The Effect of Carbon Emission Intensity Changes on Environmental Reporting Readability: Insights from Variations in Strategic Reporting Quality in the UK

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ABSTRACT

The UK *Strategic Report and Directors' Report* (SR) mandate under the *Companies Act 2013* requires UK firms to disclose carbon emissions and review their environmental matters and performance. We examine the impact of changes in carbon emission intensity on environmental reporting readability and the moderating role of firms' rigor in the application of the SR mandate. Using proprietary PwC UK data covering FTSE 350 firms, we find that an increase in carbon emission intensity is associated with less readable environmental reporting. Additional analyses indicate that reduced readability is primarily driven by managerial obfuscation incentives in response to poor carbon performance (i.e., rising carbon intensity), rather than by increased firm-related environmental complexity associated with higher carbon emission intensity. However, rigorous SR implementation mitigates deteriorating readability when carbon emission intensity rises by reducing managerial incentives to obscure information through better incentive alignment. Additional analyses show that the association between rising carbon intensity and diminished readability, as well as the moderating role of SR, is prevalent in the following contexts: 1) firms with increasing, rather than decreasing, carbon intensity, reflecting asymmetric carbon reporting behaviour; 2) firms that set emission reduction targets but fail to lower carbon intensity; and 3) firms with lower foreign institutional ownership, due to reduced monitoring by these stakeholders.

Keywords: Carbon Emission Intensity, Strategic Reporting Mandate, Environmental Reporting Readability, United Kingdom

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1. Introduction

We examine whether firms provide less readable environmental reporting when their greenhouse gas (GHG) / carbon emission intensity increases and examine whether the rigorous implementation of the UK Strategic Reporting (SR) mandate mitigates this concern. Regulators globally are consulting stakeholders to standardize environmental reporting, aiming to enhance accountability and transparency by improving the information available to shareholders. These efforts include the U.S. Securities and Exchange Commission's (SEC) 2024 Climate Ruling (SEC, 2024), the European Union's (EU) Corporate Sustainability Reporting Directive (CSRD) effective reporting year 2025 (EU, 2022), and the International Sustainability Standards Board's (ISSB) S1 and S2 standards released in 2023 (International Financial Reporting Standards [IFRS], 2023a),[1] among others.

The UK, however, has been at the forefront of such reporting. Since the *Strategic Report and Directors' Report Regulations* (SR, here onwards) under the *Companies Act 2013*, UK-listed firms must disclose in their annual reports: (1) the quantity of GHG emissions and a ratio expressing the intensity of emissions in relation to firm's activities (such as revenue or assets); (2) the same information for the preceding year, highlighting any differences (*Companies Act 2013* No. 1970, Part 3(7)); and (3) a narrative review of environmental matters and performance (*Companies Act 2013* No. 1970, Part 2(3)).

The motivation for this study is two-fold. First, existing research shows that mandatory carbon disclosure within the SR mandate reduced UK firms' tendency to engage in selective carbon disclosure, a form of greenwashing (Delmas & Burbano, 2011; Grewal et al., 2022). While the choice to engage in selective disclosure is reduced due to mandatory prescriptive carbon reporting under the SR mandate (Grewal et al., 2022), the management still holds the discretion on how to shape their environmental narratives as they are largely unregulated. Thus, environmental narratives still offer a vehicle for managers to engage in greenwashing via linguistic manipulation of environmental disclosures, thereby

[1] In June 2023 the ISSB issued its first two IFRS sustainability disclosure standards, IFRS S1 *General Requirements for Disclosure of Sustainability-related Financial Information* and IFRS S2 *Climate-related Disclosures*.

increasing the information processing costs of users of the annual report (Bloomfield, 2002; Courtis, 2004; Rennekamp, 2012). Therefore, this study examines the first research question: Do firms provide less readable environmental reporting when their carbon emission intensity increases?

Second, the Financial Reporting Council (FRC) provides detailed guidance on SR implementation, encouraging communication principles such as conciseness, use of plain English, and future-orientation to improve reporting quality and clarity (FRC, 2012, 2014). However, the degree to which firms adhere to these principles in their environmental narratives remains largely unregulated and may vary depending on how strongly firms embrace the SR requirements. To address this gap, we use proprietary PwC UK reporting quality data to capture how rigorously firms comply with SR, addressing the second research question: Can rigorous SR implementation mitigate less readable environmental reporting accrued to firms with increased carbon emission intensity?

Bushee et al. (2018) identify two components of linguistic complexity in firm disclosures: (1) the information component, capturing complex language necessary to convey business transactions and strategy; and (2) the obfuscation component, arising from managerial incentives to obscure information (Bloomfield, 2008; Bushee et al., 2018). This study posits competing arguments for why an increase in carbon emission intensity (poor carbon performance) may lead to less readable environmental reporting. First, an increase in carbon emission intensity may require causal details on internal and external factors that led to poor performance, as well as reporting on plans to reduce emissions, thereby contributing to information component-related complexity in environmental reporting (Asay et al., 2018; Bushee et al., 2018). Second, several theoretical frameworks, including agency, legitimacy, and attribution theories, among others suggest that firms may engage in opportunistic corporate reporting driven by managerial self-interest and legitimacy concerns (Merkl-Davies & Brennan, 2007; Fabrizio & Kim, 2019). Therefore, an increase in carbon emission intensity may incentivize firms to mask their poor performance by obfuscating environmental reporting, thereby contributing to obfuscation component-related complexity in environmental reporting.

Building on the previous, we propose that rigorous SR implementation may influence both the components of linguistic complexity (information and obfuscation) in environmental reporting when firms' carbon emission intensity increases. First, rigorous SR implementation can reduce the information component by enhancing firms' understanding of environmental matters and application of effective SR principles, improving the clarity and accessibility of environmental narratives. However, extensive carbon disclosure requirements may also lead to cluttered environmental reporting as firms err on the side of inclusion rather than omission to avoid regulatory scrutiny (Athanasakou et al., 2020), thereby increasing information component complexity. Second, rigorous implementation of the SR mandate may reduce the obfuscation component through SR's forward-looking and broad stakeholder-focus, which aligns managerial incentives with long-term shareholder value creation (Obeng et al., 2021). Alternatively, the extensive carbon disclosure requirements under SR may provide opportunities for obfuscation, as managers might obscure poor carbon performance through complex environmental reporting to address legitimacy concerns (Fabrizio & Kim, 2019). Thus, the above arguments highlight tension in how SR moderates the relationship between increasing carbon intensity and environmental reporting complexity, with competing views on its effects on both, the information and obfuscation components of linguistic complexity (Bushee et al., 2018).

We measure carbon performance by subtracting the industry's change in carbon emission intensity from the firm's change, where positive (negative) values indicate an increase (decrease) relative to the industry (Qian & Schaltegger, 2017; Tomar, 2023). Environmental reporting complexity is measured using the Bog index as it captures complexity more accurately without assuming all multi-syllabic words as difficult, addressing concerns with the Fog index (Bonsall et al., 2017; Loughran & McDonald, 2014). We use machine learning to classify environmental reporting narratives from annual reports and subject these narratives for the estimation of *Environmental_Bog,* the firm-level proxy of environmental reporting readability. Higher *Environmental_Bog* values represent lower readability. Finally, we use proprietary PwC UK reporting quality data to capture the rigor of UK firms' compliance with SR requirements.

Using a sample of 1,020 firm-year observations from the UK Financial Times Stock Exchange (FTSE) 350 firms, we find that increased carbon emission intensity is associated with less readable environmental reporting, consistent with prior research (Fabrizio & Kim, 2019). However, rigorous implementation of the SR mandate attenuates this effect. These findings are robust across various endogeneity tests, including propensity score matching, entropy balancing, Heckman's two-stage model, and two-stage least squares estimation.

We then disentangle whether deteriorating environmental reporting readability when carbon intensity rises is due to a firm-related complex environment when carbon emission intensity rises or due to managerial information obfuscation incentives. We separate the firm-related complexity in environmental reporting using a residuals approach by regressing environmental reporting complexity against firm-related environmental complexity variables, with fitted values capturing firm-related complexity (i.e., information component) and residuals capturing the discretionary component of environmental reporting complexity (i.e., obfuscation component). We find that increase in carbon intensity increases the obfuscation-related complexity in environmental reporting but is not related with the firm-related environmental complexity. Rigorous SR implementation however mitigates obfuscation-related complexity by aligning managerial incentives with the long-term interest of stakeholders (Obeng et al., 2021). Further, we also find a first-order effect of deeper SR implementation on reducing firm-related environment complexity in reporting, likely due to improved managerial understanding of environmental matters, thereby leading to clearer reporting.

Linguistic analysis of environmental reporting suggests that firms exhibiting increasing carbon emission intensity provide significantly greater past focus, reduced present focus, and greater use of negations in their environmental reporting. Using a structural equation model (SEM) (Fornell & Larcker, 1981), we find that past focus and use of negations mediate the relationship between increased carbon emission intensity and reduced environmental report readability, consistent with obfuscation explanation for reduced readability.

Additional analysis compares the effect on readability for firms with increasing versus decreasing carbon emission intensity. We find that firms with increasing intensity provide more complex environmental disclosures, whereas those with decreasing intensity do not provide more readable disclosures, highlighting asymmetric carbon reporting behaviour. Further, we find that firms with increasing carbon intensity are more likely to produce less readable environmental reporting when they have previously set emission reduction targets, however, rigorous SR practices mitigate incentives to obscure poor carbon performance. Finally, we provide evidence that firms with high foreign institutional ownership maintain readable environmental reporting despite increased carbon intensity likely due to better monitoring and pressure for high-quality climate reporting (Bose et al., 2024). In contrast, firms with low foreign institutional ownership produce less readable reports under increased carbon intensity due to negligible monitoring or pressure for high-quality climate reporting facing these firms, however, rigorous SR practices mitigate this effect.

We offer several contributions to the literature. First, we contribute to the literature examining environmental performance and environmental disclosure (Patten, 2002; Al-Tuwaijri et al., 2004; Cho & Patten, 2007; Meng et al., 2014). We show that firms' carbon performance has implications on their environmental reporting readability. Specifically, firms are asymmetric in their reporting such that an increase in carbon emission intensity leads to complex environmental reporting, while a decrease in carbon emission intensity does not. We show that firms resort to linguistic manipulation to manage stakeholder impressions through their environmental narratives when the opportunity for selective carbon disclosure is constrained by the UK SR mandate (Grewal et al., 2022).

Second, this study contributes to the literature examining the impacts of the SR mandate. Prior literature documents the benefits of SR including reduced emissions (Downar et al., 2021), constrained selective carbon disclosure (Grewal et al., 2022), and improved capital market information environment (Wang et al., 2024). This study further contributes by showing that rigorous compliance with SR enhances the readability of environmental narratives, especially for poor carbon performance firms that are fraught with obfuscation incentives. Further, SR enhances communication by improving firms' understanding of environmental issues, thereby reducing firm-related complexity in environmental reporting as a first-order effect.

Third, this study introduces a novel machine learning technique to classify environmental narratives in annual reports as such information is pervasively disclosed across various sections due to the integrated approach to reporting. For example, the SR mandate requires firms to prepare a strategic report that includes financial and non-financial content elements, as well as a directors' report discussing governance of risks, environmental, and other matters (FRC, 2014). Therefore, capturing environmental narratives throughout different sections of the annual report.

We offer practical contributions by providing insights to standard setters and advisory groups developing standards that meet stakeholder demand for improved integration between financial and non-financial reporting. This includes the ISSB's issuance of sustainability reporting standards S1 and S2 in 2023 (IFRS, 2023a) and the IFRS Foundation's efforts to develop additional standards promoting deeper integration beyond S1 (IFRS, 2023b; 2023c). Similarly, the European Financial Reporting Advisory Group (EFRAG) established a think tank in 2023 to advance this connectivity (EFRAG, 2023). These bodies can use the UK's SR mandate as a model, given its proven effectiveness in improving environmental reporting readability (as shown in this study) and delivering capital market benefits (Wang et al., 2024).

Second, this study cautions stakeholders that firms with poor carbon performance may obfuscate environmental disclosures to manipulate perceptions. As investor interest in non-financial information grows given the significant investments in climate change and environmental sustainability strategies (Eurosif, 2018), improving the readability of environmental reports particularly benefits less sophisticated users by lowering their cognitive burden and processing costs (Bloomfield, 2002; Courtis, 2004; Rennekamp, 2012), thus facilitating informed decision-making. Finally, aligning with the FRC's efforts to reduce the complexity of non-financial reporting in annual reports (FRC, 2009; 2011; 2012), firms can leverage SR practices to deepen their understanding of environmental matters, enabling more effective communication and increasing decision-usefulness for information users.

The study is organized as follows: Section 2 reviews the UK institutional setting and prior literature; Section 3 develops hypotheses; Section 4 outlines the research design; Section 5 presents main results and robustness analyses; Section 6 offers additional analyses; Section 7 concludes.

2. Background and Related Literature

2.1 Background

In the UK, mandatory reporting of GHG emissions began with the Climate Change Levy in 2001, though disclosures were only to regulatory authorities, not the public (Kauffmann et al., 2012). Momentum for public carbon disclosure increased with the European Union Emission Trading Scheme (EUETS) in 2005 for the energy and industrial sectors. The Climate Change Act of 2008 required the UK government to decide by 2012 whether London Stock Exchange (LSE)-listed companies should report GHG emissions or justify non-disclosure (Grewal, 2022). The Department for Environment, Food, and Rural Affairs (DEFRA) was handed the responsibility to consult stakeholders and decide whether GHG emissions disclosure should be mandated. DEFRA reported stakeholder concerns about regulatory burdens in a March 2012 meeting (DEFRA, 2012). In June 2012, citing concerns about climate change and investors' demand for transparency in GHG information, Deputy Prime Minister Nick Clegg announced that all LSE-listed firms must report annual GHG emissions for fiscal years ending on or after September 30, 2013, in the Directors' Report section of the annual report (GOV.UK, 2012; FRC, 2014).

The *Companies Act 2013* SR regulations enacted the mandatory requirement for UK-listed firms to disclose their GHG emissions and report on environmental matters in their annual reports (FRC, 2014; 2018). Specifically, firms must disclose: (1) the annual quantity of GHG emissions and at least one ratio expressing emissions relative to a quantifiable factor associated with the company's activities, and (2) the same information for the preceding year, noting any differences (Companies Act 2013 No. 1970, Part 3(7)). Such reporting of GHG emissions is one small part of the SR mandate.

The primary purpose of the Strategic Reporting regulation is to provide shareholders with a comprehensive and insightful portrayal of a company's business model, strategy, risks, performance, positions, and prospects, encompassing material financial and non-financial information—including environmental matters and performance—for the benefit of firm shareholders (FRC, 2014). The FRC provides detailed guidance on SR to help firms effectively implement SR reporting practices and communication principles, with minor updates in 2018 and 2022 (FRC, 2014, 2018, 2022). The guidance encourages effective SR communication principles such as connectivity, future orientation, materiality, conciseness, use of plain language, comparability, and reliability of information (FRC, 2014).

We select the UK as the empirical setting for several reasons. First, the SR mandate applies to all UK-listed firms, unlike other regimes that often focus on specific industries (e.g., EUETS) (Clarkson et al., 2015; Downar et al., 2021; Tomar, 2023), enhancing generalizability beyond specific sectors. Second, the SR mandate is prescriptive regarding required disclosures, unlike other ESG mandates like the EU directives. It mandates all firms to disclose their GHG emissions, provide a narrative review of environmental performance, and include a year-over-year comparison, creating a level playing field and preventing selective disclosure (Grewal, 2022). Finally, the availability of UK PwC's data on the rigor of firms' SR practices allows examining the variation in firms' implementation of the SR mandate, which differs from studies that focus on SR as a singular event or shock (Downar et al., 2021; Grewal et al., 2022; Jiang & Tang, 2023).

2.2 Related Literature

2.2.1 Environmental Performance and Disclosure

Firms engage in environmental efforts driven by three main motivations: competitiveness, legitimation, and ecological responsibility (Bansal & Roth, 2000). Competitiveness-driven firms focus on environmental innovation in processes and products to gain a competitive edge (Nehrt, 1996). Those motivated by legitimation align with stakeholder norms—such as the local community, customers, and government—to reduce reputational risks and maintain their "license to operate" (Neu et al., 1998; Bansal & Roth, 2000; Hooghiemstra, 2000; Bansal & Clelland, 2004). Lastly, ecologically responsible firms undertake environmental initiatives because they believe it is the right thing to do, acknowledging corporate responsibilities beyond economic gains to address significant social issues (Buchholz, 1991).

A strand of literature has explored the relationship between environmental performance and disclosure levels, yielding mixed findings. Ingram and Frazier (1980) found a weak association between environmental disclosures and performance, suggesting that lack of external monitoring allows management to misuse discretion, enabling poor performers to bias disclosures to appear better. Similarly, Wiseman (1982) observed that firms' environmental disclosures in annual reports were incomplete and unrelated to their actual environmental performance.

Subsequent research yields mixed findings on whether good environmental performers disclose more. Patten (2002) finds a negative relationship between environmental performance and disclosure levels, especially in non-environmentally sensitive industries, suggesting that firms in sensitive industries already face socio-political exposure, reducing the need for extra disclosures. Similarly, Cho and Patten (2007) find that worse environmental performers use environmental disclosures as a legitimizing tool, with higher disclosure levels among poor performers, particularly in sensitive industries. Conversely, Al-Tuwaijri et al. (2004) found that good environmental performance is associated with good economic performance and more extensive environmental disclosures of pollution measures. Similarly, Clarkson et al. (2008) conducted a content analysis based on Global Reporting Initiative (GRI) guidelines and found a positive association between environmental performance and the level of discretionary environmental disclosures.

Research has also explored firms' use of environmental disclosures to manage stakeholder perceptions. Cho et al. (2010) find that poor environmental performers use more optimistic and less certain language than better performers, suggesting manipulation of impressions through language and tone. Similarly, Cho et al. (2012) document that firms manipulate standalone sustainability reports using graphical presentations, engaging in enhancement (emphasizing positives) and obfuscation. Meng et al. (2014) observe that in China, poor performers disclose more "soft" information, while good performers provide more "solid" information. In the UK context, Moussa et al. (2022) find that environmentally sensitive firms disclose "soft" (qualitative) or "semihard" (qualitative with a timeframe or quantitative) environmental targets to manage impressions and legitimize themselves, whereas good environmental performers tend to set "hard" (quantitative with a timeframe) targets.

We extend this literature by examining firms' GHG emission intensity reduction performance, focusing on how carbon performance affects firms' environmental reporting, in particular environmental report readability. By exploring this relationship, we aim to deepen the understanding of how firms use reporting to manage stakeholder impressions, aligning with insights from Cho et al. (2010, 2012) and Meng et al. (2014) on strategic disclosure content and presentation.

2.2.2 Carbon (GHG Emissions) and Disclosure

Existing research shows that firms' carbon emissions significantly influence investor perceptions and market valuations. Jacobs et al. (2010) find that philanthropic donations for environmental causes and ISO 14001 certifications elicit positive market reactions, but voluntary emission reductions receive negative responses, suggesting investors may view some environmental initiatives unfavorably. Similarly, Fisher-Vanden et al. (2011) report that firms voluntarily reducing emissions experience negative abnormal stock returns, indicating such commitments may conflict with maximizing firm value. Matsumura et al. (2014) reveal that while disclosing carbon emissions negatively affects firm value, non-disclosure results in even greater penalties. Overall, this research indicates that capital markets consider both carbon emission levels and related environmental information when valuing firms.

Prior literature on the strategic use of GHG disclosure presents mixed findings. Kim and Lyon (2011) find that U.S. firms voluntarily reporting reductions in emissions often do so even when their emissions increase, suggesting strategic environmental disclosure, especially among large firms facing significant stakeholder and regulatory pressure. Similarly, Depoers et al. (2016) find that French firms report lower GHG emissions in corporate reports than in Carbon Disclosure Project (CDP) responses. In contrast, Luo and Tang (2014) find that CDP disclosures from firms in the US, UK, and Australia reliably reflect true carbon performance, aligning with signaling theory. Subsequent literature also highlights the role of carbon disclosure in influencing both carbon performance and the cost of equity. Qian and Schaltegger (2017) find that increased carbon disclosure results in an 'outside-in' effect that leads to improvements in carbon performance. Bui et al. (2020) show that while higher GHG emission intensity raises firms' cost of equity, extensive carbon disclosure can mitigate this penalty, suggesting that transparency reduces the investor premium required for poor carbon performance.

