Climate Reporting Based on Task Force on Climate-related Financial Disclosures (TCFD) Framework

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Abstract:

This study investigates the effectiveness and informativeness of the TCFD framework, which underpins the new climate-related disclosure regulations established by the U.S. Securities and Exchange Commission (SEC) and the recently issued IFRS S2 Climate Disclosures standard. Using a large sample of U.S. firms over a 12-year period around the launch of the TCFD framework in 2017, we exploit this event as a quasi-natural experiment and apply a difference-in-differences approach. Our findings yield two main results. First, post-2017, TCFD supporters disclose significantly more information across total climate disclosures and within the Governance, Strategy, and Risk Management pillars compared to non-supporters, although no significant difference is observed in the Metrics pillar. Second, following 2017, investors react positively and significantly to changes in total climate disclosures, as well as disclosures in the Governance and Strategy pillars, made by TCFD-supporting firms in their 10-K filings. Overall, our findings support the SEC's and ISSB's decision to incorporate the TCFD framework into climate disclosure regulations and standards, as TCFD support results in enhancing the quality of climate-related disclosures in mainstream reporting.

Keywords: Climate Risks, TCFD, Disclosure, Market valuation, Textual analysis, AI technology

1. Introduction

In 2017, the Task Force on Climate-related Financial Disclosures (TCFD) introduced a framework comprising four pillars—Governance, Strategy, Risk Management, and Metrics— with the objective of promoting consistent, comparable, and decision-useful information regarding climate-related financial risks and opportunities within mainstream financial reporting. As of today, more than 4,900 institutions and firms globally have supported the TCFD framework, which also serves as the foundation for key regulatory initiatives, including the U.S. Securities and Exchange Commission's (SEC) new climate-related disclosure rules and the recently introduced IFRS S2 Climate Disclosures standard.

Despite widespread regulatory endorsement, empirical research on the actual impact of TCFD-driven disclosures remains limited. Seven years after the finalisation of the TCFD framework, there is little evidence to determine whether these disclosures facilitate the communication of material climate-related information that supports informed and efficient capital allocation decisions. This study addresses a critical gap in the literature by evaluating the effectiveness of the TCFD framework in fostering more comprehensive and decision-useful climate-related disclosures.

This investigation is especially relevant in the U.S. context, where regulatory efforts have long sought to improve the transparency and materiality of climate-related financial disclosures. In 2005, the SEC mandated the disclosure of material climate risks, followed by additional guidance in 2010 on applying existing disclosure requirements. However, persistent concerns over the inadequacy of such disclosures led the SEC to issue its 2024 climate-related disclosure rule, which explicitly integrates the TCFD framework in an effort to standardise climate reporting practices. In its justification for the new rule, the SEC (2024)[1] acknowledged that:

"We agree with the many commenters that the current state of climate-related disclosure has resulted in inconsistent, difficult-to-compare, and frequently boilerplate disclosures, and has therefore proven inadequate to meet the growing needs of investors for more detailed, consistent, reliable, and comparable information about

[1] https://www.federalregister.gov/documents/2024/03/28/2024-05137/the-enhancement-and-standardization-of-climate-related-disclosures-for-investors#footnote-11-p21670

climate-related effects on a registrant's business and financial condition to use in making their investment and voting decisions."

Unlike broader sustainability frameworks that often focus on a wide range of stakeholder needs and emphasise firms' impacts on climate change, the TCFD framework is specifically designed to address the needs of financial users by concentrating on firms' financial dependencies on climate-related risks. This shift presents significant challenges for both the preparation and effective use of the disclosed information. Climate-related financial risks are inherently complex, long-term, and unique, and thus may fall outside the expertise and experience of both the preparers and users of corporate risk disclosures. Consequently, key questions emerge regarding the efficacy of the TCFD framework: Does the adoption of the TCFD framework lead to higher levels of climate-related disclosures in firms' annual reports? If so, is this increase merely quantitative, characterised by the disclosure of non-material information, or does it result in material disclosures that have a tangible impact on market pricing and investor decisions?

To address these questions, we employ deep learning natural language processing models to quantify total climate disclosures, as well as disclosures across the TCFD pillars, in the annual reports of a large sample of U.S. firms from 2011 to 2023. We document that, although only 25% of firms in the financial sector support the TCFD, these supporters disclose climate-related information approximately twice as much as non-supporters. However, while a larger proportion of firms in polluting industries (utilities, chemicals, and energy) support the TCFD, their level of disclosures is comparable to that of non-supporters in the chemicals sector and slightly lower in the energy sector.

Moreover, exploiting the 2017 launch of the TCFD framework as a quasi-natural experiment, we apply a difference-in-differences approach and reveal that post-2017, TCFD supporters disclose significantly more information across total climate disclosures and the Governance, Strategy, and Risk Management pillars compared to non-supporters. However, no significant difference is observed for the Metrics pillar. Metrics disclosures require firms to report their greenhouse gas (GHG) emissions, the metrics used to assess climate-related risks, and targets along with performance against those targets (e.g., achieving net-zero emissions by 2040). Prior to 2017, existing climate-related standards already emphasise the disclosure of GHG emissions and other sustainability metrics (TCFD, 2017). Additionally,

many U.S. firms are already mandated to disclose both GHG emissions and climate change impacts under U.S. government regulations (Cong et al., 2020). Therefore, the TCFD framework may not have significantly impacted disclosures under the Metrics pillar.

Furthermore, using a short-window market reaction test, we find that after 2017, there is a strong positive association between three-day abnormal returns around the 10-K filing date and changes in total climate disclosures, as well as in the Governance and Strategy pillars, for supporters. We do not find this positive and significant association for non-supporters. We also examine abnormal short-window trading volume as an alternative measure of stock market reaction and find a positive and significant trading volume reaction for TCFD supporters in 2018, further corroborating our findings based on stock price reactions. This suggests that changes in climate-related disclosure by TCFD supporters in 10-K filings are viewed as credible and material by market participants, reinforcing the importance of transparency in climate-related financial reporting.

The findings of this study contribute to the literature in several important ways. First, our study makes a significant contribution to the literature on TCFD reporting, a relatively underexplored area (Bingler et al., 2022; Demaria & Rigot, 2021; Demers et al., 2024). The most closely related research is by Bingler et al. (2022), who utilise BERT models to analyse climate risk disclosures in annual reports from a sample of 301 TCFD-support firms, including only 53 from the US, between 2014 and 2019. They observe a slight increase (approximately 2.2%) in the level of disclosure by TCFD supporters post-2017, which they attribute to a reorganisation of existing information rather than a substantive enhancement. Bingler et al. conclude that TCFD support is largely "cheap talk," with firms cherry-picking and reporting non-material climate information. Their analysis does not account for market reactions, which are crucial for evaluating whether TCFD supporters provide material information. Even restructuring current information, which results in increased comparability or minor improvements in disclosure, might be sufficiently significant to prompt a market response. In contrast, our study explores the market's response to changes in climate disclosure. We also extend their analysis by examining a 12-year period surrounding 2017 to investigate the impact of adopting the TCFD on climate reporting and comparing TCFD supporters with non-supporters. This approach addresses the concern that increases in climate risk

disclosure might occur for both TCFD-supporting and non-supporting firms, as there is a general trend of increasing disclosure length in annual reports, as documented in the literature (e.g., Beatty et al., 2019; Dyer et al., 2017).

Another relevant study is by Demers et al. (2024), which analysed voluntary TCFD-aligned information reported to the CDP from 2018 to 2022, the years following the launch of the TCFD. Their findings yielded mixed results regarding the market relevance of TCFD-compliant climate-related disclosures. By utilising median annual bid-ask spreads and year-end market equity values, they suggested that these disclosures might be perceived as "cheap talk," with the market failing to recognise the TCFD-estimated financial impacts of climate risks and opportunities as credible or material enough to influence prices. In contrast, our study employs advanced natural language processing (NLP) techniques to quantify climate-related disclosures in annual reports, as encouraged by the TCFD, rather than relying on corporate TCFD disclosures submitted to the CDP. The CDP survey, which comprises both closed- and open-ended questions and spans over 100 pages, is highly time- and resource-intensive for investors. Moreover, if a company opts to keep its responses confidential, only the CDP's investor signatories—primarily money managers and institutional investors—have access to this information. These limitation renders the CDP an inadequate source for investigating the value relevance of TCFD reporting. Additionally, by employing a narrow event window, we assess the value relevance of TCFD reporting while leveraging event-study methodology to minimise issues related to omitted variable bias; this approach also provides a relatively clean test for reverse causality.

Second, we contribute to the literature on textual analysis using NLP techniques to identify climate-relevant information in text data, which largely relies on keyword-based methods to extract climate-relevant information from text (Berkman et al., 2024; Ding et al., 2023; Engle et al., 2020; Sautner et al., 2023). Keyword-based approaches tend to generate false positives, leading to low precision, particularly for the analysis of 10-K regulatory reports (Varini et al., 2021). In addition, in the era of Artificial Intelligence (AI), companies have recognised that a considerable portion of share trading is influenced by recommendations provided by robots and algorithms, so they avoid words that are considered negative by computational algorithms (Cao et al., 2023, 2024). We contribute to the current

literature by investigating value relevance of climate-related reporting, quantifying these disclosures using a deep learning context-based algorithm that is able to interpret words in their context superior to keyword-based approaches (Kölbel et al., 2024). For example, while other methods might encode the word "environment" similarly in the phrases "working environment improvements for employee productivity" and "green environment initiatives in urban planning," context-based algorithms like BERT and GPT consider the context and provide distinct representations for "environment" in each phrase.

Third, we complement the existing literature, which predominantly examines the relevance of disclosing greenhouse gas emissions—the firm's direct impact on climate change (e.g., (Aswani et al., 2024; Bolton & Kacperczyk, 2021; Choi & Luo, 2021; Clarkson et al., 2015; Griffin et al., 2017; Hsu et al., 2023; Matsumura et al., 2014)—by exploring the informativeness disclosing firms' dependencies on climate change, with a focus on the TCFD framework. Carbon emissions reflect backward-looking operational performance and fail to capture all aspects of climate risk. While they may serve as a reasonable proxy for regulatory risk, they do not indicate a firm's physical risk exposure. The TCFD framework, however, provides forward-looking insights that capture transition risks, physical risks, and potential opportunities arising from climate change (TCFD, 2017). This enhances the existing body of research, as investors are increasingly seeking and incorporating forward-looking information that covers all aspects of climate change.

