Whether Voluntary GHG Disclosure Could Help Improve Subsequent GHG Performance-New Global Evidence

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Abstract

In light of the Conference of Parties 26, carbon information reporting has become ever-increasingly important. Prior studies presented much evidence on whether environmental disclosure could reliably reflect environmental performance. However, very limited evidence has been provided on if environmental disclosure could drive firms to improve future environmental performance. Based on the competing theoretical predictions from the legitimacy theory and the "outside-in" management perspectives, this study provides new international insight into if carbon disclosure improvements could motivate future carbon performance improvement based on a change analysis. Particularly, the investigation uses a recently available carbon data set of both developed economies and developing economies from the Carbon Disclosure Project and other publicly available media platforms. We find that an improvement in carbon disclosure indicates a future carbon performance deterioration in developed economies, however, carbon disclosure changes are not related to future carbon performance changes in developing economies when using performance data from the Carbon Disclosure Project. When using performance data from other publicly available media platforms, carbon disclosure changes are not related to future carbon performance changes at all internationally. This indicates that the carbon information disclosed on other public media platforms has been intentionally beautified. Thus, firms' carbon performance changes from these platforms lose track of the prior changes in firms' carbon disclosure.

Key Words: GHG Disclosure; GHG Performance; GHG Disclosure Strategy; GHG Disclosure Environment; GHG Information Disclosure Differences; GHG Disclosure Platform

1 Introduction

Since the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, climate change risks and controlling anthropogenic carbon emissions to mitigate such risks have become increasingly frequently discussed issues in society. Greenhouse gases (GHG) or carbon information disclosure has been widely used to communicate firms' alleged commitment and efforts to climate change mitigation and carbon emissions controlling practices to shareholders and the wider stakeholders. However, the extant literature shows that extensive GHG disclosure does not necessarily reflect the underlying GHG performance.

The "disclosure-performance gap" has been constantly documented in corporate social responsibility (CSR, subsuming GHG-related issues) disclosure studies (Bansal & Clelland, 2004; Hassan, Romilly, & Environment, 2018; Ioannou & Serafeim, 2014). Prior studies predominantly focus on examining the direction of association (no association; positive association; negative association) between CSR-related disclosure and corresponding CSR-related performance using a cross-sectional research design (Griffin, Lont, & Sun, 2017; Hassan, 2018). These studies provide mixed and confusing results, most importantly, the research question of these studies could be summarized as "is there an association between CSR-related disclosure and CSR-related performance? If there is, whether good (bad) CSR performers disclose more (less) extensively about firms' CSR involvement." The focus of this kind of research question is "Who tends to disclose and how extensive the disclosure tends to be" (Qian & Schaltegger, 2017; Siddique, Akhtaruzzaman, Rashid, & Hammami, 2021). Little evidence, nevertheless, has been provided on how the underlying CSR-related performance changes as a result of the changes in regular CSR-related disclosure.

CSR-related disclosure, especially GHG-related disclosure is largely unstandardized and varied speaking of the form and measurement of such disclosure[1] (Johnson, Theis, Vitalis, & Young, 2019). And firms could disclose their commitment and dedication to climate change and portray themselves as leaders through rhetorical GHG disclosure even without substantial GHG

[1] CSR-related disclosure comes in various forms, like independent CSR reports, website disclosure or disclosure as part of firms' annual reports, firms could choose how to disclose their CSR information as they see fit.[(Cahan, De Villiers, Jeter, Naiker, & Van Staden, 2016)]. Specifically, in the area of GHG reporting, although recently, in some of the world's most advanced economies, there are government-led schemes that require firms that meet certain standards to report GHG emissions. These schemes only cover a proportion of firms within the country. For example, the US Environment Protection Agency requires firms that meet certain carbon emissions threshold to report carbon emissions information at facility level from 2010 {(United States Environmental Protection Agency, 2016)}. The UK requires that listed firms report their GHG emissions information in firms' annual directors' report {(GOV.UK, 2013)}. Most importantly, these GHG reporting requirements vary significantly across countries and territories.

investment and management (Milne, Kearins, & Walton, 2006). This indicates that changes in GHG disclosure may not have any substantial influence on the changes in firms' underlying GHG performance. However, once regular GHG disclosure is established in a firm, rhetorical GHG disclosure could not sustain forever, as talking big with no real actions would expose the disclosing firm to increasingly uncontrollable social and political costs (Dye, 1985; Qiu, Shaukat, & Tharyan, 2016; Schaltegger & Wagner, 2006). This indicates a chance for corporate GHG disclosure changes to shape the changes in firms' underlying GHG performance.

In this paper, we use a truly international dataset for the years 2009-2014 and a "changes" research design to investigate how changes in firms' GHG disclosure associate with subsequent probable changes in firms' underlying GHG performance. We chose this period under investigation to ensure comparability and practical significance as recent papers in this research area are generally focused on the period between 2008 and 2015 (Le Luo, 2019; Qian & Schaltegger, 2017; Siddique et al., 2021). Depending on the findings of this empirical study, outside GHG information demanders like shareholders and the wider stakeholders, could have a better understanding of what's behind firms' GHG disclosing behaviour, and whether continuous GHG disclosure could have any substantial implications on the improvement of firms' GHG performance. Also, if the results find that firms only use GHG disclosure as a substitute for real involvement in climate change mitigating activities, that is, changes in GHG disclosure are not or negatively associated with subsequent changes in GHG performance, then this indicates that generally accepted standardised GHG disclosure guidelines, measurement of GHG performance, international cooperation among governments and regulators on normalising GHG reporting and accounting would be recommended for governments and policymakers. If the results find that firms are improving underlying GHG performance as a result of regular GHG disclosure, that is, changes in GHG disclosure are positively associated with subsequent changes in GHG performance. Then, regulations and legislation that could effectively encourage firms to make regular GHG-related disclosure voluntarily or compulsorily would be recommended for governments and policymakers. This is because regular GHG disclosure itself can motivate practising firms to materially mitigate their GHG impact.

The rest of the paper is arranged as follows: section2 goes through relevant literature and theoretical predictions, at the end of which the hypotheses would be given. Section3 introduces the data employed, sampling method, empirical model and variables used in this paper. Section4 analyses the empirical evidence obtained to test the hypotheses advanced. Following this, the conclusions of this paper would be given in section5.

2 Literature Review, Theories and Hypotheses

2.1 Evidence regarding General Environmental Disclosure-Performance Relationship

The investigation of general environmental disclosure-performance association starts with some evidence in professional literature claiming that there is an insignificant demand for social disclosure information from investors and other outside stakeholders (Buzby & Falk, 1979; Duff And Phelps Inc, 1976; Opinion Research Corporation, 1974) in the 1970s of the US. Ingram and Frazier (1980) argue that this situation may be because there is a lack of quality for social disclosure at that time or because corporate social involvement information is not relevant to external information users' decision models. To test the hypotheses, they investigate the environmental disclosure-performance association in 40 US firms under the regulation of the Council on Economic Priorities[2]. Their results find that there is no significant association between firms' environmental disclosure and environmental performance. Thus, they argue that it is the lack of quality in social disclosure that keeps the demand for social disclosure low. Following their studies, future studies focus on the disclosure-performance gap and provide contradictory results about the relationship of interest.

After Ingram and Frazier (1980)'s seminal work, studies in this research area predominantly provide "in levels" North American evidence based on cross-sectional research design. These studies interchangeably use social, environmental, CSR disclosure and performance in their respective research, however, the nature of their research question is to examine the direction of association (no association; negative association; positive association) regarding the environmental disclosure-performance relationship. Specifically, studies that use North American data before the year 1980 primarily identify no association (Freedman & Wasley, 1990; Ingram & Frazier, 1980; Wiseman, 1982). Studies that use North American data after the year 1980 (inclusive) before the year 1994 primarily identify a negative association (Bewley & Li, 2000; Hughes, Anderson, & Golden, 2001; Dennis M Patten, 2002). Studies that use North American data after the year 1994 (inclusive) primarily identify a positive association (Al-Tuwaijri, Christensen, & Hughes, 2004; Clarkson, Li, Richardson, & Vasvari, 2008).