In the UK context, Downar et al. (2021) demonstrate that mandatory GHG emission reporting under the SR mandate reduces firms' emissions without harming financial performance. Similarly, Alsaifi (2021) observes that improved carbon disclosure is associated with better carbon performance among UK firms. Further, Grewal et al. (2022) find that the UK's SR mandate reduces firms' selective carbon disclosure, a form of greenwashing, due to its prescriptive requirements compelling full disclosure. Jiang and Tang (2023) report that the SR mandate increases firms' voluntary CDP survey responses and improves their CDP leadership quality index.

In summary, carbon disclosure can signal actual performance and influence stakeholder decision-making. The UK's SR mandate has enhanced carbon reporting transparency and encouraged better carbon performance without financial detriment. This study investigates whether poor carbon performance created an incentive for firms to reduce the readability of environmental narratives to obfuscate their poor environmental performance. It also explores whether rigorous SR practice can mitigate managerial obfuscation in environmental reporting when UK firms exhibit poor carbon performance.

2.2.3 CSR / Environmental Performance and Disclosure Readability

Existing literature explores the link between aggregate or environmental dimensions of CSR performance and reporting readability. Nazari et al. (2017) and Wang et al. (2018) find that U.S. firms with stronger CSR performance produce more readable CSR reports. Li et al. (2022) report a positive relationship between sustainability performance and attributes such as optimism, certainty, clarity, and high readability in Australian firms' sustainability reports. Fabrizio and Kim (2019) find that firms with unfavorable news use linguistic obfuscation in their responses to the annual CDP survey to balance the pressure for comprehensive disclosures with the desire to maintain a positive image. This strategy makes unfavorable information harder for stakeholders to process, reducing the negative impact on ratings from information intermediaries. These studies indicate that strong environmental performance leads to clearer, more readable disclosures, while poor performance prompts firms to use obfuscation to manage stakeholder perceptions. Gao et al. (2023) demonstrate that CSR report readability significantly influences investor decision-making by affecting information processing fluency.

While this study aligns with Fabrizio and Kim (2019) in examining linguistic obfuscation, it differs in key aspects. Fabrizio and Kim measure obfuscation in voluntary CDP survey responses using the Fog index, whereas we examine readability in mandated strategic reports in the UK using the Bog index. They use the lack of governance mechanisms to reduce GHG emissions as a proxy for negative environmental news; we use increases in carbon emission intensity as UK firms must explain yearly differences under the SR mandate.

3. Theory and Hypotheses Development

3.1 Carbon Emission Intensity and Environmental Reporting Readability

Readability refers to how easily a message can be understood, influencing its decision-usefulness (Barnett & Leoffler, 1979; Lim et al., 2018). Bushee et al. (2018) identify two components of linguistic complexity in firm disclosures: (1) the information component, capturing firm-related complexity necessary to convey business transactions and strategy; and (2) the obfuscation component, arising from managerial incentives to obscure information (Bloomfield, 2008; Bushee et al., 2018). This study posits that an increase in carbon emission intensity leads to less readable environmental reporting for two reasons: (1) deteriorating carbon performance may require more complex explanations regarding factors that led to an increase in carbon emissions and strategies to reduce emissions in the future; (2) managers may obfuscate reports to conceal poor performance. Conversely, decreased carbon emission intensity is unlikely to reduce readability, as favourable news is easier to communicate with negligible incentives to obfuscate (Aerts, 2005; Clatworthy & Jones, 2001). The following subsections discuss how increases in carbon emission intensity affect environmental reporting readability, based on the two complexity components: information and obfuscation (Bushee et al., 2018).

3.1.1 Carbon Intensity Increase and Environmental Reporting Complexity – Information Component

Bloomfield (2008) provides an ontological explanation for annual report complexity for firms with poor performance. He argues that part of the complexity in annual reports may arise from the necessity of using complex language to communicate negative performance, such as during a loss year. This is often more challenging to describe, as it may include detailed explanations to explain poor performance, compared to a typical year of good performance (Bloomfield, 2008).

Asay et al. (2018) provide experimental evidence that bad news disclosures are less readable than good news disclosures when managers aim to portray the firm favourably. They suggest that managers (1) unconsciously distance themselves from bad news using passive voice, and (2) consciously include more causal explanatory language and future-oriented discussions. They also find that managers may be unaware of this reduced readability, driven by increased use of negations (e.g., "not doing well" instead of "doing poorly"). Using causal language to explain events enhances understandability (Koonce et al., 2011). Zhang et al. (2019) find that causal language provides incremental information and thus reduces analysts' information processing costs and uncertainty. Research suggests poor performance increases managers' incentives to provide additional information to meet investor demand (Merkley, 2014) and is associated with more future-oriented information (Li, 2008; Matsumoto et al., 2011). This supports the idea that bad news disclosures may be less readable because poor performance environments are inherently more complex, requiring technical-informative language that reduces information asymmetry, but also reduces readability (Bloomfield, 2008; Asay et al., 2018; Bushee et al., 2018; Zhang et al., 2019).

From a technical-informative perspective, environmental narratives may become more complex when a firm demonstrates poor carbon performance. This complexity arises because the firm may provide comprehensive explanations of the internal and external factors contributing to its challenging operational environment that led to an increase in carbon emission intensity. Consistent with Asay et al. (2018), managers unconsciously distance themselves from bad news information (by focusing on external factors such as industry) and provide detailed causal explanations (reasons for inefficiency or emissions increase) and future-oriented information (ongoing plans and commitments to reduce emissions). In doing so, the firm not only addresses its current poor performance but also seeks to avoid legitimacy concerns. Consequently, the inclusion of detailed causal explanations and forward-looking information may increase the information component complexity (Bloomfield, 2008; Bushee et al., 2018).

Overall, this discussion suggests that rising emissions may inherently result in more complex disclosures as firms use causal language to explain the underlying factors behind increasing emissions and include forward-looking statements detailing plans for carbon emission intensity improvements. While these more elaborate narratives can be informative, they may also be less readable (Bushee et al., 2018). In contrast, when firms achieve good performance (i.e., reductions in emissions intensity), the narrative is often more straightforward and less complex, focusing on specific actions and outcomes.

3.1.2 Carbon Intensity Increase and Environmental Reporting Complexity – Obfuscation Component

The discretions in narrative reporting allow managers to manage stakeholder impressions through strategic manipulation of annual report disclosures (Yuthas et al., 2002; Li, 2008; Lo et al., 2017), which can involve obfuscation—deliberately making the message unclear or confusing (Merkl-Davies & Brennan, 2007). The opportunity for impression management in annual reports is increasing in the UK setting, with UK FTSE 100 annual reports averaging 147,000 words or 237 pages and growing annually by approximately 5,800 words or almost eight pages (Thomas, 2023; QCA, 2023). While this growth can enhance decision-usefulness, it also enables managerial obfuscation as the content of narrative disclosures is largely unregulated (Merkl-Davies & Brennan, 2007; Delmas & Burbano, 2011; Lyon & Montgomery, 2015).

Various theoretical frameworks, including agency theory, legitimacy theory, and attribution theory have been relied on to examine incentives behind managerial impression management (Merkl-Davies & Brennan, 2007). Impression management is defined as the "*conscious or unconscious attempt* *to control images projected in real or imagined social interactions*" (Schlenker, 1980, p. 6). While primarily a theory of human behaviour, it has been extensively applied to organizational contexts, particularly in response to legitimacy threats (Elsbach, 1994; Elsbach & Kramer, 1996). Firms aim to present a favourable image, even if actual performance does not align with this favourable image, to mitigate legitimacy threats and maintain or enhance their stock prices (Hooghiemstra, 2000).

Based on agency theory (Eisenhardt, 1989; Baiman, 1990), managerial discretion in disclosures can be opportunistic and self-interested (Abrahamson & Park, 1994; Hooghiemstra, 2000; Courtis, 2004; Aerts, 2005; Li, 2008; Lo et al., 2017). Poor carbon performance can create conflicts of interest between managers and shareholders, particularly those (e.g., powerful institutional investors) with an increased focus on green and sustainable investment (Eurosif, 2018). Markets penalize firms for carbon emissions, with even greater penalties for non-disclosure (Matsumura et al., 2014). Firms with unfavourable news may use obfuscation to balance disclosure pressure and image maintenance (Fabrizio & Kim, 2019). Managers may downplay failures and highlight successes (Adelberg, 1979). Thus, increased carbon emission intensity may lead managers to obfuscate poor carbon performance to manage investor impressions who may price protect themselves and even divest from unsustainable firms (Fink, 2020).

Attribution theory also supports the management obfuscation hypothesis. It suggests a self-serving bias where individuals attribute successes to internal factors and failures to uncontrollable or external factors. Poor carbon performance may prompt firms to use technical language and external attributions (Aerts, 2005), leading to complex reporting. Managers may use technical language to explain poor carbon performance to shift the blame to external or uncontrollable factors such as regulatory changes, economic conditions, extreme events, resource constraints, and technical difficulties (Aerts, 2001; Clatworthy & Jones, 2003; Merkl-Davies & Brennan, 2007), thereby resulting in complex environmental reporting. Consistent with this, poor performers exhibit more optimism and less certainty and manipulate reports to enhance positives and obfuscate negatives (Cho et al., 2010, 2012), with this effect likely greater under conditions of high agency conflict. Conversely, good carbon performance encourages managers to use clear language to infer cause-effect statements in environmental reporting, attributing carbon emission reduction success to managerial efforts (Aerts, 2005).

Legitimacy theory offers another important framework for understanding firms' impression management incentives. Firms take action to meet evolving societal bounds and norms to ensure their continued legitimacy (Dowling & Pfeffer, 1975; Hooghiemstra, 2000). Corporate disclosures, particularly regarding social and environmental issues, can shape perceptions of a firm's legitimacy (Cho et al., 2010, 2012; Meng et al., 2014; Fabrizio & Kim, 2019; Moussa et al., 2022). These disclosures are primarily made in response to the firm's external environment (Guthrie & Parker, 1990) and public pressure (Neu et al., 1998). Neu et al. (1998) articulate that firms prefer to provide environmental disclosures in annual reports due to the proximity to the audited financial statements, which inflate a sense of credibility. This helps to convey the environmental message that shapes the way stakeholders perceive and feel about the firm. Therefore, when firms' carbon performance is poor, they may obfuscate the reality of their environmental performance, making it difficult to understand or deflect attention from stakeholders without the expertise to decipher the intricate explanations. By making the environmental reporting appear more sophisticated or framing their environmental performance in a more favourable light, this approach enables them to manage stakeholder perceptions and prevent potential backlash. This desire for legitimacy can motivate poor performers to reduce readability through obfuscation (Fabrizio & Kim, 2019).

Overall, the largely unregulated yet increasing environmental narratives allow managers of UK firms to manage stakeholder impressions via obfuscation (Merkl-Davies & Brennan, 2007; Grewal et al., 2022; Jiang & Tang, 2023). Consequently, poor carbon performance can prompt firms to obfuscate environmental performance by providing complex environmental reporting, managing shareholders' perceptions (Baiman, 1990), attributing failures to external or uncontrollable factors (Aerts, 2005), and maintaining legitimacy (Hooghiemstra, 2000), which impairs the readability of environmental reporting (Bloomfield, 2008; Bushee et al., 2018).

The preceding discussion suggests firms will produce complex environmental reporting when carbon emission intensity increases due to (1) inherent difficulty in explaining poor performance and/or (2) managers' incentives to obscure poor performance (Bloomfield, 2008; Fabrizio & Kim, 2019).

Conversely, a decrease in carbon emission intensity signifies better environmental performance which facilitates communication and reduces managerial obfuscation in their textual disclosures (Li et al., 2022; Nazari et al., 2017). This leads to the formulation of the following hypothesis. This leads to the following hypothesis:

H1: *An increase in carbon emission intensity is related to less readable environmental reporting.*

3.2 SR's Moderating Role in the Impact of Carbon Emission Intensity Changes on Readability

Building on H1, we propose that rigorous SR implementation can influence the two components of linguistic complexity, the information and obfuscation components (Bushee et al., 2018), when firms' carbon emission intensity increases. The following subsections discuss the competing arguments of how SR can either increase or decrease both components of linguistic complexity, thereby creating tension in the moderating effect of SR on the relationship between increasing carbon emission intensity and reduced environmental reporting proposed in H1.

3.2.1 SR's Impact on Information Component Complexity when Carbon Emission Intensity Increases

Rigorous implementation of the SR mandate can influence the information component of linguistic complexity as follows: a) On one hand, SR can enhance firms' understanding of environmental matters, coupled with adherence to SR communication principles, leading to clearer and accessible discussions, thereby reducing information component-related complexity in environmental reporting (FRC, 2014; Burke & Clarke, 2016; Bushee et al., 2018); and b) On the other hand, greater disclosure requirements from the SR mandate can result in cluttered environmental reporting. Particularly, firms may excessively disclose information to meet materiality thresholds, avoid regulatory scrutiny, and maintain legitimacy (Athanasakou et al., 2020; Thomas, 2023), thereby increasing information component-related complexity in environmental reporting. The competing arguments are presented in subsections below.

3.2.1.1 Arguments for SR to Reduce Information Component Complexity when Carbon Emission Intensity Increases

One argument is that rigorous implementation of the SR mandate is likely to enable managers to develop a better understanding of their environmental matters and performance. This deeper understanding, coupled with effective implementation of SR communication principles allows managers to more effectively articulate their environmental performance and matters, thereby improving the readability of the informative-environmental disclosures.

Related literature exploring the implementation of the IR framework shows that IR practices foster tight coordination across different departments and improve communication and transparency in the reporting process, leading to a shared understanding of firm matters (Stubbs & Higgins, 2014; Burke & Clark, 2016; Guthrie et al., 2017). As per the IR literature, establishing cross-functional teams is integral to IR implementation, ensuring that information is harmonized for both external reporting and internal planning processes (Stubbs & Higgins, 2014). This "shared sense of doing" fosters deeper social binding within the organization (Vitolla & Raimo, 2018) and encourages knowledge-sharing and constructive dialogue among employees, managers, and the board (Lai et al., 2018; Dimes & de Villiers, 2020, 2024). Drawing on these insights from the IR literature, a rigorous implementation of the SR mandate—one that similarly fosters cross-functional coordination, shared understandings, and open dialogue—can help managers develop a more holistic grasp of environmental issues, performance, and strategic initiatives. Moreover, the SR mandate emphasizes the use of plain English, minimized technical jargon, and a focus on material issues. By encouraging managers to highlight the key drivers of poor environmental performance, these guidelines can help produce more relevant and accessible disclosures (FRC, 2014). Adhering to SR's communication principles can also reduce stakeholders' cognitive load by lowering linguistic complexity (Bloomfield, 2002; Courtis, 2004; Lang & Stice-Lawrence, 2015), ultimately enhancing the readability of informative-environmental narratives.

In conclusion, the rigorous implementation of SR practices can improve managerial comprehension of their environmental issues and performance. Improved understanding, combined with the effective implementation of SR principles, can enhance the clarity and readability of environmental matters. Therefore, a streamlined narrative facilitated by deeper SR implementation is expected to discourage the use of complex technical jargon, while the use of plain language helps firms offer simpler and digestible explanations for poor performance without sacrificing informativeness, thereby reducing the information component-related complexity in environmental reporting.

3.2.1.2 Arguments for SR to Increase Information Component Complexity when Carbon Emission Intensity Increases

Existing SR research shows that due to the prescriptive nature of the SR mandate, the quantity of narrative disclosures in annual reports has increased, particularly environmental disclosures (Hummel & Rötzel, 2019; Grewal et al., 2022). Extensive environmental reporting from compliance with the SR mandate (FRC 2014; Grewal et al., 2022) combined with the regulatory focus on materiality that emphasizes inclusion over omission, firms may err on the side of caution by providing comprehensive checklists of environmental disclosures in their reporting, contributing to uninformative clutter (Athanasakou et al., 2020; Thomas, 2023). This may result in overly detailed and convoluted narratives on environmental matters and carbon performance, that impairs readability. As noted by the FRC, firms may disclose increased information merely to align with industry peers, avoid drawn-out discussions with auditors, or out of concern that omissions could be scrutinized by regulators (FRC, 2009, 2011; Thomas, 2023). Consistent with this, increased carbon emission intensity may incentivize managers to provide extensive disclosures on environmental matters, to merely comply or avoid regulatory scrutiny. This can lead to information overload and clutter, obscuring material environmental information. In the UK context, Athanasakou et al. (2020) find a U-shaped relationship between annual report narratives and the cost of equity capital, where increased levels of disclosure initially reduce the cost of equity, but beyond a certain point, increased disclosure leads to an increase in the cost of equity. They attribute the increase to the presence of uninformative clutter at higher levels of disclosures, which reduces the clarity and usefulness of the reports, ultimately raising the cost of equity capital.

Therefore, extensive carbon reporting required by the SR mandate, combined with a regulatory emphasis on including material information, may lead firms to over-disclose environmental information by providing comprehensive disclosures on poor carbon performance, resulting in uninformative clutter and impaired readability due to overly detailed and convoluted narratives (Athanasakou et al., 2020; Thomas, 2023). This information overload, motivated by desires to comply or avoid regulatory scrutiny, can obscure material information and reduce the clarity and usefulness of environmental disclosures (Athanasakou et al., 2020), thereby increasing the information component-related complexity in environmental reporting

3.2.2 SR's Impact on Obfuscation Component Complexity when Carbon Emission Intensity Increases

Rigorous implementation of the SR mandate can influence the obfuscation component of linguistic complexity as follows: a) On one hand, SR's forward-looking disclosure requirements can align incentives of managers with shareholders' long-term orientation (Serafeim, 2015; Obeng et al., 2021), reducing incentives to obfuscate information, thereby incentivizing informative and future-oriented discussions on firm carbon performance and environmental matters. Further, SR's broader stakeholder focus can also reduce the incentives to obfuscate information as firms align their reporting with diverse stakeholder needs to maintain their social license to operate and address legitimacy concerns (Zhang et al., 2021); b) On the other hand, SR's extensive carbon disclosure requirements may also increase opportunities for information obfuscation, resulting in managers providing obfuscated environmental information to deter attention away from poor carbon performance (Bloomfield, 2008; Bushee et al., 2018). The competing arguments are discussed in the subsections below.

3.2.2.1 Arguments for SR to Reduce Obfuscation Component Complexity when Carbon Emission Intensity Increases

The SR mandate emphasizes a forward-looking orientation as a key communication principle, along with connectivity, conciseness, and the use of plain language (FRC, 2014). This forward-looking perspective can align managers' incentives with those of shareholders who prioritize long-term value creation (Obeng et al., 2021). This alignment can reduce the incentive to engage in obfuscation as managers demonstrate commitment to long-term value creation by reporting on plans to tackle increasing carbon emission intensity. Related IR literature indicates that future-oriented reporting underlying IR attracts long-term investors (Serafeim, 2015) and contributes to positive future cash flows (Barth et al., 2017). Obeng et al. (2021) suggest that transparent, forward-looking IR disclosures improve incentive alignment between managers and shareholders. Bui et al. (2020) find that high carbon emission intensity is associated with a greater cost of equity capital, but this penalty is alleviated by extensive carbon disclosures. Therefore, rigorous SR implementation can induce a future focus and mitigate managerial myopia by aligning managers' incentives with those of the shareholders, thereby reducing the tendency to obscure poor environmental performance, such as increasing carbon emissions.

Further, the SR mandate requires a broad stakeholder focus, including employees, customers, suppliers, communities, and other key groups alongside shareholders (FRC, 2014). This inclusive approach may shift corporate reporting from a narrow, shareholder-centric view to addressing the expectations of diverse stakeholders who are increasingly concerned about environmental issues. Under legitimacy theory, firms strive to align their reporting with societal norms and values to maintain their social license to operate (Suchman, 1995). Obfuscation in environmental reporting can erode trust among stakeholders and damage a company's reputational capital, especially when it comes to critical issues like carbon emissions (Lyon & Montgomery, 2015). Existing research shows that CSR reporting alleviates reputational damage and plays an insurance-like or value-protection role during crisis periods (Zhang et al., 2021), such as when carbon emission intensity rises. Rigorous SR implementation can foster such stakeholder-centric reporting, reducing managerial incentives to obfuscate information, thereby strengthening stakeholder trust and maintaining legitimacy. Therefore, rigorous SR practice can align reporting with broader stakeholder groups, thereby reducing managerial incentives to obfuscate environmental reporting when carbon emission intensity increases.

