

Determinants and Consequences of Corporate Greenhouse Gas Reporting

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Thomas Markus Pioch
aus Lübeck

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Gutachter: Prof. Dr. Frank Schiemann

Gutachterin: Prof. Dr. Brigitte Eierle

Gutachter: Prof. Dr. Max Götttsche

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1 Introduction

The need to urgently address climate change has become imperative due to its multifaceted impact on economies, politics, and societies. Economically, the increasing frequency and intensity of extreme weather events linked to climate change poses significant risks to infrastructure, agriculture, and insurance markets, leading to substantial economic losses and hindering sustainable development efforts. Indeed, the global economy is already committed to a 19% reduction in income over the next 26 years, regardless of future carbon emissions (Kotz et al., 2024). This level of income loss already exceeds the cost of mitigation. In the past, economists have also argued that a 3 °C target for global warming is optimal, from a cost-benefit analysis point of view. This evaluation may have underestimated the probability and potentially catastrophic outcome of climate tipping points, which are much closer than previously assumed and could already be crossed at an increase of 1-2 °C global warming (Lenton et al., 2019). Moreover, current policies are estimated to limit global warming to between 2.2 and 3.4 °C by the year 2100 (Climate Action Tracker, 2023) and many countries are not on a path which will realistically reach net zero by 2050 (European Environment Agency, 2019).

However, the transition to a low-carbon economy also presents substantial economic opportunities in renewable energy, clean technologies, and green infrastructure, with the potential for job creation and innovation. Seventy-two countries have analyzed and highlighted these potentials, with regards to their unique economies, in Long Term Low Emission Development Strategies (LT LEDS) submitted to the United Nations Framework Convention on Climate Change (UNFCCC, 2024).

Politically, climate change can exacerbate existing tensions and conflicts over scarce resources, migration, and geopolitical competition, potentially destabilizing regions and increasing social inequalities. In the mid-term, the impacts of climate change are projected to intensify, with rising sea levels, disruption to global supply chains, and increased pressure on food and water security, posing significant challenges to global stability and prosperity. Therefore, urgent action to mitigate greenhouse gas (GHG) emissions, enhance resilience, and promote sustainable development is essential if we are to avoid the worst impacts of climate change.

Research into climate change policy and the significant role that private companies are playing, with regards to carbon emissions, is crucial for informing effective mitigation and adaptation strategies that can address the challenges posed by global warming. Investigations into policy

instruments, such as emission trading systems and mandates to report emissions, provide valuable insights into their efficacy, feasibility, and potential impacts on various stakeholders. By examining the design, implementation, and outcomes of these policies, researchers can identify best practices, assess their effectiveness in reducing GHG emissions, and evaluate their economic, social, and environmental implications. Furthermore, research helps to identify barriers to policy adoption and implementation, as well as opportunities for enhancing policy coherence, coordination, and effectiveness across different levels of governance. Additionally, research contributes to the development of innovative policy solutions, such as carbon pricing mechanisms, renewable energy incentives, and climate finance instruments, which can promote the transformation towards a low-carbon future.

Therefore, this dissertation demonstrates in four separate papers key aspects and challenges of corporate GHG emission reporting and the connected data quality issues, the methodological implications on established econometric analyses of filling data gaps through estimations, the consequences of introducing a mandatory reporting regulation on a firm's emissions and the multi-faceted determinants that influence managers' decisions to invest in GHG reduction.

2 Research Objective

The objective of this cumulative dissertation is to provide a thorough investigation into corporate carbon emissions, as they are the key lever for reductions and the possibility of meeting climate goals. Corporations can be linked to nearly all anthropogenic carbon emissions, as providers of the fossil fuels private households consume, by burning fuels directly to generate heat and electricity, and through manufacturing processes, with just 57 companies linked to 80% GHG emissions since 2016 (The Guardian, 2024). However, corporations are also the providers of innovative clean technologies, like electric mobility, renewable energy sources, or energy-efficient household heating. Understanding the barriers to accurate corporate GHG emission reporting and the resulting (in)consistency of the data between sources, and between third party data providers that rely on these sources, is crucial to understanding why corporations reduce (or fail to reduce) their emissions and what impact this has on their financial performance. This fundamental information can help create more robust research designs when answering questions connected to corporate GHG emissions, and it can also inform policy development regarding mandates to report according to distinct guidelines. The recent efforts of European policy makers to increase the coherence of corporate reporting include the proposal

for a regulation of ESG (Environmental, Social, Governance) ratings (Council of the European Union, 2024) or the EU Taxonomy, which provides precise guidance on the calculation of GHG emissions embedded in activities. Thus, the first paper in this dissertation explores the comparability and consistency of corporate GHG emission data that are available to the public via third-party data providers, such as Bloomberg or Thomson Reuters.