In addition to the evidence from North America, other studies also provide additional "in levels" evidence (Font, Walmsley, Cogotti, McCombes, & Häusler, 2012; Sutantoputra, Lindorff, & Johnson, 2012) regarding the relationship of interest from specific industries and other regions.

[2] The Council on Economic Priorities is a non-profit institution dedicated to analysing and rating corporate social and environmental activities in the US.

However, these studies further add to the jumbled landscape of this literature with their conflicting evidence.

2.2 Evidence regarding the GHG Disclosure-Performance Relationship

In the wake of the successful convention of the United Nations Framework Convention on Climate Change (UNFCCC), another group of studies ramifies on prior research to specifically examine GHG disclosure, and GHG performance (Freedman & Jaggi, 2004, 2005, 2009). Most recently, Luo and Tang (2014), Luo (2019) and Siddique et al. (2021) particularly revisit the disclosure-performance association problem in CSR-related areas focusing on GHG emission issues using the data from the CDP[3] database. However, these studies again focus on the "in levels" evidence of who would disclose more and who would disclose less. Relatedly, Bui et al. (2020) investigate the moderation effects of climate governance on firms' GHG disclosure-performance relationship based on a sample of S&P500 firms from 2013-2015. Based on both "in levels" and "in difference" evidence, they suggest that good GHG performers use more extensive GHG disclosure to distinguish themselves from bad performers, and climate governance within firms reduces the degree of exaggeration of good GHG performance via extensive GHG disclosure. However, these results still provide mixed perspectives that leave the literature split and contradictory, and they do not provide any solution to this.

Closely related to this research, Qian and Schaltegger (2017) investigate whether improvement in GHG disclosure could lead to improvement in the underlying GHG performance. They employ a changes analysis of Global 500 firms drawing on the corresponding GHG emissions data from the CDP database for the years 2008-2012. Their results find that increment in GHG disclosure is significantly associated with a subsequent improvement in the underlying GHG performance. This indicates that regular GHG disclosure could serve as a mechanism for firms to sustainably mitigate their impact on climate change. However, Global 500 firms are the world's largest businesses. They have strong international social and political influence, which, in turn, creates strong social and political surveillance on their operations and strong enough pressure for them to substantially improve their GHG performance through consecutive disclosure. The rationale behind this is that if Global 500 firms only use GHG disclosure as a legitimising device, the disclosure-performance gap would grow uncontrollably over time, and so is the risk of "being busted" and losing the trust of shareholders and the wider stakeholders.

[3] CDP stands for Carbon Disclosure Project. It is a non-profit organisation that encourages GHG information disclosure on a global basis.

In the wider international backdrop, we do not know whether regular GHG disclosure behaviour would help firms to really improve their GHG performance. Following Qian and Schaltegger (2017)'s seminal work, from the "outside-in" management perspective, we intend to re-investigate whether changes in voluntary GHG disclosure is associated with any subsequent changes in firms' underlying GHG performance in a truly international setting. Again, by choosing a similar period under investigation (2009-2014), we would like to either add to or challenge Qian and Schaltegger (2017)'s findings based on international evidence. Additionally, although this paper does not explore any "in levels" evidence regarding the GHG disclosure-performance association, the theoretical arguments presented in prior studies provide good theoretical start-points for this piece of research.

2.3 Legitimacy Theory: GHG Disclosure Is a Substitute for GHG Performance

The legitimacy theory argues that CSR is a kind of social pressure that firms are faced with, thus, the corresponding disclosure is a passive reaction to such pressure (Bewley & Li, 2000; Cho & Patten, 2007; Dennis M Patten, 2002). Following the legitimacy theory's argument, the sole drive for firms to make GHG disclosure is because management expects a negative impact on the firms' interest if climate change risks are unattended. And "to say" is always much cheaper and easier than "to act". If a beautifully fashioned GHG report would well suffice to establish a positive image among demanding shareholders and the wider stakeholders, there is no motivation for firms to spend non-trivial costs on something that is not core to its business (Cho, Guidry, Hageman, & Patten, 2012; Dennis M. Patten, 2015).

From the point of view of legitimacy theory, it is unlikely that the improvement in GHG performance would associate with a previous increment in GHG disclosure, or if there is a change of GHG performance subsequent to a previous increment in GHG disclosure, this change would be negative, as the increment in GHG disclosure could be used to conceal the subsequent possible deterioration in firms' GHG performance (Milne & Gray, 2013; Qian & Schaltegger, 2017). Thus, the first two hypotheses would be:

H1: There is no association between changes in GHG disclosure and the subsequent changes in GHG performance.

H2: There is a negative association between changes in GHG disclosure and the subsequent changes in GHG performance.

2.4 "Outside-in" Management Perspectives: GHG Disclosure Provides Motivation for GHG Performance"

Schaltegger and Burritt (2010) argue that when firms use corporate disclosure to respond to shareholders' and the wider stakeholders' specific concerns in CSR-related areas, the behaviour of disclosure itself would help firms to develop a system of measurement and corporate management infrastructure of the specific CSR concerns. The measurement system and management infrastructure would, in turn, motivate firms to improve the corresponding CSR performance. This mechanism is dubbed the "outside-in" approach that leads to corporate sustainable development (Schaltegger & Burritt, 2010). The CSR-related disclosure could help firms understand shareholders' and the wider stakeholders' concerns in detail, and bring these concerns into the operations of firms (Schaltegger & Wagner, 2006).

Similarly, GHG disclosure is expected to shape management's GHG management strategies, consequently positive changes in underlying GHG performance (Plumlee, Brown, Hayes, & Marshall, 2015). As is argued by Topping (2012), disclosure of GHG performance-related statistics is expected to be associated with the corresponding changes in management's GHG management strategic thinking that could transform disclosure into real performance. As such, another hypothesis that is worth investigating is:

H3: There is a positive association between changes in GHG disclosure and the subsequent changes in GHG performance.

In addition, prior studies have found that CSR-related disclosure in developing countries is minimal and is mainly resulting from governmental regulations and legal judgments etc. (Jackson et al., 2006; Parker, 2011; Luo et al., 2013). Also, financial constraint is the major factor that affects firms' CSR involvement and disclosure, but factors without enforcing powers like academics, NGOs and social expectations have little influence on firms' CSR involvement and disclosure (Ali, Frynas, & Mahmood, 2017; Ali & Rizwan, 2013). This is associated with the underdeveloped regulatory environment and social and cultural environment regarding CSR in developing economies (Le Luo, Tang, & Lan, 2013; Martinsson, Pham-Khanh, & Villegas-Palacio, 2013). However, in developed economies, not only microeconomic and legal factors but also non-enforcing factors like social, and cultural factors could effectively drive firms' CSR involvement and disclosure (Ali et al., 2017). Social pressure from NGOs and media plays a key role in firms' CSR involvement and disclosure (Ali & Frynas, 2018; Ali et al., 2017). Under such significantly different CSR involvement and disclosure environments, it is reasonable to argue that the GHG disclosure-performance relationship would take on different patterns between developing economies and developed economies. Thus, another hypothesis of interest would be:

H4: There is a difference between developing economies and developed economies regarding the relationship between changes in GHG disclosure and the subsequent changes in GHG performance.

3 Research Design

3.1 Sample and Data

To conduct the analyses in this paper, we use firm-specific "carbon emissions amounts", "carbon disclosure scores" and "climate change mitigation related management levels within firms", which measure where the highest level of direct responsibility for climate change mitigation is positioned in firms from the CDP's climate change database. The sample is selected from all the firms that have been involved in the CDP's climate change project for the years 2010-2015 (the CDP's climate change projects for 2010-2015 collect GHG emissions-related data from involved firms for the years 2009-2014) with a publicly available CDP questionnaire disclosure score for at least one year for years 2009-2014. This ensures that every firm-year observation included in the sample has a valid CDP disclosure score. The period 2009-2014 is selected as the period under investigation because the CDP's climate change questionnaire stays largely consistent in this period, thus the information collected through these questionnaires provides good horizontal and vertical comparability across firms and between years. In addition, the CDP has been using questionnaire completion bands that measure the consecutive 4 levels (disclosure; awareness; management; leadership) that firms move through towards carbon stewardship instead of disclosure scores since 2016 (CDP, 2022).