Fourth, our research extends the existing body of work on the informativeness of corporate disclosures in mainstream reports by employing a narrow-window event study methodology. This encompasses Management's Discussion and Analysis (MD&A) disclosures (S. V. Brown & Tucker, 2011) and risk disclosures (Beatty et al., 2019; Campbell et al., 2014, 2019; Filzen, 2015; Hope et al., 2016). Although these studies generally find that such disclosures are informative, Beatty et al. (2019) note a decline in the informativeness of risk disclosures following the 2009 financial crisis. This study advances the literature by specifically examining the informativeness of climate risk disclosures in corporate annual reports. Climate-related financial risks are fundamentally different from many other risks routinely priced by markets, often involving considerably more complex underlying factors. Investors tend to underreact to complex disclosures in 10-K filings (You & Zhang, 2009). Moreover, mainstream corporate risk

reporting is continually evolving to address the limitations of its own approach to materiality, which may be more pronounced for climate risks. The impacts of climate-related issues are not always clear or direct (TCFD, 2017), and they necessitate substantially extended time horizons (Carney, 2015) to internalise. This complexity, along with a lack of agreement on materiality, can lead to non-material disclosures driven by concerns about litigation.

Finally, our study contributes to policymaking on climate risk disclosures in regulatory filings by addressing the debate surrounding the usefulness of TCFD reporting, which forms the foundation of the newly established climate-related disclosure rules by the SEC. It also touches on the criticisms currently facing the SEC regarding existing climate disclosures in regulatory filings. Our study provides empirical evidence suggesting that the TCFD-support results in a higher level of disclosure, and the market reacts positively to this transparency.

2. TCFD Framework and Hypotheses Development

2.1. TCFD Framework

The final TCFD recommendations, published in June 2017, aimed to provide a robust framework for companies to disclose consistent, comparable, and decision-useful climate-related financial information (TCFD, 2017). The Task Force sought to balance the needs of users (investors, lenders, and insurance underwriters) with the challenges faced by preparers, recognising companies' concerns regarding the burdens imposed by multiple disclosure frameworks and investors' frustrations with non-comparable reporting. To address these issues, the Task Force developed a unified and accessible framework intended to align existing climate-related disclosure regimes (TCFD, 2023).

The TCFD broadens the scope of climate-related matters for all companies by shifting the focus from reporting a firm's impact on climate change—typically disclosed by those with significant climate-related impacts, such as greenhouse gas emissions—to reporting financial risks and opportunities stemming from climate change's effects on a company's operations. Even companies with net-zero emissions remain exposed to climate risks due to global emissions from all sectors (Unerman et al., 2018).

The 2017 framework recommended that firms disclose climate-related financial information across four key areas: governance, strategy, risk management, and metrics and targets. Specific recommended disclosures within each area are outlined in Figure 1[2].

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material.	Disclose how the organization identifies, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.
Recommended Disclosures	**Recommended Disclosures**	**Recommended Disclosures**	**Recommended Disclosures**
a) Describe the board's oversight of climate-related risks and opportunities.	a) Describe the climate-related risks and opportunities the organization has identified over the short, medium, and long term.	a) Describe the organization's processes for identifying and assessing climate-related risks.	a) Disclose the metrics used by the organization to assess climate-related risks and opportunities in line with its strategy and risk management process.
b) Describe management's role in assessing and managing climate-related risks and opportunities.	b) Describe the impact of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.	b) Describe the organization's processes for managing climate-related risks.	b) Disclose Scope 1, Scope 2, and, if appropriate, Scope 3 greenhouse gas (GHG) emissions, and the related risks.
	c) Describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios, including a 2°C or lower scenario.	c) Describe how processes for identifying, assessing, and managing climate-related risks are integrated into the organization's overall risk management.	c) Describe the targets used by the organization to manage climate-related risks and opportunities and performance against targets.

Figure 1: Recommendations and Supporting Recommended Disclosures.

The TCFD recommendations (TCFD, 2017) have become central to climate risk reporting, with major sustainability reporting frameworks now referencing them to align their guidance. In the U.S., the SEC issued new climate-related disclosure regulations in 2024, explicitly integrating the TCFD framework to standardise climate reporting practices. Additionally, the International Sustainability Standards Board (ISSB), supported by the International Organisation of Securities Commissions (IOSCO) and various national regulators, has released the IFRS S2 climate disclosure standard based on TCFD recommendations. Following the ISSB's publication of this TCFD-aligned climate-related disclosure standard, the Financial Stability Board (FSB) considers the TCFD's mission complete and has transferred its responsibilities to the ISSB (IFRS, 2023).

2.2. Hypotheses Development

[2] Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures. 2017. Retrieved October 2, 2024, from https://assets.bbhub.io/company/sites/60/2021/10/FINAL-2017-TCFD-Report.pdf.

Our first hypothesis examines whether supporting the TCFD framework leads to more comprehensive climate-related disclosures in the annual reports of TCFD-supporting firms compared to those of non-supporting firms. While Regulation S-K mandates that managers disclose all material risks, including climate risks, the multifaceted nature of climate risk—with often unclear or indirect impacts on firms (TCFD, 2017) and uncertainties around timing, scale, and pace—poses challenges in making materiality judgements on climate-related issues. Coupled with a lack of consensus on materiality approaches in mainstream reporting (CDSB, 2018; Edgley et al., 2015), this has created an environment where firms may view climate reporting as largely voluntary. Consequently, the decision to disclose climate risks in annual reports often hinges on an analysis of the associated costs and benefits. Prior research suggests that managers typically exhibit a self-serving bias (e.g., Healy & Palepu, 2001), tending to disclose favourable information, which creditors, boards, labour unions, and capital markets all use in various decision-making processes. Given that climate risks are frequently perceived as negative factors that can adversely impact firm value—due to potential physical damage to facilities, workforce disruptions, supply chain interruptions, regulatory costs, increased insurance expenses, reputational damage, and other future costs—it is not surprising that managers may prefer vague, boilerplate statements over meaningful climate risk disclosures. Furthermore, climate reporting may reveal proprietary insights to competitors or investors, leading managers to avoid such disclosures. The incentive to withhold unfavourable information may be counterbalanced by potential legal penalties or SEC sanctions for failing to disclose such information, with lengthy climate risk disclosures serving as "the cheapest form of insurance" (Beatty et al., 2019; Huang et al., 2022).

In addition to litigation concerns, the motivation for providing more disclosures can be elucidated through socio-political and legitimacy theories, as well as signalling theory. According to socio-political and legitimacy theories, disclosure is seen as a response to stakeholder pressure, suggesting that increased climate-related disclosures reflect a reaction to growing stakeholder demand for information on how climate change impacts firms. From a signalling theory perspective, firms have an incentive to disclose more climate-related information to signal their commitment to sustainability to society and their stakeholders. Therefore, both TCFD-supporting and non-supporting firms have incentives to enhance

their climate-related disclosures. The TCFD's 2023 status report indicates an increasing trend in the level of climate reporting over the six years since the launched of TCFD framework. Additionally, Bingler et al. (2022) observe a slight increase (approximately 2.2%) in disclosures by TCFD-supporting firms post-2017. Given the general upward trend in text disclosures reported in the literature (e.g., Beatty et al., 2019; Dyer et al., 2017), this increase in climate reporting for TCFD-supporting firms may reflect this broader trend, which could also be occurring among non-supporters. Consequently, there may be no significant difference between TCFD supporters and non-supporters regarding climate reporting, with TCFD support potentially serving as a form of greenwashing. Thus, TCFD-supporting firms may have an incentive to signal their focus on managing climate-related issues to capital markets merely by supporting the TCFD, without substantial differences compared to non-supporters. Therefore, it is not evident that supporting the TCFD leads to more comprehensive climate reporting for supporters compared to non-supporters, especially considering that climate-related financial risks are highly complex, long-term, and may necessitate in-depth technical analysis beyond the expertise of corporate disclosure preparers.

However, in 2017, the TCFD aimed to balance the needs of disclosure users with the challenges faced by preparers by developing a unified, accessible framework that builds on existing climate reporting frameworks. If these goals are achieved, TCFD support should indeed lead to more comprehensive climate reporting for several reasons. Firstly, by leveraging existing climate reporting regimes, the administrative burden and disclosure costs for preparers are expected to increase only minimally, suggesting that preparation costs may not prevent TCFD-supporting firms from disclosing more comprehensive climate information. Secondly, the accessible framework ensures that climate reporting is not confined to firms with significant climate-related impacts, such as greenhouse gas emissions; rather, it encourages companies to assess the effects of climate change on their operations. This means that TCFD-supporting firms should disclose risks arising not only from their own emissions but also from global emissions collectively. Consequently, even if a firm achieves net-zero emissions, it remains exposed to climate risks stemming from the activities of others. Thus, TCFD support compels firms without a high impact on climate—who may not have reported climate risks previously—to disclose risks arising from others. Thirdly, the TCFD encourages firms to consider climate-related issues that may become material

in the future. The TCFD also recommends that disclosures on risk and governance be regarded as material in all cases, given that climate risk is non-diversifiable (TCFD, 2017). For TCFD-supporting firms, materiality assessments of certain climate-related risks and governance issues may deem them immaterial in boardrooms; nevertheless, these risks still need to be disclosed. As a result, such reporting can lead to increased disclosures, even if these risks were not previously considered material and had not been reported prior to supporting the TCFD. Fourthly, TCFD-supporting firms are required to disclose climate information in their annual reports. Since climate reporting in mainstream channels is not common practice, and firms typically do not disclose climate information through these channels (O'Dwyer & Unerman, 2020), TCFD support can lead to a higher level of disclosure in annual reports compared to non-supporters by simply transferring existing information from sustainability reports to annual reports. Therefore, our first hypothesis is as follows:

H1: TCFD-supporting firms increase the level of climate-related disclosure in their annual reports following the launch of the TCFD framework in 2017, compared to non-supporters.

Even if TCFD-supporting firms disclose more climate information following the launch of the TCFD framework, it remains unclear whether these disclosures are informative for investors. The increase in climate disclosures may reflect either new information, potentially revealing previously unknown climate risks and opportunities, or a growing number of non-material disclosures, or the transfer of already known information from sustainability reports to annual reports. Therefore, the second hypothesis of this study centres on whether changes in climate-related disclosures by TCFD-supporting firms are material enough to influence investors' decisions and trigger market reactions, or if they merely reflect an increase in the quantity of non-material information.

Previous studies document market responses to risk disclosures in 10-K filings (Beatty et al., 2019; Campbell et al., 2014, 2019; Filzen, 2015; Hope et al., 2016). However, climate-related financial risks differ fundamentally from many other risks routinely priced by markets, often involving more complex and underlying factors. Investors tend to underreact to complex disclosures in 10-K filings (You & Zhang, 2009). Furthermore, it has been argued that TCFD recommendations are predominantly

conceptual, which could result in disclosures that are excessively detailed and technical (Jona & Soderstrom, 2023). Prior research suggests that information that is costly to extract from financial reports is less effectively incorporated into market prices (Bonsall IV et al., 2017; Lee, 2012). Consequently, the complex and technical nature of TCFD reporting may hinder the immediate incorporation of new material information into market prices. Moreover, this complexity may fall outside the expertise of preparers, making it more challenging to implement substantial changes in climate reporting. As mainstream corporate risk reporting continues to evolve and address its limitations related to materiality, there is a risk that these limitations may be transferred to TCFD disclosures. This concern is heightened by the fact that the impacts of climate-related issues are often unclear or indirect (TCFD, 2017) and require significantly extended time horizons for proper internalisation (Carney, 2015). Consequently, the interplay between the complexity of TCFD reporting and a lack of consensus on materiality may impede meaningful progress in improving the quality of climate reporting by preparers.