Overall, the SR mandate's emphasis on forward-looking reporting can align managerial incentives with long-term shareholder interests, reducing the motivation to obscure poor environmental performance. Further, SR's expanded reporting scope considers a broad range of stakeholders, which can incentivize firms to provide transparent and reliable information to build trust, and maintain legitimacy, thereby further diminishing incentives to obfuscate poor environmental performance.

3.2.2.2 Arguments for SR to Increase Obfuscation Component Complexity when Carbon Emission Intensity Increases

Hummel and Rötzel (2019) report that the quantity of narrative disclosures in annual reports, particularly environmental disclosures, has increased. While extensive carbon disclosure requirements provide firms with opportunities to present decision-useful information, it can also allow firms to include excessive or irrelevant information to divert attention from poor performance or legitimacy concerns (Merkl-Davies & Brennan, 2007; Bloomfield, 2008), thereby enabling managerial obfuscation. Grewal et al. (2022) highlight that the SR mandate reduced opportunities for selective carbon disclosure, a form of greenwashing. However, when the mandate's prescriptive carbon disclosure requirements limit selective reporting, firms may instead resort to increasing the linguistic complexity of environmental narratives to obfuscate poor performance. Extensive environmental reporting requirements under the SR mandate could incentivize impression management or obfuscation as firms seek to maintain legitimacy and influence contractual outcomes (Hooghiemstra, 2000; Wruck & Wu, 2021), potentially offsetting readability improvements. The expanded scope for environmental disclosures (FRC, 2014; Grewal et al., 2022; Jiang & Tang, 2023) may enable firms to use narratives to divert attention from critical environmental issues, such as poor carbon governance (Fabrizio & Kim, 2019). This can result in longer, less readable commentaries when carbon emission intensity increases, exacerbating obfuscation-related complexity in environmental reporting (Bloomfield, 2008; Bushee et al., 2018).

The preceding subsections presented contrasting arguments regarding how the SR mandate may influence the two components of linguistic complexity in environmental reporting. On one hand, SR can reduce information-related complexity when carbon emission intensity increases by fostering managers' understanding of environmental issues and promoting effective communication principles, such as plain language and materiality, which enhance the readability of disclosures. On the other hand, SR's extensive disclosure requirements and regulatory emphasis on inclusion may encourage over-disclosure, resulting in overly detailed and convoluted narratives that increase information complexity. Similarly, for obfuscation-related complexity, SR's forward-looking orientation and stakeholder-focused approach may align managerial incentives with stakeholders' long-term value creation goals, reducing the likelihood of obfuscation when carbon emission intensity rises. However, the expanded scope for environmental disclosures may also create opportunities for managers to obscure poor performance through lengthy and complex narratives. Thus, the moderating effect of rigorous SR on the relationship between rising carbon emission intensity and reduced readability remains contested. These discussions lead to the formulation of the following hypothesis in null form:

H2: *Rigorous SR does not moderate the relationship between increased carbon emission intensity and reduced environmental reporting readability.*

4. Research Design

4.1 Sample and Data

Table 1 Panel A shows the sample construction procedures. The sample construction begins with the proprietary PwC UK data covering the FTSE 350 firms listed on the LSE from the period 2010-2021. Firms in the financial and utilities industry are excluded due to their different operating and financial structures (Loughran & Ritter, 1997).[2] After merging all the data and removing observations with missing control variables, the sample comprises 178 unique firms and 1,020 firm-year observations from 2013-2021—the period following the SR regulation mandate. Variable definitions are provided in Appendix A.

[Insert Table 1]

Table 1 Panel B shows the industry distribution for the sample firms. The industry classification is based on the UK Standard Industrial Classification (SIC). The observations are distributed across 13 industry sectors. The largest number of observations are from the manufacturing sector (24.41%), followed by wholesale and retail trade (13.43%), professional, scientific, and technical activities (12.16%), and construction (12.06%).

4.2 Empirical Models

Hypothesis 1 (H1) posits that an increase in carbon emission intensity is associated with less readable environmental reporting. Hypothesis 2 (H2), proposed in null form, suggests that rigorous implementation of SR does not moderate this deteriorating effect on readability. To test H1 and H2, we employ the following Ordinary Least Squares (OLS) models, respectively:

$$\begin{aligned}
Environmental_Bog_{i,t} &= \beta_0 Constant_{i,t} + \beta_1 Chg_CarbonIntensity_{i,t} + \beta_2 SRrank_{i,t} + \beta_3 Earnings_{i,t} \\
&+ \beta_4 Size_{i,t} + \beta_5 MTB_{i,t} + \beta_6 Firm_Age_{i,t} + \beta_7 GEOG_Segments_{i,t} \\
&+ \beta_8 PROD_Segments_{i,t} + \beta_9 Governance_Score_{i,t} + \beta_{10} Env_RD_Exp_{i,t} \\
&+ \beta_{11} EmissionOffsets_Dummy_{i,t} + \beta_{12} ESGLink_Dummy_{i,t} \\
&+ \beta_{13} CSRCommittee_Dummy_{i,t} + \beta_{14} EnvControversies_Dummy_{i,t} \\
&+ \beta_{15-n} YearFE_{i,t} + \beta_{m-k} IndustryFE_{i,t} + \varepsilon_{i,t} \qquad (1)
\end{aligned}$$

[2] Removed industry sectors include: Financial and insurance activities; Real estate activities; Electricity, gas, steam, and air conditioning supply; and Water supply; sewerage, waste management, and remediation activities.

$$
\begin{aligned}
Environmental\_Bog_{i,t} \\
= {} & \beta_0 Constant_{i,t} + \beta_1 Chg\_CarbonIntensity_{i,t} + \beta_2 High\_SR_{i,t} \\
& + \beta_3 (Chg\_CarbonIntensity_{i,t} \times High\_SR_{i,t}) + \beta_4 Earnings_{i,t} + \beta_5 Size_{i,t} \\
& + \beta_6 MTB_{i,t} + \beta_7 Firm\_Age_{i,t} + \beta_8 GEOG\_Segments_{i,t} + \beta_9 PROD\_Segments_{i,t} \\
& + \beta_{10} Governance\_Score_{i,t} + \beta_{11} Env\_RD\_Exp_{i,t} \\
& + \beta_{12} EmissionOffsets\_Dummy_{i,t} + \beta_{13} ESGLink\_Dummy_{i,t} \\
& + \beta_{14} CSRCommittee\_Dummy_{i,t} + \beta_{15} EnvControversies\_Dummy_{i,t} \\
& + \beta_{16-n} YearFE_{i,t} + \beta_{m-k} IndustryFE_{i,t} + \varepsilon_{i,t} \qquad (2)
\end{aligned}
$$

The dependent variable, *Environmental_Bog,* proxies for firm environmental reporting readability, where higher (lower) values indicate low (high) readability. The main test variable in Model (1) is *Chg_CarbonIntensity* which captures the change in a firm's carbon emission intensity relative to the previous year benchmarked against the industry's change, with positive (negative) values indicating an increase (decrease) in carbon emission intensity. To support H1, the coefficient on *Chg_CarbonIntensity* is expected to be positive and significant. The model also controls for *SRrank* which captures the SR quality of a firm, decile ranked in each industry year.

The coefficient of interest in Model (2) is the interaction between *Chg_CarbonIntensity* and *High_SR*. *High_SR* is an indicator that equals 1 if the *SRrank* is higher than the industry-year mean, 0 otherwise. A negative (positive) and significant coefficient on the interaction term suggests rigorous SR mitigates (worsens) deteriorating readability when carbon emission intensity rises. The measurement of all variables is detailed in Appendix A. In all empirical models, the variables are standardized for ease of interpretation and comparison of effect sizes. Year- and industry-fixed effects are added to control for heterogeneity (Fabrizio & Kim, 2019).

4.2.1 Measure of Environmental Reporting Readability

Prior literature often employs readability metrics to assess the complexity of corporate reporting, particularly the Fog index (Li, 2008; Loughran & McDonald, 2014; Lo et al., 2017). However, Loughran and McDonald (2014) critique the Fog index for overemphasizing multi-syllabic words as indicators of complexity. To address this limitation, Bonsall et al. (2017) propose the Bog index, which refines readability measurement by reducing the over-penalization of complex words. The Bog index is calculated as:

$$Bog = Sentence\ bog + Word\ bog - Pep \qquad (3)$$

Sentence Bog assesses complexity arising from sentence length by squaring and scaling the average sentence length against a standard limit of 35 words per sentence. *Word Bog* captures issues related to plain English usage and word difficulty. *Pep* accounts for writing attributes that enhance reader understanding, such as the use of names and interesting words. A higher Bog index indicates lower readability.[3] To create a firm-level measure of environmental reporting readability (*Environmental_Bog*), we first extract environmental narratives from annual reports. Since environmental disclosures are integrated throughout various sections of annual reports given the integrated approach to reporting (FRC, 2014) —such as the Strategic Report and Directors' Report— (FRC, 2014), we employ machine learning and natural language processing to extract the environmental narratives interspersed in a firm's annual report. These procedures are outlined below.

4.2.1.1 Text Classification – Classifying Environmental Reporting Narratives in Annual Reports

Textual analysis is increasingly used in accounting and finance research (Loughran & McDonald, 2016; Bae et al., 2023; Bochkay et al., 2023). We use machine learning and natural language processing to classify corporate disclosures, which outperform traditional dictionary-based methods (Siano & Wysocki, 2020; Frankel et al., 2021).

We use a corpus-based, language-independent approach for semantic text classification to identify latent word similarities within the training corpus (Altınel & Ganiz, 2018). Recognizing that domain-specific knowledge improves accuracy (Brill, 1993), we trained the model on a manually annotated corpus of environmental narratives from 23 UK FTSE firms' annual reports.[4] The narratives were classified into six categories based on the IR framework: financial, natural, social & relationship, human, intellectual, manufactured, and an additional unclassified.[5] The primary focus is the natural capital category, which covers environmental matters. Including the other categories enhances the

[3] Refer to Wright (2009) and Bonsall et al. (2017) for an in-depth explanation and validation of the measure.
[4] These companies' 2014 annual reports were manually annotated, with each narrative extract (sentence or paragraph) classified into the following categories: financial, natural, social & relationship, human, intellectual, manufactured, and unclassified (serving as a control category). The 2014 annual reports represent the second year following the implementation of the SR mandate in 2013. Additionally, these companies were recognized on the IIRC's best reporting practices website, making them an ideal selection for creating the training corpus.
[5] These categories, known as 'the six capitals,' are derived from the IR framework, which shares similar reporting content elements as well as communication principles with the SR mandate and was released concurrently in 2013 (IIRC, 2013; FRC, 2014).

model's ability to distinguish environmental narratives from other types, thereby improving classification accuracy (see Appendix B for the annotation guide).

The training corpus is pre-processed to remove numbers, punctuation marks, special characters, and stop words.[6] Words are stemmed to their morphological roots using Porter's algorithm (Porter, 1980),[7] reducing feature dimensionality and enhancing model efficiency (Bochkay et al., 2023). Since machine learning algorithms cannot read text directly, features must be extracted from the text and weighted via some function. Three techniques were tested: term frequency (*tf*), term frequency-inverse document frequency (*tf-idf*), and word2vec. The traditional *tf* weighting approach relies on the frequency of the words in a document and is analogous to the bag of words approach (Bochkay et al., 2023; Loughran & Mcdonald, 2016). On the other hand, *tf-idf* is the product of term frequency and inverse document frequency (Bae et al., 2023), defined by Sebastiani (2002) as

$$tfidf(t_k, d_j) = \#(t_k,\ d_j)\ .\ log\frac{|Tr|}{\#Tr(t_k)} \tag{4}$$

where $\#(t_k,\ d_j)$ denotes the number of times the word t_k occurs in document d_j. $|Tr|$ is the total number of documents. $\#Tr(t_k)$ denotes the document frequency of the term t_k, i.e. the number of documents in Tr in which the word t_k occurs. Essentially, the *tf-idf* weighting captures the uniqueness of a word in a document, alleviating the issue of over-weighting common words associated with *tf.* It relies on the intuition that: (i) the more often a word occurs in a document (a narrative reporting category, in the case of this study), the more it is representative of its content; and (ii) the more documents a word occurs in, the less it is discriminating (Sebastiani, 2002). Thus, capturing features (words) unique to a narrative reporting category. The third technique, word2vec, leverages the contextual relationships between words in a corpus to create dense vector representations, where each word's position in the vector space reflects its semantic similarity and usage patterns within the text (Mikolov et al., 2013). We use *tf-idf* to extract features for classifier training, given it provided the highest estimated classification accuracy.

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[6] Stop words, such as 'it,' 'also,' 'too,' 'all,' 'a,' and 'as,' occur in abundance in any text. Removing these words increases accuracy and efficiency of the model.
[7] For instance, words 'connected,' 'connecting,' 'connection,' and 'connections' would be stemmed to their morphological root which is 'connect'.

To train the text classification model using the *tf-idf* features, we use the ranger algorithm, a fast implementation of random forests optimized for high-dimensional data such as text (Wright & Ziegler, 2017). The training was conducted using out-of-bag (OOB) sampling, a technique implemented in random forests. In OOB sampling, each tree is trained on a bootstrap sample containing approximately 63% of the data, while the remaining 37%—the OOB data—serves as a test set for that tree.[8] By aggregating the OOB predictions across all trees, the model can internally estimate prediction error, providing an unbiased performance measure (Breiman, 2001).

The confusion matrix below illustrates the classification performance of the text classifier based on the training corpus, with diagonal entries indicating correct predictions. The model achieved an overall accuracy of approximately 68%, with the natural capital category displaying the following performance metrics: 97.51% accuracy, 73.28% recall, 82.74% precision, and a 77.73% F1 score. These results are comparable to benchmarks in prior literature (Siano & Wysocki, 2020).[9]

Confusion Matrix

True / Predicted	Financial	Human	Intellectual	Manufactured	Natural	Social_Relationship	Unclassified
Financial	1559	2	29	5	2	35	206
Human	8	465	17	0	0	149	57
Intellectual	95	30	952	24	24	202	248
Manufactured	55	5	95	125	15	35	162
Natural	7	2	23	2	417	98	20
Social_Relationship	45	82	156	6	28	1359	225
Unclassified	285	26	208	27	18	260	1722

To further validate the model, we conduct Latent Dirichlet Allocation (LDA). LDA is a generative probabilistic model which models documents as a mixture of topics, and each topic as a mixture of words (Blei et al., 2003). The results from implementing a 6-topic LDA model, corresponding to the six narrative reporting themes, are detailed in Figures 1 and 2 in Appendix C. Figure 1 shows the LDA-predicted topics as a mixture of words, where beta represents the probability of each word occurring in a topic. Figure 2 illustrates the probability of each topic from Figure 1

[8] We train the text classification model using 400 trees, which provided the best balance between accuracy and efficiency compared to different iterations starting from 10 trees.

[9] Accuracy reflects the proportion of correctly predicted instances (both true positives and true negatives) out of the total predictions made. Accuracy = (TP+TN)/(TP+TN+FP+FN). Recall (Sensitivity) measures the proportion of true positive correctly identified out of all actual positive instance, measuring how well the model detects positives. Recall (Sensitivity) = TP/(TP+FN). Precision measures the proportion of true positives out of all predicted positives, showing how many of the predicted positives are actually correct. Precision = TP/(TP+FP). F1 Score is the harmonic mean of precision and recall, balancing the trade-off between false positives and false negative for overall effectiveness. F1 Score = 2*[(Precision*Recall)/(Precision+Recall)] (Bochkay et al., 2023).

appearing in a document, corresponding to each reporting category. For example, Topic 2 in Figure 1 includes words like ‘water,’ ’emissions, ’ ’energy,’ ‘carbon,’ ‘climate,’ and ‘environmental,’ suggesting a focus on environmental matters. This is corroborated in Figure 2, where Topic 2 has the highest probability of being present in the classified text for natural capital reporting. The LDA results align well with the classified categories, especially for the natural capital category.

For final validation, we compare the top 15 words for each classification category derived from both the training corpus and the classified text from the sample annual reports in Appendix D (Figures 3 and 4). The consistency of these words across both sets provided further confirmation of the classification method's effectiveness. For example, in the manually annotated natural capital category, common words include ‘water,’ ‘emissions,’ ‘climate,’ ‘carbon,’ ‘environmental,’ ‘waste,’ ‘greenhouse,’ and ‘reduction.’ Similarly, in the classified natural capital category, frequent terms such as ‘water,’ ‘emissions,’ ‘energy,’ ‘carbon,’ ‘waste,’ ‘climate,’ and ‘environmental’ are observed. This alignment indicates robustness and accuracy, reinforcing the validity of the text classification methodology.

Finally, the trained model is applied to annual reports from 2013 to 2021 to extract environmental narratives. The *Environmental_Bog* is computed for these narratives using the Bog index per Model (3), quantifying the complexity of environmental reporting (Bonsall et al., 2017).

4.2.2 Measure of Change in Carbon Emission Intensity

We capture the change in a firm’s carbon emission intensity relative to the previous year benchmarked against the industry’s change. *Chg_CarbonIntensity* is calculated as follows:

$$Chg\_CarbonIntensity = \left(\frac{Emissions_{firm,t}}{Sales_{firm,t}} - \frac{Emissions_{firm,t-1}}{Sales_{firm,t-1}}\right) - \left(\frac{Emissions_{industry,t}}{Sales_{industry,t}} - \frac{Emissions_{industry,t-1}}{Sales_{industry,t-1}}\right) \quad (5)$$

Carbon emission intensity is calculated as total emissions in year *t* scaled by total revenue (Aswani et al., 2014). Following Qian and Schaltegger (2017), the change in a firm’s carbon emission intensity is calculated as the annual difference between a firm’s carbon emission intensity in year *t* and year *t*-1. The firm’s change in carbon emission intensity is then adjusted for a change in industry carbon industry change, resulting in the final measure, *Chg_CarbonIntensity*. This study adjusts firms' carbon emission intensity relative to the industry average, as firms operating under a mandatory carbon disclosure regime benchmark their GHG emissions performance against industry peers to evaluate their progress (Tomar, 2023). A positive (negative) value for *Chg_CarbonIntensity* indicates that the firm's carbon emission intensity has increased (decreased) relative to the industry average.

4.2.3 Measure of Strategic Reporting Quality

This study assesses the rigor of UK firms' SR implementation using proprietary data from PwC UK, which has evaluated the reporting quality of FTSE 350 firms since 2008, with SR mandate-based criteria applied from 2013.[10] Therefore, we utilize data from 2013 onwards (Wang et al., 2024). PwC's assessment measures the existence and quality of reporting across various content elements of reporting and the degree of connectivity between these content elements. Firms are, for example, evaluated on how well their strategy discussions are integrated to risks, business models, and sustainability issues, and whether they provide future-oriented information (such as target KPIs for future years).

The construction of the SR rank measure utilizes PwC scoring questions. We first create a scaled SR score (*Scaled_SR_Score*), dividing each firm's raw score (*Firm_SR_Score*) by the total available score for that year (*Total_Available_SR_Score*). PwC's scoring questions vary annually due to regulatory updates. Thus, following Barth et al. (2017) and Wang et al. (2024), the raw scores are converted into a rank (*SRrank*) from 1 to 10, within each year-industry combination, ensuring accurate relative performance within their respective industry and year contexts.

4.2.4 Control Variables

The empirical model controls for several firm characteristics affecting the readability of environmental reporting, drawing on prior studies (Li, 2008; Lo et al., 2017; Lim et al., 2018; Fabrizio & Kim, 2019). Larger firms (*Size*; log of total revenue) have more resources and face greater regulatory pressures to provide leading to higher-quality climate change information (Clarkson et al., 2008; Matsumura et al., 2014). More profitable firms (*Earnings*; operating earnings scaled by total assets) are better equipped to meet compliance targets and produce readable environmental reports (Qian & Schaltegger, 2017; Bose et al., 2023). Firms with growth opportunities, measured by the market-to-book ratio (*MTB*), have complex and uncertain business models, which can lead to more intricate annual

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[10] This study gratefully acknowledges PwC UK for generously providing access to their valuable data for conducting this study.

reports (Li, 2008). This can extend to their carbon emissions patterns, which can complicate environmental reporting (Fabrizio & Kim, 2019). Firm age (*Firm_Age*; years since the firm first appears in the Compustat daily stock return file) is included because older firms are likely to have better infrastructure to manage and report climate issues (Bose et al., 2023). The complexity of a firm's operations, measured by geographical (*GEOG_Segments*) and product segments (*PROD_Segments*), can lead to more complex reports (Li, 2008; Fabrizio & Kim, 2019). Governance effectiveness, measured by the Refinitiv ESG governance score (*Governance_Score*), is controlled for, as strong governance can reduce impression management and improve environmental disclosure quality (Osma & Guillamón-Saorín, 2011; Walls et al., 2012).