This sample selection process gives a sample of 6366 firm-year observations that correspond to 1646 firms, 44 countries and 19 regions. Because this research uses changes analysis, by taking the first difference of the CDP's climate change disclosure scores and other variables included in the original sample data, we get a sample of 4562 firm-year observations that correspond to 1646 firms, 44 countries and 19 regions. In addition, according to the 1646 firms included in the sample, scope1[4] and scope2 carbon emissions data of these firms from Thomson

[4] Scope1 includes direct carbon emissions from owned or controlled sources (fuel combustion, company vehicles, fugitive emissions); Scope2 includes indirect emissions from purchased electricity, heat, steam, and cooling; Scope3 includes all other indirect emissions within a firm's value chain. USEPA. 2016. Learn about the greenhouse gas

Reuters' Asset4 database are also added, and carbon emissions data from Asset4 are used in the analyses to alternatively create a set of proxies for GHG performance, besides those created using GHG emissions data from the CDP's database (the reason why alternative GHG emissions data are used is explained in section3.2).

Besides the overall international analysis, this paper also tests the hypotheses respectively for the developing economies and developed economies subgroups. Whether a country is a member of the OECD's Development Assistance Committee (DAC) is chosen as the criterion to split the sample. This criterion is selected, because the criteria to gauge whether a country or territory could be considered a developed economy include but are not limited to a number of different aspects, such as "gross domestic product (GDP)", "gross national product (GNP)", "per capita income", "industrialization level", "widespread infrastructure level" and "general living standard" etc. (Investopedia, 2019). And different professional entities (UN HDI; World Bank; IMF etc.) have produced their specific lists of developed economies based on various methodologies considering a different set of relevant criteria. However, countries that are members of the DAC are consistently included in different lists of developed economies. Choosing this criterion to split the sample into developing economies and developed economies subgroups avoids disputes between different lists of developed economies. Consequently, the 4562 firm-year observations are further split into 452 observations from developing economies that correspond to 237 firms, 19 countries and 4110 observations from developed economies that correspond to 1409 firms, 23 countries.

3.2 Empirical Model and Variables

To test the hypotheses advanced, the following empirical model is employed:

$$\begin{aligned} \Delta CI_{i,t+1}(-) = {} & a_0 + a_1 \Delta CD_{i,t} + a_2 \Delta ROA_{i,t} + a_3 \Delta Q_{i,t} + a_4 \Delta FR_{i,t} + a_5 CGRANK_{i,t} \\ & + a_6 \Delta SIZE_{i,t} + a_7 \Delta IO_{i,t} + a_8 \Delta SG_{i,t} + a_9 \Delta AN_{i,t} \\ & + a_{10} \Delta ESG_{i,t} + a_{11} IND_{i,t} + v_{i,t} \end{aligned}$$

, where CI is firms' GHG emissions intensity, it is calculated as firms' "scope1", "scope1+scope2", "scope1+scope2+scope3" (in thousand metric tonnes) over firms' yearly total inflation-adjusted revenue (in million USD) respectively. For the purpose of identification, "scope1" GHG intensity is denoted as A1CI, "scope1+scope2" GHG intensity is denoted as A2CI and "scope1+scope2+scope3" GHG intensity is denoted as A3CI. "Scope1" GHG intensity is

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reporting program (ghgrp). [Online]. Available from: https://www.epa.gov/ghgreporting/learn-about-greenhouse-gas-reporting-program-ghgrp.

examined independently because GHG Emission Trading Schemes all over the world at the current stage only include scope1 GHG emissions, thus, scope1 GHG emissions get a significant amount of attention and management within firms (Cooper, 2015; Qian & Schaltegger, 2017). Prior studies predominantly use scope1 direct GHG emissions plus scope2 indirect emissions to proxy for firms' overall GHG emissions (Hassan et al., 2018; Jaggi, Allini, Macchioni, & Zampella, 2018; Le Luo, 2019; Qian & Schaltegger, 2017), however, this neglects the GHG emissions related to firms' operations downstream of their value chains. Considering which situation, A3CI is included separately as a proxy for firms' true overall GHG performance.

In addition, because Depoers et al. (2016) identify that the reported GHG emissions in large French companies' reports are significantly lower than those in the CDP's climate change questionnaires, and also Thomson Reuters' Asset4 database independently collects firms' scope1 direct and scope2 indirect GHG emissions from global media coverage, including corporate reports, webpages, online media etc. In this study, to control for the impact of potential differences of reported GHG emissions from different channels on the results we obtain, a parallel set of GHG intensity proxies are produced and alternatively used in the empirical model above. B1CI and B2CI are calculated respectively using "scope1" GHG emissions, and "scope1+scope2" GHG emissions from Thomson Reuters' Asset4 database. B3CI is calculated using "scope1+scope2" GHG emissions from Thomson Reuters' Asset4 database plus "scope3" GHG emissions from the CDP database over firms' yearly total inflation-adjusted revenue. Using revenue-scaled GHG emissions to proxy for firms' GHG performance is consistent with prior studies (Depoers et al., 2016; Le Luo, 2019; Le Luo & Tang, 2014; Qian & Schaltegger, 2017). Also, because the proxies for GHG performance are intensity measures, following Qian and Schaltegger (2017), we inversed the signs of CI, so that ΔCI(-) could be intuitively explained as the improvement of GHG performance (decrease of GHG intensity).

CD denotes the extensiveness of firms' voluntary GHG disclosure. It is measured by the CDP's climate change questionnaire disclosure scores. The CDP's climate change questionnaire disclosure score measures firms' completion level of the CDP's climate change questionnaire. It's an integer number that ranges from 0 to 100 inclusive. For the convenience of interpretation, when calculating the changes of CD, after taking the difference of the CD for two consecutive years, the difference is divided by 100. This is consistent with the practice of Qian and Schaltegger (2017).

ROA denotes firms' return on assets, it is calculated as the ratio of income before extraordinary items (in million USD) of the current year over the total assets (in million USD) at the end of last year. Prior studies have documented that there is a mixed relationship between firms' financial performance and CSR-related involvement and performance, (Hassan et al., 2018; Schnietz & Epstein, 2005; Wahba, 2008). Firms' return on assets is controlled for its potential effects on GHG performance.

Q denotes Tobin's Q, which is a measure of firms' market-to-book ratio. This measure is calculated as the ratio of the market value of common equity of a firm (in million USD) plus the book value of its common equity (in million USD) minus the book value of its total assets (in million USD) over the book value of its total assets. This factor is controlled in the empirical model as evidence suggests that firms with higher Tobin's Q are associated with more employable intangible assets, more positive NPV investment opportunities and more proactive CSR strategies (Barth, McNichols, & Wilson, 1997; Friede, Busch, & Bassen, 2015; McWilliams & Siegel, 2011). In addition, recent studies identify that environmental performance is positively associated with Tobin's Q (Hassan, 2018; Hassan et al., 2018). FR denotes firms' financial risk, this measure is calculated as firms' leverage level, which equals firms' book value of total debt including current (in million USD) over firms' book value of total assets (in million USD). Using firms' leverage levels to catch firms' financial risk is consistent with several prior studies (Bansal & Clelland, 2004; Beck, 1992; Fama & French, 1993; Mulhall & Bryson, 2013). In addition, evidence shows that when firms raise leverage level, the demand for better information transparency from various stakeholders would also increase (McWilliams & Siegel, 2011), leverage level is associated with firms' posture towards CSR-related issues and firms' CSR strategies (Benlemlih, Shaukat, Qiu, & Trojanowski, 2018; Chapple, Clarkson, & Gold, 2013).