With reporting irregularities and data gaps, users (including researchers, financial analysts, economic analysts, and policy analysts) must sometimes rely on estimations rather than reported data. The sophistication of estimation models varies between different third-party data providers and the exact methods are often proprietary. However, robust results from analyses using these data are important for making informed decisions. Several studies, for example, have found a negative firm value effect of carbon emissions (Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023). To test the robustness of these results, the second paper in this dissertation replicates the regression model used by Matsumura et al. (2014) and examines the influence of different estimation models on the results and their predictive power and potential bias. It also distinguishes the firm value effect of carbon emissions by Scope 1 (direct emissions from operation) and Scope 2 (indirect emissions from purchased energy) and by a firm's level of relative performance in each scope.

Policy instruments that increase the transparency of corporate GHG emissions and improve their reliability and comparability are important for enabling informed decisions. Reporting quality and quantity increases under mandatory climate reporting regimes, such as the European Emission Trading System (EU ETS) (Comyns, 2016). The EU ETS, however, comes with a price attached, which is meant to provide an incentive for corporations to reduce their emissions. The question of whether and how reporting leads to emission reduction is still being investigated (Downar et al., 2021; Haque & Ntim, 2018; Jouvenot & Krueger, 2020; Qian & Schaltegger, 2017; Tomar, 2019). The Greenhouse Gas Reporting Program (GHGRP) in the United States offers a unique research setting to assess the extent to which the mandatory reporting of verified and comparable data for GHG emissions promotes real change in corporations, since there is no price attached to it. The third paper uses a 'difference in differences' approach to investigate the effect on carbon emission reductions when corporations must report under the GHGRP.

Given the different aspects of GHG emission reporting discussed so far, the question remains, at which point do corporate managers decide to invest into emission reductions? Mandates to report do not necessarily include a carbon price or reduction targets, pricing systems only cover

certain installations, and voluntary reporting leads to issues in data consistency and comparability. These factors are important for the reporting firm as well, not only for data users. Different theoretical perspectives (such as institutional or legitimacy theory) offer explanations as to why reporting may have a positive impact on the reporting corporation but, for managers, these outcomes may not be tangible enough. Allowance prices, like in the early stages of the EU ETS, may not be high enough to justify additional investment in emission reduction and voluntary reporting requires a lot of effort but may still lead to unwanted representation of the corporation due to the nature of how the data is collected and disseminated by third-party providers. The fourth paper explores the different potential reasons behind managers' decisions to invest in GHG emission reduction in a factorial survey design, in order to uncover the determining factors.

3 Theoretical Perspectives

There are several theoretical perspectives that can be utilized to explain observable corporate GHG emission reductions. Institutional and related theories explain emission reductions from the perspective of corporations' environment of business relations and regulations. Organizational factors influence the decision-making within a corporation and, lastly, individual factors can guide managers' attitudes towards sustainability related issues.

Firstly, institutional theory highlights how organizations are influenced by institutional pressures, which can be categorized into coercive, mimetic, and normative pressures (DiMaggio & Powell, 1983). Coercive pressure, stemming from regulations or environmental expectations, mandates firms to comply. Mimetic pressure arises from uncertainty, prompting firms to emulate the behaviors of others. Normative pressure is driven by professional norms from institutions like universities and trade associations. Mandatory climate reporting is primarily linked to coercive pressure. Legislation forces firms to disclose carbon emissions to avoid penalties. Indirectly, societal expectations and political efforts to combat climate change also pressure firms to enhance their carbon performance. This coercive pressure focuses on improving carbon emissions relative to economic output, ensuring firms' legitimacy without hindering their economic development.

Secondly, and related to institutional theory, is legitimacy theory. This was defined by Suchman (1995) as "actions deemed appropriate within social norms" and is crucial for firms. Legitimate firms access critical resources and avoid penalties that threaten their survival (Deegan, 2002).

Coercive pressure not only seeks to maintain legitimacy within social norms but also responds to political influences (DiMaggio & Powell, 1983). Regulations like the GHGRP force the public disclosure of emissions, affecting organizational behavior and reinforcing legitimacy as a "license to operate" (Deegan, 2002). Climate change is a legitimacy issue, with increasing public concern and regulatory changes (e.g., EU Directive, EPA GHGRP). Firms feel pressured to improve their carbon performance and engage in social reporting. To keep global warming below 2 °C, while ensuring growth, firms must reduce GHG emissions by 5% per year (Randers, 2012). Consequently, managing carbon emissions has become vital, with the number of companies reporting an internal carbon pricing to CDP having risen from 150 in 2014 to 850 in 2020 (CDP, 2020).