On the other hand, by focusing on the needs of capital providers, including investors, the TCFD aims to enhance the quality of mainstream financial disclosures and provide a unified, standardised framework for companies to disclose consistent, comparable, and decision-useful climate-related financial information (TCFD, 2017). If the TCFD achieves its goals, disclosures by TCFD-supporting firms should have greater informational content, and investors should therefore pay more attention to such disclosures. Furthermore, based on the TCFD principles for effective disclosure underpinning its recommendations, firms are required to disclose the specific climate-related risks and opportunities to which their organisation is exposed (TCFD, 2017). Previous studies have shown that greater specificity leads investors to place more weight on disclosed risk information, facilitating the incorporation of this information into stock prices, and resulting in a stronger market reaction to more specific disclosures (Hope et al., 2016).

The literature documents a negative association between market valuation and both general risk disclosures (Campbell et al., 2014; Filzen, 2015; Beatty et al., 2019) and climate-related extreme weather risk disclosures (Griffin et al., 2023; Nagar & Schoenfeld, 2024) in annual reports. This negative market response arises from the fact that such disclosures often highlight the adverse aspects of risk (bad news),

which is typically associated with higher volatility of future earnings, leading to an increased uncertainty premium. However, the TCFD framework stipulates that firms should not only disclose the specific climate-related risks and opportunities but also provide detailed information on their strategic and risk management decisions regarding these risks (e.g., mitigation, transfer, acceptance, or control) and the steps they plan to take to seize these opportunities. As such, this could result in highlighting the positive aspects of climate-related issues, rather than the adverse aspects, thereby signalling good news. Furthermore, standardised disclosures, which facilitate cross-company comparisons of climate-related information, and a higher degree of specificity regarding these risks and opportunities, are expected to reduce variance in the uncertainty premium and, consequently, the expected cost of capital. This, in turn, would lead to higher stock prices and abnormal returns for firms adhering to the TCFD framework, relative to those that do not. This expectation aligns with theoretical perspectives suggesting that enhanced disclosure has a unidirectional effect on firm value by reducing the cost of capital (e.g., S. Brown, 1979; Diamond & Verrecchia, 1991; Easley & O'hara, 2004). Therefore, we expect to observe a positive association between market reactions and changes in climate reporting following the 2017 launch of the TCFD framework for supporters. Our second hypothesis is formulated as follows:

H2: There is a positive and significant association between investor responses and enhancements in climate reporting within annual reports by TCFD-supporting firms, compared to non-supporting firms.

Testing the above hypothesis by comparing market responses to changes in climate reporting between TCFD-supporting and non-supporting firms not only evaluates whether the TCFD has achieved its goals in advancing the quality of mainstream climate reporting but also seeks to address an unresolved question in the literature: whether standardised or customised disclosures are more informative (Dyer et al., 2017), given that the TCFD framework mandates standardised disclosure.

3. Data and Research Design

3.1. Sample selection

In this study, data on U.S. firms' fiscal years from 2011 to 2022, spanning a 12-year period surrounding the TCFD's launch in 2017, are collected from various sources. As the focus of this study is to investigate the impact of TCFD support, and given that supporters are required to disclose climate-

related information in their annual reports, we use 10-K filings as the primary source of climate reporting. Our sample initially includes 51,628 annual reports from all firms, filed between 2012 and 2023 on the SEC EDGAR platform, provided their filings contain disclosures related to business descriptions (Item 1), risk factors (Item 1A), and Management's Discussion and Analysis (MD&A—Item 7). We extract Items 1, 1A, and 7 from the 10-K filings, as the SEC's 2010 interpretive guidance identifies these sections as the most relevant for climate change disclosures (Eccles & Krzus, 2018; Matsumura et al., 2022).

Upon extracting and cleaning the text from the relevant items of the 10-K filings, BERT-like models fine-tuned by Bingler et al. (2023)—specifically ClimateBERT/DistilRoBERTa-Base-Climate-Detector and ClimateBERT/DistilRoBERTa-Base-Climate-TCFD—are employed to score total climate disclosures and TCFD pillars. The Climate-Detector model classifies the extracted paragraphs into climate-relevant and non-climate-relevant categories. Subsequently, the Climate-TCFD model further classifies the climate-relevant paragraphs into the four TCFD recommendation categories. To obtain a firm-level measure for non-climate, climate, and TCFD pillar disclosures, the total number of words classified as non-climate-related, climate-related, and within each TCFD disclosure category are aggregated to generate overall scores, considering both length and relevance.

The scoring using these BERT models is validated by comparing their performance to that of the GPT-4 model, using 241 paragraphs from TCFD annual status reports for the years 2020–2023 as the dataset. While the results indicate promising performance in classifying paragraphs as climate-related or non-climate-related for the GPT-4 model, with an accuracy of 89%, the Climate-Detector model further improves this result by reducing the misclassification rate by 81%. For classifying TCFD pillars, the Climate-TCFD model outperforms the GPT-4 model, achieving an overall accuracy of 87% compared to the GPT-4 model's accuracy of 53%. Appendix A provides examples of firm-level scores, and Appendix B includes details on the validation test.

To collect TCFD support data, we use both TCFD-provided lists and hand-collected information from SEC EDGAR, employing a search rubric with the term "TCFD." This approach includes firms that have not officially informed TCFD of their support. ESG data are obtained from Sustainalytics, while data on institutional ownership, filing dates, and 8-K filings come from SEC EDGAR. Accounting items,

share prices, and analyst data are retrieved from the Center for Research in Security Prices (CRSP), I/B/E/S, and Compustat databases. The data are merged using various company identifiers, including CIK, Gvkey, Permno, CUSIP, and ticker, resulting in a sample of 45,767 firm-year observations. To mitigate the impact of outliers and ensure the robustness of the regression results, all continuous variables are winsorised at the 1st and 99th percentiles.

3.2 Research Design

Disclosure Dynamics: The Role of TCFD Support

Exploiting the launch of the TCFD framework in 2017 as a quasi-natural experiment, we employ a difference-in-differences (DiD) approach to establish a causal relationship between TCFD support and the extent of climate reporting. We analyse changes in climate disclosures in 10-K filings for treatment firms (those supporting TCFD) before and after the framework's introduction and compare them to the corresponding changes in control firms during the same period. The DiD effect captures the differential changes in climate reporting between treatment and control firms from the pre- to post-launch period of the framework.

The DiD method allows us to control for potential time trends related to climate change matters that are independent of the TCFD framework, such as societal carbon awareness or firms' green motives, both of which typically exhibit an increasing trend over time. By comparing the disclosure changes between treatment and control firms, we account for potential confounding factors (e.g., concurrent economic or regulatory changes) that impact all firms, as changes in climate reporting for control firms likely reflect such effects. Therefore, the DiD design isolates the effects of TCFD support on climate disclosures. Our DiD model is presented below:

$$\textit{Climate Risk disclosure} = \alpha + \beta 1\ \textit{Treatment}_i + \beta 2\ \textit{Post} + \beta 3\ \textit{Treatment}_i \times \textit{Post} + \gamma\ \textit{Controls}_{it} + \varepsilon_{it}$$

Where *Climate Risk disclosure* refers to the total amount of climate-related disclosures, encompassing both the overall climate risk disclosure and the individual TCFD pillars: Governance, Strategy, Risk Management, and Metrics. The variable *Treatment* is a binary indicator, which equals one for TCFD-supporting firms and zero otherwise, while *Post* is a binary indicator that equals one for the period after 2017 and zero otherwise. The interaction term *Treatment* × *Post* is the key variable of

interest; its coefficient captures the change in climate disclosures reporting after 2017 for treatment firms relative to control firms. We expect β3 to be positive.

Following the literature, we control for the determinants of voluntary climate-related disclosure in annual reports, including total non-climate disclosures (*Non-climate disclosure*), Environmental, Social, and Governance scores (*ESG*), the ratio of firms providing climate risk disclosures to the total number of firms in the industry (*PropDis*), R&D expenses (*RD*), current performance (*ΔEarnings*), total accruals (*Accrual*), the book-to-market ratio (*BTM*), firm size (*Size*), past performance (*PastLoss*), the number of business segments (*Segment*), the number of data items in COMPUSTAT (*NumItem*), leverage (*LEV*), a high institutional ownership indicator (*InsInvestors*), the number of analysts following (*NumAnalyst*), the number of 8-K filings (*Num8K*), litigation risk (*Litigation*), a Big N auditor indicator (*Big4*), and stock-return volatility (*RetVolatility*). To control for time trends in disclosures and other unobservable time-invariant industry or firm characteristics that might impact voluntary disclosures, we also include year fixed effects and, alternatively, industry and firm fixed effects in the model. All of the t-statistics are based on standard errors clustered at the firm level, and all variables are defined in Appendix C.

Market reaction to changes in unexpected climate risk disclosure

To test our second hypothesis, which examines the market response to the information content of climate reporting in annual reports post-2017 for supporters compared to non-supporters, we estimate the following model. We regress three-day abnormal returns and abnormal trading volume around the 10-K filing date on the unexpected changes in climate risk disclosures for the years following the launch of the TCFD for both supporters and non-supporters.

$$\boldsymbol{AR^{10K}_{-1,+1}}_{it} = \boldsymbol{\alpha + \beta 1\ \Delta climateRiskDisclousre_{it} + \ IndustryEffects} + \varepsilon_{it}$$

Where *AR* refers to the three-day abnormal return, with the three-day window beginning one trading day before the 10-K release. Following Campbell et al. (2014), the expected return is calculated using the firm's loading on the market return and the returns from two hedge portfolios (HML and SMB from the Fama-French database), measured over the previous 250 trading days. In addition to abnormal returns, three-day abnormal trading volume is used as an alternative measure of stock market reaction. Following Hope et al. (2016), abnormal trading volume is calculated as the average daily trading volume

in the three-day event window [-1, +1] minus the average daily trading volume in the [-60, -11] window, scaled by the trading volume in the [-60, -11] period.