CGRANK measures corporate management infrastructure construction level related to climate change mitigation within a firm. Specifically, it equals "2" if the highest level of direct responsibility for climate change mitigation in a firm is a subset of the board or some committee appointed by the board; it equals "1" if the highest level of direct responsibility for climate change mitigation in a firm is a manager or an officer; it equals "0" if there is no management establishment of overall responsibility for climate change mitigation in a firm. This factor is controlled for its potential effect on firms' willingness and tendency to perform well in GHG emission management, as prior studies find that firms with a position on the board or in the management that takes overall responsibility for CSR-related issues tend to perform overall better in CSR than firm without such a position (Brooks & Oikonomou, 2018; Stanny & Ely, 2008). This measure is not in differenced form because, in a period of 6 years in a row, firms' GHG-related management setting barely changes. SIZE denotes the economic scale of firms, it is calculated as the natural log of the market value (in million USD) of the equity of a firm. Firms' size has been constantly controlled in prior CSR disclosure and performance-related research, as it is argued that larger firms are exposed to stronger social and political pressure, this, in turn, motivates firms to perform better in CSR-related areas, and provide better CSR-related information transparency (Chapple et al., 2013; Clarkson, Fang, Li, & Richardson, 2013).

IO denotes the institutional ownership of companies, it is calculated as the shares of a company owned by institutional investors over all shares outstanding of a company. Because CDP's climate change project is backed up by total US$100 trillion assets (as of 2019) from over 650 biggest institutional investors across the world that are "climate change crisis" concerned. For firms that take part in the CDP's climate change questionnaire, firms' institutional ownership may, to some degree, drive management's decision to participate. SG denotes firms' sales growth, it is calculated as the difference of sales revenue in million USD at "t" and sales revenue in million USD at "t-1" over sales revenue in million USD at "t-1". We control for this factor in this model as prior evidence shows that management that is good at creating cash flow from sales tends to adopt proactive strategies in CSR-related issues (Cahan et al., 2016; De Villiers, Naiker, & Van Staden, 2011; Stanny, 2013). Thus, firms' sales growth may have a potential effect on firms' GHG performance.

AN denotes the newness of firms' properties, plants and equipment (PPE), it is calculated as the ratio of a firm's net PPE (in million USD) at each year end over its gross PPE (in million USD) at each year-end. This factor is controlled as prior evidence shows that firms with newer PPE are more likely to use clean technologies that are environmentally and climate-friendly (Clarkson, Li, Richardson, & Vasvari, 2011; Qian & Schaltegger, 2017). Thus, firms with newer PPE are expected to have better environmental performance and GHG performance than firms with older PPE. ESG denotes Thomson Reuters' firm-specific environmental, social and governance (ESG) score. It is expected that firms with good overall ESG scores would also perform well in GHG emissions reduction activities. IND is a dummy variable that equals "1", if a firm is from one of these high-GHG exposure industries: "Energy", "Industrials", "Materials" and "Utilities". Following Qian and Schaltegger (2017), this dummy is included as climate change-related risks and GHG emissions issues could be more relevant in high-GHG exposure industries, as they are faced with greater social and political costs (Cho et al., 2012; Cho & Patten, 2007). This, in turn, could have implications for firms' GHG performance improvement plans.

4 Results

4.1 Implications from Summary Statistics

Table 1 Panel A presents the descriptive statistics of undifferenced CDP climate change disclosure scores, the undifferenced six measures of GHG intensity for the full sample, the developing economies subsample and the developed economies subsample. For the full sample, we could see that generally, firms that have a relatively high disclosure score tend to make their disclosure scores public. In addition, the differences in the same scope of GHG intensity from different channels indicate that it is necessary to see if the obtained regression results would be sensitive to these identified differences. For the descriptive statistics of the two subsamples, we could see that firms from developing economies generally have higher CDP disclosure scores than firms from developed economies through the CDP's platform. This may indicate that the threshold disclosure score for firms in

Table 1: Panel A. Descriptive statistics of overall corporate GHG profile for the full sample and breakdown of sample by development level group

Variable	Full Sample					DEV=0		DEV=1		t-stat p-value	Wilcoxon p-value
	Mean	Q1	Median	Q3	Std.Dev.	Mean	Median	Mean	Median		
	n=6366 (1646 firms)					n=711 (237 firms)		n=5655 (1409 firms)			
CD	75.992	65.000	80.000	92.000	19.696	79.643	83.000	75.532	79.000	p<0.01	p<0.01
A1CI	0.190	0.004	0.015	0.140	0.408	0.336	0.073	0.171	0.014	p<0.01	p<0.01
B1CI	0.215	0.004	0.017	0.180	0.457	0.344	0.086	0.199	0.016	p<0.01	p<0.01
A2CI	0.256	0.018	0.048	0.247	0.473	0.512	0.191	0.223	0.042	p<0.01	p<0.01
B2CI	0.275	0.019	0.051	0.263	0.530	0.547	0.206	0.243	0.045	p<0.01	p<0.01
A3CI	0.443	0.023	0.071	0.393	0.848	0.806	0.251	0.397	0.061	p<0.01	p<0.01
B3CI	0.429	0.022	0.071	0.388	0.805	0.703	0.197	0.394	0.063	p<0.01	p<0.01

"CD" is the CDP's climate change questionnaire disclosure score; "A1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD); "A2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD); "A3CI" is the ratio of (scope1+scope2+scope3) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B3CI" is the ratio of [(scope1+scope2) from Thomson Reuters' Asset4 database+scope3 from the CDP] carbon emissions (in thousand metric tonnes) over firms' inflation-adjusted sales revenue (in million USD); "DEV"= 1 if a country is a member of DAC.

Table 1: Panel B. Descriptive statistics of variables for the full sample and breakdown of sample by development level group

Variable	Full Sample Mean	Q1	Median	Q3	Std.Dev.	DEV=0 Mean	DEV=0 Median	DEV=1 Mean	DEV=1 Median	t-stat p-value	Wilcoxon p-value
	n=4562 (1646 firms)					n=452 (237 firms)		n=4110 (1409 firms)			
ΔCD	5.885	0.000	4.000	10.000	10.161	6.350	5.000	5.885	4.000	insig	insig
ΔA1CI(-)	-0.001	-0.001	0.000	0.001	0.112	-0.013	-0.000	-0.001	0.000	p<0.05	p<0.01
ΔB1CI(-)	0.004	-0.001	0.000	0.002	0.114	-0.012	0.000	0.004	0.000	p<0.05	p<0.01
ΔA2CI(-)	-0.002	-0.004	0.000	0.003	0.137	-0.016	0.000	-0.002	0.000	p<0.05	p<0.01
ΔB2CI(-)	0.000	-0.004	0.000	0.004	0.141	-0.011	-0.001	0.000	0.000	p<0.05	p<0.01
ΔA3CI(-)	-0.019	-0.012	0.000	0.007	0.490	-0.061	-0.002	-0.019	0.000	p<0.1	p<0.01
ΔB3CI(-)	-0.018	-0.014	0.000	0.007	0.477	-0.046	-0.000	-0.018	0.000	p<0.1	p<0.01
CGRANK	1.778	2.000	2.000	2.000	0.463	1.778	2.000	1.848	2.000	p<0.01	insig
ΔQ	0.030	-0.091	0.025	0.163	0.399	-0.012	0.001	0.030	0.025	p<0.05	p<0.05
ΔROA	-0.001	-0.014	0.000	0.014	0.039	-0.006	-0.002	-0.001	0.000	p<0.01	p<0.01
ΔFR	0.001	-0.020	0.000	0.018	0.050	0.005	0.003	0.001	0.000	p<0.1	p<0.01
ΔAN	-0.007	-0.021	-0.007	0.007	0.047	-0.009	-0.010	-0.007	-0.007	insig	p<0.05
ΔSG	-0.010	-0.118	-0.014	0.080	0.195	-0.030	-0.027	-0.010	-0.014	p<0.05	insig
ΔSIZE	0.071	-0.084	0.085	0.239	0.302	0.018	0.044	0.071	0.085	p<0.01	p<0.01
ΔIO	0.003	-0.002	0.000	0.003	0.055	-0.001	0.000	0.003	0.000	insig	insig
ΔESG	0.485	-4.480	0.340	5.710	14.620	-0.085	0.325	0.485	0.340	insig	insig

"CD" is the CDP's climate change questionnaire disclosure score; "A1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD); "A2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD); "A3CI" is the ratio of (scope1+scope2+scope3) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "B3CI" is the ratio of [(scope1+scope2) from Thomson Reuters' Asset4 database+scope3 from the CDP] carbon emissions (in thousand metric tonnes) over firms' inflation-adjusted sales revenue (in million USD); "DEV"= 1 if a country is a member of DAC; "insig." means insignificant.

developing economies to make their CDP disclosure scores public is higher than that for firms in developed economies.