Beyond these theories, there are organizational factors which shape managers' decisions to invest in carbon emission reducing activities and could explain observed carbon performance improvements.

The empirical literature generally supports a positive relationship between carbon performance and financial performance (Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014). Trumpp et al. (2015) identified a U-shaped relationship, where low carbon performance is negatively associated with financial performance but high carbon performance is positively associated. This suggests that managers should assess their firm's carbon performance relative to their peers. Firms with low carbon performance might find investments in carbon reduction both urgent and rewarding compared to the top performers in the industry.

Investment decisions hinge on how quickly expenditure pays off, either through cost savings (e.g., from high carbon prices under emission trading regimes) or increased sales (e.g., an improved reputation from better carbon performance). The debate on the financial benefits of environmentally responsible behavior has shifted from whether it "pays to be green" (Hart & Ahuja, 1996) to "when does it pay to be green" (Albertini, 2013; Hoang et al., 2020). The time horizon for these benefits is crucial, influencing managers' decisions on whether financial benefits from carbon emission reductions are realized in the short or long term.

Incentive systems also play a crucial role in promoting sustainable behavior among managers (Renwick et al., 2013; Yuriev et al., 2018). Rewards systems, including bonuses or other monetary benefits, aim to foster a sustainability-oriented corporate climate (Eccles et al., 2014). Empirical research shows that integrating sustainability aspects into incentive systems enhances

overall sustainability performance (Ott & Endrikat, 2022; Velte, 2016) and specifically improves carbon performance (Haque, 2017). Therefore, the structure of a firm's incentive systems—whether compensation is based solely on financial performance or also on carbon performance—can significantly influence managers' decisions to invest in carbon emission reductions.

Lastly, the intrinsic motivations behind managers' decisions to invest in sustainability-related activities have been explored in multiple studies and sustainable value orientation has been identified as an important driver for managers' behavior (Gond et al., 2017; Hafenbrädl & Waeger, 2017). For example, Chin et al. (2013) found conservative-leaning CEOs in the US investing less than liberal-leaning ones and requiring larger financial incentives.

These theoretical perspectives and organizational and individual factors are the foundation of this dissertation's attempt to shed light on the intricacies of corporate GHG emission reporting, the reasons behind observable emission reductions or carbon performance improvements and the management approach to investments in emission reduction. The following sections provide short summaries of each paper.

4 Research Papers

The following sections provide summaries of each of the research papers considered in this cumulative dissertation. The full version of each paper is included in the appendices. The state of each paper is as of July 31st 2025.

- Busch, T., Johnson, M., & Pioch, T. (2020). **Corporate carbon performance data: Quo vadis?** *Journal of Industrial Ecology*, 26(1), 350–363. <https://doi.org/10.1111/jiec.13008>
- Pioch, Thomas (2024). **Re-examining the firm value effect of carbon emissions.** Available on SSRN. <http://dx.doi.org/10.2139/ssrn.5332509>
- Bauckloh, T., Klein, C., Pioch, T., & Schiemann, F. (2023). **Under Pressure? The Link Between Mandatory Climate Reporting and Firms' Carbon Performance.** *Organization & Environment*, 36(1), 126–149. <https://doi.org/10.1177/10860266221083340>
- Hahn, R., Pioch, T., Reimsbach, D., Schiemann, F. (2025). **What Drives Carbon-Reducing Investments? A Vignette Experiment on Managers' Decision Making From a Multilevel Perspective.** *Business Strategy and the Environment*, 34(3), 3008-3026. <http://dx.doi.org/10.1002/bse.4134>

4.1 Corporate carbon performance data: Quo Vadis?

Corporate carbon performance (CCP) data has become a central topic in various domains, including politics, finance, and academia, due to its critical role in climate change mitigation. Despite its growing importance, several unresolved issues persist regarding the comparability and consistency of CCP data. These issues are significant because various stakeholders—such as corporate managers, investors, academic researchers, and policymakers—rely on comprehensive and high-quality CCP data to set realistic carbon reduction targets, measure progress, and make informed decisions. The quality of CCP data has been extensively discussed in the literature, with a particular focus on firm-internal drivers and motivations for accounting and disclosing such data. Key drivers include regulatory pressures, enhancing a firm's reputation, greater transparency, risk mitigation, and improving financial performance. For example, Hahn et al. (2015) argued that CCP data disclosure can potentially reduce the principal-agent problem of asymmetric information by increasing transparency. Similarly, Clarkson et al. (2008) suggested that companies disclose CCP data voluntarily through sustainability reports or initiatives like the Carbon Disclosure Project (CDP), to signal superior performance to investors and other stakeholders.

