting principles (US GAAP) from the standard setters. COP 26 (Conference of the Parties in the 26th Annual Summit) announced the International Sustainability Standard Board (ISSB) on Nov 3, 2021, partnering with the Climate Disclosure Standard Board (CDSB) and Value Reporting Foundation (VRF). However, the ISSB is in its very early phase of establishing its leadership, as per the update from Erkki Liikanen (chair of the IFRS Foundation Trustees) on Feb 16, 2022. In the absence of sustainability standards, corporations'

[7]https://www.ifrs.org/groups/international-sustainability-standards-board/.

transparent environment-related disclosures can help market participants know the potential future costs of the firm that may need to pay for its carbon emissions (Matsumura et al., 2014).

It is important to mention that all companies whom the CDP approached didn't respond. Therefore, the environmentally related data was not available for non-responding companies; hence it became a significant limitation of this study and led to a self-selection bias. The results could differ if there were mandatory disclosure, and all companies would provide their environmental data. Furthermore, mandatory disclosures can provide investors and other stakeholders more reliable information to make informed decisions. Therefore, this study also recommends that these environmental disclosures be required as part of annual or verified environmental sustainability reports. In addition, it can further encourage green accounting by integrating environmental costs into the business's financial results (Dhar et al., 2020).

This research provides several grounds for future research. Our work is focused on voluntary environmentally related data collected from the CDP. However, it would be interesting if it is possible to perform a similar analysis in a global set-up using the optional information revealed about the company's environmentally related information contained in its annual reports and to know how investors perceive this information as a part of the yearly reports. In addition, it would be worth researching if a company discloses through more than one channel, for example, via 10-K reports and the CDP's report. If this happens, do the firms disclose similar or different information?

Furthermore, this study does not include the companies that declined to publicly disclose their carbon emissions amounts in the sample to test H2 and H3 because of the lack of data in the CDP's database. Possibly, the results might differ if the data were known for all companies, whether they had chosen to disclose to the CDP or not for analysis. It will be worth performing a country-specific analysis if the climate-related data is available for all disclosure and nondisclosure companies. Last but not least, it would be worth exploring if these sustainability efforts increase companies' intangible assets, as in the study by Konar and Cohen (2001).

Overall, this study ends on a positive note. Around fifty-five percent of the total corporations that the CDP approached for their environmentally related disclosures reported to the CDP. It indicates that these firms are already in the fight against climate change and actively working on business and environmental sustainability, and these efforts can pay off in a mandatory environmental-related disclosure setup.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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