The model also considers various firm-related factors that may influence environmental reporting. Environmental R&D expenses (*Env_RD_Exp*), can lead to longer, more complex reports due to disclosures about technological innovations to reduce emissions (Costa-Campi et al., 2017). The model also controls for emission offsets (*EmissionOffsets_Dummy*), as reliance on offsets can create uncertainty and require detailed explanations, reducing readability (Haya et al., 2020). Additionally, the model controls for executive compensation linked to ESG performance (*ESGLink_Dummy*), as ESG-linked pay can lead to clearer emissions disclosures, though it may also incentivize obfuscation if firms perform poorly on ESG metrics (Cohen et al., 2023).

The model also considers various firm-related factors that may influence environmental reporting. We control firms' environmental R&D expenses (*Env_RD_Exp)*. Firms that invest in environmental R&D are expected to disclose relevant information regarding investment to reduce emissions and meet regulatory policies (Costa-Campi et al., 2017). Disclosing complex innovations and technologies to reduce emissions may increase report length and reduce readability. Next, firms relying on carbon offsets may face challenges in demonstrating actual emission reductions, creating uncertainty about whether targets have been met (Haya et al., 2020). This uncertainty may require detailed explanations regarding the sources of offsets and their contribution to emission reductions, reducing readability. We control for executive compensation linked to ESG performance (*ESGLink_Dummy*). While ESG-linked pay can improve ESG performance (Cohen et al., 2023), and thereby encourage clearer disclosures, it can also incentivize obfuscation if firms underperform on ESG metrics. The presence of a CSR committee (*CSRCommittee_Dummy*) is included, as it can enhance reporting readability by aligning the firm's actions with stakeholder expectations (Radu & Smaili, 2022). Finally, environmental controversies (*EnvControversies_Dummy*) are controlled for, as firms involved in controversies may produce less readable reports (Fabrizio & Kim, 2019). Finally, the model includes year and industry-fixed effects, with firm-level clustered standard errors.

4.3 Descriptive Statistics

Table 2 Panel A reports the sample descriptive statistics. All continuous variables are winsorized at the 1st and 99th percentiles to account for outliers. The mean (median) *Environmental_Bog* of 93.63 (93) suggests that the readability of environmental reporting of UK firms is generally poor, resonating with the FRC's (2009; 2011) concerns that complexity in annual reports is prevalent in CSR reporting.[11] The primary test variable (*Chg_CarbonIntensity*) shows a mean (median) value of -1.023 (-1.350) CO2 emissions per million dollars of revenue, indicating an average reduction in firms' carbon emission intensity relative to the previous year, consistent with Downar et al. (2021) who report reductions in firm carbon emissions following the SR mandate. The *SRrank* of UK firms, as measured by the PwC data has a mean of 5.097, on a scale of 1 to 10, consistent with Wang et al. (2024) who report 0.523, on a scale of 0 to 1, using the same PwC proprietary data. Among the environmental variables, few firms invest in environmental R&D to reduce environmental impact, and on average, 5.2% of the firms have emissions offsets, 42.4% link executive compensation to ESG performance, 79% have a CSR committee, and 2.5% are involved in environmental controversies.

[Insert Table 2]

Table 2 Panel B presents the difference of means test between low and high *SRrank* firms. *High_SR* equals 1 if a firm's *SRrank* exceeds the industry-year mean, and 0 otherwise. The univariate analysis shows that low *SRrank* firms have a higher average *Environmental_Bog* (94.675) compared to high *SRrank* firms (92.781), with a statistically significant difference (p = 0.026) at the 5% level, indicating more readable environmental reporting among those with greater SR compliance. While high

[11] The Bog index is interpreted as follows: 0 to 20 = excellent; 21 to 40 = good; 41 to 70 = average; 71 to 100 = poor; 101 to 130 = bad; 131 to 1000 = dreadful; 1000+ = gobbledygook. Thus, a mean Bog index score of 93+ falls into the 'poor' category, indicating that the text is hard to understand (Bonsall & Miller, 2017).

SRrank firms show a reduction in carbon emission intensity compared to an increase in low *SRrank* firms, the difference is not significant. Additionally, high *SRrank* firms tend to be smaller, have more geographical and product segments, better governance scores, more emission offsets, and a higher proportion of CSR committees than low *SRrank* firms.

Table 2 Panel B also reports the difference of means test for covariates across carbon emission intensity decrease and increase subsamples. Firms with a carbon emission intensity decrease (*Chg_CarbonIntensity* < 0) have a lower average *Environmental_Bog* (92.98) compared to those with an increase (*Chg_CarbonIntensity* > 0), with the difference being significant at the 5% level ($p = 0.026$). Overall, firms exhibiting increased carbon emission intensity tend to be smaller, show lower growth, are younger, have higher governance scores, and use fewer emission offsets.

Figure 5 shows the scaled average *Environmental_Bog* (y-axis) for carbon emission intensity decrease and increase groups (x-axis), separated by high *SRank* (green) and low *SRank* (red) firms. *Environmental_Bog* is higher when carbon emission intensity increases, consistent with H1. However, the increase in *Environmental_Bog* is less pronounced for firms with high *SRrank* compared to those with low *SRrank*, indicating that while rising emissions contribute to greater reporting complexity, high *SRrank* firms experience this effect to a lesser extent. This is indicative that better SR compliance potentially mitigates the impact of increasing carbon intensity on *Environmental_Bog*.

[Insert Figure 5]

Table 3 presents the correlation matrix, with Spearman (Pearson) correlations in the lower (upper) diagonal. *Environmental_Bog* is positively correlated with *Chg_CarbonIntensity*, though not significantly. *SRrank* is significantly and negatively correlated with *Environmental_Bog*. However, these correlations do not account for potential confounding factors and should be interpreted cautiously. The highest correlation between independent variables is between *Earnings* and *MTB* (Spearman$[\rho]$ = 0.67, Pearson$[\rho]$ = 0.71). The variance inflation factor (VIF) reported from Models (1) and (2) shows no multicollinearity concerns, as all VIFs are below the threshold of 10 (Kennedy, 1992).

[Insert Table 3]

5. Empirical Results

5.1 Main results

Table 4 presents the main results. Column (1) shows that *Chg_CarbonIntensity* is positively related to *Environmental_Bog* at a 5% significance level (coefficient = 0.046, p-value = 0.022), supporting H1. This indicates that an increase in carbon emission intensity results in less readable environmental reporting, consistent with Fabrizio and Kim (2019). Section 6.1 attempts to disentangle whether deteriorated readability when carbon emission intensity rises is due to a firm-related complex environment when carbon emissions rise or managers' incentives to obscure poor performance using complex language (Bloomfield, 2008; Fabrizio & Kim, 2019). *SRrank* is significantly and negatively related to *Environmental_Bog* at a 10% significance level (coefficient = -0.071, *p*-value = 0.097), suggesting a first-order effect of rigorous SR implementation in enhancing environmental reporting readability.

[Insert Table 4]

Column (2) shows that the interaction between *Chg_CarbonIntensity* and *High_SR* is negatively related to *Environmental_Bog* at the 5% significance level (coefficient = -0.086, *p*-value = 0.040). This indicates that rigorous implementation of SR mitigates the reduced readability caused by increased carbon emission intensity. Section 6.1 disentangles whether SR's role in mitigating deteriorating readability when carbon emission intensity rises is due to improved managerial comprehension of environmental performance and matters, or due to reduced obfuscation incentives. Among other variables, *GEOG_Segments* has a significantly positive relationship with *Environmental_Bog*, indicating that firms with more geographic segments produce more complex environmental reports due to the need to address regional environmental impacts and regulations. Additionally, *CSRCommittee_Dummy* is significantly negatively related to reporting complexity, suggesting that firms with a CSR committee provide better oversight, improving the clarity and rigor of environmental reporting (Velte & Stawinoga, 2020; Radu & Smaili, 2022).

5.2 Robustness Analyses

5.2.1 Propensity Score Matching

To address potential endogeneity concerns from sample selection bias, this study employs propensity score matching (PSM) (Rosenbaum & Rubin, 1983). Since the distribution of firms with high versus low *SRrank* may not be random, PSM reduces variation in confounding variables affecting *Environmental_Bog*. To implement PSM, the *High_SR* indicator is used which equals 1 if *SRrank* is greater than the industry-year mean (i.e., treatment group), and 0 otherwise (i.e., control group). A probit model regresses *High_SR* on the control variables from Model (1), generating propensity scores to match treatment firms with control firms within a caliper width of 0.01. This process results in 784 matched firm-year observations, ensuring similar firm attributes with differing *SRrank*. Untabluted analysis shows that covariate balance is achieved after PSM, as the difference-in-means test reveals no significant differences between treatment and control groups, validating the matching process. Table 4 Columns (3) and (4) present results for H1 and H2, respectively, using the PSM-matched sample. Column (3) confirms *Chg_CarbonIntensity* remains positively and significantly related to Environmental_Bog (coefficient = 0.051, *p-value* = 0.018). Column (4) shows the interaction *Chg_CarbonIntensity* * *High_SR* remains negatively and significantly related to *Environmental_Bog* (coefficient = -0.099, *p-value* = 0.042), supporting core findings.

5.2.2 Entropy Balancing

To address potential biases from functional form misspecification and sample selection bias, this study applies entropy balancing (EB) (Hainmueller, 2012). Compared to PSM, EB optimally weights control observations (*High_SR* = 0) to match treatment observations (*High_SR* = 1), ensuring covariate balance while retaining the sample size. Untabulated results show that covariates differ before EB but are balanced across all three moments (mean, variance, skewness) post-EB, ruling out confounding factors. Models (1) and (2) are re-estimated with reweighted covariates. Table 5 Column (5) confirms *Chg_CarbonIntensity* is positively related to *Environmental_Bog* at the 1% significance level (coefficient = 0.059, *p*-value = 0.008), while Column (6) shows the interaction *Chg_CarbonIntensity* * *High_SR* is negatively related at the 5% significance level (coefficient = -0.084, *p*-value = 0.050). These results reinforce the main findings.

5.2.3 Heckman Sample Selection Test

PSM and EB address sample selection bias from observable characteristics. To account for potential bias from unobservable characteristics, a Heckman two-stage model is employed (Heckman, 1979; Tucker, 2011). In the first stage, a probit regression is run with *High_SR* as the dependent variable, using an instrumental variable that determines the likelihood of greater compliance with SR but does not directly affect environmental reporting readability. The first-stage probit model is specified as follows:

$$\begin{aligned} High\_SR_{i,t} = \; & \beta_0 Constant_{i,t} + \beta_1 GC\_Signatory_{\,i,t} + \beta_2 ROA_{i,t} + \beta_3 Size_{i,t} + \beta_4 MTB_{i,t} \\ & + \beta_5 Leverage_{i,t} + \; + \beta_6 Firm\_Age_{i,t} + \beta_7 Big4_{i,t} + \beta_8 Board\_Size_{i,t} \\ & + \beta_9 Board\_Independence_{i,t} + \beta_{10} Board\_GenderDiversity_{i,t} \\ & + \beta_{11} Board\_AverageTenure_{i,t} + \beta_{12} Board\_Skills_{i,t} + \beta_{13} AC\_Independence_{i,t} \\ & + \beta_{14} CSR\_Score_{i,t} + \beta_{15-n} YearFE_{i,t} + \beta_{m-k} IndustryFE_{i,t} \\ & + \; \varepsilon_{i,t} \end{aligned} \qquad (6)$$

GC_Signatory is the instrumental variable, set to 1 if a firm is a voluntary signatory of the United Nations Global Compact (UNGC), a non-binding initiative promoting sustainable and socially responsible practices (UNGC, n.d.), 0 otherwise. Voluntary participation signals a firm's commitment to addressing stakeholder needs and aligning with global sustainability standards (Cetindamar, 2007; Malafronte & Pereira, 2020), influencing rigorous implementation of SR but not directly affecting the readability of environmental reporting. Model (6) incorporates key determinants of SR, drawing from prior disclosure and IR literature. Firm profitability (*ROA*) and size (*Size*) are included, as both are associated with greater resources and external pressures, leading to better disclosure (Dhaliwal et al., 2014; Bose et al., 2024). Growth opportunities (*MTB*) are included, as high-growth firms provide more extensive information to reduce information asymmetry (Clarkson et al., 2008). *Leverage* is also controlled, with no predicted direction, as financial constraints can lead to either selective disclosure or more comprehensive reporting to satisfy creditors (Clarkson et al., 2011; Ott et al., 2017). *Firm_Age* is included without a predicted direction, as older firms often have established sustainability reporting infrastructure, while younger firms may enhance non-financial disclosures to build investor confidence (Haniffa & Cooke, 2005; Li et al., 2008; Bose et al., 2023).

The model further includes audit firm size (*Big4*), board size (*Board_Size*), board independence (*Board_Independence*), and board gender diversity (*Board_GenderDiversity*) as determinants of SR quality, as these factors are linked to enhanced monitoring and better reporting practices (Liao et al., 2015; Obeng et al., 2021). We also control for board average tenure (*Board_AverageTenure*), recognizing its potential impact on CSR performance, however, no specific direction is predicted as the balance between accumulated firm knowledge and potential loss of independence with longer tenure (Patro et al., 2018). *Board_Skills* (members with industry or financial expertise) are controlled, as such expertise helps manage stakeholder conflicts (Harjoto et al., 2015). Audit committee independence (*AC_Independence*) is also controlled, as it enhances the accuracy and completeness of annual reports (Raimo et al., 2021). Lastly, firms' *CSR_Score* is included, since higher CSR firms are linked to greater engagement in integrated reporting practices (Obeng et al., 2021).

[Insert Table 5]

Table 5 Column (1) presents the stage one probit model results, showing that *GC_Signatory* is positively and significantly related to High_SR at the 1% level (coefficient = 0.246, *p*-value = 0.000), indicating that UNGC signatories are more likely to have implemented SR rigorously (Cetindamar, 2007). The partial *F*-test (*F*-stat = 33.503, *p*-value = 0.000) exceeds the recommended threshold of 8.96 for single instruments confirming *GC_Signatory* as a strong instrument (Stock et al., 2002). Models (1) and (2) are then re-estimated with the inverse Mills' ratio (*IMR*) to account for unobservable selection bias. Column (2) shows that *Chg_CarbonIntensity* remains positively related to *Environmental_Bog* at the 5% level (coefficient = 0.051, *p*-value = 0.012). Column (3) confirms the interaction term *Chg_CarbonIntensity* * *High_SR* is negatively and significantly related to *Environmental_Bog* at the 5% level (coefficient = -0.090, *p*-value = 0.038), consistent with the main findings.

5.2.4 Two-Stage Least Squares (2SLS) Estimation

To address endogeneity from unobserved factors affecting both SRrank and *Environmental_Bog*, a Two-Stage Least Squares (2SLS) approach is employed to mitigate omitted variable bias and simultaneity (Larcker & Rusticus, 2010; Hung et al., 2012). Similar to the Heckman model, *GC_Signatory* is used as the instrumental variable. *High_SR* is regressed on *GC_Signatory* and covariates from Models (1) and (6). The fitted values of *High_SR* are then used in the second stage to replace *High_SR*. Table 6 shows the results. Column (1) confirms that *GC_Signatory* is positively and significantly related to *High_SR* at the 1% level (coefficient = 0.275, *p*-value = 0.000). Column (2) shows that *Chg_CarbonIntensity* is positively related to *Environmental_Bog* at the 5% level (coefficient = 0.052, *p*-value = 0.011), while Column (3) shows that the interaction *Chg_CarbonIntensity* * $\widehat{High\_SR}$ is negatively and significantly related to *Environmental_Bog* at the 1% level (coefficient = -0.244, *p*-value = 0.006), supporting the core findings. To validate the 2SLS approach, two tests are conducted. The partial *F*-test (27.75) confirms the instrument's strength, exceeding the threshold of 8.96 (Stock et al., 2002). Additionally, Column (4) over-identifying restrictions test shows no significant correlation between the instrumental variable and second-stage residuals, with a negative adjusted R-squared of -3.5%, validating the instrument and the 2SLS model (Larcker & Rusticus, 2010).

[Insert Table 6]

6. Additional Analyses

6.1 What Mechanisms Drive Poor Environmental Reporting Readability with Rising Carbon Intensity, and SR's Mitigating Role?

The main findings revealed that increased carbon emission intensity negatively impacts the readability of environmental reporting, while rigorous SR practice mitigates this effect. This section examines the underlying mechanisms that drive the above relationships. First, this section attempts to disentangle whether the decline in readability associated with rising carbon emission intensity stems either from a firm-related complex environment surrounding carbon emission intensity increase, which makes environmental reporting more intricate; or from managerial incentives to obfuscate information. Second, it examines whether SR's mitigating role in preserving readability under rising carbon emission intensity is driven by its ability to enhance managerial comprehension of environmental performance and effective SR communication principles; or by SR's forward-looking orientation and stakeholder-centric focus, which aligns managerial and shareholder incentives and reduce incentives to obscure environmental information.

To examine the competing explanations, We regress *Environmental_Bog* on variables representing firm-specific environmental complexity using Model (7) below:

$$\begin{aligned} Environmental\_Bog_{i,t} &= \beta_0 Constant_{i,t} + \beta_1 Environmental\_Score_{i,t} + \beta_2 Size_{i,t} \\ &+ \beta_3 GEOG\_Segments_{i,t} + \beta_4 PROD\_Segments_{i,t} \\ &+ \beta_5 High\_Ind\_Emissions\_Dummy_{i,t} + \beta_{6-n} YearFE_{i,t} + \varepsilon_{i,t} \qquad (7) \end{aligned}$$

The fitted values from Model (7) serve as a proxy for firm-related complexity in environmental reporting (*Environmental_Bog_Predicted*), while the residuals capture the discretionary or obfuscation component of environmental reporting complexity (*Environmental_Bog_Residuals*). The model includes firm-specific environmental factors that may contribute to environmental reporting complexity. Specifically, it includes *Environmental_Score*, which reflects the quality of a firm's environmental practices that may influence reporting complexity. Firm *Size*, *GEOG_Segments*, and *PROD_Segments* as measures of firm resources and complexity, which can influence environmental reporting complexity, consistent with Model (1). To address industry-specific factors, we include a dummy variable (*High_Ind_Emissions_Dummy*) set to 1 for firms operating in high carbon-emitting industries and 0 otherwise. Year-fixed effects are included to control for annual regulatory changes and macroeconomic factors that could affect firm environmental reporting complexity. Industry-fixed effects are excluded to ensure the fitted values from Model (7) (i.e., *Environmental_Bog_Predicted*) capture only firm-level complexity. Including industry-fixed effects would render the fitted values comprising the industry-related effects as opposed to only firm-related effects. Results from Model (7) are reported in Table 7 Column (1).

[Insert Table 7]

We re-estimate Models (1) and (2) by replacing *Environmental_Bog* first with the residuals from Model (7) (*Environmental_Bog_Residuals*) and then with the fitted values from Model (7) (*Environmental_Bog_Predicted*). The results of this analysis are presented in Table 7 Columns (2)-(5). Column (2) shows a positive relationship between *Chg_CarbonIntensity* and *Environmental_Bog_Residuals* at the 5% significance level (coefficient = 0.038, *p*-value = 0.050). In contrast, Column (4) indicates no significant relationship between *Chg_CarbonIntensity* and *Environmental_Bog_Predicted* (coefficient = 0.006, *p*-value = 0.147). These findings suggest that the reduced readability of environmental reporting associated with increased carbon emission intensity is more likely driven by managerial obfuscation incentives to conceal poor carbon performance rather than by firm-related environmental complexity when carbon emissions rise.