We use unexpected changes in climate disclosures to identify meaningful shifts in climate information and to mitigate boilerplate issues associated with non-financial reporting. To measure unexpected climate-related disclosures (*ΔclimateRiskDisclousre*), we follow Campbell's (2014) approach by using the residuals from regressing climate disclosures on lagged climate disclosures and the determinants of voluntary climate disclosures, estimating the following model:

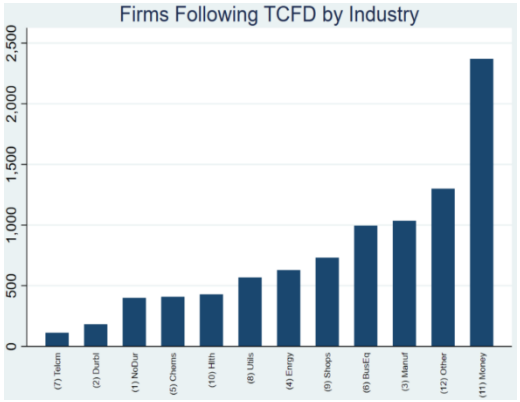
$$\boldsymbol{ClimateRiskDisclousre_{it} = \alpha + \beta 1\ ClimateRiskDisclousre_{it-1} + \gamma\ Controls_{it}}$$

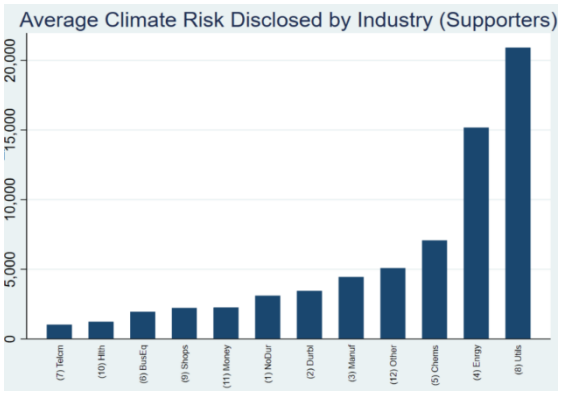
Where *ClimateRiskDisclosure* refers to the total amount of climate-related disclosures, encompassing both the overall climate risk disclosure and the individual TCFD pillars, the controls are the determinants of voluntary climate disclosures as defined previously.

4. Empirical Results

4.1. Climate reporting in practice for both TCFD-supporters and non-supporters

Figure 1 presents the number of TCFD-supporting firms (treated firms) in our sample for each industry, along with the total climate disclosures in the annual reports of these firms within each industry.

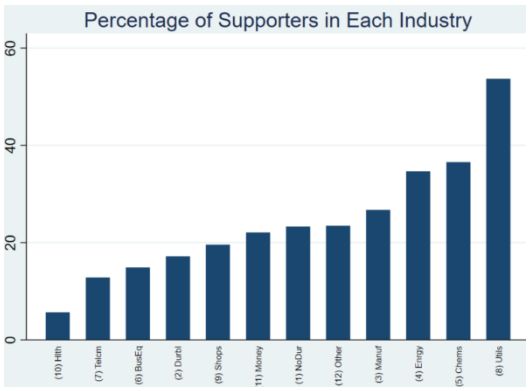




As shown in Figure 1, a significant portion of TCFD-supporting firms in our firm-year observations originates from the financial industry. However, firms in polluting industries disclose a greater volume of climate-related information. These industries are subject to stricter climate disclosure requirements (e.g., reporting under the Toxic Release Inventory) and face increased pressure from stakeholders to provide such disclosures. For example, Grewal et al. (2021) document that ExxonMobil

consistently offers a high level of ESG disclosures. Additionally, tracking relevant greenhouse gas (GHG) emissions is relatively straightforward in these sectors, resulting in lower information costs for gathering climate data.

Figure 2 compares the number of TCFD-supporting firms to non-supporting firms by industry, as well as the total climate disclosures reported by these two groups within each industry. The figure reveals that although only 25% of firms in the financial sector support the TCFD, these supporters disclose approximately twice as much climate-related information as non-supporters. Additionally, while a larger proportion of firms in high-polluting industries (Utilities, Chemicals, and Energy) support the TCFD, their disclosure levels are comparable to non-supporters in the Chemicals sector and slightly lower in the Energy sector.



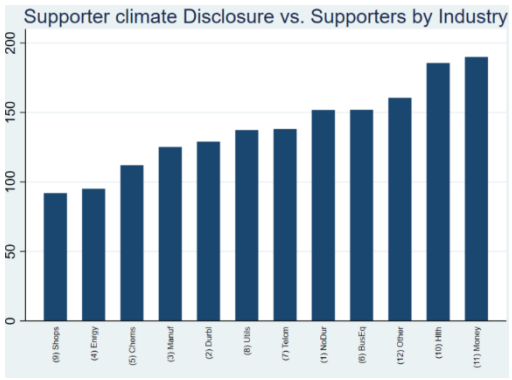
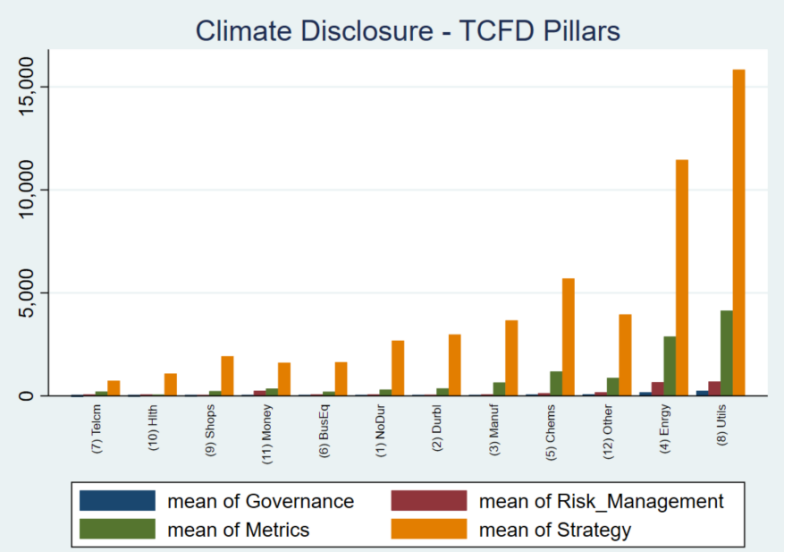
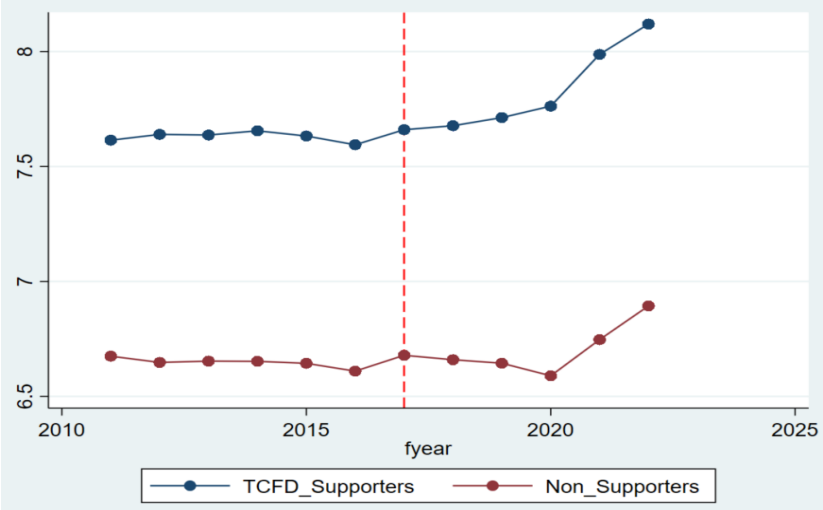


Figure 3 shows that across all industries, TCFD-supporting firms disclose more information on the Strategy pillar, followed by Metrics, Risk Management, and Governance. This finding is consistent with reports from the TCFD in their annual status updates for 2021, 2022, and 2023. According to these reports, companies are more likely to disclose information regarding their climate-related risks and opportunities (Strategy a) than on any other recommended disclosures. Additionally, in line with TCFD implementation guidance, more detailed explanations are required for strategy disclosures, followed by metrics, risk management, and governance. This trend likely contributes to a greater prevalence of climate-related paragraphs within these pillars in annual reports.



4.2. Trend for climate reporting for both TCFD-supporters and non-supporters

Figure 4 presents the time trend of climate disclosure for TCFD-supporting and non-supporting firms over a 12-year period surrounding the launch of the TCFD framework.



As shown in Figure 4, there is a general upward trend in the proportion of climate reporting across all firms, with TCFD-supporting firms disclosing more climate information over time. Climate disclosures for both supporters and non-supporters appear to trend at the same rate in the years preceding 2017, thereby supporting the parallel trends assumption for the difference-in-differences approach. However, after 2017, climate reporting for TCFD supporters increases, while no such increase is observed among non-supporters. This suggests that 2017 marks a significant increase in climate reporting for the treatment group, but not for the control group.

To further assess the parallel trends assumption, we follow Almeida et al. (2009) by modifying the breakpoint for the Post variable to 2016, 2015, and 2014. This adjustment allows us to demonstrate that the observed effect is isolated to periods occurring only after the launch of the TCFD framework. Results reported in Table 4 indicate that the coefficient on the interaction term is insignificant for the years preceding 2017, implying parallel trends in climate disclosures for treatment and control firms prior to the launch of the TCFD framework. Therefore, the difference in the real effects of TCFD support between supporters (treatment) and non-supporters (control) is observed only after the framework is introduced.

4.3. Descriptive statistics

Table 1, Panel A, presents the full-sample descriptive statistics for the key variables, while Panel B shows the pairwise correlations between climate-related disclosures and the factors influencing them. As shown in Panel A, the mean values for climate reporting are generally lower compared to non-climate disclosures. However, the standard deviations for climate reporting are large—approximately twice the mean—whereas the standard deviations for non-climate disclosures are about half the mean. This suggests that, while there is little variation across firms in terms of non-climate disclosures, there is considerable variation in climate reporting. This indicates that climate disclosures are not widely adopted by public firms in the U.S. during our sample period, leaving substantial room for improvement. Additionally, we identify treatment firms, which account for 29.72% of the total observations. Approximately 20% of observations are from the post-period following the launch of the TCFD framework.