The quality of CCP data has been assessed, in terms of several desirable characteristics, including verifiability, reliability, comparability, and consistency. Previous studies have examined how firms internally gather and report CCP data according to guidelines like the Greenhouse Gas Protocol, which was established almost 25 years ago as a standardized framework for accounting and reporting greenhouse gas emissions. However, the consistency of CCP data across firms from an external stakeholder's perspective has been less extensively studied (Andrew & Cortese, 2011; Matisoff et al., 2013). Consistency issues become particularly evident when comparing CCP data between different third-party data providers. Major providers include Bloomberg, CDP, ISS Ethix, MSCI, Sustainalytics, Thomson Reuters, and Trucost. These providers use data from corporate reports and their estimation methods, especially when company-reported data are not available. Third-party estimations can vary significantly due to differences in the underlying methodologies and the assumptions used. For example, ISS Ethix uses sub-sector specific models to estimate CCP data, while MSCI employs different estimation methods based on previous emission intensities and non-linear regressions (ISS-Ethix Climate Solutions, 2019; MSCI ESG Research, 2019). The literature identifies several challenges related to the consistency of CCP data. For instance, mandatory reporting schemes, such as the U.S. Environmental Protection Agency's GHGRP and the European Union Emission Trading Scheme (EU ETS), only cover a portion of a company's emissions at the

facility level. As a result, they fail to capture the complete emissions profile of companies, leading to inconsistencies. Voluntary reporting schemes, such as those encouraged by the CDP, also face challenges due to varying reporting standards and methodologies, which hinder comparability across firms (Perrault Crawford & Clark Williams, 2010; Sullivan & Gouldson, 2012). Research has shown that the consistency of CCP data decreases as the complexity of carbon accounting increases from direct emissions (Scope 1) to indirect emissions (Scopes 2 and 3). Scope 3 emissions, which encompass indirect emissions from a company's value chain, are particularly problematic. For example, Matisoff et al. (2013) found that, while the comparability of corporate carbon emission data improved over time for Scopes 1 and 2, it remained poor for Scope 3. This is a significant issue, as Scope 3 emissions often constitute the majority of a company's total carbon footprint.

Third-party estimation methods play a crucial role in filling data gaps when companies do not report their emissions. These methods include process analysis (PA), input-output analysis (IOA), and hybrid approaches that combine elements of both. PA uses primary and secondary production process data, while IOA allocates carbon emissions based on input-output tables of national accounts. Hybrid approaches, considered the state of the art in carbon footprinting, merge the strengths of both PA and IOA to provide more comprehensive estimations (Wiedmann, 2009). Despite their importance, third-party estimations introduce further inconsistencies. For example, Sustainalytics uses historical company data and non-linear regressions to estimate emissions, while Thomson Reuters applies one of three different methods, depending on data availability. Such variations lead to different results for the same company, as demonstrated by the discrepancies in Scope 3 emission estimations between ISS Ethix and Trucost.

The study finds significant inconsistencies in CCP across different third-party providers, with consistency decreasing from Scope 1 to Scope 2 and 3. Mandatory and voluntary reporting schemes do not substantially improve consistency and estimations are less consistent than directly reported data. However, the combination of Scope 1 and Scope 2 emission estimations into one metric improves consistency. To address these issues, several steps can be taken. Academic researchers should be mindful of the consistency of CCP data in their studies, as it can significantly affect empirical results. They should scrutinize outliers, use separate models for company-reported and third-party estimated data, and carefully select data sources. Corporate managers should ensure that different CCP data communicated externally are consistent and align their reporting with third-party estimates. Investors should advocate for standardized reporting approaches to enhance data comparability and reliability. Data providers

should increase transparency in their estimation methodologies, clearly indicating the assumptions and models used. This transparency would help users understand the limitations and strengths of the data provided. Policymakers should push for standardized CCP reporting frameworks that can be universally adopted, ensuring consistency and reliability in carbon performance data. Overall, addressing the inconsistencies in CCP data is crucial for creating a level playing field among firms, supporting informed investment decisions, and facilitating effective climate policies. Achieving high levels of CCP data consistency will ultimately support global efforts to mitigate climate change by providing reliable data for measuring, analyzing, and comparing corporate carbon performance.