Table 1 Panel B presents the descriptive for variables in their first differenced form. The signs of the changes in all six first-differenced GHG intensity measures are reversed so that they could be intuitively explained as improvements or increments in GHG performance. We could see that, for the changes of "scope1", "scope1+scope2", "scope1+scope2+scope3" GHG intensity measures, the improvement of GHG performance reported through the CDP's platform is on average lower than that reported through other channels (corporate reports, webpages, online media etc.). This indicates that firms are trying to beautify their climate change mitigation achievement through channels like corporate reports, webpages, online media etc.

This is consistent with Depoers et al. (2016)'s finding that firms in France tend to downplay their climate change impact in corporate reports compared with what these firms reported through the CDP's platform. This is probably because corporate reports, website disclosure or online media disclosure are literally the most accessible and cost-effective ways for related stakeholders to know how firms manage their GHG impact. These differences in reported changes in GHG emissions measures may also be reflected in the regression results.

We could also see that firms from developed economies generally have significantly better improvement in GHG performance for the period under investigation than firms from developing economies. This is consistent with what is observed in Table 1 Panel A that firms from developing economies on average have significantly higher GHG intensity than firms from developed economies. For most variables included in the empirical model, there is a significant difference between the means of changes of the same variable between firms from developed economies and firms from developing economies.

4.2 Tests for Hypotheses

4.2.1 Tests for Hypotheses Using GHG Emissions Data All from the CDP Database

Table 2 Panel A presents the OLS [5] regression results of the empirical model that investigates the association between changes in firms' voluntary GHG disclosure extensiveness

[5] OLS stands for Ordinary Least Squares. In this study, because we use changes analyses to investigate the relationship of interest, for one thing, Random Effects Generalised Least Squares equals OLS in this study, as there is lots of negative serial correlation in our data due to the process of differencing our data, for another, first differenced data has already differenced out any time-invariant factors using repeated observations over time, using first-differenced data has the same effect of using Fixed Effects Generalised Least Squares [see, (Wooldridge, 2010)]. Thus, in the main analyses of this study, we only report results from OLS regression.

and the subsequent changes in firms' GHG performance using "scope1" GHG intensity based on GHG emissions data from the CDP for the period under investigation. Column 1 presents the results for the full sample. We could see that for every 1% increase in the improvement of voluntary GHG disclosure extensiveness, there is a subsequent decrease of reduction of scope1 GHG intensity by 0.053 ($p<0.05$) metric tonnes per thousand revenue in USD. This indicates that the increment of voluntary GHG disclosure is associated with a subsequent deterioration in firms' underlying GHG mitigation achievement. In addition, for every one-unit increase in the improvement of firms' market-to-book ratio and sales growth, there is an increase of reduction of scope1 GHG intensity by 0.021 ($p<0.05$) metric tonnes per thousand revenue in USD, and an increase of reduction of scope1 GHG intensity by 0.044 ($p<0.01$) metric tonnes per thousand revenue in USD respectively. This is consistent with the "slack finance" and "luxury good" arguments of CSR (Aerts, Cormier, & Magnan, 2008; Buchner, Trabacchi, Mazza, Abramskiehn, & Wang, 2015; Cormier & Magnan, 1997; Freedman & Jaggi, 1992). In addition, if a firm is in high-GHG exposure industries, it would experience an extra decrease of reduction of scope1 GHG intensity by 0.008 (IND, $p<0.1$) metric tonnes per thousand revenue in USD in the subsequent period compared with other firms that are not in high-GHG exposure industries.

For firms from developing economies (column 2), we could see that there is no statistically significant association between changes of voluntary GHG disclosure and the subsequent changes in scope1 GHG performance. However, as the improvement in ROA (coefficient=0.158, $p<0.1$) and Tobin's Q (coefficient=0.013, $p<0.05$) is significantly positively associated with the subsequent improvement in scope1 GHG mitigation achievement, the "slack finance" and "luxury good" arguments of climate change mitigating issues persist for firms from developing economies. Again, if a firm is in high-GHG exposure industries, it would experience an extra decrease of reduction of scope1 GHG intensity by 0.008 (IND, $p<0.1$) metric tonnes per thousand revenue in USD in the subsequent period compared with other firms that are not in high-GHG exposure industries. Considering that firms from developing economies have higher average CDP disclosure scores (see Table 1 Panel A) than firms from developed economies, the evidence indicates that firms from developing economies use voluntary GHG disclosure as a substitute for real GHG mitigating activities involvement, there is no association between GHG performance and GHG disclosure for firms from developing economies for the period under investigation.

In column 3, we could see that the results obtained for firms from developed economies stay highly consistent with those based on the full sample. For firms from developed economies, the improvement in voluntary GHG disclosure is significantly negatively associated with the subsequent improvement in scope1 GHG performance. Firms in developed economies use voluntary GHG disclosure to conceal the deterioration of their underlying GHG mitigation achievement. Thus, overall, through the results obtained in Table 2 Panel A, **H1** is true for firms from developing economies, and **H2 is** true for firms from developed economies. Consequently, **H4** is true. The results obtained using scope1 GHG intensity based on GHG emissions data from the CDP support the legitimacy theory's prediction.

Table 2: Panel A. The results of the empirical model using A1CI as the GHG performance proxy

VARIABLES	(1) $\Delta A1CI_{t+1}$(-)	(2) $\Delta A1CI_{t+1}$(-)	(3) $\Delta A1CI_{t+1}$(-)
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	-0.053**	-0.019	-0.053**
	(0.023)	(0.019)	(0.024)
ΔQ_t	0.021**	0.013**	0.022**
	(0.009)	(0.006)	(0.009)
ΔFR_t	0.004	0.017	0.003
	(0.061)	(0.068)	(0.062)
CGRANK	-0.001	0.020*	-0.001
	(0.006)	(0.010)	(0.006)
$\Delta SIZE_t$	-0.011	-0.021*	-0.011
	(0.011)	(0.012)	(0.012)
ΔIO_t	0.032	-0.235**	0.034
	(0.049)	(0.092)	(0.050)
ΔROA_t	0.001	0.158*	-0.002
	(0.075)	(0.084)	(0.077)
ΔSG_t	0.044***	0.013	0.045***
	(0.014)	(0.009)	(0.015)
ΔAN_t	0.072	0.072	0.074
	(0.063)	(0.061)	(0.065)
ΔESG_t	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
IND_t	-0.008*	-0.008*	-0.008*
	(0.005)	(0.004)	(0.005)
Constant	0.006	-0.032	0.006
	(0.011)	(0.021)	(0.011)
Observations	4562	452	4110
R-squared	0.017	0.579	0.017

"A1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2 Panel B presents the OLS regression results of the empirical model using "scope1+scope2" GHG intensity based on GHG emissions data from the CDP for the period under investigation. Column 1 presents the results for the full sample. We could see that for every 1% increase in the improvement of voluntary GHG disclosure extensiveness, there is a subsequent decrease of reduction of "scope1+scope2" GHG intensity by 0.075 ($p<0.01$) metric tonnes per thousand revenue in USD. This is consistent with Table 1 Panel A.