Table 1- Panel A Descriptive Statistics

	N	Mean	SD	Min	p25	Median	p75	Max
Non-ClimateDisclo	45767	26.297	14.214	0	16.36	23.584	33.289	144.1
ClimateDisclo	45767	2.972	5.189	0	.423	1.027	2.726	87.418
Treatment	45767	.2	0.400	0	0	0	0	1
Post	45767	.473	0.499	0	0	0	1	1
GovDisclo	45767	.034	0.110	0	0	0	0	3.395
RiskDisclo	45767	.115	0.270	0	0	0	.116	4.061
StraDisclo	45767	2.384	4.067	0	.33	.863	2.265	58.191
MetrDisclo	45767	.439	1.081	0	0	.052	.312	26.842
ESG	44829	47.139	13.287	7.3	37.87	50	56	91
InsInvestors	45767	.444	0.497	0	0	0	1	1
PropDis	45767	.109	0.135	.007	.028	.058	.146	.659
RD	45767	.061	0.141	0	0	0	.047	.834
ΔEarnings	40726	.017	0.771	-65.401	-.026	.003	.03	38.64
Accrual	45474	-.062	0.132	-.765	-.088	-.04	-.006	.298
BTM	45620	.582	0.597	-.907	.22	.463	.813	3.39
LogMV	45701	6.737	2.178	.274	5.195	6.775	8.232	14.744
PastLoss	45767	.541	0.498	0	0	1	1	1
Segment	45767	1.445	0.632	0	.693	1.386	1.946	4.174

LEV	45638	.385	0.343	0	.089	.351	.567	1.825
Litigation	45767	.301	0.458	0	0	0	1	1
Big4	45701	7.89	4.753	0	5	6	9	26
NumAnalyst	44400	8.278	7.902	0	2	6	12	58
NumItem	45767	197.63	39.803	5	169	198	227	321
Num8K	45208	3.331	5.912	0	0	0	6	64
RetVolatility	34529	.001	0.007	0	0	0	.001	.815
$ABVOL_{-1,+1}^{10K}$	41727	.628	1.588	-.885	-.189	.188	.839	10.23
$CAR_{-1,+1}^{10K}$	34529	0	0.088	-.879	-.026	-.001	.023	3.62
$BHAR_{-1,+1}^{10K}$	34529	0	0.089	-.722	-.026	-.002	.022	3.873
$SCAR_{-1,+1}^{10K}$	34529	.008	1.759	-28.215	-.681	-.033	.656	79.576

Table 1- Panel B: Correlation Matrix

Variables	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23
(1) Non-ClimDis	1																						
(2) ClimateDis	-0.20***	1																					
(3) GovDisclo	-0.09***	0.53***	1																				
(4) RiskDisclo	-0.02***	0.64***	0.40***	1																			
(5) StraDisclo	-0.20***	0.99***	0.50***	0.58***	1																		
(6) MetrDisclo	-0.18***	0.87***	0.44***	0.59***	0.79***	1																	
(7) ESG	-0.14***	0.11***	0.01*	0.06***	0.10***	0.14***	1																
(8) InsInvestors	0.08***	0.03***	0.05***	0.02***	0.03***	0.01***	-0.15***	1															
(9) PropDis	-0.39***	0.76***	0.40***	0.44***	0.76***	0.67***	0.16***	0.02***	1														
(10) RD	0.30***	-0.17***	-0.09***	-0.13***	-0.17***	-0.15***	0.02***	-0.11***	-0.22***	1													
(11) ΔEarnings	-0.01***	0.02***	0.01***	0.01***	0.02***	0.01**	0.01*	0	0.02***	-0.03***	1												
(12) Accrual	-0.02***	-0.05***	-0.01**	-0.03***	-0.05***	-0.03***	-0.01	0.07***	-0.03***	-0.26***	0.17***	1											
(13) BTM	-0.02***	0.06***	0.04***	0.08***	0.06***	0.06***	0.02***	-0.16***	0.06***	-0.17***	-0.01	0.11***	1										
(14) LogMV	0.09***	0.16***	0.12***	0.13***	0.15***	0.16***	-0.06***	0.47***	0.13***	-0.26***	-0.02***	0.16***	-0.30***	1									
(15) PastLoss	0.14***	0.01	-0.01*	-0.02***	0.02***	-0.04***	0	-0.16***	-0.02***	0.32***	0.01***	-0.24***	0.08***	-0.40***	1								
(16) Segment	-0.18***	0.13***	0.09***	0.05***	0.13***	0.12***	0.09***	0.19***	0.19***	-0.24***	0	0.08***	-0.04***	0.38***	-0.13***	1							
(17) LEV	0.06***	0.11***	0.06***	0.04***	0.12***	0.09***	-0.11***	0.09***	0.08***	-0.15***	0.01**	-0.04***	-0.21***	0.17***	-0.01***	0.10***	1						
(18) Litigation	0.21***	-0.23***	-0.13***	-0.19***	-0.22***	-0.20***	-0.01**	-0.01*	-0.31***	0.48***	-0.01***	-0.16***	-0.17***	-0.11***	0.24***	-0.16***	-0.15***	1					
(19) Big4	-0.11***	-0.05***	-0.05***	-0.02***	-0.05***	-0.06***	-0.01***	-0.22***	-0.04***	0	0.01	-0.01**	0.13***	-0.38***	0.06***	-0.16***	-0.10***	-0.04***	1				
(20) NumAnalyst	0.09***	0.14***	0.10***	0.14***	0.13***	0.15***	0.06***	0.32***	0.13***	-0.09***	-0.02***	0.01***	-0.17***	0.70***	-0.19***	0.25***	0.12***	0.05***	-0.30***	1			
(21) NumItem	-0.12***	0.12***	0.08***	0.02***	0.12***	0.11***	0.08***	0.30***	0.18***	-0.23***	-0.01***	0.05***	-0.17***	0.56***	-0.14***	0.64***	0.24***	-0.06***	-0.27***	0.45***	1		
(22) Num8K	0.17***	0.05***	0.09***	0.03***	0.06***	-0.01***	-0.51***	0.16***	0	0.01*	0.01	-0.01***	-0.01	0.16***	0.04***	-0.02***	0.13***	0.01*	-0.03***	0.04***	0.05***	1	
(23) RetVolatility	0.03***	-0.02***	-0.02***	-0.02***	-0.02***	-0.03***	-0.04***	-0.08***	-0.03***	0.11***	-0.01*	-0.08***	0	-0.15***	0.12***	-0.07***	-0.01	0.07***	0.04***	-0.08***	-0.10***	0.01**	1

4.4. Supporting TCFD and Climate Risk Disclosure

Table 2 reports the results of the regression from model (1). As shown in column 1, the coefficient on the key interaction term, $Treatment_i \times Post$, is positive with a magnitude of 0.277 and significant at the 5% level (t-statistic = 2.15). This result indicates that total climate related disclosure significantly improves in treatment firms from the pre- to the post period following the launch of the TCFD framework in 2017, compared to the corresponding change in climate reporting in control firms. This reflects a significant increase in the extend of climate related disclosures induced by the TCFD-framework shock. This finding also aligns with the prediction in H1 that following TCFD result in more comprehensive climate related disclosures.

This result is robust, even after controlling for industry, firm, year, and industry-year fixed effects. While some control variables exhibit insignificant effects on the dependent variables, or their directions are inconsistent with economic expectations, non-climate disclosures, ESG scores, firm size, book-to-market ratio, leverage, the proportion of industry peers disclosing, and segments all show positive and significant relationships with climate reporting. This suggests that firms tend to disclose more climate risk information when they are larger, disclose more non-climate information, carry more debt in their capital structure, have a higher book-to-market ratio, perform better on ESG metrics, have more industry peers disclosing, and operate in more segments. These firms also tend to have lower institutional ownership and lower accruals. Overall, the characteristics of the firms and differences between industries do not account for the actual changes in climate reporting observed in the study.

Table 2: DD Analysis

	(1) ClimateDisclo	(2) ClimateDisclo	(3) ClimateDisclo	(4) ClimateDisclo	(5) ClimateDisclo	(6) ClimateDisclo
Treatment	.41512**	.40504**	.41608**			
	(2.12714)	(2.06276)	(2.11502)			
Post	.00853		23.8662	-.09191**		
	(.14121)		(.4194)	(-2.5201)		
Treatment × Post	.27745**	.29188**	.23163*	.19066*	.20085*	.20862**
	(2.14859)	(2.25934)	(1.83782)	(1.83263)	(1.94421)	(2.30739)
Non-Climate Disclosure	.03275***	.03249***	.03324***	.07537***	.07542***	.07469***
	(7.0983)	(7.01165)	(7.02259)	(6.63136)	(6.60193)	(6.55468)
ESG	.00842***	.0085**	.00772**	-.00209	-.00351*	-.0025
	(2.97251)	(2.5373)	(2.2117)	(-1.31054)	(-1.68714)	(-1.21072)
InsInvestors	-.19426**	-.26578**	-.27635**	-.06338*	-.07383*	-.05463
	(-1.99579)	(-2.21672)	(-2.23205)	(-1.72953)	(-1.6982)	(-1.20476)
PropDis	19.10321***	18.31305***	-28.84458	15.0245***	13.14645***	25.25478
	(6.63342)	(6.0957)	(-.18845)	(6.59265)	(5.52877)	(.25074)
RD	-1.52394***	-1.54809***	-1.57469***	.25151**	.23049**	.10905

	(-4.62367)	(-4.67585)	(-4.66894)	(2.23122)	(2.02086)	(.96629)
ΔEarnings	.05935**	.05764**	.04229*	-.00569	-.00543	-.00875
	(2.14708)	(2.09843)	(1.67685)	(-.60171)	(-.58347)	(-.93484)
Accrual	-1.31237***	-1.30595***	-1.39226***	-.124	-.16322**	-.16978**
	(-5.63916)	(-5.58482)	(-5.75489)	(-1.58085)	(-2.08625)	(-2.18651)
BTM	.39783***	.40493***	.41866***	.12519***	.11381**	.11643**
	(4.05865)	(4.08104)	(4.11981)	(2.80711)	(2.52726)	(2.53727)
LogMV	.24397***	.24647***	.2442***	.07634***	.07705***	.0713***
	(4.61508)	(4.61232)	(4.42128)	(3.30895)	(3.22688)	(2.96991)
PastLoss	.43487***	.44356***	.42926***	-.07325*	-.07344*	-.10871***
	(4.49249)	(4.53269)	(4.2193)	(-1.77654)	(-1.74766)	(-2.7845)
Segment	.21345**	.21194*	.21544**	.18668**	.19524***	.19779***
	(1.97297)	(1.95775)	(1.97933)	(2.56368)	(2.67832)	(2.69845)
LEV	.79407***	.78787***	.81023***	-.01809	-.03614	-.03802
	(5.85362)	(5.79344)	(5.81579)	(-.27076)	(-.53609)	(-.53392)
Litigation	-.45175*	-.44984*	-.44793*			
	(-1.88756)	(-1.8803)	(-1.84154)			
Big4	.01097	.00999	.009	.00505	.00466	-.00067
	(1.15659)	(1.054)	(.93261)	(1.07183)	(.98992)	(-.15437)
NumAnalyst	-.01128	-.01044	-.00893	-.00425	-.00438	-.0009
	(-.97922)	(-.89955)	(-.7479)	(-.62704)	(-.64392)	(-.12691)
NumItem	-.01048***	-.01016***	-.01035***	.00217	.00257*	.00299**
	(-4.41891)	(-4.2286)	(-4.25445)	(1.47701)	(1.74172)	(2.30902)
Num8K	.01385**	.0144*	.01532*	.00467	-.00304	.00296
	(2.52494)	(1.81172)	(1.854)	(1.22929)	(-.60727)	(.59236)
RetVolatility	4.79309*	4.96872*	5.1504**	-1.85013**	-1.20351	-1.80024**
	(1.89135)	(1.92835)	(1.99497)	(-2.3491)	(-1.58495)	(-2.10472)
Constant	-.55795	-.60556	5.04367	-1.76281***	-1.55848***	-1.9914
	(-.63117)	(-.66853)	(.2607)	(-3.51044)	(-3.0718)	(-.27202)
Observations	30518	30518	30518	30604	30604	30518
R-squared	.62229	.62252	.62715	.0801	.08324	.1142
Industry FE	YES	YES	NO	NO	NO	NO
Firm FE	NO	NO	NO	YES	YES	YES
Year FE	NO	YES	NO	NO	YES	YES
Industry-Year FE	NO	NO	YES	NO	NO	YES

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1*

Table 3 presents the results from model (1), focusing on the composition of total climate disclosures for individual TCFD pillars, including Governance, Strategy, Risk Management, and Metrics. The coefficient on $Treatment_i \times Post$ for Governance, Strategy, and Risk Management is positive and significant, with values of 0.025, 0.020, and 0.28 (t-statistics of 5.74, 2.40, and 2.82, respectively). This indicates that TCFD-supporting firms disclose more information related to these pillars following the launch of the TCFD framework. However, there is no significant impact of TCFD adoption on Metrics disclosures.