Columns (3) and (5) test the moderating role of rigorous SR on the impact of *Chg_CarbonIntensity* on *Environmental_Bog_Residuals* and *Environmental_Bog_Predicted*, respectively. Column (3) shows that the interaction between *Chg_CarbonIntensity* and *High_SR is negatively related to* the discretionary component of environmental reporting complexity (*Environmental_Bog_Residuals*) at a 10% significance level (coefficient = -0.076, *p*-value = 0.071), suggesting that rigorous SR reduces managerial obfuscation incentives when carbon emission intensity increases. However, Column (5) indicates that the interaction between *Chg_CarbonIntensity* and *High_SR* is not significant (coefficient = -0.005, *p*-value = 0.590), implying that rigorous SR does not influence the firm-related environmental complexity component of environmental reporting (*Environmental_Bog_Predicted*) when carbon emission intensity rises. Nonetheless, Columns (4) and (5) highlight the first-order effect of SR in reducing firm-related complexity in environmental reporting.[12] Collectively, these results suggest that the decline in environmental reporting readability associated with increasing carbon emission intensity is more likely driven by managerial obfuscation incentives. However, rigorous SR implementation can mitigate these incentives, improving environmental reporting readability through its second-order effect. Additionally, the analysis highlights the first-order effect of rigorous SR practices in reducing firm-related complexity in environmental reporting.

We further conduct three robustness tests for this approach, following Evdokimov et al. (2022). First, we estimate Model (2) with *Environmental_Bog_Residuals* as the dependent variable, using the following specifications (untabulated), respectively: (i) excluding control variables, (ii) including only the regressors from Model (7), and (iii) including both the regressors from Model (7) and the control variables from Model (2). Finally, to further validate the results, we re-estimate Model (2) using the original measure of environmental reporting readability, *Environmental_Bog*, incorporating all control

[12] We conduct three robustness tests for this approach, following Evdokimov et al. (2022). First, we estimate Model (2) with *Environmental_Bog_Residuals* as the dependent variable, using the following specifications: (i) excluding control variables, (ii) including only the regressors from Model (7), and (iii) including both the regressors from Model (7) and the control variables from Model (2). The findings (not tabulated) are consistent with those reported in Table 7.

variables from Model (2) alongside the regressors from Model (7). The findings remain consistent to those reported in Table 7.

Collectively, these results suggest that the decline in environmental reporting readability associated with increasing carbon emission intensity is more likely driven by managerial obfuscation incentives. However, rigorous SR implementation can mitigate these incentives, improving environmental reporting readability through its second-order effect. Additionally, the analysis highlights the first-order effect of rigorous SR practices in reducing firm-related complexity in environmental reporting.

To further investigate the mechanisms underlying poor readability when carbon emission intensity increases, we examine the following linguistic features of environmental reporting: past focus, present focus, future focus, use of negations, and causal language. If the deterioration in readability is driven by obfuscation, as suggested by the preceding analysis, we expect firms to place greater emphasis on the past while reducing focus on the present and future (Merkl-Davies et al., 2011). Additionally, consistent with psychological literature, firms may attempt to obscure poor carbon performance by using more negations as a way of deception (Adams & Jarvis, 2006; Larcker & Zakolyukina, 2012; Newman et al., 2003). Furthermore, if managerial obfuscation incentives are indeed responsible for the decline in readability, poorly performing firms are less likely to include causal statements since causal reasoning provides incremental information linking performance outcomes to their underlying causes (Zhang et al., 2019). Table 8 presents the results from Model (1) re-estimated by replacing *Environmental_Bog* with the five linguistic characteristics of environmental reporting: *focuspast*, *focuspresent*, *focusfuture*, *negate*, and *cause*.

[Insert Table 8]

Table 8 Columns (1)-(3) reveal that an increase in carbon emission intensity is significantly associated with greater focus on the past, reduced focus on the present, and no significant relationship with future focus, respectively. Column (4) indicates that rising carbon emission intensity is significantly related to increased use of negations, which prior literature identifies as a marker of deception (Larcker & Zakolyukina, 2012). Consistent with expectation, Column (5) shows insignificant effect of increasing carbon intensity on *cause* , suggesting that firms with higher carbon emission intensity are less likely to include causal statements about poor carbon performance. Regarding SR's influence on specific linguistic characteristics, SR reduces past focus and increases future focus, aligning with the forward-looking disclosure requirements in the SR mandate.

Next, we employ structural equation modelling to assess whether the five linguistic features of environmental reporting mediate the relationship between increases in carbon emission intensity and reduced environmental reporting readability. Consistent with Table 8, Figure 6 illustrates that the use of negations and past focus significantly mediate this relationship. This reinforces the explanation that rising carbon emission intensity is associated with lower readability in environmental reporting likely due to managerial information obfuscation incentives as opposed to firm-related environmental complexity when carbon intensity increases.

6.2 Carbon Emission Intensity Increase versus Decrease

We explore whether the relationship between carbon emission intensity changes and environmental reporting readability differs for increases versus decreases in carbon intensity. Firms with increased carbon intensity are likely to exhibit managerial obfuscation to mitigate negative stakeholder reactions. Thus, firms reporting increases are expected to produce less readable environmental reports than those with decreases. Further, we expect rigorous SR implementation to mitigate obfuscation incentives for firms with deteriorating carbon performance (increased carbon intensity), consistent with the analysis in section 5.5.1. In contrast, firms with improving carbon performance (decreased carbon intensity) are likely to produce more readable reports *a priori* as their incentives to obfuscate are likely to be negligible, making rigorous SR practices less impactful on their readability.

To test, Model (2) is re-estimated using subsamples of firms with carbon emission intensity increases (*Chg_CarbonIntensity* > 0) and carbon emission intensity decreases (*Chg_CarbonIntensity* < 0). Table 5.9 reports results. The positive relationship between *Chg_CarbonIntensity* and *Environmental_Bog i*s observed in firms with an increased carbon emission intensity (coefficient = 0.173, *p*-value = 0.003) at a one percent significance level per Column (1), but not in those with decreases (coefficient = 0.011, *p*-value = 0.893) per Column (2). These results highlight the asymmetric effect of firms' carbon performance on environmental reporting readability: While an increase in carbon emission intensity reduces environmental reporting readability due to obfuscation incentives; a decrease in carbon emission intensity does not necessarily improve environmental reporting readability, though it does not decrease it either. Further, Column (1) shows that greater compliance with SR curbs obfuscation incentives in firms that exhibit increases in carbon emission intensity (*Chg_CarbonIntensity* * *High_SR*), mitigating the deteriorating effect on readability (coefficient = -0.119, *p*-value = 0.072). However, Column (2) shows that this effect is not significant in firms that exhibit decreases in carbon emission intensity (coefficient = -0.053, *p*-value = 0.526) due to reduced or negligible incentives to obscure information.

[Insert Table 9]

6.2 Emission Reduction Targets

We explore whether the relationship between changes in carbon emission intensity and environmental reporting readability, along with the moderating role of SR, varies between firms that set emission reduction targets and those that do not. Moussa et al. (2022) suggest that environmentally sensitive UK firms often set symbolic "soft" or "semi-hard" targets to manage stakeholder perceptions, while firms with strong environmental performance set "hard" targets.[13] This suggests that firms may engage in impression management if they fail to meet emission reduction targets, and thus engage in impression management. Particularly, firms with poor carbon performance, indicated by increased carbon intensity, are likely to provide more complex environmental reporting to obscure their failure in reducing emissions, especially if they have set reduction targets. This obfuscation helps manage stakeholder impressions and avoid backlash. In contrast, firms without reduction targets face less pressure to justify deteriorating emissions intensity, as they have not committed to specific performance goals.

Rigorous compliance with the SR mandate can mitigate obfuscation in firms that set emission reduction targets but exhibit increasing carbon emission intensity through the forward-looking and stakeholder-centric nature of SR requirements. As per the IR literature, forward-looking and broader

[13] Moussa et al. (2022) categorize targets into three types: *soft targets*, which are qualitative and lack a specific timeframe; *semi-hard targets*, which are either qualitative with a set timeframe or quantitative without a timeframe; and *hard targets*, defined as quantitative with a clear timeframe.

stakeholder orientation in integrated reporting can align managerial incentives with shareholders' long-term orientation (Serafeim, 2015; Obeng et al., 2021). Further, SR's broad stakeholder focus can incentivize firms to provide transparent disclosures to avoid legitimacy concerns and backlash from diverse stakeholders. Therefore, rigorous implementation of SR practices can mitigate obfuscation incentives accrued to poor carbon performance firms that have set emission reduction targets by improving managerial and shareholder incentive alignment and improving stakeholder monitoring through SR's diverse stakeholder-focussed reporting requirements. For firms without emission reduction targets, poor carbon performance is less likely to result in complex reporting since they are not accountable for specific goals, making SR's role in reducing complexity less pronounced as there are fewer obfuscation incentives.

To test this, Model (2) is re-estimated for subsamples based on whether firms have set emission reduction targets (*TargetEmissions* = 1) or not (*TargetEmissions* = 0). Table 9 Column (3) shows that firms with emission reduction targets provide less readable environmental reporting when their carbon emission intensity increases (coefficient = 0.082, *p*-value = 0.010), but rigorous SR implementation mitigates this (coefficient = -0.070, *p*-value = 0.083). In contrast, Column (4) shows no significant relationships for firms without targets. These results suggest that obfuscation is more common when firms set targets but fail to reduce emissions and emphasize the crucial role of high-quality SR compliance in promoting transparency, especially for firms with emission reduction targets but exhibit poor carbon performance.

6.3 Foreign Institutional Ownership

In this section, we examine whether the relationship between increased carbon emission intensity and reduced environmental reporting readability, and the mitigating role of SR, varies between firms with high foreign institutional ownership relative to those with low foreign institutional ownership. Krueger et al. (2020) highlight institutional investors' growing concerns about the financial implications of climate risks, especially regulatory ones, for their portfolio firms. As a result, institutional investors increasingly incorporate climate-related filters into investment and asset valuation decisions, forming environmentally friendly portfolios (Fink, 2020).

Foreign institutional investors significantly influence corporate reporting, pushing firms to provide accurate forecasts and engage high-quality auditors (Tsang et al., 2019; Kim et al., 2019). European foreign investors, in particular, emphasize social responsibility due to societal norms, encouraging firms to adopt these values (Dyck et al., 2019). Faced with divestment threats and pressure from these investors, firms incorporate these expectations into their policies and practices (Gillan & Starks, 2007, Fischer & Baron, 2015). Bose et al. (2024) find that higher foreign institutional ownership leads to better-quality climate change disclosures, driven by these investors' greater informational needs, which in turn enhance firm valuations. In contrast, domestic institutional ownership tends to have less influence on climate change disclosures, as these investors are familiar with the local business landscape and have fewer incentives to push for comprehensive environmental reporting (Bose et al., 2024). In some cases, domestic investors may even discourage such disclosures due to concerns over proprietary information costs, increased compliance expenses, litigation risks, and the heightened public scrutiny that can accompany voluntary reporting (Li et al., 1997; Matsumura et al., 2014; Bose et al., 2024).

Drawing on Bose et al. (2024), we argue that firms with high foreign institutional ownership are less likely to produce complex environmental reporting when carbon emission intensity increases due to greater monitoring and pressure for high-quality climate disclosures from these investors. Consequently, the role of rigorous SR implementation in curbing obfuscation incentives is diminished, as these incentives are less prevalent in firms with substantial foreign institutional ownership. However, these firms may still benefit from greater compliance with the SR mandate through a first-order effect, as it promotes clear communication and improves understanding of environmental matters. Conversely, firms with low foreign institutional ownership are more likely to obscure environmental reporting when carbon emission intensity increases due to reduced monitoring and lower demand for comprehensive disclosures (Bose et al., 2024). In these cases, rigorous SR implementation is expected to reduce obfuscation and improve transparency in reporting.

To test this, a subsample analysis is conducted based on foreign institutional ownership, calculated as the proportion of foreign ownership to total ownership (*ForeignOwnership*). High foreign institutional ownership is set to 1 if *ForeignOwnership* is above the mean, and 0 otherwise. Table 9

Column (5) shows that changes in carbon emission intensity do not affect environmental reporting readability in firms with high foreign institutional ownership (coefficient = 0.135, *p*-value = 0.244). Consequently, there is no observable impact of rigorous SR implementation on reducing reporting complexity for firms with poor carbon performance, as indicated by the non-significant *Chg_CarbonIntensity* * *High_SR* interaction (coefficient = -0.110, *p*-value = 0.380). However, greater SR compliance still significantly improves readability (coefficient = -0.265, *p*-value = 0.017), suggesting that even with low obfuscation incentives, rigorous SR practices enhance the clarity of environmental disclosures, as a first-order effect. In contrast, Column (6) shows that in firms with low foreign institutional ownership, increases in carbon emission intensity are significantly linked to poorer environmental reporting readability (coefficient = 0.115, *p*-value = 0.033). However, rigorous SR implementation reduces obfuscation, as indicated by the significantly negative coefficient on *Chg_CarbonIntensity* * *High_SR* (coefficient = -0.147, *p*-value = 0.020). This suggests that, in the absence of strong monitoring by foreign institutional investors, these firms may engage in obfuscation, but greater SR compliance mitigates this tendency.

7. Conclusion

This study examines the impact of changes in carbon emission intensity on the readability of environmental reporting and explores whether rigorous compliance with the SR mandate can moderate this relationship. According to Bushee et al. (2018), textual complexity in firm disclosures consists of two components: technical-informative and obfuscation. We hypothesize that an increase in carbon intensity leads to less readable reporting due to: (1) the firm-related complexity of explaining poor performance, which may require detailed explanations and future commitments (information component), and (2) managerial incentives to obscure negative information (obfuscation component) (Bloomfield, 2008; Bushee et al., 2018). We further propose that greater adherence to the SR mandate can moderate this effect, either by increasing or decreasing both components of environmental reporting complexity. Specifically, SR can reduce information component complexity by improving managerial comprehension of environmental matters or decrease information component complexity due to the broader disclosure requirements of SR that may result in overly detailed and/or convoluted narratives. Similarly, SR's forward-looking and stakeholder-centric focus can decrease obfuscation component complexity by aligning managerial incentives with the long-term interest of stakeholders, including shareholders, or increase obfuscation component complexity due to its broad disclosure requirements, creating greater opportunities to obfuscate environmental information to deter attention away from poor carbon performance.

Using a sample of 1,020 firm-year observations of UK FTSE 350 firms from 2013-2021, we find that an increase in carbon emission intensity is associated with reduced environmental reporting readability. However, rigorous SR practices mitigate the negative impact of increased carbon intensity on reporting readability. These findings hold up to several endogeneity tests. Further analysis suggests that when firms exhibit increasing carbon emission intensity, the decline in readability is explained by managerial obfuscation rather than firm-related complexity in environmental reporting. Consistent with Obeng et al. (2021) who find that high-quality integrated reporting practices reduce agency costs, rigorous SR implementation mitigates obfuscation-related complexity by aligning managerial incentives with the long-term interest of stakeholders (i.e., a second-order effect). Further, a deeper implementation of SR reduces the firm-related complexity in environmental reporting by improving managerial understanding of environmental matters, thereby leading to clearer reporting (i.e., a first-order effect). Analysis of linguistic characteristics of environmental reporting suggests that firms exhibiting increasing carbon emission intensity provide greater past focus, reduced present focus, and more negations in their environmental reporting. A structural equation model shows that past focus and use of negations mediate the relationship between increased carbon emission intensity and reduced environmental report readability, consistent with obfuscation explanation for reduced readability when carbon emissions rise.

Additional analyses reveal the asymmetric effect of a firm's carbon performance on reporting readability: While an increase in carbon emission intensity reduces readability, a decrease does not improve it. Moreover, the role of strong SR application in reducing reporting complexity is mainly observed in firms with increasing carbon emission intensity, but not in those with decreasing intensity. The study also shows that firms with rising carbon emission intensity tend to produce less readable environmental narratives, especially when they have previously committed to emission reduction targets, to obscure poor performance related to these commitments. However, rigorous SR practices can help counter this obfuscation. Additionally, we find that firms with high foreign institutional ownership are less likely to engage in complex reporting when carbon intensity rises, likely due to these stakeholders' pressure for high-quality disclosures (Bose et al., 2024). In contrast, firms with lower foreign institutional ownership are more prone to producing complex environmental narratives when carbon intensity increases, likely because of weaker external monitoring. In such cases, rigorous implementation of the SR mandate reduces textual complexity by reducing incentives to obfuscate.

This study provides evidence that firms may use linguistic manipulation in their environmental narratives to manage stakeholder impressions when the opportunities for selective carbon disclosure under the UK SR mandate are constrained (Grewal et al., 2022). We also contribute by demonstrating that rigorous SR practices improve the readability of environmental reports, particularly for firms with increased carbon emission intensity. SR practices lead to less complex reporting for firms with poor carbon performance by improving firms' understanding of environmental matters (a first-order effect) and reducing managerial obfuscation (a second-order effect).

This study offers valuable insights for standard setters and advisory groups, such as IFRS, EFRAG, ISSB, SEC, and EU regulators, as they develop standards that meet evolving stakeholder information needs by improving the integration of financial and non-financial reporting, particularly environmental reporting. These bodies can emulate UK's SR mandate as a model, given its proven success in enhancing environmental reporting readability and benefiting capital markets (Wang et al., 2024). As investor interest in non-financial information grows (Eurosif, 2018), improving readability can benefit less sophisticated users by reducing their cognitive burden and information processing costs (Bloomfield, 2002; Courtis, 2004; Rennekamp, 2012), leading to more informed decision-making.

While this study addresses endogeneity concerns through a range of robustness tests, such as omitted variable bias, sample selection bias, and simultaneity, some limitations remain. First, the study focuses primarily on carbon emission intensity as a measure of environmental performance, potentially overlooking other critical environmental dimensions such as water usage, biodiversity, and waste management, which may also affect reporting practices and readability. Second, the study does not directly measure managerial intent or motivations behind obfuscation, relying instead on textual proxies that may capture unintended complexities unrelated to deliberate obfuscation. Third, while the linguistic characteristics of environmental narratives are analysed, the study does not examine how stakeholders, such as investors or regulators, perceive and interpret these disclosures, leaving room for future research to assess the effectiveness of these narratives in meeting their informational needs.

Future research could also explore environmental issues beyond carbon and GHG emissions, such as waste disposal, water efficiency, and biodiversity, to assess whether firms show similar behaviours when failing or succeeding in these areas. This aligns with the ISSB's plans to expand disclosures on biodiversity, ecosystems, and related risks, building on initiatives like the Task Force on Nature-related Financial Disclosures (TNFD). ISSB Chair Emmanuel Faber emphasized: *"Beyond climate, we are committed to building out the global baseline of sustainability-related financial disclosure to meet the needs of investors. Feedback indicated a significant and growing need among investors for improved disclosures around biodiversity, ecosystems and ecosystems services as well as human capital, as a key source of value for companies"* (IFRS, 2024).