For firms from developing economies (column 2), we could see that there is again no statistically significant association between changes of voluntary GHG disclosure and the subsequent changes in "scope1+scope2" GHG performance. Again, as the improvement in ROA (coefficient=0.804, $p<0.1$) is significantly positively associated with the subsequent improvement in "scope1+scope2" GHG performance, the "slack finance" and "luxury good" arguments of climate change mitigating issues also apply to firms from developing economies. If the improvement of a firm's Thomson Reuters' ESG score increases by 1 unit, there would be an increase of reduction of "scope1+scope2" GHG intensity by 0.001 metric ton ($p<0.1$) per thousand revenue in USD. Overall, the results obtained stay consistent with those from the previous table. There is no association between GHG performance and GHG disclosure for firms from developing economies for the period under investigation.

In column 3, we could see that the results obtained for firms from developed economies again stay highly consistent with those based on the full sample. For firms from developed economies, the improvement in voluntary GHG disclosure is significantly negatively associated with the subsequent improvement in scope1+scope2 GHG performance. Thus, the results obtained using scope1+scope2 GHG emissions stay consistent with those obtained using scope1 GHG emissions.

Table 2 Panel C presents the OLS regression results of the empirical model using "scope1+scope2+scope3" GHG intensity based on GHG emissions data from the CDP for the period under investigation. Again, the results obtained are highly consistent with those obtained from Table 2 Panel A and Table 2 Panel B. They once again confirm that **H1** is true for firms from developing economies, and **H2** is true for firms from developed economies. And **H4** is true. Overall, the results presented in Table 2 Panel A, Table 2 Panel B and Table 2 Panel C are highly consistent with each other, suggesting that the improvement of voluntary GHG disclosure is associated with a subsequent deterioration of firms' underlying GHG mitigation achievement. However, for firms from developing economies, changes in firms' voluntary disclosure are not indicative of any subsequent underlying GHG performance change. The results so far suggest that improvement of firms' voluntary GHG disclosure extensiveness is either solely used as a legitimising tool with no effect on subsequent changes of firms' underlying GHG performance or used to cover for subsequent deterioration of firms' underlying GHG mitigation achievement.

Table 2: Panel B. The results of the empirical model using A2CI as the GHG performance proxy

	(1)	(2)	(3)
VARIABLES	$\Delta A2CI_{t+1}(-)$	$\Delta A2CI_{t+1}(-)$	$\Delta A2CI_{t+1}(-)$
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	-0.075***	-0.034	-0.074**
	(0.029)	(0.102)	(0.030)
ΔQ_t	0.025**	0.045	0.025**
	(0.011)	(0.032)	(0.012)
ΔFR_t	-0.038	-0.126	-0.042
	(0.075)	(0.361)	(0.076)
CGRANK	-0.000	0.051	-0.001
	(0.007)	(0.055)	(0.007)
$\Delta SIZE_t$	-0.016	-0.084	-0.016
	(0.014)	(0.062)	(0.014)
ΔIO_t	0.023	-1.340***	0.031
	(0.061)	(0.489)	(0.062)
ΔROA_t	-0.015	0.804*	-0.031
	(0.093)	(0.450)	(0.094)
ΔSG_t	0.063***	0.009	0.063***
	(0.017)	(0.050)	(0.018)
ΔAN_t	0.040	0.413	0.038
	(0.078)	(0.323)	(0.080)
ΔESG_t	-0.000	0.001*	-0.000
	(0.000)	(0.001)	(0.000)
IND_t	-0.012**	-0.028	-0.011*
	(0.006)	(0.021)	(0.006)
Constant	0.008	-0.081	0.008
	(0.013)	(0.110)	(0.013)
Observations	4562	452	4110
R-squared	0.019	0.455	0.018

"A2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Tests for Hypotheses Using GHG Emissions Data from Other Channels

Table 3 Panel A, B, C present the OLS regression results of the empirical model that investigates the association between changes of firms' voluntary GHG disclosure extensiveness and the subsequent changes in firms' GHG performance using scope1 GHG intensity, "scope1+scope2" GHG intensity, "scope1+scope2+scope3" GHG intensity based on GHG emissions data from other channels (corporate reports, webpages, online media etc. Note, however, that scope3 emissions are from the CDP database, as Thomson Reuters' Asset4 database does not provide scope3 emissions) respectively for the period under investigation. We could see that all the results shown in Table 3 Panel A, B, C indicate that there is no association between changes in firms' voluntary GHG disclosure extensiveness and the subsequent changes in firms' underlying GHG performance. The finding is consistent through the full sample, the developing economies subsample and the developed economies subsample. Although the results are still under legitimacy theory's prediction, the probable reason for these different findings could be that the data of the improvement of firms' underlying GHG performance from channels like corporate reports, webpages, online media etc. for the period under investigation have been intentionally beautified to give better impressions on shareholders and the wider stakeholders. Because the data have been beautified, the changes of firms' underlying GHG performance from these channels do not contain any information about the changes of firms' voluntary GHG disclosure extensiveness. In this case, the GHG disclosure from these channels is merely used as a legitimising tool. These regression results reflect the descriptive statistics shown in Table 1 Panel B.

In sum, all the empirical evidence obtained supports the legitimacy theory's prediction over the association between changes in firms' voluntary GHG disclosure extensiveness and the subsequent changes in firms' underlying GHG performance. That is, for firms from developing economies, the changes in firms' voluntary GHG disclosure extensiveness do not contain any information of subsequent changes in firms' underlying GHG performance. For firms from developed economies, the improvement in firms' voluntary GHG disclosure extensiveness is associated with subsequent deterioration of improvement in firms' underlying GHG performance.

Table 2: Panel C. The results of the empirical model using A3CI as the GHG performance proxy

VARIABLES	(1) $\Delta A3CI_{t+1}(-)$	(2) $\Delta A3CI_{t+1}(-)$	(3) $\Delta A3CI_{t+1}(-)$
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	-0.190*	0.068	-0.198*
	(0.114)	(0.242)	(0.117)
ΔQ_t	0.017	0.146*	0.013
	(0.044)	(0.076)	(0.046)
ΔFR_t	0.160	-0.188	0.157
	(0.295)	(0.859)	(0.301)
CGRANK	-0.014	0.061	-0.016
	(0.028)	(0.131)	(0.028)
$\Delta SIZE_t$	-0.017	-0.433***	-0.009
	(0.055)	(0.148)	(0.057)
ΔIO_t	-0.105	-3.176***	-0.087
	(0.241)	(1.165)	(0.245)
ΔROA_t	-0.287	-0.134	-0.282
	(0.365)	(1.071)	(0.372)
ΔSG_t	0.231***	0.251**	0.233***
	(0.069)	(0.118)	(0.071)
ΔAN_t	-0.047	1.095	-0.069
	(0.307)	(0.770)	(0.315)
ΔESG_t	0.001	0.002	0.001
	(0.001)	(0.002)	(0.001)
IND_t	-0.020	-0.119**	-0.018
	(0.024)	(0.050)	(0.024)
Constant	0.022	-0.008	0.024
	(0.052)	(0.262)	(0.052)
Observations	4562	452	4110
R-squared	0.010	0.440	0.010

"A3CI" is the ratio of (scope1+scope2+scope3) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Thus, in contrast with Qian and Schaltegger (2017)'s finding that changes in firms' voluntary GHG disclosure extensiveness is positively associated with the subsequent changes in firms' underlying GHG performance, this paper finds exactly otherwise. The reason for this completely different finding could be that Qian and Schaltegger (2017) only draw on data from the world's largest firms (Global 500 constituents). And because Global 500 firms are the world's largest businesses, they have strong international social and political influence, which, in turn, creates strong social and political surveillance on their operations and strong enough pressure for them to substantially improve their GHG performance based on consecutive disclosure. The rationale behind this is that if Global 500 firms only use GHG disclosure as a legitimising device, the disclosure-performance gap would grow uncontrollably over time, and so is the risk of "being busted" and bankruptcy consequently. After including firms of other sizes in a wider international backdrop, our results show that firms mainly use GHG disclosure as a legitimising tool for their operations and a substitute for real involvement in climate change mitigation activities for the period under investigation.