The Metrics pillar requires firms to report their greenhouse gas (GHG) emissions, the metrics used to assess climate-related risks, and targets along with performance against those targets (which are often based on emissions, e.g., achieving net-zero emissions by 2040). In the U.S., many companies are already required to report their emissions, for instance, to the U.S. Environmental Protection Agency starting in 2010 (U.S. Federal Register, 2009). Furthermore, prior to 2017, many existing climate-related standards focus on the disclosures of climate-related information, such as GHG emissions and other sustainability metrics (TCFD, 2017). As a result, the introduction of the TCFD framework may not significantly influence the extent of disclosures under the Metrics pillar.

Table 3: DD Regression-TCFD Pillars

	(1) GovDisclo	(2) RiskDisclo	(3) StraDisclo	(4) MetrDisclo
Treatment	.00229	.02778**	.26177*	.12328**
	(.4429)	(2.54977)	(1.68856)	(2.53301)
Post	-.00283	-.00883**	.09759**	-.0774***
	(-1.62308)	(-2.34202)	(1.98836)	(-5.63842)
Treatment × Post	.02458***	.0195**	.28127***	-.04789
	(5.7371)	(2.40266)	(2.82311)	(-1.28416)
Non-Climate Disclosure	.00036***	.00197***	.02658***	.00384***
	(2.60725)	(6.59345)	(7.17255)	(3.94414)
ESG	.00002	.0003*	.00705***	.00104
	(.20838)	(1.81489)	(3.10635)	(1.55228)
InsInvestors	.00551**	-.00267	-.13255*	-.06454***
	(2.34101)	(-.5003)	(-1.68157)	(-2.99925)
PropDis	.29245***	.46009***	13.52324***	4.82743***
	(3.14929)	(2.58683)	(5.86624)	(6.21752)
RD	-.00644	-.07371***	-1.30054***	-.14324***
	(-.91587)	(-4.88396)	(-4.61515)	(-2.72241)
ΔEarnings	.00117	.00357	.05058**	.00403
	(1.29439)	(1.63326)	(2.11563)	(.79223)
Accrual	-.00449	-.06253***	-1.04402***	-.20133***
	(-.89314)	(-4.86065)	(-5.33614)	(-4.48457)
BTM	.00406*	.00815*	.30872***	.0769***
	(1.77627)	(1.73096)	(3.81584)	(3.82605)
LogMV	.00181	.01037***	.18019***	.05161***
	(1.63666)	(3.54149)	(4.25951)	(4.48792)
PastLoss	.00536**	.01198**	.38252***	.03501*
	(2.17509)	(2.27828)	(4.8627)	(1.74784)
Segment	.00438	-.00079	.14305	.06681***
	(1.33107)	(-.13501)	(1.61614)	(2.91947)
LEV	.00127	.00404	.69363***	.09513***
	(.41245)	(.58008)	(6.27052)	(3.53442)
Litigation	-.02449***	-.03729**	-.33163*	-.05834
	(-2.641)	(-2.45829)	(-1.66433)	(-1.62457)
Big4	-.00015	.00126**	.00964	.00022
	(-.73868)	(2.00305)	(1.21231)	(.1133)
NumAnalyst	-.00019	-.00042	-.00774	-.00292
	(-.65813)	(-.59223)	(-.86727)	(-1.09012)
NumItem	-.00002	-.00045***	-.00908***	-.00093*
	(-.30134)	(-4.02807)	(-4.73811)	(-1.83725)
Num8K	.00103***	.00032	.01522***	-.00271**
	(5.26224)	(.71984)	(3.43626)	(-2.30684)
RetVolatility	.04576	.24773*	3.90329*	.59631*
	(1.03629)	(1.82702)	(1.71772)	(1.81348)
Constant	-.05747**	-.05172	.15341	-.60218**
	(-2.52097)	(-.95468)	(.21431)	(-2.30359)
Observations	30518	30518	30518	30518
R-squared	.2063	.33753	.60045	.52441
Industry FE	YES	YES	YES	YES
Firm FE	NO	NO	NO	NO
Year FE	NO	NO	NO	NO

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1

To determine whether changes in climate reporting are truly driven by the introduction of the TCFD framework, we rerun the DiD test using 2014, 2015, and 2016 as hypothetical implementation years for the framework. If the launch of the TCFD framework is the primary cause of the observed findings, we would expect no significant results using these hypothetical implementation years. Table 4 shows that rerunning the tests with these hypothetical implementation years yields no significant results for the coefficient of interest ($Treatment_i \times Post$), suggesting that the observed difference in climate reporting changes between supporters (treatment) and non-supporters (control) occurs only after the actual launch of the TCFD framework.

Table 4: Parallel Trend- DD Regression -Validity Test

	(1) ClimateDisclo	(2) ClimateDisclo	(3) ClimateDisclo	(4) ClimateDisclo	(5) ClimateDisclo	(6) ClimateDisclo
Treatment	.45241**	.43747**	.47481**			
	(2.24959)	(2.17878)	(2.31655)			
Post 2016	.02007			.99446		
	(.34969)			(.94592)		
Treatment × Post 2016	.1595			.14395		
	(1.17018)			(1.5495)		
Post 2015		.06795			-.32827	
		(1.14232)			(-.392)	
Treatment × Post 2015		.15926			.13582	
		(1.21792)			(1.48698)	
Post 2014			.06543			.07339
			(1.05276)			(.07773)
Treatment × Post 2014			.08448			.1267
			(.64994)			(1.35321)
Controls	Included	Included	Included	Included	Included	Included
Observations	30518	30518	30518	30518	30518	30518
R-squared	.62222	.62225	.62221	.11375	.11368	.1136
Industry FE	YES	YES	YES	NO	NO	NO
Firm FE	NO	NO	NO	YES	YES	YES
Industry-Year FE	NO	NO	NO	YES	YES	YES

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1*

4.5. Supporting TCFD and Stock-Market Reactions

Table 5 reports the results of examining the association between unexpected changes in climate reporting and short-window market reactions for both supporters and non-supporters before and after the year 2017. This analysis aims to determine whether the increase in the extent of climate reporting, as shown in the DiD analysis, is material enough to influence investors' decisions and trigger market reactions, or whether it merely reflects an increase in the quantity of non-material information. We use a two-stage regression model to calculate unexpected climate change disclosures. In the first-stage regression, we follow Campbell et al. (2014) and estimate model (3), including climate disclosures from year $t-1$ as a determinant. In the second stage, we use the first-stage residuals as the independent variable of interest in the market reaction models. The results are presented in Panel A of Table 5. The coefficient on unexpected changes in climate reporting is positive and significant for the 3-day window abnormal returns, including buy-and-hold, cumulative, and standardised abnormal returns, but only for supporters in 2018. This suggests that increases in the extent of climate reporting by TCFD-supporting firms are material and credible to investors, as they react positively to these changes. We also find a positive association between the 3-day window abnormal volume and changes in climate reporting, but only for supporters in 2018, corroborating the abnormal return analyses. Overall, these findings support our second hypothesis, which posits a positive and significant association between investor responses and enhanced climate reporting in the annual reports of TCFD-supporting firms.

Table 5 -Panel A: Market Response to Unexpected Changes in Climate Risk Disclosure- for TCFD- support Firms

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$
ΔClimateDisclo	.00584	.00059	-.00034	.00042***	-.0004	-.00067
	(1.35482)	(.59215)	(-.5282)	(2.71738)	(-1.24188)	(-.65407)
Constant	.03621***	.01657	.00506	-.01541***	.04098***	.01026***
	(7.0406)	(.92961)	(.24082)	(-1609.9216)	(323.70144)	(12.10962)
Observations	522	523	539	551	562	536
R-squared	.10022	.14945	.07605	.08255	.11645	.09161
Industry FE	YES	YES	YES	YES	YES	YES
	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$
ΔClimateDisclo	.0051	.00064	-.00032	.00042***	-.00038	-.00052
	(1.3542)	(.65646)	(-.49043)	(2.70755)	(-1.20999)	(-.52955)
Constant	.03641***	.01618	.00598	-.01547***	.04357***	.01032***
	(8.10117)	(.93092)	(.27934)	(-1637.9098)	(345.84191)	(11.90566)
Observations	522	523	539	551	562	536
R-squared	.10445	.13779	.07532	.08484	.11004	.09516
Industry FE	YES	YES	YES	YES	YES	YES
	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$
ΔClimateDisclo	.12624	.04025	-.05147**	.01165**	-.0135	.00583
	(1.54273)	(1.47831)	(-2.53053)	(2.34249)	(-1.15229)	(.26878)
Constant	.24435***	.19321***	.29039***	.33627***	.31934***	.29795***
	(4.36381)	(5.08595)	(6.06538)	(7.00843)	(6.90863)	(3.99718)
Observations	1.03363***	1.17707	.61501	-.26491***	1.55591***	.25277***
R-squared	(9.20519)	(1.22331)	(1.02644)	(-3.16036)	(14.7574)	(9.23579)
Industry FE	406	406	435	400	426	375
ΔClimateDisclo	.27765	.28523	.30726	.35277	.30518	.29127
	YES	YES	YES	YES	YES	YES

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$
ΔClimateDisclousre	-.00052	.00176	-.01368	.01238*	.00625	.00544
	(-.01969)	(.07693)	(-1.32591)	(1.75802)	(1.39267)	(.4361)
Constant	-.36785***	1.09954***	1.11807**	-.30445***	.87101***	-.14451
	(-11.75253)	(3.33843)	(2.28006)	(-705.22319)	(489.6106)	(-1.61961)
Observations	522	523	539	551	562	536
R-squared	.14325	.09765	.13298	.22336	.12327	.08964
Industry FE	YES	YES	YES	YES	YES	YES

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1

However, the results presented in Panel B of Table 5 indicate that, after 2017, the stock market responded negatively to changes in climate reporting by non-supporters. Specifically, for 2019 and 2020, there is a significant negative association between changes in climate reporting and 3-day window abnormal returns, consistent with the declining trend in climate reporting depicted in Figure 4 for these years. In 2018, a significant negative relationship is observed between abnormal trading volume and changes in climate reporting for non-supporters, while for 2019 and 2020, the relationship remains negative but is not statistically significant. Stock price reactions capture the collective consensus of investors regarding the impact of a specific event, whereas trading volume reactions reflect divergences in individual investors' expectations about future price movements. Consequently, trading volume may increase or decrease even in the absence of price changes, and stock prices may fluctuate without corresponding changes in trading activity (Bamber & Cheon, 1995; Beaver, 1968).