Table 1 Sample Construction

Panel A: Sample Construction

	#Remaining Firms	#Remaining Firm-years
PwC reporting quality data (2010 – 2021)	496	2,867
Observations remaining after removing firms in financial and utility industries	210	1,534
Observations remaining after removing missing control variables	191	1,361
Observations remaining after filtering for years 2013-2021	178	1,020
Sample for H1 and H2 testing	178	1,020

Panel B: Industry Distribution

	N	%
Accommodation and food service activities	37	3.63
Administrative and support service activities	60	5.88
Arts, entertainment and recreation	13	1.27
Construction	123	12.06
Human health and social work activities	12	1.18
Information and communication	89	8.73
Manufacturing	249	24.41
Mining and quarrying	78	7.65
Other service activities	5	0.49
Professional, scientific and technical activities	124	12.16
Public administration and defence; compulsory social security	26	2.55
Transportation and storage	67	6.57
Wholesale and retail trade; repair of motor vehicles and motorcycles	137	13.43
Total	1,020	100%

Table 2 Sample Data

Panel A: Descriptive Statistics

	N	Mean	St. Dev.	Min	Pctl(25)	Median	Pctl(75)	Max
Environmental_Bog	1,020	93.625	13.381	56	85	93	102	146
Chg_CarbonIntensity	1,020	-1.023	63.754	-319.868	-7.133	-1.350	1.324	369.911
SRrank	1,020	5.097	2.861	1	3	5	8	10
High_SR	1,020	0.554	0.497	0	0	1	1	1
Earnings	1,020	0.104	0.088	-0.103	0.054	0.092	0.139	0.464
Size	1,020	0.892	0.632	0.004	0.491	0.739	1.138	3.676
Firm_Age	1,020	3.522	0.170	2.124	3.482	3.549	3.598	3.645
MTB	1,020	1.512	1.541	0.074	0.594	1.023	1.904	10.101
GEOG_Segments	1,020	1.512	0.593	0.000	1.099	1.609	1.946	2.398
PROD_Segments	1,020	1.529	0.522	0.000	1.386	1.609	1.946	2.398
Governance_Score	1,020	0.630	0.179	0.201	0.505	0.644	0.769	0.950
Env_RD_Exp	1,020	0.005	0.055	0.000	0.000	0.000	0.000	0.581
EmissionOffsets_Dummy	1,020	0.052	0.222	0	0	0	0	1
ESGLink_Dummy	1,020	0.424	0.494	0	0	0	1	1
CSRCommittee_Dummy	1,020	0.790	0.407	0	1	1	1	1
EnvControversies_Dummy	1,020	0.025	0.155	0	0	0	0	1

Panel B: Difference of Means Test between Low and High SR groups

	Low SR versus High SR				**Decrease vs Increase in Emissions Intensity**			
	Low SR	High SR	Difference	*p*-value	Decrease	Increase	Difference	*p*-value
Environmental_Bog	94.675	92.781	1.894	0.026	92.981	94.961	-1.980	0.026
Chg_CarbonIntensity	2.202	-3.621	5.824	0.143	-19.057	36.347	-55.404	0
SRrank	2.624	7.088	-4.464	0.000	5.190	4.904	0.287	0.135
Earnings	0.106	0.103	0.002	0.657	0.115	0.082	0.032	0
Size	0.946	0.848	0.097	0.015	0.934	0.805	0.128	0.002
MTB	1.517	1.508	0.009	0.925	1.619	1.292	0.327	0.001
Firm_Age	3.521	3.523	-0.002	0.841	3.528	3.509	0.020	0.094
GEOG_Segments	1.465	1.550	-0.085	0.022	1.496	1.546	-0.050	0.207
PROD_Segments	1.495	1.557	-0.062	0.057	1.535	1.518	0.017	0.635
Governance_Score	0.603	0.651	-0.048	0.000	0.622	0.645	-0.023	0.051
Env_RD_Exp	0.002	0.008	-0.006	0.058	0.004	0.008	-0.003	0.429
EmissionOffsets_Dummy	0.033	0.067	-0.034	0.011	0.060	0.036	0.023	0.087
ESGLink_Dummy	0.404	0.439	-0.035	0.267	0.413	0.446	-0.033	0.320
CSRCommittee_Dummy	0.710	0.855	-0.145	0.000	0.778	0.816	-0.039	0.146
EnvControversies_Dummy	0.022	0.027	-0.005	0.636	0.022	0.030	-0.008	0.447

Figure 5: The *Impact of Carbon Emission Intensity Change on Environmental Reporting Readability, Differentiated by SR Quality*

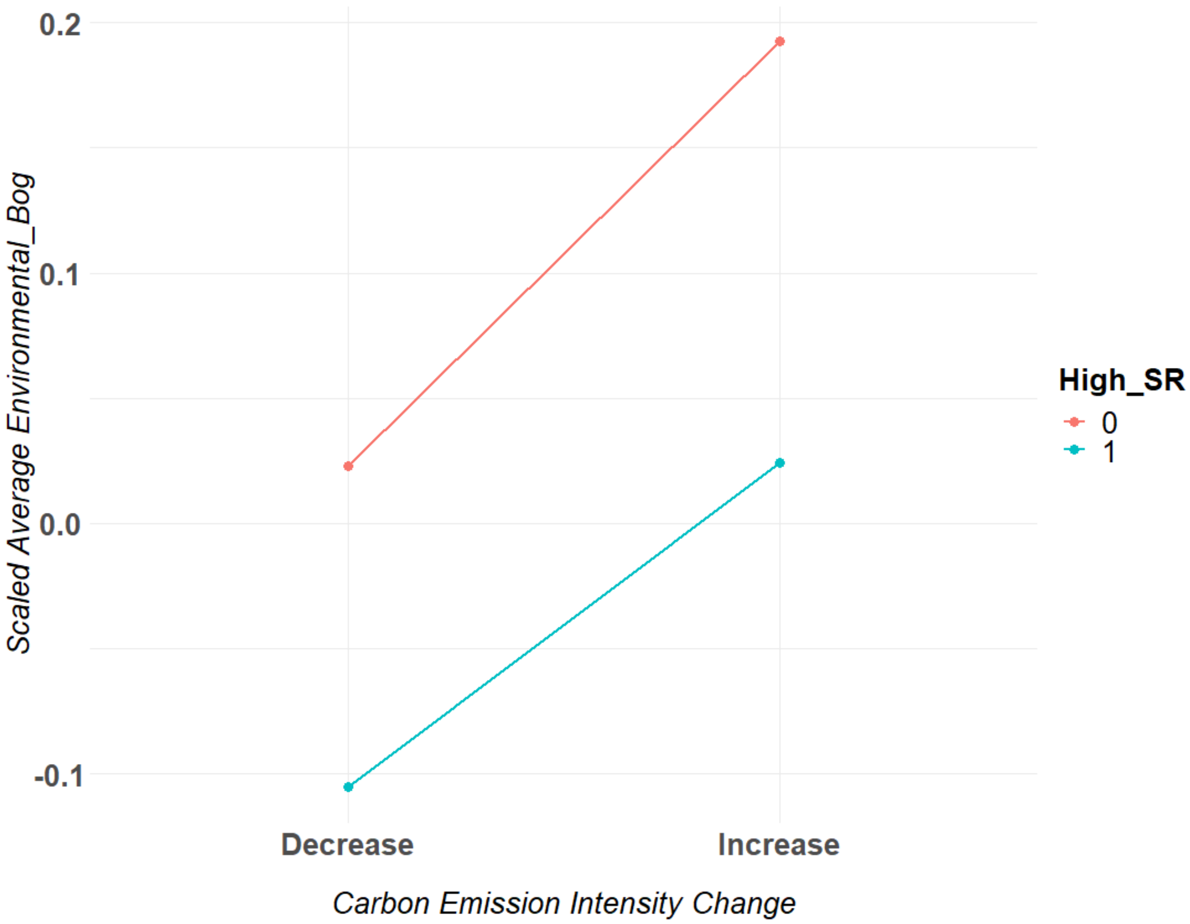

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Table 3 Correlation Matrix

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*VIF**	*VIF#*
1 Environmental_Bog		0.06	-0.09**	-0.07*	-0.06*	0.02	0.03	-0.06	0.27***	0.10***	0.06	0.02	-0.01	-0.01	-0.07*	0.03		
2 Chg_CarbonIntensity	0.02		-0.03	-0.05	-0.14***	-0.05	-0.06	-0.03	0.02	0.02	0.02	0.00	0.01	-0.03	-0.01	-0.02	1.21	2.65
3 SRrank	-0.08*	-0.05		0.78***	0.01	-0.07*	0.01	0.00	0.07*	0.06	0.10**	0.09**	0.09**	-0.03	0.18***	0.03	4.01	
4 High_SR	-0.05	-0.03	0.78***		-0.01	-0.08*	0.01	-0.00	0.07*	0.06	0.13***	0.06	0.08*	0.03	0.18***	0.01		1.32
5 Earnings	-0.06	-0.08*	-0.00	-0.05		0.36***	0.07*	0.71***	-0.06	-0.23***	-0.15***	-0.04	-0.02	-0.07*	-0.21***	-0.03	1.86	1.88
6 Size	-0.02	-0.06	-0.08*	-0.08**	0.32***		-0.08*	0.35***	-0.08**	-0.10***	-0.09**	-0.04	0.02	-0.09**	-0.12***	-0.05	1.72	1.74
7 Firm_Age	-0.04	-0.07*	0.01	0.01	-0.14***	-0.15***		-0.05	0.10**	0.05	0.10**	0.00	0.02	0.10**	0.04	-0.02	1.50	1.50
8 MTB	-0.05	-0.02	-0.03	-0.05	0.67***	0.30***	-0.05		-0.14***	-0.20***	-0.19***	-0.03	0.02	-0.10**	-0.23***	-0.08*	1.91	1.92
9 GEOG_Segments	0.29***	0.00	0.08*	0.08*	-0.03	-0.05	-0.03	-0.08*		0.30***	0.18***	0.10***	-0.01	0.08**	0.04	0.08**	1.92	1.97
10 PROD_Segments	0.08*	-0.03	0.07*	0.07*	-0.23***	-0.09**	-0.03	-0.20***	0.34***		0.13***	0.03	0.06	0.10**	0.20***	0.11***	1.53	1.56
11 Governance_Score	0.07*	0.03	0.10***	0.13***	-0.13***	-0.08**	0.19***	-0.17***	0.17***	0.13***		0.04	0.10**	0.34***	0.29***	0.10***	1.92	1.94
12 Env_RD_Exp	0.02	0.02	0.08*	0.04	-0.04	-0.05	0.00	-0.01	0.08*	-0.00	0.03		0.02	-0.08*	0.05	-0.02	7.26	7.39
13 EmissionOffsets_Dummy	-0.00	-0.04	0.09**	0.08*	-0.05	0.03	0.01	-0.05	-0.01	0.05	0.11***	0.02		0.04	0.08*	0.02	1.31	1.32
14 ESGLink_Dummy	0.00	0.00	-0.03	0.03	-0.06	-0.09**	0.22***	-0.13***	0.09**	0.08*	0.34***	-0.07*	0.04		0.14***	0.02	1.57	1.58
15 CSRCommittee_Dummy	-0.08**	-0.02	0.18***	0.18***	-0.19***	-0.11***	0.06	-0.21***	0.05	0.23***	0.28***	0.05	0.08*	0.14***		0.08**	1.36	1.35
16 EnvControversies_Dummy	0.04	-0.04	0.02	0.01	-0.03	-0.05	0.01	-0.13***	0.08*	0.13***	0.10***	-0.02	0.02	0.02	0.08**		1.46	1.47

Note: Correlations computed with the Spearman (lower diagonal) and Pearson (upper diagonal) methods with listwise-deletion. The *p*-values are denoted as follows: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.
* Variance inflation factor from Model (1).
# Variance inflation factor from Model (2).

Table 4 Change in Carbon Intensity and Environmental Reporting Readability

	Dependent variable: *Environmental_Bog*					
	(1)	(2)	(3)	(4)	(5)	(6)
	Base		PSM		EB	
Chg_CarbonIntensity	0.046**	0.097***	0.051**	0.100***	0.059***	0.098***
	(0.022)	(0.007)	(0.018)	(0.005)	(0.008)	(0.007)
SRrank	-0.071*		-0.077*		-0.074*	
	(0.097)		(0.092)		(0.089)	
High_SR		-0.126*		-0.150*		-0.138*
		(0.087)		(0.057)		(0.072)
*Chg_CarbonIntensity * High_SR*		-0.086**		-0.099**		-0.084**
		(0.040)		(0.042)		(0.050)
Earnings	-0.059	-0.059	-0.036	-0.032	-0.056	-0.054
	(0.310)	(0.308)	(0.558)	(0.606)	(0.318)	(0.337)
Size	0.085	0.088	0.086	0.090	0.090	0.096
	(0.164)	(0.141)	(0.191)	(0.166)	(0.145)	(0.120)
MTB	-0.012	-0.009	-0.012	-0.012	-0.045	-0.044
	(0.837)	(0.880)	(0.853)	(0.854)	(0.451)	(0.459)
Firm_Age	0.013	0.014	-0.0001	-0.001	0.027	0.027
	(0.833)	(0.817)	(0.999)	(0.989)	(0.607)	(0.610)
GEOG_Segments	0.186***	0.187***	0.204***	0.210***	0.176***	0.177***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)
PROD_Segments	0.002	0.005	0.003	0.006	-0.005	-0.002
	(0.976)	(0.928)	(0.954)	(0.909)	(0.931)	(0.974)
Governance_Score	0.028	0.031	0.018	0.020	0.015	0.016
	(0.587)	(0.557)	(0.757)	(0.731)	(0.777)	(0.765)
Env_RD_Exp	-0.023	-0.026	0.056	0.047	-0.036*	-0.036*
	(0.256)	(0.197)	(0.263)	(0.349)	(0.087)	(0.083)
EmissionOffsets_Dummy	0.076	0.065	-0.201	-0.222	0.131	0.114
	(0.612)	(0.663)	(0.320)	(0.265)	(0.541)	(0.586)
ESGLink_Dummy	-0.038	-0.037	-0.119	-0.121	-0.095	-0.094
	(0.613)	(0.620)	(0.163)	(0.157)	(0.253)	(0.254)
CSRCommittee_Dummy	-0.268*	-0.274*	-0.315**	-0.324**	-0.260*	-0.269*
	(0.062)	(0.057)	(0.032)	(0.028)	(0.062)	(0.052)
EnvControversies_Dummy	-0.059	-0.070	-0.057	-0.040	-0.075	-0.089
	(0.726)	(0.674)	(0.811)	(0.868)	(0.729)	(0.676)
Constant	-0.402	-0.329	-0.381	-0.289	-0.399	-0.308
	(0.137)	(0.216)	(0.146)	(0.265)	(0.133)	(0.233)
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
N	1,020	1,020	784	784	1,020	1,020
Adjusted R^2	0.121	0.121	0.144	0.145	0.131	0.132

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents the results of the Hypotheses 1 and 2, estimating Model (1) and Model (2), respectively. Columns (1) and (2) show results using the base model. Columns (3) and (4) show the regressions using the PSM-matched sample. Columns (5) and (6) show results after covariates are reweighted using EB. Refer to Appendix A for variable definitions. The p-values are provided in parentheses. Standard errors are clustered by firm.

Table 5 Heckman Two-Stage Model

	Dependent variable: *High_SR*		*Dependent variable:* *Environmental_Bog*	
	(1)		(2)	(3)
	Stage One		Stage Two	
GC_Signatory	0.246***	*Chg_CarbonIntensity*	0.051**	0.104***
	(0.000)		(0.012)	(0.005)
ROA	0.531	*SRrank*	-0.032	
	(0.201)		(0.469)	
Size	-0.005	*High_SR*		-0.056
	(0.925)			(0.437)
MTB	0.150**	*Chg_CarbonIntensity * High_SR*		-0.090**
	(0.049)			(0.038)
Leverage	0.158***	*Earnings*	-0.044	-0.043
	(0.000)		(0.450)	(0.459)
Firm_Age	0.004	*Size*	0.043	0.045
	(0.925)		(0.478)	(0.457)
Big4	0.873***	*MTB*	-0.010	-0.007
	(0.000)4		(0.872)	(0.908)
Board_Size	0.126***	*Firm_Age*	0.018	0.019
	(0.000)		(0.767)	(0.737)
Board_Independence	0.004	*GEOG_Segments*	0.189***	0.190***
	(0.439)		(0.000)	(0.000)
Board_GenderDiversity	-0.001	*PROD_Segments*	0.021	0.024
	(0.870)		(0.704)	(0.654)
Board_AverageTenure	-0.025	*Governance_Score*	0.078	0.081
	(0.509)		(0.155)	(0.137)
Board_Skills	-0.003	*Env_RD_Exp*	-0.025	-0.026
	(0.220)		(0.233)	(0.204)
AC_Independence	0.001	*EmissionOffsets_Dummy*	0.117	0.114
	(0.867)		(0.443)	(0.455)
CSR_Score	1.551***	*ESGLink_Dummy*	-0.030	-0.032
	(0.000)		(0.686)	(0.667)
Constant	-2.917***	*CSRCommittee_Dummy*	-0.233	-0.232
	(0.000)		(0.114)	(0.116)
		EnvControversies_Dummy	0.001	-0.017
			(0.997)	(0.917)
		Inverse Mills Ratio (IMR)	0.336	0.348
			(0.129)	(0.106)
		Constant	-0.639**	-0.618**
			(0.040)	(0.045)
Year Fixed Effect	Yes	Year Fixed Effect	Yes	Yes
Industry Fixed Effect	Yes	Industry Fixed Effect	Yes	Yes
Observations	998	*N*	998	998
Pseudo R^2	0.216	Adjusted R^2	0.132	0.133

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents the result associated with Heckman's two-stage selection model. Refer to Appendix A for variable definitions. The *p*-values are provided in parentheses. Standard errors are clustered by firm.

Table 6 Two Stage Least Squares Estimation

	Dependent variable:
	High_SR
	(1)
	Stage One
GC_Signatory	0.275***
	(0.000)
ROA	0.519
	(0.166)
Size	0.001
	(0.989)
MTB	0.149*
	(0.081)
Leverage	0.158***
	(0.000)
Firm_Age	-0.007
	(0.871)
Big4	0.845***
	(0.000)
Board_Size	0.128***
	(0.000)
Board_Independence	0.005
	(0.264)
Board_GenderDiversity	0.0002
	(0.972)
Board_AverageTenure	-0.026
	(0.498)
Board_Skills	-0.002
	(0.423)
AC_Independence	0.002
	(0.753)
CSR_Score	1.684***
	(0.000)
GEOG_Segments	0.045
	(0.199)
PROD_Segments	-0.058
	(0.192)
Governance_Score	-0.091
	(0.235)
Env_RD_Exp	0.038
	(0.407)
EmissionOffsets_Dummy	0.084
	(0.559)
ESGLink_Dummy	-0.027
	(0.787)
CSRCommittee_Dummy	0.119
	(0.305)
EnvControversies_Dummy	-0.206
	(0.746)
Constant	-3.393***
	(0.000)
Year Fixed Effect	Yes
Industry Fixed Effect	Yes
Observations	998
Pseudo R^2	0.222

	Dependent variable:		
	Environmental_Bog		*Residuals*
	(2)	(3)	(4)
	Stage Two		
Chg_CarbonIntensity	0.052**	0.183***	
	(0.011)	(0.000)	
$\widehat{High\_SR}$	-0.884***	-0.903***	
	(0.008)	(0.007)	
Chg_CarbonIntensity * $\widehat{High\_SR}$		-0.244***	
		(0.006)	
Earnings	-0.036	-0.027	0.0003
	(0.530)	(0.641)	(0.997)
Size	0.031	0.031	-0.000
	(0.605)	(0.605)	(0.995)
MTB	-0.003	-0.008	0.002
	(0.959)	(0.891)	(0.975)
Firm_Age	0.012	0.015	-0.001
	(0.833)	(0.780)	(0.986)
GEOG_Segments	0.209***	0.211***	0.001
	(0.000)2	(0.000)	(0.982)
PROD_Segments	0.013	0.013	-0.001
	(0.801)	(0.806)	(0.982)
Governance_Score	0.078	0.078	-0.001
	(0.134)	(0.132)	(0.979)
Env_RD_Exp	-0.016	-0.015	0.001
	(0.433)	(0.463)	(0.945)
EmissionOffsets_Dummy	0.164	0.159	-0.0003
	(0.290)	(0.304)	(0.999)
ESGLink_Dummy	-0.035	-0.027	-0.001
	(0.638)	(0.714)	(0.985)
CSRCommittee_Dummy	-0.167	-0.157	0.005
	(0.271)	(0.302)	(0.972)
EnvControversies_Dummy	-0.038	-0.059	-0.002
	(0.814)	(0.711)	(0.993)
Constant	0.063	0.053	-0.007
	(0.847)	(0.871)	(0.981)
GC_Signatory			0.034
			(0.813)
SRrank			-0.015
			(0.732)
Year Fixed Effect	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes
N	998	998	998
Adjusted R^2	0.141	0.143	-0.035

Note: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

This table presents the result associated with two-stage least squares estimation (2SLS). Refer to Appendix A for variable definitions. The *p*-values are provided in parentheses. Standard errors are clustered by firm.

Table 7 Carbon Emission Intensity and Environmental Reporting: Obfuscation or Firm-Related Complexity?