Table 3: Panel A. The results of the empirical model using B1CI as the GHG performance proxy

	(1)	(2)	(3)
VARIABLES	$\Delta B1CI_{t+1}(-)$	$\Delta B1CI_{t+1}(-)$	$\Delta B1CI_{t+1}(-)$
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	0.010	-0.024	0.009
	(0.021)	(0.043)	(0.021)
ΔQ_t	0.004	0.016*	0.004
	(0.007)	(0.008)	(0.007)
ΔFR_t	-0.016	0.062	-0.013
	(0.053)	(0.130)	(0.055)
CGRANK	0.002	0.033	0.001
	(0.005)	(0.024)	(0.005)
$\Delta SIZE_t$	-0.004	-0.023	-0.003
	(0.009)	(0.018)	(0.010)
ΔIO_t	0.030	0.925***	0.024
	(0.041)	(0.239)	(0.042)
ΔROA_t	0.019	-0.028	0.019
	(0.066)	(0.195)	(0.067)
ΔSG_t	0.044***	-0.006	0.049***
	(0.013)	(0.023)	(0.013)
ΔAN_t	0.057	0.146	0.059
	(0.060)	(0.145)	(0.061)
ΔESG_t	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
IND_t	-0.006	0.004	-0.006
	(0.004)	(0.010)	(0.004)
Constant	-0.001	-0.061	-0.001
	(0.010)	(0.049)	(0.010)
Observations	4562	452	4110
R-squared	0.015	0.497	0.016

"B1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD).

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Panel B. The results of the empirical model using B2CI as the GHG performance proxy

VARIABLES	(1) $\Delta B2CI_{t+1}$(-)	(2) $\Delta B2CI_{t+1}$(-)	(3) $\Delta B2CI_{t+1}$(-)
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	-0.010	0.019	-0.010
	(0.027)	(0.130)	(0.028)
ΔQ_t	0.009	0.003	0.009
	(0.009)	(0.025)	(0.010)
ΔFR_t	-0.002	0.109	-0.003
	(0.069)	(0.380)	(0.071)
CGRANK	0.004	0.073	0.004
	(0.007)	(0.072)	(0.007)
$\Delta SIZE_t$	-0.014	0.035	-0.016
	(0.012)	(0.051)	(0.013)
ΔIO_t	-0.000	0.461	-0.004
	(0.055)	(0.651)	(0.055)
ΔROA_t	0.091	0.471	0.085
	(0.088)	(0.588)	(0.089)
ΔSG_t	0.053***	0.011	0.055***
	(0.016)	(0.067)	(0.017)
ΔAN_t	0.015	0.119	0.015
	(0.079)	(0.403)	(0.081)
ΔESG_t	-0.000	0.000	-0.000
	(0.000)	(0.001)	(0.000)
IND_t	-0.013**	-0.036	-0.012**
	(0.006)	(0.027)	(0.006)
Constant	-0.003	-0.129	-0.003
	(0.013)	(0.143)	(0.013)
Observations	4562	452	4110
R-squared	0.014	0.170	0.013

"B2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from Thomson Reuters' Asset4 database over firms' inflation-adjusted sales revenue (in million USD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Panel C. The results of the empirical model using B3CI as the GHG performance proxy

VARIABLES	(1) $\Delta B3CI_{t+1}$(-)	(2) $\Delta B3CI_{t+1}$(-)	(3) $\Delta B3CI_{t+1}$(-)
	Full Sample	**DEV=0**	**DEV=1**
ΔCD_t	-0.081	0.166	-0.088
	(0.107)	(0.224)	(0.110)
ΔQ_t	-0.000	-0.004	-0.003
	(0.036)	(0.043)	(0.039)
ΔFR_t	0.243	-0.424	0.239
	(0.276)	(0.656)	(0.284)
CGRANK	-0.008	0.184	-0.011
	(0.027)	(0.124)	(0.027)
$\Delta SIZE_t$	-0.017	-0.028	-0.014
	(0.049)	(0.088)	(0.051)
ΔIO_t	0.102	-1.441	0.108
	(0.210)	(1.124)	(0.213)
ΔROA_t	-0.061	-0.960	-0.045
	(0.348)	(1.015)	(0.355)
ΔSG_t	0.182***	0.204*	0.182***
	(0.065)	(0.115)	(0.067)
ΔAN_t	-0.099	1.156	-0.135
	(0.313)	(0.696)	(0.322)
ΔESG_t	0.001	-0.000	0.001
	(0.001)	(0.001)	(0.001)
IND_t	-0.013	-0.115**	-0.011
	(0.022)	(0.047)	(0.023)
Constant	0.007	-0.290	0.009
	(0.050)	(0.248)	(0.051)
Observations	4562	452	4110
R-squared	0.007	0.298	0.007

"B3CI" is the ratio of [(scope1+scope2) from Thomson Reuters' Asset4 database+scope3 from the CDP] carbon emissions (in thousand metric tonnes) over firms' inflation-adjusted sales revenue (in million USD).

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3 Controlling for Endogeneity: Instrumental Variables Models

In addition to the main results reported from the OLS models above, we also control for potential endogeneity problems. Specifically, we use the "instrumental variables" method to separate the part of the variation of "ΔCD_t" that is not associated with the error term in the empirical model. Also, as heteroscedasticity is detected in the data we use, the standard errors of instrumental variables' coefficient estimates are not consistent, GMM is implemented in the two-stage least squares regression process to allow for reliable inference [see (Cheng, Ioannou, & Serafeim, 2014)].

Particularly, two instruments ("$\Delta CDCYM_t$" and "$\Delta CDCIM_t$") are generated for "ΔCD_t" by calculating the changes in region-year average of "CD_t" ("$\Delta CDCYM_t$") and the changes in region-industry average of "CD_t" ("$\Delta CDCIM_t$"), excluding each firm's contribution to the average. Using industry or country (region) average of independent variables as instruments are consistent with a few prior studies (Cheng et al., 2014; Friedberg, 2003; Hanlon, Rajgopal, & Shevlin, 2003; Lev & Sougiannis, 1996). The reason for using the region-year average and the region-industry average of the changes in firms' voluntary GHG disclosure extensiveness is that the changes in the extensiveness of firms' voluntary GHG disclosure are systematically affected by that of other firms in the same region over time, and by that of other firms within the same industry in the same region (Cheng et al., 2014; Ioannou & Serafeim, 2012; Le Luo et al., 2013).

Table 4 Panel A and Table 4 Panel B present the two-stage least squares regression results (imposing the GMM option to allow for heteroscedasticity in the data) of the empirical model using A1CI and A2CI respectively to proxy for firms' GHG performance. The purpose of this process is to see whether the observed negative relationship between "the changes of firms' voluntary GHG disclosure extensiveness" and "subsequent changes in firms' GHG performance" would persist when factoring out endogenous disturbances in our data. As is shown in these tables, the results stay highly consistent with those obtained through OLS regression.