4.2 Re-examining the firm value effect of carbon emissions

In the evolving landscape of environmental sustainability, accurate data on corporate carbon emissions have become critical. Such data are essential for regulators, who need to develop effective climate policies, and for investors to accurately assess firm values. Companies' carbon emissions, which are indicators of their environmental footprint, can significantly influence their financial performance and market valuation (Friede et al., 2015; Matsumura et al., 2014). However, the inconsistency and occasional lack of corporate emission data require the use of estimation models to fill in the gaps. Policies, such as the European Emission Trading System (EU ETS) and California's Cap-and-Trade Program, rely heavily on accurate emission data and governments and regulatory bodies worldwide have established targets to mitigate climate change. For example, the European Union's Green Deal aims for net-zero emissions by 2050 and various U.S. states have set specific reduction targets (Center for Climate and Energy Solutions, 2022). Accurate data not only aids in monitoring compliance but it also helps when extending regulatory frameworks into new sectors. Furthermore, the firm value effect of carbon emissions is substantial. Studies have shown that carbon emissions can decrease firm value significantly, with reductions ranging from \$39 to \$212 per additional ton of emissions (Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023). This effect arises due to stakeholder pressure, increased capital costs, potential liabilities from fines, and regulatory risks. Accurate carbon emission data is thus crucial for capital markets, helping investors incorporate environmental risks into their valuation models.

Corporate carbon emissions data are typically collected through voluntary disclosure platforms like the CDP, regulatory filings, or mandated disclosure programs such as the EU ETS and the GHGRP. Data providers (such as Refinitiv) compile these reports and estimate emissions for

firms that do not disclose them. The consistency of reported data across different providers is relatively high (Busch et al., 2020). However, estimated data can vary significantly, highlighting the need for accurate and reliable estimation models. Two main approaches are commonly used to estimate carbon emissions: simple ratio-based models and regression-based models. Ratio-based models, such as those used by Refinitiv, calculate emissions based on the latest available data, adjusting for changes in factors like the number of employees or revenue. Regression-based models, like those proposed by Griffin et al. (2017), use financial and operational variables to predict emissions. Both models have their strengths and limitations. Ratio-based models are straightforward and can produce estimates for a wide range of firms but they may lack precision, especially when firms actively manage their emissions. Regression-based models can be more accurate but are often limited by the availability and quality of financial and operational data.

The study compares the accuracy of these estimation models against actual reported emissions from Refinitiv, for U.S. firms between 2014 and 2020. The results indicate that ratio-based models tend to underestimate emissions by a significant margin, while regression-based models show a decline in explanatory power over time. This decline suggests that, as firms increasingly manage their emissions, traditional estimation models may become less effective. Notably, the Refinitiv CO₂-Model, which uses historical emissions data to estimate future emissions, showed the least bias and highest predictive accuracy. This model estimated emissions to be within the same or adjacent decile as reported emissions 87% of the time, for combined Scope 1 and Scope 2 emissions. In contrast, other models showed larger discrepancies, with estimated emissions falling into different deciles in about 75% of cases. After examining the accuracy of the estimation models, the relationship between carbon emissions and firm value was examined using the valuation model by Matsumura et al. (2014), which includes total assets, liabilities, and operating income as variables. The analysis confirmed that increased carbon emissions generally decrease firm value, with Scope 2 emissions having a more significant negative impact than Scope 1 emissions. This distinction is important because Scope 2 emissions can be more easily mitigated by switching to cleaner energy sources, while Scope 1 emissions are often directly tied to the firm's core activities. Consequently, capital markets penalize firms more heavily for high Scope 2 emissions, reflecting the greater potential for these firms to reduce their carbon footprint without compromising operational efficiency. Interestingly, the effect of Scope 1 and Scope 2 emissions can also be distinguished according to a firm's relative performance in each scope. Firms with a low relative performance in Scope 1 but high relative

performance in Scope 2 show significant penalties for their Scope 1 emissions but insignificant penalties for Scope 2, and vice versa.