Stage One and Two Results

	Dependent variable:					
	Environmental_Bog		*Environmental_Bog_Residuals*		*Environmental_Bog_Predicted*	
	Stage One		*Stage Two*			
	(1)		(2)	(3)	(4)	(5)
Environmental_Score	-1.293***	*Chg_CarbonIntensity*	0.038**	0.083**	0.006	0.009
	(0.000)		(0.050)	(0.020)	(0.147)	(0.240)
Size	0.023	*SRrank*	-0.030		-0.037***	
	(0.456)		(0.469)		(0.000)	
GEOG_Segments	0.264***	*High_SR*		-0.059		-0.058***
	(0.000)			(0.407)		(0.000)
PROD_Segments	0.056*	*Chg_CarbonIntensity*High_SR*		-0.076*		-0.005
	(0.077)			(0.071)		(0.590)
High_Ind_Emissions_Dummy	0.194***	*Earnings*	-0.044	-0.043	-0.013	-0.014
	(0.003)		(0.442)	(0.449)	(0.226)	(0.195)
Constant	0.536***	*Size*	0.040	0.043	0.038***	0.039***
	(0.002)		(0.474)	(0.447)	(0.000)	(0.000)
		MTB	-0.033	-0.031	0.019*	0.020*
			(0.556)	(0.575)	(0.077)	(0.065)
		Firm_Age	0.016	0.017	-0.007	-0.007
			(0.792)	(0.772)	(0.242)	(0.218)
		GEOG_Segments	-0.060	-0.059	0.248***	0.247***
			(0.226)	(0.235)	(0.000)	(0.000)
		PROD_Segments	-0.042	-0.039	0.041***	0.041***
			(0.392)	(0.428)	(0.000)	(0.000)
		Governance_Score	0.131***	0.132***	-0.100***	-0.100***
			(0.008)	(0.007)	(0.000)	(0.000)
		Env_RD_Exp	-0.015	-0.016	-0.008**	-0.009***
			(0.448)	(0.408)	(0.014)	(0.003)
		EmissionOffsets_Dummy	0.134	0.130	-0.075*	-0.082**
			(0.335)	(0.350)	(0.061)	(0.040)
		ESGLink_Dummy	-0.048	-0.050	0.014	0.016
			(0.488)	(0.471)	(0.377)	(0.295)
		CSRCommittee_Dummy	-0.134	-0.134	-0.143***	-0.148***
			(0.332)	(0.330)	(0.000)	(0.000)
		EnvControversies_Dummy	-0.018	-0.029	-0.036	-0.036
			(0.903)	(0.842)	(0.307)	(0.335)
		Constant	-0.139	-0.107	-0.257***	-0.221***
			(0.601)	(0.683)	(0.000)	(0.000)
Year FE	Yes		Yes	Yes	Yes	Yes
Industry FE	No		Yes	Yes	Yes	Yes
Observations-	1,020		1,020	1,020	1,020	1,020
Adjusted R^2	0.112		0.038	0.039	0.852	0.849

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents Model (7) in Column 1, regressing *Environmental_Bog* against firm-related environmental complexity variables. Columns (2)-(5) results from re-estimated Models (1) and (2) by replacing *Environmental_Bog* first with residuals from Model (7) and then with fitted values from Model (7). The *p*-values are provided in parentheses. Standard errors are clustered by firm.

Table 8 Change in Carbon Emission Intensity and Environmental Reporting Linguistic Characteristics

	Dependent variable:				
	focuspast	*focuspresent*	*focusfuture*	*negate*	*cause*
	(1)	(2)	(3)	(4)	(5)
Chg_CarbonIntensity	0.033***	-0.032*	0.006	0.011*	0.015
	(0.007)	(0.078)	(0.528)	(0.059)	(0.540)
SRrank	-0.058**	-0.036	0.048**	-0.0004	0.037
	(0.012)	(0.183)	(0.039)	(0.982)	(0.217)
Earnings	-0.003	-0.012	-0.031	0.017	0.178***
	(0.925)	(0.781)	(0.352)	(0.417)	(0.002)
Size	-0.009	0.022	0.026	0.007	-0.098*
	(0.782)	(0.560)	(0.208)	(0.593)	(0.057)
MTB	-0.053*	0.072*	0.042*	0.011	-0.031
	(0.091)	(0.084)	(0.080)	(0.467)	(0.610)
Firm_Age	-0.037**	0.039**	0.005	0.002	0.018
	(0.033)	(0.039)	(0.698)	(0.849)	(0.545)
GEOG_Segments	-0.004	0.078**	0.025	0.025	0.030
	(0.881)	(0.037)	(0.379)	(0.180)	(0.461)
PROD_Segments	-0.063**	-0.056	0.038*	0.002	-0.012
	(0.018)	(0.123)	(0.078)	(0.902)	(0.763)
Governance_Score	0.021	-0.026	-0.006	-0.011	-0.006
	(0.450)	(0.471)	(0.778)	(0.482)	(0.874)
Env_RD_Exp	0.037***	-0.027*	0.011***	0.006*	-0.004
	(0.000)	(0.081)	(0.009)	(0.093)	(0.698)
EmissionOffsets_Dummy	-0.025	-0.118	0.054	0.029	0.089
	(0.772)	(0.204)	(0.409)	(0.606)	(0.423)
ESGLink_Dummy	-0.064	-0.048	-0.031	0.001	-0.045
	(0.119)	(0.339)	(0.317)	(0.965)	(0.442)
CSRCommittee_Dummy	-0.042	-0.238***	-0.063	-0.037	0.141
	(0.519)	(0.009)	(0.293)	(0.343)	(0.144)
EnvControversies_Dummy	-0.146	-0.011	0.049	0.044	0.170
	(0.117)	(0.924)	(0.499)	(0.269)	(0.429)
Constant	2.014***	2.720***	0.863*	0.685**	2.739***
	(0.000)	(0.000)	(0.055)	(0.041)	(0.000)
Year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Observations	1,020	1,020	1,020	1,020	1,020
Adjusted R^2	0.075	0.095	0.201	0.071	0.151

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents regressions results from Model (1) re-estimated by replacing dependent variable *Environmental_Bog* with linguistic characteristics of environmental reporting: *focuspast, focuspresent, focusfuture, negate*, and *cause*, in Column (1)-(5). The *p*-values are provided in parentheses. Standard errors are clustered by firm.

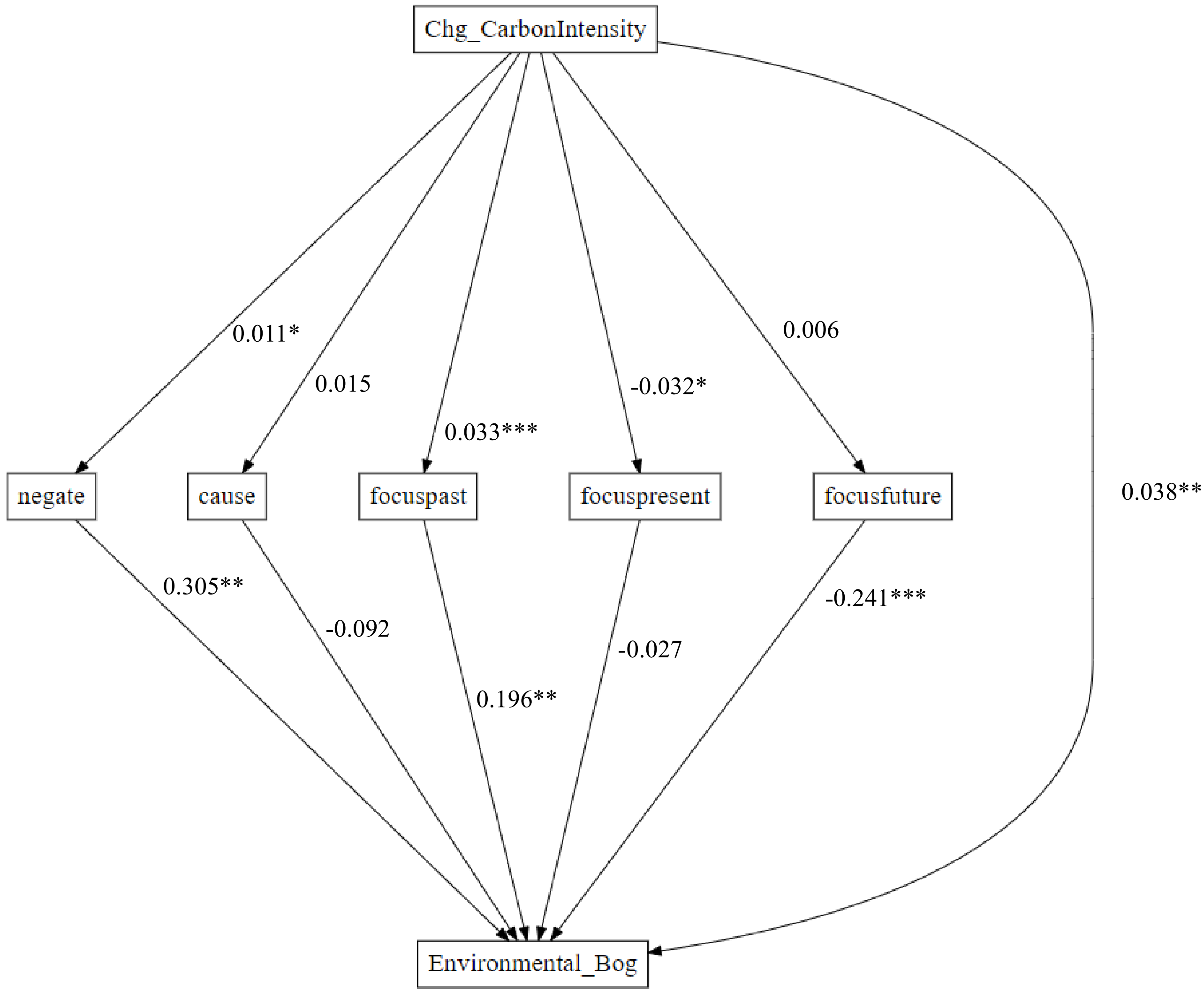

Figure 6: *Structural equation model showing the relationships between Chg_CarbonIntensity, mediators—negate, cause, focuspast, focuspresent, focusfuture—and the dependent variable, Environmental_Bog. The model controls for all covariates from Model (1) and includes firm-level clustered standard errors.*

Table 9 Additional Analyses

	Dependent variable: *Environmental_Bog*					
	(1)	(2)	(3)	(4)	(5)	(6)
	Chg_Carbon Intensity > 0	*Chg_Carbon Intensity* < 0	*Target Emissions=1*	*Target Emissions=0*	High *Foreign Ownership*	Low *Foreign Ownership*
Chg_CarbonIntensity	0.173***	0.011	0.082***	0.162	0.135	0.115**
	(0.003)	(0.893)	(0.010)	(0.161)	(0.244)	(0.033)
High_SR	-0.086	-0.136	-0.115	0.055	-0.265**	-0.028
	(0.505)	(0.145)	(0.149)	(0.684)	(0.017)	(0.789)
*Chg_CarbonIntensity * High_SR*	-0.119*	-0.053	-0.070*	-0.085	-0.110	-0.147**
	(0.072)	(0.526)	(0.083)	(0.510)	(0.380)	(0.020)
Earnings	-0.025	-0.092	-0.044	-0.090	-0.058	-0.055
	(0.779)	(0.189)	(0.519)	(0.337)	(0.554)	(0.543)
Size	0.057	0.100	0.073	0.067	0.109	0.094
	(0.549)	(0.113)	(0.288)	(0.350)	(0.226)	(0.209)
MTB	-0.043	0.022	0.027	-0.062	-0.003	-0.024
	(0.672)	(0.751)	(0.734)	(0.444)	(0.977)	(0.802)
Firm_Age	0.048	0.014	-0.114***	0.085	0.022	0.049
	(0.518)	(0.830)	(0.005)	(0.261)	(0.839)	(0.329)
GEOG_Segments	0.086	0.220***	0.204***	0.174*	0.147	0.310***
	(0.377)	(0.000)	(0.000)	(0.083)	(0.158)	(0.000)
PROD_Segments	0.079	-0.025	0.002	-0.004	0.119	-0.083
	(0.330)	(0.637)	(0.972)	(0.963)	(0.144)	(0.265)
Governance_Score	-0.007	0.052	0.055	0.029	-0.040	0.115
	(0.938)	(0.345)	(0.355)	(0.744)	(0.628)	(0.102)
Env_RD_Exp	-0.019	-0.035*	-0.019	-0.024	-0.013	-0.012
	(0.518)	(0.083)	(0.401)	(0.579)	(0.615)	(0.701)
EmissionOffsets_Dummy	0.219	-0.005	0.138	0.285	-0.074	0.022
	(0.566)	(0.975)	(0.375)	(0.369)	(0.729)	(0.912)
ESGLink_Dummy	0.059	-0.074	-0.113	0.150	0.022	-0.086
	(0.657)	(0.410)	(0.210)	(0.248)	(0.852)	(0.432)
CSRCommittee_Dummy	-0.399*	-0.253*	-0.187	-0.111	-0.144	-0.345*
	(0.052)	(0.084)	(0.343)	(0.598)	(0.448)	(0.066)
EnvControversies_Dummy	0.270	-0.211	-0.051	-0.148	0.057	-0.121
	(0.147)	(0.427)	(0.703)	(0.631)	(0.873)	(0.561)
Constant	0.100	-0.502*	-0.473	-0.476	-0.282	-0.398
	(0.801)	(0.089)	(0.187)	(0.223)	(0.497)	(0.332)
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
N	332	688	633	379	462	406
Adjusted R^2	0.093	0.114	0.133	0.119	0.169	0.153

Note: *p<0.1; **p<0.05; ***p<0.01

This table presents the regression results for the following sub-samples: (i) increases and decreases in firm carbon emission intensity in Columns (1) and (2), respectively; (ii) sub-samples of firms that set emission reduction targets and firms that do not in Columns (3) and (4), respectively; (iii) high and low foreign institutional ownership in Columns (5) and (6), respectively. Refer to Appendix A for variable definitions. The *p*-values are provided in parentheses. Standard errors are clustered by firm.

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Appendix A – Variable Definitions

Variable	Definition	Source
Environmental_Bog	*Bog Index* = Measure of plain English following Bonsall et al. (2017) as follows: $Bog = Sentence\ bog + Word\ bog - Pep$ *Sentence bog* identifies readability issues stemming from sentence length. The measure uses average sentence length across the document and squares and scales this average length by a standard long sentence limit of 35 words per sentence. *Word bog* comprises two main sub-components: 1) plain English style problems and 2) word difficulty. *Pep* identifies the writing attributes that facilitate the understanding of the readers. A higher *Bog* indicates a less readable annual report. *Environmental_Bog* is measured on environmental narratives, extracted from annual reports using machine learning and natural language processing techniques. Specifically, a text classification model is developed to classify different narrative reporting themes in the annual reports, of which one category is environmental narrative reporting.	Software StyleWriter.
Chg_CarbonIntensity	$Chg\_CarbonIntensity =$ $\left(\frac{Emissions_{firm,t}}{Sales_{firm,t}} - \frac{Emissions_{firm,t-1}}{Sales_{firm,t-1}}\right) - \left(\frac{Emissions_{industry,t}}{Sales_{industry,t}} - \frac{Emissions_{industry,t-1}}{Sales_{industry,t-1}}\right)$ Where *Emissions* capture the total emissions of the firm or industry and *Sales* is the total sales of the firm or industry. A positive value of *Chg_CarbonIntensity* indicates that the firm's carbon intensity has increased relative to the industry average, while a negative value suggests that the firm's carbon intensity has decreased relative to the industry average.	Refinitiv ESG
Firm_SR_Score	Firm raw SR quality score in year t.	PwC UK
Total_Available_SR_Score	Total raw SR quality score available in year *t*. This is based on the rating questions used by PwC UK to rate companies' reporting quality each year. For example, if there are 20 questions used by PwC UK in year *t*, and each question is worth 1 point, then the total raw IR quality score available in year *t* is 20.	PwC UK
Scaled_SR_Score	Scaled firm SR quality score in year *t*. Calculated as *Firm_SR_Score/Total_Available_SR_Score.*	PwC UK
SRrank	The quality of a firm's SR practice is measured by ranked decile *Scaled SR Score* (1-10) in each industry-year combination.	PwC UK
High_SR	Equal to 1 if *SRrank* is greater than or equal to mean(SRrank), and 0 otherwise.	PwC UK
Earnings	Operating earnings scaled by total assets at the fiscal year-end.	Compustat
Size	Log of total revenue at fiscal year-end.	Compustat
MTB	(Market value of equity + book value of liabilities)/book value of total assets, measured at the end of the fiscal year.	Compustat
Firm_Age	Number of years since a firm first appears in the Compustat daily stock return file.	Compustat
GEOG_Segments	Natural log of the number of geographic segments.	Datastream via Refinitiv

PROD_Segments	Natural log of the number of product segments.	Datastream via Refinitiv
Governance_Score	Governance pillar score from the Refinitiv ESG database. The governance pillar score captures how well a firm manages its governance issues related to management, shareholders, and CSR strategy. A higher value indicates more effective governance and thus lower agency costs.	Refinitiv ESG
Env_RD_Exp	Total amount of environmental R&D costs (without clean-up and remediation costs) scaled by revenue. It captures the data on R&D costs for the development of products and services aimed at improving environmental impact reduction and innovation.	Refinitiv ESG
EmissionsOffsets_Dummy	Equal to 1 if the firm has CO2 offsets, credits, and allowances purchased and/or produced by the company during the fiscal year, and 0 otherwise.	Refinitiv ESG
ESGLink_Dummy	Equal to 1 if the firm compensation policy includes remuneration for the CEO, executive directors, non-board executives, and other management bodies based on ESG or sustainability factors, 0 otherwise.	Refinitiv ESG
CSRCommittee_Dummy	Equal to 1 if the firm has a CSR committee, and 0 otherwise.	Refinitiv ESG
EnvControversies_Dummy	Equal to 1 if the firm is involved in environmental controversies since the last fiscal year, 0 otherwise.	Refinitiv ESG
GC_Signatory	Equal to 1 if the firm is a signatory of the United Nations Global Compact , and 0 otherwise.	Refinitiv ESG
ROA	Net income scaled by total assets.	Compustat
Leverage	Long-term liabilities scaled by total assets.	Compustat
Big4	Equal to 1 if the firm's auditor is one of the big four audit firms, 0 otherwise.	Compustat
Board_Size	Measured as the total number of board members.	Refinitiv ESG
Board_Independence	Percentage of independent board members.	Refinitiv ESG
Board_GenderDiversity	Percentage of females on the board.	Refinitiv ESG
Board_AverageTenure	The average tenure of the board members.	Refinitiv ESG
Board_Skills	Percentage of board members who either have an industry-specific background or a strong financial background.	Refinitiv ESG
AC_Independence	Percentage of independent members in the audit committee.	Refinitiv ESG
CSR_Score	Refinitiv's corporate social reporting score reflects a company's practices to communicate that it integrates the financial, social and environmental dimensions into its day-to-day decision-making processes.	Refinitiv ESG
IMR	Inverse Mills Ratio (*IMR*) ratio, calculated from stage one of Heckman's two-stage model.	Stage one Heckman
$\widehat{High\_SRrank}$	Predicted value of *SRrank* from the first stage of the two-stage least squares estimation.	Stage one 2SLS
Residuals	Residuals calculated from stage two of 2SLS estimation.	Stage two 2SLS
Environmental_Score	Firm Environmental Score from ESG Refinitiv Database.	Refinitiv ESG
High_Ind_Emissions_Dummy	Equals to 1 if a firm operates in high emitter industry in each year-industry combination, 0 otherwise.	Refinitiv ESG
Environmental_Bog_Residuals	Residuals calculated from Model (7).	Residuals from Model (7)

Environmental_Bog_Predicted	Fitted values of *Environmental_Bog* obtained from Model (7)	Fitted values from Model (7)
focuspast	LIWC category " focuspast ": was, had, were, been, etc. Simple count divided by the number of words	LIWC-22
focuspresent	LIWC category "focuspresent": is, are, I'm, can, etc. Simple count divided by the number of words	LIWC-22
focusfuture	LIWC category "focusfutrue": will, going to, have to, may, etc. Simple count divided by the number of words	LIWC-22
negate	LIWC category "negate": no, not, never, etc. Simple count divided by the number of words	LIWC-22
cause	LIWC category "cause": how, because, make, why, etc. Simple count divided by the number of words	LIWC-22
TargetEmissions	Equal to 1 if the company has set short-term or long-term emission reduction targets, and 0 otherwise.	Refinitiv ESG
ForeignOwnership	Foreign institutional ownership is calculated as the proportion of foreign ownership to total ownership.	FactSet