Table 4: Panel A. The results of the empirical model using A1CI as the GHG performance proxy-instrumental variables

	(1)	(2)	(3)	(4)
	Full Sample		**DEV=1**	
VARIABLES	First stage	$\Delta A1CI_{t+1}$(-)	First stage	$\Delta A1CI_{t+1}$(-)
ΔCD_t		-0.042**		-0.045*
		(0.021)		(0.024)
$\Delta CDCYM_t$	0.002***		0.002***	
	(0.001)		(0.001)	
$\Delta CDCIM_t$	-0.079***		-0.112***	
	(0.012)		(0.017)	
ΔQ_t	-0.009	0.018**	-0.010	0.019**
	(0.008)	(0.008)	(0.008)	(0.008)
ΔFR_t	-0.054	0.026	-0.052	0.027
	(0.054)	(0.048)	(0.053)	(0.048)
CGRANK	-0.003	0.001	-0.002	0.000
	(0.005)	(0.004)	(0.005)	(0.004)
$\Delta SIZE_t$	0.000	-0.010	0.002	-0.010
	(0.010)	(0.010)	(0.010)	(0.011)
ΔIO_t	0.024	0.034	0.001	0.034
	(0.054)	(0.030)	(0.060)	(0.030)
ΔROA_t	0.075	0.000	0.080	-0.001
	(0.066)	(0.066)	(0.063)	(0.067)
ΔSG_t	-0.004	0.046***	-0.011	0.048***
	(0.014)	(0.015)	(0.013)	(0.015)
ΔAN_t	0.057	0.070	0.060	0.073
	(0.049)	(0.046)	(0.049)	(0.047)
ΔESG_t	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
IND_t	0.010**	-0.008*	0.010***	-0.009*
	(0.004)	(0.005)	(0.004)	(0.005)
Constant	0.041***	0.003	0.030***	0.004
	(0.009)	(0.007)	(0.008)	(0.007)
Observations	4562	4562	4110	4110
R-squared	0.182	0.016	0.217	0.017
Kleigergen-Raap rk Wald F		31.799		30.199
(Weak instruments test)				
Hansen J statistics		1.032		1.019
(overidentification restrictions test)		(0.310)		(0.313)

"A1CI" is the ratio of scope1 carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "ΔCDCYM" is the region-year average of "CD"; "ΔCDCIM" is r the region-industry average of "CD"

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Panel B. The results of the empirical model using A2CI as the GHG performance proxy-instrumental variables

	(1)	(2)	(3)	(4)
	Full Sample		**DEV=1**	
VARIABLES	First stage	$\Delta A2CI_{t+1}$(-)	First stage	$\Delta A2CI_{t+1}$(-)
ΔCD_t		-0.063**		-0.065**
		(0.026)		(0.030)
$\Delta CDCYM_t$	0.002***		0.002***	
	(0.001)		(0.001)	
$\Delta CDCIM_t$	-0.079***		-0.112***	
	(0.012)		(0.017)	
ΔQ_t	-0.008	0.024**	-0.010	0.020**
	(0.008)	(0.010)	(0.008)	(0.010)
ΔFR_t	-0.054	-0.035	-0.052	-0.002
	(0.054)	(0.061)	(0.053)	(0.058)
CGRANK	-0.001	-0.000	-0.002	0.001
	(0.005)	(0.005)	(0.005)	(0.005)
$\Delta SIZE_t$	-0.001	-0.015	0.001	-0.011
	(0.010)	(0.014)	(0.010)	(0.014)
ΔIO_t	0.024	0.030	0.000	0.032
	(0.054)	(0.037)	(0.060)	(0.038)
ΔROA_t	0.078	-0.020	0.083	-0.043
	(0.066)	(0.079)	(0.063)	(0.080)
ΔSG_t	-0.004	0.061***	-0.011	0.064***
	(0.014)	(0.019)	(0.013)	(0.020)
ΔAN_t	0.060	0.037	0.060	0.031
	(0.049)	(0.059)	(0.049)	(0.059)
ΔESG_t	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
IND_t	0.009**	-0.012**	0.009***	-0.011*
	(0.004)	(0.006)	(0.004)	(0.006)
Constant	0.041***	0.007	0.030***	0.004
	(0.009)	(0.008)	(0.008)	(0.008)
Observations	4562	4562	4110	4110
R-squared	0.182	0.019	0.217	0.017
Kleigergen-Raap rk Wald F		31.827		30.307
(Weak instruments test)				
Hansen J statistics		0.077		1.709
(overidentification restrictions test)		(0.781)		(0.191)

"A2CI" is the ratio of (scope1+scope2) carbon emissions (in thousand metric tonnes) from the CDP over firms' inflation-adjusted sales revenue (in million USD); "ΔCDCYM" is the region-year average of "CD"; "ΔCDCIM" is r the region-industry average of "CD"

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5 Conclusions

Recent evidence (Qian & Schaltegger, 2017), based on data from the world's largest firms (Global 500 constituents), shows that regular GHG disclosure could serve as a mechanism that motivates firms to gradually improve their underlying GHG performance, that is, the improvement of firms' voluntary GHG disclosure extensiveness is positively associated with subsequent improvement in firms' underlying GHG performance. However, this evidence is based on a limited sample selection of large multinational firms. It is not clear whether the evidence would persist when drawing on wider international data.

Using a sample of 4562 "in changes" firm-year observations that correspond to 1646 firms, 44 countries (the sample is further split into 452 observations from developing economies that correspond to 237 firms and 4110 observations from developed economies that correspond to 1409 firms), this paper re-investigates whether there is any influence of changes in the extensiveness of firms' voluntary GHG disclosure on potential subsequent changes in firms' underlying GHG performance. The results indicate that, when using reported GHG emissions data from the CDP database, the improvement of voluntary GHG disclosure is associated with subsequent deterioration of firms' underlying GHG performance. However, for firms from developing economies, changes in firms' voluntary disclosure do not contain any information about subsequent underlying GHG performance changes. The proposed **H1** and **H2** under the prediction of legitimacy theory are true respectively for firms from developing economies and firms from developed economies.

When using reported GHG emissions data from other channels like corporate reports, webpages, online media etc., nevertheless, the results suggest that there is no association between changes in firms' voluntary GHG disclosure extensiveness and the subsequent changes in firms' underlying GHG performance. The finding is consistent throughout the full sample, the developing economies subsample and the developed economies subsample. The probable reason for these different findings, when compared with the results obtained using reported GHG emissions data from the CDP database, could be that the GHG performance data from channels like corporate reports, webpages, online media etc. have been intentionally beautified to give better impressions on concerned stakeholders. Because the data have been beautified, the changes in firms' underlying GHG performance from these channels lose track of the changes in firms' voluntary GHG disclosure extensiveness. However, even though the results obtained using GHG emissions data from other channels have changed, compared with those obtained using GHG emissions data from the CDP database. The results are still consistent with the legitimacy theory's prediction.

Overall, the results obtained in this paper are on the opposite side of what Qian and Schaltegger (2017) have identified in their study, this could be because Global 500 firms are the world's largest businesses, and they have strong international social and political influence, which, in turn, creates strong social and political surveillance on their operations and strong enough pressure for them to substantially improve their GHG performance based on consecutive disclosure. This is because if Global 500 firms only use GHG disclosure as a legitimising device, the disclosure-performance gap would grow uncontrollably over time, and they may go bankrupt in the end. However, this rationale may not be true for firms that are with a smaller economic scale and less social and political influence, the social and political surveillance received by these firms may not generate strong enough motivation for these firms to proactively improve their GHG performance. Thus, when including data from a wider international backdrop to investigate the same relationship of interest, we get totally different evidence.

It is worth noting that the "in changes" evidence regarding the association between firms' GHG performance and firms' GHG disclosure identified in this paper suggests that, for the period under investigation, legitimacy theory has predominant explanatory power over the association between firms' GHG performance and firms' GHG disclosure. For the period under investigation, firms all over the world prevailingly use voluntary GHG disclosure as a legitimising tool, a substitute for substantial climate change mitigation activities involvement, rather than a channel that reliably communicates firms' underlying GHG performance to climate change concerned shareholders and the wider stakeholders. This, in turn, indicates that heavy GHG emitters are potentially using extensive GHG disclosure to greenwash themselves. As GHG disclosure is valuation related for climate change concerned investors, this provides motivations for governments and regulators to work out the corresponding measures to prevent firms from misleading the relevant investors and correct the economic anomaly in this area. For example, governments and regulators could roll out the requirement of standardised compulsory GHG disclosure based on international cooperation.

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