These findings underscore the need for firms to manage their carbon emissions proactively, particularly Scope 2 emissions, to protect their market value. For policymakers, the results highlight the importance of accurate emission data in designing effective climate policies and the need for ongoing refinement of emission estimation models. Moreover, as regulatory pressures and market expectations around carbon emissions continue to grow, firms that fail to disclose their emissions accurately or manage them effectively may face increased financial risks. Investors are likely to demand greater transparency and accountability, and firms that lag in environmental performance could see their valuations suffer. The study's findings align with previous research, confirming that higher carbon emissions are associated with lower firm value. However, it also emphasizes the critical role of accurate and reliable carbon emission data, both reported and estimated, in understanding the financial impact of emissions. The distinction between Scope 1 and Scope 2 emissions is particularly significant, with Scope 2 emissions exerting a more substantial impact on firm value, due to their potential for mitigation through cleaner energy sources.

4.3 Under Pressure? The Link Between Mandatory Climate Reporting and Firms' Carbon Performance

The increasing societal and regulatory pressure on firms to disclose their carbon emissions has significant implications for their operational behaviors and carbon performance. This study uses legitimacy theory to explore whether mandatory climate reporting, specifically the GHGRP introduced by the U.S. Environmental Protection Agency (EPA) in 2010, leads to substantive improvements in firms' carbon performance. The GHGRP mandates firms to report emissions from facilities emitting 25,000 metric tons or more of carbon dioxide equivalent annually, covering a significant portion of U.S. emissions. This regulation provides a unique setting to examine the impacts of mandatory reporting on both carbon intensity and absolute carbon emissions of firms, as it does not include a price on carbon.

Drawing from legitimacy theory, the study hypothesizes that mandatory climate reporting increases societal pressure on firms to improve their carbon performance to maintain their legitimacy, or their "license to operate". This theoretical framework posits that firms are driven to align their operations with societal norms and values, particularly in the face of heightened awareness and concern about climate change (Deegan, 2002; Dowling & Pfeffer, 1975). The

public disclosure mandated by the GHGRP exposes firms to scrutiny, encouraging them to enhance their carbon efficiency to meet these societal expectations (Newson & Deegan, 2002).

The study utilizes a difference-in-differences design, covering the period from 2007 to 2016, to estimate the effects of the GHGRP on the carbon performance of affected firms compared to unaffected firms. The results indicate that firms subject to the GHGRP show a significant improvement in carbon intensity, which measures the efficiency of carbon emissions relative to total assets. This improvement is robust across various model specifications and sample compositions. However, the analysis reveals a contrasting trend in absolute carbon emissions: affected firms did not reduce their total emissions as much as unaffected firms, post-GHGRP implementation. This suggests that, while mandatory reporting drives efficiency improvements, it does not necessarily lead to overall emission reductions.

The findings contribute to the literature in several ways. First, they extend the scope of research on the implications of climate reporting from voluntary to mandatory regimes, highlighting the differential impacts on carbon intensity and absolute emissions. Prior studies primarily focused on voluntary reporting and its limited effects on carbon performance (Haque & Ntim, 2018; Qian & Schaltegger, 2017) or on mandatory reporting in the context of existing carbon pricing mechanisms (Downar et al., 2021; Jouvenot & Krueger, 2020). This study isolates the effects of mandatory reporting in the absence of such mechanisms, providing clearer insights into the direct impact of disclosure requirements. Second, the study underscores the importance of distinguishing between carbon intensity and absolute emissions when evaluating carbon performance. While improvements in carbon intensity reflect better operational efficiency, absolute emission reductions are crucial for achieving broader climate goals. The differential effects observed in the study suggest that mandatory reporting may drive firms to enhance efficiency without necessarily decreasing their total emissions, which is a critical consideration for policymakers aiming to design effective climate regulations. Third, the study's findings emphasize the role of legitimacy in driving a firm's responses to environmental regulations. The observed improvements in carbon intensity among GHGRP-regulated firms align with legitimacy theory, indicating that firms respond to mandatory reporting by improving their efficiency to meet societal expectations. This contrasts with the often criticized use of voluntary reporting for impression management, where firms disclose favorable information to maintain legitimacy without substantial operational changes (Archel et al., 2009; Deegan, 2002). The study also highlights the potential limitations of mandatory reporting when attempting to achieve comprehensive emission reductions. The lesser reduction in absolute emissions among regulated firms suggests that, while mandatory reporting induces efficiency improvements,

additional measures, such as carbon pricing or more stringent reduction targets, may be necessary to drive significant reductions in total emissions. This is particularly relevant in the context of global climate goals, such as those outlined in the Paris Agreement, which require substantial decreases in overall carbon emissions to mitigate climate change (Rogelj et al., 2018).