Table 5 -Panel B: Market Response to Unexpected Changes in Climate Risk Disclosure- for Non- supports

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$	$BHAR^{10K}_{-1,+1}$
ΔClimateDisclousre	.00087	.00016	-.00013	-.00114	-.00949**	-.00269*
	(.27238)	(.08192)	(-.04485)	(-.42122)	(-2.41708)	(-1.78828)
Constant	-.00393	-.03139	-.02824	-.02226	-.00422	-.04553*
	(-.17643)	(-1.14056)	(-.90368)	(-.56801)	(-.08565)	(-1.95638)
Observations	1644	1762	1813	1926	1995	1981
R-squared	.03747	.01302	.02397	.03271	.02591	.02623
Industry FE	YES	YES	YES	YES	YES	YES
	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$	$CAR^{10K}_{-1,+1}$
ΔClimateDisclousre	.00099	.00013	-.00009	-.00129	-.00936**	-.00251*
	(.30905)	(.06479)	(-.03028)	(-.48384)	(-2.11684)	(-1.6755)
Constant	-.00304	-.03219	-.02462	-.02307	-.00504	-.04461*
	(-.13791)	(-1.1573)	(-.78229)	(-.58676)	(-.10404)	(-1.78596)
Observations	1644	1762	1813	1926	1995	1981
R-squared	.04166	.01694	.0241	.03181	.02471	.0273
Industry FE	YES	YES	YES	YES	YES	YES
	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$	$SCAR^{10K}_{-1,+1}$
ΔClimateDisclousre	.00765	-.00632	.0481	-.03287	-.21482**	-.03517*
	(.17453)	(-.12873)	(.83904)	(-.69625)	(-2.48549)	(-1.80452)
Constant	-.03153	-.26315	.2649	-1.22257	-.669	-.68378**
	(-.05206)	(-.54133)	(.89189)	(-1.10089)	(-.70137)	(-2.18544)
Observations	1644	1762	1813	1926	1995	1981
R-squared	.03707	.02326	.03344	.035	.0313	.02406
Industry FE	YES	YES	YES	YES	YES	YES

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$	$ABVOL^{10K}_{-1,+1}$
ΔClimateDisclousre	-.06262	.00129	-.00744	-.09702**	-.06563	-.03025
	(-1.54073)	(.03087)	(-.16422)	(-1.96344)	(-1.3701)	(-1.06988)
Constant	.55822	.43056*	1.67416***	2.11981*	2.32055***	2.05601
	(1.46443)	(1.72893)	(2.89244)	(1.89815)	(5.16449)	(1.59529)
Observations	1644	1762	1813	1926	1995	1981
R-squared	.04977	.06011	.03996	.0427	.03255	.03126
Industry FE	YES	YES	YES	YES	YES	YES

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1

Table 6 presents the results of the analysis examining the association between unexpected changes in climate reporting and market reactions within a 3-day window around the filing date, focusing on the composition of total climate disclosures across the individual TCFD pillars: Governance, Strategy, Risk Management, and Metrics, for TCFD-supporting firms. We estimate the market reaction model on unexpected disclosures, measured separately for each pillar, using the first-stage residuals from estimating model (3), which includes the individual TCFD pillar disclosures from year t − 1 as determinants.

The results in Table 6 indicate that, in 2018, the coefficient on unexpected changes in disclosures for the Strategy pillar is positive and significant for the 3-day window abnormal returns, including buy-and-hold, cumulative, and standardised abnormal returns. In contrast, for the Risk Management pillar, the coefficient is negative and significant for the 3-day window buy-and-hold abnormal returns and cumulative abnormal returns, although it is not significant for standardised abnormal returns.

Additionally, the respective positive and negative associations between market reactions (abnormal returns) and disclosures on Strategy and Risk Management are also evident in abnormal trading volume.

As reported in Table 6, we find a positive and significant coefficient on changes in climate reporting based on the Governance pillar for the year 2020, suggesting that meaningful improvements in governance practices require time to be implemented and subsequently reflected in climate governance disclosures. One possible explanation is that enacting real changes in governance can be logistically complex, involving the restructuring of teams, redefining roles, and revising processes. Additionally, firms must monitor the effectiveness of these changes and make further adjustments as necessary. This ongoing evaluation can extend the timeline for realising the full impact of governance changes.

Table 6: Market Response to Unexpected Changes in Climate Risk Disclosure-TCFD Pillars

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$BHAR_{-1,+1}^{10K}$	$BHAR_{-1,+1}^{10K}$	$BHAR_{-1,+1}^{10K}$	$BHAR_{-1,+1}^{10K}$	$BHAR_{-1,+1}^{10K}$	$BHAR_{-1,+1}^{10K}$
ΔGovernanceDisclo	.10338	-.00214	-.00742	-.0311	.05536	.05729*
	(1.56635)	(-.08108)	(-.15488)	(-1.01561)	(1.01972)	(1.79557)
ΔStrategyDisclo	.00666	.00021	.00314	.00534**	-.00029	.00041
	(1.04784)	(.09839)	(1.14232)	(2.37358)	(-.15036)	(.23409)
ΔRiskManagementDisclo	.01329	.03144	.00066	-.02698	.02027	.0099
	(.49496)	(1.08762)	(.03675)	(-1.49949)	(.95842)	(.69868)
ΔMetricDisclo	-.002	-.00041	-.00653	-.00608*	-.00256	-.01012
	(-.24133)	(-.16109)	(-1.18988)	(-1.80177)	(-.64563)	(-1.29743)
Constant	.04252***	.01716	.00609	-.01243***	.04334***	.01229**
	(6.56272)	(.95833)	(.28589)	(-4.82376)	(16.16257)	(2.15532)
Observations	522	523	539	551	562	536
R-squared	.10838	.15452	.08133	.09293	.12098	.10623
Industry FE	YES	YES	YES	YES	YES	YES
	$CAR_{-1,+1}^{10K}$	$CAR_{-1,+1}^{10K}$	$CAR_{-1,+1}^{10K}$	$CAR_{-1,+1}^{10K}$	$CAR_{-1,+1}^{10K}$	$CAR_{-1,+1}^{10K}$
ΔGovernanceDisclo	.10312	-.00194	-.00817	-.03075	.06574	.05676*
	(1.6187)	(-.07321)	(-.17138)	(-.99735)	(1.20933)	(1.82216)
ΔStrategyDisclo	.00561	.00028	.00324	.00516**	.00005	.00044
	(1.01523)	(.13778)	(1.17666)	(2.34073)	(.02444)	(.25589)
ΔRiskManagementDisclo	.01144	.03012	-.0001	-.02518	.01975	.00834
	(.45559)	(1.07246)	(-.00573)	(-1.45064)	(.91261)	(.60545)
ΔMetricDisclo	-.00149	-.00031	-.00651	-.00595*	-.00327	-.00915
	(-.19729)	(-.12293)	(-1.19308)	(-1.78186)	(-.79987)	(-1.24942)
Constant	.04188***	.01675	.00703	-.01263***	.04576***	.01255**
	(7.05188)	(.95902)	(.32411)	(-4.96399)	(16.66359)	(2.28474)
Observations	522	523	539	551	562	536
R-squared	.11267	.1421	.08072	.09482	.11569	.10877
Industry FE	YES	YES	YES	YES	YES	YES
	$SCAR_{-1,+1}^{10K}$	$SCAR_{-1,+1}^{10K}$	$SCAR_{-1,+1}^{10K}$	$SCAR_{-1,+1}^{10K}$	$SCAR_{-1,+1}^{10K}$	$SCAR_{-1,+1}^{10K}$
ΔGovernanceDisclo	2.41871	-.40706	.53268	-.89557	1.92705	1.3138**
	(1.22225)	(-.43584)	(.24755)	(-.71122)	(1.34975)	(2.52243)
ΔStrategyDisclo	.00966	.0577	.05296	.16329**	.0609	-.00461
	(.10451)	(1.0292)	(.79781)	(2.43855)	(.92097)	(-.16749)
ΔRiskManagementDisclo	.22272	.44754	-.48741	-.78275	-.07217	.02896
	(.31122)	(.75697)	(-.86141)	(-1.47605)	(-.0859)	(.13091)
ΔMetricDisclo	.08602	-.071	-.14145	-.16348	-.17374	-.10036
	(.5267)	(-.83196)	(-.97388)	(-1.6191)	(-1.25842)	(-1.14453)
Constant	1.33163***	.66203	-.00845	-.76821***	2.25514***	.37481***
	(9.81204)	(.88105)	(-.01199)	(-9.0616)	(22.08705)	(3.09278)
Observations	522	523	539	551	562	536
R-squared	.11913	.1437	.08845	.12124	.10801	.13553
Industry FE	YES	YES	YES	YES	YES	YES

	Y = 2015	Y= 2016	Y= 2017	Y = 2018	Y = 2019	Y= 2020
	$ABVOL_{-1,+1}^{10K}$	$ABVOL_{-1,+1}^{10K}$	$ABVOL_{-1,+1}^{10K}$	$ABVOL_{-1,+1}^{10K}$	$ABVOL_{-1,+1}^{10K}$	$ABVOL_{-1,+1}^{10K}$
ΔGovernanceDisclo	-.33272	-1.08491***	.96629	.51927	-.3208	.67881**

	(-.57725)	(-2.60089)	(.72683)	(.85846)	(-.44678)	(2.24575)
ΔStrategyDisclo	.03083	.04768	-.03016	.0819*	.01704	.01077
	(.78912)	(1.57918)	(-.99457)	(1.81695)	(.61032)	(.55019)
ΔRiskManagementDisclo	.20625	.19512	.27321	-.3897*	.03349	.15533
	(.78271)	(.62418)	(1.32111)	(-1.74255)	(.07865)	(.90212)
ΔMetricDisclo	-.10847	-.07661	-.05843	-.08395	-.01777	-.08098
	(-1.5199)	(-1.56993)	(-.95201)	(-1.16477)	(-.30163)	(-1.20303)
Constant	-.29492***	1.10031***	1.10687**	-.20757***	.87136***	-.13567
	(-5.41054)	(3.36412)	(2.24753)	(-4.39989)	(16.903)	(-.94179)
Observations	522	523	539	551	562	536
R-squared	.14637	.10442	.13769	.23011	.12386	.09519
Industry FE	YES	YES	YES	YES	YES	YES

t-values are in parentheses
*** p<.01, ** p<.05, * p<.1

5. Conclusion

In 2017, the TCFD introduced its framework to enhance mainstream climate reporting, responding to the growing demand from financial stakeholders, particularly investors, for consistent, comparable, and decision-useful climate-related information. Seven years later, in 2024, the SEC issued a new climate-related disclosure rule based on the TCFD framework, aiming to standardise climate reporting practices and acknowledging that existing disclosures are inadequate to meet investors' needs. This study assesses whether the TCFD has achieved its objectives in improving climate reporting and, by evaluating the framework's effectiveness and informativeness, offers insights into the SEC's decision to integrate TCFD standards into disclosure regulations.