Online Appendix (OA)

OA.1

Table: Propensity Score Matching (PSM) and Entropy Balancing (EB) validation

Panel A: Covariate Comparison Post Propensity Score Matching (PSM)

	Low_SR	High_SR	Diff Mean	*p*-value	*t*-statistic
Environmental_Bog	0.104	-0.066	0.170	0.020	2.339
Chg_CarbonIntensity	0.051	-0.017	0.068	0.344	0.948
Earnings	-0.010	-0.023	0.013	0.852	0.187
Size	0.019	-0.031	0.049	0.475	0.715
MTB	0.002	0.005	-0.002	0.975	-0.031
Firm_Age	-0.011	-0.026	0.015	0.844	0.197
GEOG_Segments	-0.026	0.001	-0.027	0.701	-0.385
PROD_Segments	0.012	-0.010	0.023	0.745	0.325
Governance_Score	-0.012	0.073	-0.085	0.217	-1.236
Env_RD_Exp	-0.082	-0.100	0.018	0.161	1.405
EmissionOffsets_Dummy	0.033	0.046	-0.013	0.360	-0.916
ESGLink_Dummy	0.431	0.436	-0.005	0.886	-0.144
CSRCommittee_Dummy	0.804	0.804	0	1	0
EnvControversies_Dummy	0.026	0.020	0.005	0.634	0.476

Panel B: Covariate Comparison before and after Entropy Balancing across Treatment and Control groups

	Mean	**Variance**	**Skewness**		**Mean**	**Variance**	**Skewness**	**Diff Mean**	**Var Ratio**
Before EB	**Treatment (High SR)**				**Control (Low SR)**				
Earnings	-0.012	1.067	1.386	*Earnings*	0.015	0.918	0.907	-0.028	1.163
Size	-0.069	0.919	1.522	*Size*	0.085	1.090	1.644	-0.154	0.843
MTB	-0.003	1.132	3.039	*MTB*	0.003	0.839	2.648	-0.006	1.350
Firm_Age	0.006	0.972	-6.562	*Firm_Age*	-0.007	1.037	-6.384	0.013	0.938
GEOG_Segments	0.064	1.030	-0.271	*GEOG_Segments*	-0.079	0.953	-0.147	0.143	1.081
PROD_Segments	0.053	1.033	-0.847	*PROD_Segments*	-0.066	0.954	-0.642	0.120	1.083
Governance_Score	0.119	0.939	-0.361	*Governance_Score*	-0.148	1.039	-0.216	0.267	0.904
Env_RD_Exp	0.050	1.561	8.202	*Env_RD_Exp*	-0.062	0.298	16.893	0.111	5.235
EmissionOffsets_Dummy	0.067	0.063	3.446	*EmissionOffsets_Dummy*	0.033	0.032	5.214	0.034	1.967
ESGLink_Dummy	0.439	0.247	0.245	*ESGLink_Dummy*	0.404	0.241	0.388	0.035	1.022
CSRCommittee_Dummy	0.855	0.124	-2.010	*CSRCommittee_Dummy*	0.710	0.206	-0.922	0.145	0.602
EnvControversies_Dummy	0.027	0.026	5.875	*EnvControversies_Dummy*	0.022	0.022	6.499	0.005	1.202
After EB	**Treatment (High SR)**				**Control (Low SR)**				
Earnings	-0.012	1.067	1.386	*Earnings*	-0.012	1.067	1.386	0.000	1.000
Size	-0.069	0.919	1.522	*Size*	-0.069	0.919	1.523	0.000	1.000
MTB	-0.003	1.132	3.039	*MTB*	-0.003	1.132	3.039	0.000	1.000
Firm_Age	0.006	0.972	-6.562	*Firm_Age*	0.006	0.972	-6.366	0.000	1.000
GEOG_Segments	0.064	1.030	-0.271	*GEOG_Segments*	0.064	1.030	-0.271	0.000	1.000
PROD_Segments	0.053	1.033	-0.847	*PROD_Segments*	0.053	1.033	-0.846	0.000	1.000
Governance_Score	0.119	0.939	-0.361	*Governance_Score*	0.119	0.939	-0.361	0.000	1.000
Env_RD_Exp	0.050	1.561	8.202	*Env_RD_Exp*	0.050	1.563	8.194	0.000	1.000
EmissionOffsets_Dummy	0.067	0.063	3.446	*EmissionOffsets_Dummy*	0.067	0.063	3.447	0.000	1.000
ESGLink_Dummy	0.439	0.247	0.245	*ESGLink_Dummy*	0.439	0.247	0.245	0.000	1.000
CSRCommittee_Dummy	0.855	0.124	-2.010	*CSRCommittee_Dummy*	0.855	0.124	-2.010	0.000	1.000
EnvControversies_Dummy	0.027	0.026	5.875	*EnvControversies_Dummy*	0.027	0.026	5.875	0.000	1.000

Carbon Emission Intensity and Environmental Reporting: Obfuscation or Firm-Related Complexity?
Stage 2 Robustness

	Dependent variable:			
	Environmental_Bog_Residuals			*Environmental_Bog*
	(1)	(2)	(3)	(4)
	Base	Base + Stage 1 Regressors	Base + Stage 1 Regressors + Controls	Base + Stage 1 Regressors + Controls
Chg_CarbonIntensity	0.091***	0.089***	0.075**	0.081**
	(0.008)	(0.008)	(0.029)	(0.020)
High_SR	-0.060	-0.055	-0.030	-0.036
	(0.441)	(0.445)	(0.665)	(0.615)
*Chg_CarbonIntensity*High_SR*	-0.080*	-0.077*	-0.073*	-0.079*
	(0.064)	(0.073)	(0.081)	(0.058)
Environmental_Score		0.082	-0.653	-1.978***
		(0.815)	(0.160)	(0.000)
Size		0.027	0.034	0.064
		(0.618)	(0.533)	(0.266)
Earnings			-0.034	-0.036
			(0.544)	(0.535)
MTB			-0.043	-0.041
			(0.445)	(0.464)
Firm_Age			0.025	0.029
			(0.676)	(0.634)
GEOG_Segments		-0.037	-0.051	0.210***
		(0.426)	(0.304)	(0.000)
PROD_Segments		-0.028	-0.031	0.027
		(0.579)	(0.523)	(0.592)
Governance_Score			0.181***	0.183***
			(0.002)	(0.002)
Env_RD_Exp			-0.011	-0.012
			(0.575)	(0.554)
EmissionOffsets_Dummy			0.196	0.217
			(0.187)	(0.170)
ESGLink_Dummy			-0.061	-0.065
			(0.373)	(0.349)
CSRCommittee_Dummy			-0.057	-0.045
			(0.706)	(0.767)
EnvControversies_Dummy			0.024	0.025
			(0.869)	(0.864)
High_Ind_Emissions_Dummy		-0.465*	-0.490*	-0.308
		(0.098)	(0.074)	(0.266)
Constant	-0.304	-0.443	0.188	0.739*
	(0.226)	(0.165)	(0.630)	(0.060)
Year *FE*	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Observations	1,020	1,020	1,020	1,020
Adjusted R^2	0.023	0.024	0.045	0.163
Note:				*p<0.1; **p<0.05; ***p<0.01

OA.2 – Annotation Guide

Capitals	Broadly	Specific	Keywords/terms
Financial	• The pool of funds available (debt and equity finance) • Focus on the source of the funds as opposed to the application	• These funds can be obtained through financing such as debt, equity, or grants or generated through operations or investments	• Debt, equity, grants, funds, profit, retained earnings, return on investment, ROI, remuneration, expenses, profit, loss, operating profit, revenue, funding, capital, financing
Manufactured	• Human-created and production-oriented equipment and tools • Goes beyond what the company owns/controls/leases – such as roads, ports, clean air, etc. that contribute to production/provision of goods/services	• Efficient use of manufactured capital; allows an organization to be flexible/responsive to market/societal needs and innovative/faster in getting products to the market • The possible overlap between manufactured and intellectual capital o E.g., equipment (manufactured capital) manufactured using patented technology (intellectual capital)	• Equipment, buildings, tools, roads, machines, fixtures, fittings, infrastructure, government-supplied infrastructure, society, manufacture, processes, facility
Intellectual	• Intangibles that provide competitive advantages such as patents, copyrights, software/systems, procedures, and protocol • An organization's future earning potential (investment in R&D, innovation, HR, external relationships) • Primarily about internal reporting, management, and control • Can be considered as both, a product of R&D activities as well as an enabler of R&D	• Creates value by combining material, financial, and human resources • Often difficult to assess due to the perceived commercial sensitivity of information disclosed, the long-term character of such investments, and a lack of understanding of the nature of the research being undertaken by organizations • Employee competencies, customer relations, financial relationships, and communication and information technologies • Intellectual property is a part of intellectual capital. Intellectual capital also includes broader knowledge-based intangibles over which specific legal rights may not exist • How to differentiate between overlaps o Intellectual capital: Organization	• Intellectual, patent, intangibles, copyrights, R&D, innovation, research, development, license, organization, systems, protocols, procedures, technology, future, develop, research, science, next-generation, leading-edge, contract, program, agile, efficiency, solution, license, digital, transformation, adapt, concept

		○ Human capital: Individual ○ Social capital: Intra/extra-organizational networks	
Human	• People's competencies, capabilities and experience, and their motivations to innovate • Includes their alignment with the organization's governance framework, ethical values, strategy, loyalties, and motivations • Ability to lead, manage, and collaborate	• Embodies competencies, capabilities, capacity, and ability to carry out an organizational task • Competencies include tacit and implicit knowledge and attitudes • Capabilities include the ability to carry out an organizational task • Organizational culture is not part of this capital. It falls under social and relationship	• Health, safety, training, motivation, lead, manage, employee, human, labor, education, diversity, equality, rights, employee turnover, employee absenteeism, e-learning, skills, loyalty, human rights, expertise, retention, diverse, learning, workforce, female, career, graduate, women, development, talent, workplace, fatality, colleagues, worker
Social and Relationship	• This may include relationships within an organization as well as those between an organization and its external stakeholders, depending on where the social boundaries are drawn • A common feature of the social and relationship capital is the trust upon which it is built • An organization's social license to operate	• Could be the strength and efficacy of supply chain relationships (e.g., establishing quality expectations, recycling programs, etc.), community acceptance, government relations, relationship with competitors, customer loyalty • Networks together with shared norms, values, and understanding facilitate cooperation between various groups • A common feature of the social and relationship capital is the trust upon which it is built	• Community, social, relationship, corruption, network, stakeholders, investor loyalty, social investment, supply chain, values, culture, society, customer, supplier, stakeholder, consumer, values, environment, supply, support, training, diversity, government, education, human rights, trust, regulator, health, program, charity, engage, women, diversity, sustainability, responsibility, local community, ethics, fundraising
Natural	• Natural capital is defined as any stock of natural resources or environmental assets (such as soil, water, atmosphere, and ecosystems) that provide a flow of useful goods or services, now and in the future.	• Natural resources such as air, water, land, forests, minerals, biodiversity, and ecosystem health • Can be either negative or positive	• Water, natural, water, air, land, forests, soil, ecosystem, biodiversity, environment, emissions, $CO2$ emissions, energy, recycle, waste, resources, carbon, atmosphere, sustainable, greenhouse, gas, eco-friendly

OA.3 – Latent Dirichlet Allocation Topic Modelling

Figure 1

Probability of words relating to a topic

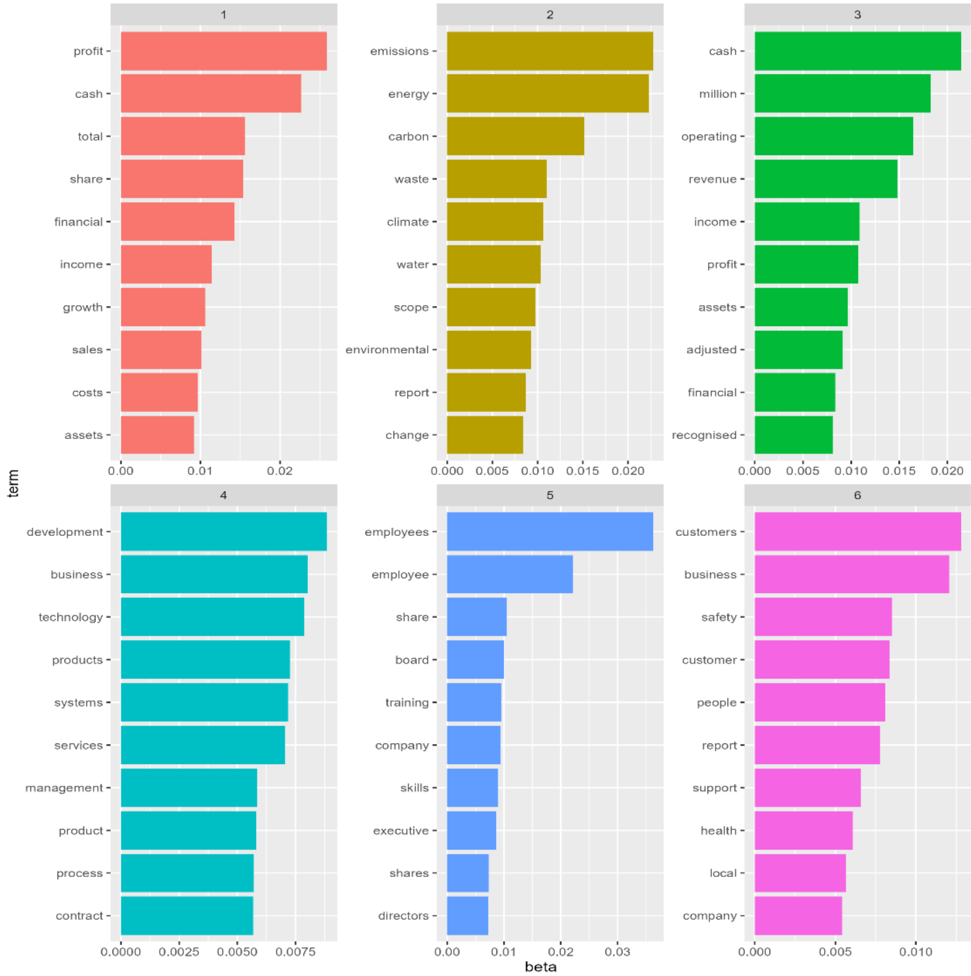
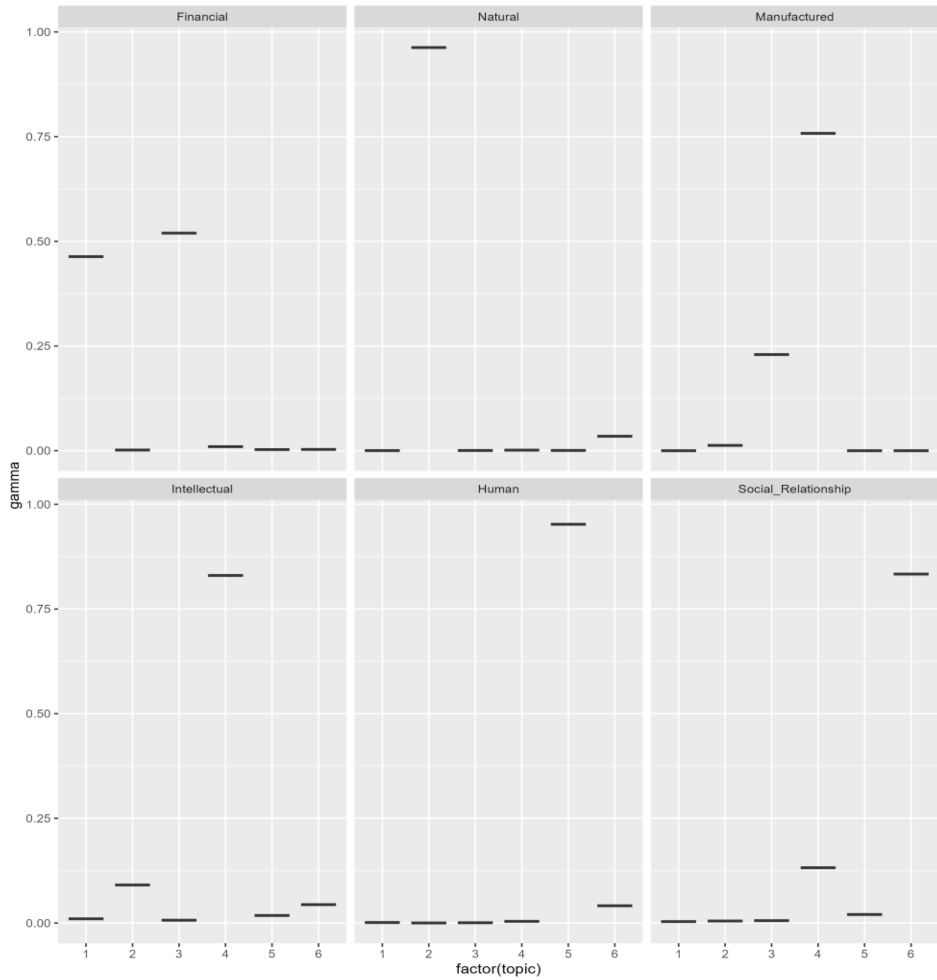


Figure 2

Probability of a topic relating to a document



OA.4 – Annotated versus Classified – Top 15 words by class

Figure 3: Annotated text

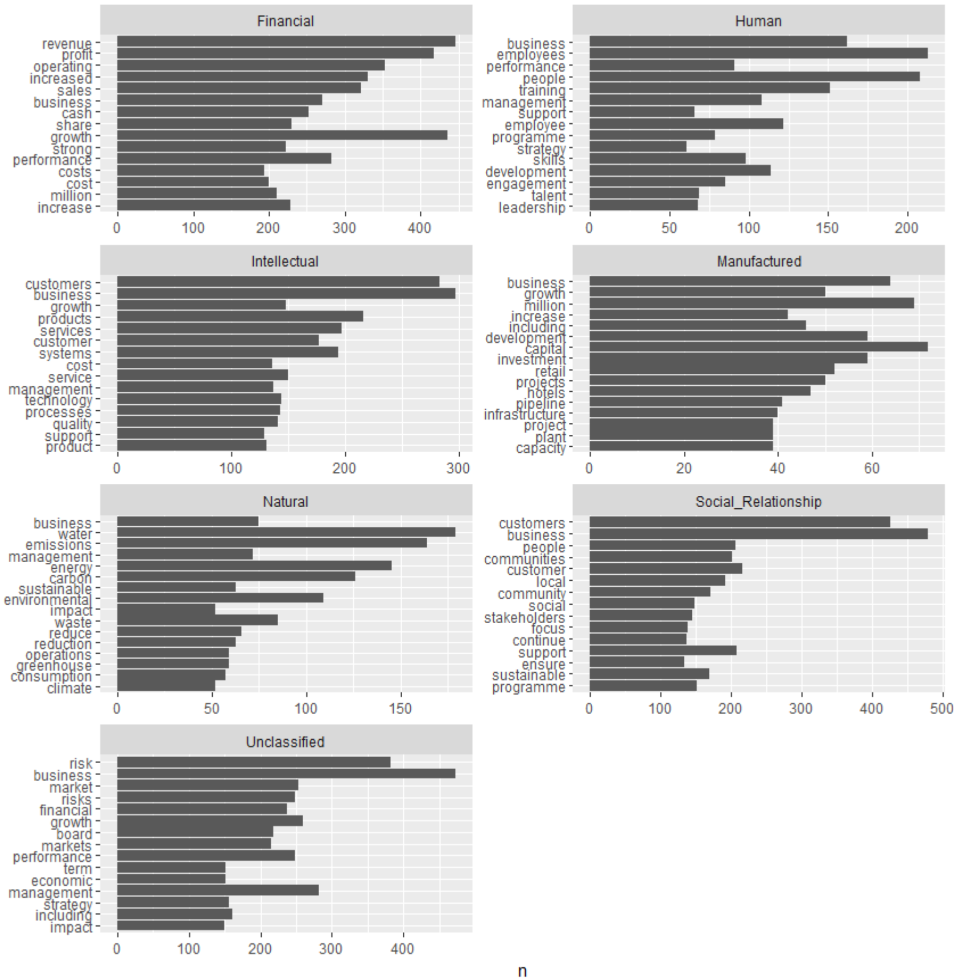


Figure 4: Classified text