4.4 What Drives Carbon-Reducing Investments? A Vignette Experiment on Managers' Decision Making From a Multilevel Perspective

Reducing carbon emissions is one of the most urgent societal imperatives of our times and is a challenge that falls most heavily on the corporate sector. Managers play a pivotal role in deciding whether to invest in carbon-reducing efforts; understanding the drivers behind these decisions is essential for promoting more sustainable corporate practices. This study explores the multifaceted influences on managers' decisions when investing in carbon emission-reducing projects, encompassing institutional, organizational, and individual-level factors.

Institutional pressures significantly influence managerial decision-making regarding carbon-reducing investment. One critical institutional factor is investor orientation. Investors, both institutional and retail, increasingly prioritize climate-related issues when allocating their funds. This trend is supported by ample evidence, including the regulatory pressures experienced by professional investors to disclose climate-related impacts and risks, particularly in regions such as the EU (Kerber & Jessop, 2021; Villiers et al., 2023). As a result, managers may adjust their investment behavior to align with investor expectations, thereby increasing their carbon-related investments. Another essential institutional factor is the regulatory environment, specifically the mandates for carbon emission disclosures. Public demand for corporate transparency about carbon emissions has grown, leading to various mandatory reporting schemes worldwide. For instance, the GHGRP (in the United States) and the EU ETS require firms to report their carbon emissions at the facility level (Bauckloh et al., 2023; Downar et al., 2021). The UK Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 mandates firm-level carbon emission reporting (UK Government, 2013). These regulatory pressures ensure that firms are held accountable for their carbon footprints which, in turn, motivates managers to invest in carbon-reducing initiatives.

At the organizational level, several factors shape managerial decisions regarding carbon-reducing investments. One of the most prominent factors is the financial impact of such investments. The literature indicates that environmentally responsible corporate behavior can

lead to financial benefits, such as cost savings under emission trading regimes with high carbon prices or increased sales due to improved reputation (Albertini, 2013; Hart & Ahuja, 1996). The time horizon of these financial benefits is crucial; investments that yield financial returns in the short term are more likely to be undertaken (Hoang et al., 2020; Stefan & Paul, 2008). Another organizational factor is the integration of carbon performance into firms' incentive systems. Incentive systems are designed to align managers' objectives with the firm's goals, often through rewards based on performance metrics. Including sustainability aspects in these systems can promote better carbon performance (Eccles et al., 2014). Empirical research shows that linking compensation to carbon performance encourages managers to invest more in carbon-reducing measures (Derchi et al., 2023; Ott & Endrikat, 2022).

Managers' personal values and beliefs also play a significant role in their decision-making processes. Factors such as a positive attitude toward the biosphere, a high level of risk aversion, and a strong belief in business ethics have been shown to influence decisions regarding investment in carbon emission reductions. These individual-level factors are robust drivers of managerial behavior, regardless of their institutional or organizational context (Bouman et al., 2020; Gond et al., 2017).

The study employs a vignette experiment to explore the relative importance of these factors and their interactions. Vignette experiments, rooted in sociological research, involve presenting participants with carefully designed hypothetical scenarios that vary in a discrete number of attributes. This method allows researchers to uncover the implicit judgments and preferences of individuals in decision-making processes (Aguinis & Bradley, 2014; Oll et al., 2018).

The study finds that the most important factors influencing managers' decisions are the number of carbon-conscious investors, the financial impact of carbon-reducing investments, and the regulatory disclosure regime. These findings suggest that investor orientation and regulatory pressures are critical drivers at the institutional level, while financial considerations are paramount at the organizational level. Interestingly, factors such as a firm's initial carbon performance relative to its peers and the design of managers' incentive systems were not significant in the decision-making process in this setting. This indicates that, while certain organizational factors are important, their influence may be overshadowed by more immediate financial impacts and regulatory demands.

The study's findings have significant implications for both research and policymaking. Empirically, the exploratory approach extends previous research by considering multiple levels of potential influence simultaneously. This holistic view is essential for understanding the

complex interplay of factors affecting managerial decisions. The study supports the notion that policies aimed at informing investors about a company's climate impact, such as mandatory sustainability-related disclosures, can have a tangible effect on corporate behavior. High carbon prices and mandated climate-related disclosures are particularly effective in motivating managers to invest in carbon-reducing measures. Moreover, the role of individual values in decision-making underscores the importance of aligning managerial beliefs with corporate sustainability goals. Screening for environmental values in hiring processes could be beneficial for firms aiming to enhance their sustainability performance.

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6 Appendix

Paper 1

Corporate carbon performance data: Quo vadis?

Corporate carbon performance data: Quo vadis?