Using a DiD approach, we find that, after 2017, firms supporting the TCFD framework disclose significantly more information in total climate disclosures and across the Governance, Strategy, and Risk Management pillars compared to non-supporting firms. Furthermore, we find that, following 2017, investors react positively and significantly to increases in total climate disclosures, with the reaction being particularly pronounced for the Governance and Strategy pillars in the 10-K filings of TCFD-supporting firms.

Overall, our results show that climate reporting aligned with the TCFD framework not only produces more comprehensive disclosures but is also valued by investors, as evidenced by the positive market reactions to changes in climate reporting by TCFD-supporting firms. This study provides empirical support for the SEC's recent decision to incorporate the TCFD framework into climate disclosure standards, highlighting its role in addressing the informational needs of the financial market. By demonstrating the effectiveness of TCFD support in improving mainstream climate reporting, our

research contributes to the ongoing policy discussion on standardised climate disclosures and reinforces the value of structured, TCFD-based frameworks.

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Appendix A. Examples of Classifications of Climate-Related Text and TCFD Pillars

We extract the text from items 1 (business descriptions), 1A (risk factors), and 7 (Management's Discussion and Analysis, or MD&A) of the 10-K filings from the SEC EDGAR for firms that file between 2012 and 2023, yielding a total of 51,628 firm-year texts. These texts are subsequently cleaned and divided into paragraphs, resulting in 18,730,608 paragraphs[3].

To classify these paragraphs, we utilise the Climate-Detector and Climate-TCFD models fine-tuned by Bingler et al. (2023), which pertain to a BERT model trained on over 17,300 human-labelled sentences specifically for the TCFD categories, along with more than 300,000 general language sentences extracted from annual reports. The first step involves categorising the paragraphs into climate-relevant and non-climate-relevant groups. Following this, the climate-relevant paragraphs are further classified into the TCFD pillars.

This process results in 1,610,750 paragraphs (8.6% of the total) being classified as climate-related. Subsequently, the Climate-TCFD model further categorises these climate-relevant paragraphs into the four TCFD recommendation categories. Table A1 provides examples of paragraphs classified by these models, illustrating both the climate-relevant and non-climate-relevant categories, as well as their classification into TCFD pillars.

Table A 1- Examples of Classifications of Climate-Related Text and TCFD Pillars

Text	Label 1	Score 1	Label 2	Score 2
In December 2010, the Company acquired The Linc Group, LLC (Linc). Linc provides end-to-end integrated facility solutions services, military base operation services, and translation and other services in support of U.S. military operations. Linc's clients include state and federal governments, commercial entities, and residential customers throughout the United States and in select international locations. The operations of Linc have been included in the Facility Solutions segment since the acquisition date. The name of Linc was changed to ABM Facility Solutions Group, LLC, in fiscal 2012.	NO	0.9957	_	_

[3] Cleaning involves removing titles, specific patterns (e.g., ##Table_start), and URLs, while division into paragraphs is based on new lines.

The recovery from the global economic crisis of 2008 and the resulting recession has been slow and uneven. Continuing concerns regarding the worldwide economic outlook and the sovereign debt crisis in Europe have contributed to increased economic uncertainty and diminished expectations for the global economy. A slowdown in the current economic recovery or a return to recession would negatively impact demand for petroleum products and prices for natural gas, oil, and NGL. These circumstances could adversely affect our results of operations, liquidity, and financial condition.	NO	0.5000	_	_
The Safety, Health, Environment, Community and Sustainability (SHECS) Committee assists the Board in overseeing its climate-related performance and governance responsibilities. The Risk Committee reviews climate-related risk and is ultimately responsible for overseeing the embedding of climate risk into the Enterprise risk (ERM) approach and setting the risk appetite for the company. The charters for these committees are available in the FY22.	YES	0.9984	Governance	0.9847
We have committed to science-based emissions targets for our operations and vehicles: reduce Scope 1 and 2 greenhouse gas (GHG) emissions by 76 percent by 2035 from a 2017 baseline and reduce Scope 3 GHG emissions from the use of sold products by 50 percent per vehicle km by 2035 from a 2019 baseline.	YES	0.9979	Metrics	0.9825
Climate risks driven by markets and customers include changes in consumer behaviours, such as a deliberate shift towards more sustainable products; potential loss of competitive advantage related to our green product proposition or pricing risks; increased market volatility and costs; and sourcing restrictions for carbon-intensive raw materials.	YES	0.9981	Strategy	0.9615
Tata Steel uses a company-wide integrated Enterprise Risk Management (ERM) process to manage climate change risks. The process identifies and assesses business risks through bottom-up, top-down, and outside-in perspectives to ensure comprehensive risk identification and minimize blind spots. Likelihood, impact, and velocity scores are assigned to each risk following a due diligence process, including scenario analysis. Appropriate early warning indicators and mitigation strategies are identified for review by the Apex Risk Committee and the Risk Management Committee (RMC) of the Board.	YES	0.9983	Risk Management	0.9607

Appendix B. Validation Tests

The performance of the Climate-Detector and Climate-TCFD models fine-tuned by Bingler et al. (2023) in identifying climate-relevant paragraphs and classifying them into the TCFD pillars is validated by comparing their performance to that of the GPT-4 model. A dataset of 241 paragraphs from TCFD annual status reports, which provide examples of climate risk disclosure under the TCFD pillars—Governance, Strategy, Risk Management, and Metrics—for the years 2020–2023 is used for this comparison. The GPT-4 model correctly classifies 215 out of 241 paragraphs, with an 11% misclassification rate. The Climate-Detector model improves on this result by correctly identifying 236 paragraphs, reducing the misclassification rate to just 2%. For classifying TCFD pillars, the Climate-TCFD model also outperforms GPT-4, achieving an overall accuracy of 87%, compared to GPT-4's accuracy of 53%. Figure A1 presents the confusion matrices for the Climate-TCFD and GPT-4 models in classifying climate-related paragraphs into TCFD pillars. The x-axis represents the predicted classes, and the y-axis represents the true classes. In a perfect model, all values in the confusion matrix would be located solely along the diagonal.

Confusion Matrix of BERT

Governance	34	1	2	0
Strategy	0	82	7	1
Risk Management	3	8	28	1
Metrics	1	8	0	65

Confusion Matrix of GPT4

Governance	18	10	9	0
Strategy	2	44	44	0
Risk Management	2	2	35	1
Metrics	2	36	6	30

Appendix C. Variables

Variable	Definition	Source
BHAR ^{10K}	Three-day buy-and-hold return from one trading day before to one after the 10-K filing date less the expected return. $[\prod_{t=-1,0,+1}(1+R_{it})]- [\prod_{t=-1,0,+1}(1+ER_{it})]$	CRSP
CAR^{10K}	Three-day cumulative abnormal return from one trading day before to one after the 10-K filing date, $\sum_{t=-1,0,+1}(R_{it}-ER_{it})$	CRSP
SCAR^{10K}	Standardised abnormal return by the variance of abnormal returns during the estimation period (the 250 trading-day period ending two trading days before the 10-K release).	CRSP
ABVOL^{10K}	Average daily trading volume: [-1, +1] minus [-60, -11], scaled by the latter's volume. Exclude earnings announcement data from [-60, -11].	CRSP
ClimateDisclo	Number of words in paragraphs classified as climate-related scaled by 1,000	SEC Edgar
GovDisclo	Number of words in paragraphs classified under the Governance pillar, scaled by 1,000.	SEC Edgar
StraDisclo	Number of words in paragraphs classified under the Strategy pillar, scaled by 1,000.	SEC Edgar
RiskDisclo	Number of words in paragraphs classified under the Risk management pillar, scaled by 1,000.	SEC Edgar
MetrDisclo	Number of words in paragraphs classified under the Metrics pillar, scaled by 1,000.	SEC Edgar
Non-ClimateDisc	Number of words in non-climate paragraphs, scaled by 1,000	SEC Edgar
PropDis	The ratio of the number of firms providing climate risk disclosure to the total number of firms in the industry-year.	SEC Edgar
Num8K	The number of 8-K files in the 1-year period before the 10-K filings	SEC Edgar
InsInvestors	An indicator variable that equals one if the firm's institutional ownership is above the median institutional ownership of all firms in the same year	SEC Edgar- 13F-Filling
FileDate	An indicator variable that equals one when the 10-K filing date is at least 90 days after the year end, zero otherwise	SEC Edgar
ESG	ESG scores. Missing data are replaced with the fitted values from the regression model for ESG scores as a function of Size, BTM, LEV, industry, and year fixed effects.	MorningStar
RD	R&D expense divided by total asset at the beginning of the fiscal year.	The merged CRSP-COMPUSTAT
ΔEarnings	The difference between net income in year t and net income in year t – 1	The merged CRSP-COMPUSTAT
Accrual	The absolute value of accruals calculated using the cash flows statement scaled by total assets	The merged CRSP-COMPUSTAT
BTM	The ratio of book value of equity to market value of equity	The merged CRSP-COMPUSTAT
Size	The natural logarithm of the market value of equity	The merged CRSP-COMPUSTAT
PastLoss	An indicator variable that equals one if the firm has one or more loss years over the previous 5 years, zero otherwise	The merged CRSP-COMPUSTAT
Segment	The natural logarithm of one plus the number of segments	The merged CRSP-COMPUSTAT
LEV	The ratio of long-term debt to total assets	The merged CRSP-COMPUSTAT
Big4	An indicator variable equal to one for firms with a Big N auditor; zero otherwise	The merged CRSP-COMPUSTAT
Litigation	An indicator variable that equals one for firms in SIC codes 2833–2836, 3570–3577, 3600–3674, 5200–5961, 7370–7374, and 8731–8734, zero otherwise	The merged CRSP-COMPUSTAT
NumItems	The number of non-missing items on COMPUSTAT in a fiscal year	The merged CRSP-COMPUSTAT
RetVolatility	variance of daily abnormal returns in year t - 1	CRSP
NumAnalyst	The number of analysts following the firm	I/B/E/S