Timo Busch  | Matthew Johnson  | Thomas Pioch

School of Business, Economics, and Social Science, University of Hamburg, Hamburg, Germany

Correspondence

Timo Busch, Business, Economics, and Social Science, University of Hamburg, Von-Melle-Park 9, Hamburg 20146, Germany.
Email: timo.busch@uni-hamburg.de

Editor Managing review: Charles Corbett

Abstract

Corporate carbon performance (CCP) has become a central topic in political, financial, and academic domains. At the same time, several characteristics of CCP data, including comparability and consistency, remain unresolved. The literature has extensively covered issues regarding the comparability of CCP data from a firm-internal perspective. However, it has not yet examined the consistency of CCP data between third-party data providers. This article investigates the degree of CCP data consistency between third-party providers according to three dimensions: scope (i.e., direct and indirect emissions), scheme (i.e., mandatory and voluntary reporting schemes), and source (i.e., data stemming from corporate reports and from third-party estimation methods). The results reveal that data on direct emissions are more consistent than data on indirect emissions, and they are especially inconsistent for Scope 3. Second, mandatory and voluntary reporting schemes do not substantially improve the consistency of CCP data, which is surprising. Third, third-party estimations are less consistent as compared to data stemming directly from corporate reports; however, the combination of Scopes 1 and 2 third-party estimated data raises consistency levels. On the basis of these results, we conclude the following key implications: academic researchers must be mindful of the consistency of CCP data, because it can significantly affect empirical results, corporate management should avoid situations where different CCP data are communicated externally, investors should engage firms to follow a standardized approach, data providers should increase the transparency about their estimation methods, and policy makers need to be aware of the importance of a sound and standardized methodology to determine CCP.

KEYWORDS

climate change, corporate carbon performance, data consistency, estimation method, industrial ecology, third-party provider

1 | INTRODUCTION

Corporate carbon performance (CCP) has emerged as a focal point in many domains: accounting and reporting schemes have been developed; a variety of actors in political, academic, and business spheres use these data; and business-related carbon emissions are considered increasingly relevant for investors' market valuation of firms (Griffin, Lont, & Sun, 2017; Hahn, Reimsbach, & Schiemann, 2015; Matsumura, Prakash, & Vera-Munoz, 2014). This momentum building can be observed in the following example: the European Union (EU) released an action plan on "Financing Sustainable Growth" (EU Commission, 2018a), which highlights the role of financial markets for climate change mitigation. Recently, a Task Force on Climate-related Financial Disclosures (TCFD, 2017) published its recommendations on disclosing information about the financial risks and opportunities presented by climate change.

To set realistic carbon reduction targets at the firm-level and measure progress, corporate managers, financial investors, academic researchers, and policymakers require comprehensive and high-quality CCP data. However, current CCP data reveal severe shortcomings in both regards. In

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terms of comprehensiveness, CCP data are typically available for large listed companies only, neglecting significant economic areas, such as supply chains and small and medium-sized enterprises. In terms of quality, the literature has extensively covered how companies should gather and report CCP data from a firm-internal perspective (Downie & Stubbs, 2013; Hahn et al., 2015), but has assessed only to a limited extent the consistency of CCP data across firms from an external stakeholder perspective (Andrew & Cortese, 2011; Marland, Buchholz, & Kowalczyk, 2013; Matisoff, Noonan, & O'Brien, 2013; Stanny, 2018).

Furthermore, the consistency of CCP data between third-party data providers has not yet been analyzed in a systematic manner. Third-party data providers, including Bloomberg, CDP, ISS Ethix, MSCI, Sustainalytics, Thomson Reuters, and Trucost, have established extensive datasets covering thousands of firms' carbon emissions over many years. We match this provided data over multiple years and address the following research questions: (RQ1) How consistent are CCP data between different third-party data providers in general?; (RQ2) To what extent do mandatory and voluntary reporting schemes affect the consistency of CCP data between third-party providers?; and (RQ3) How consistent are estimation methods between third-party providers?

We applied correlation analyses to measure consistency of CCP data offered by major third-party data providers. The analyses distinguish three dimensions of CCP data: scope (i.e., direct and indirect emissions), scheme (i.e., mandatory and voluntary reporting schemes), and source (i.e., data stemming from corporate reports and from third-party estimations). The results show that the consistency of CCP data is high for direct emissions, and progressively decreasing in Scope 2 to 3 indirect emissions. Subsequently, the results highlight that mandatory and voluntary reporting schemes do not substantially improve the consistency of CCP data between data providers. This is especially surprising for mandatory reporting schemes, that is, the EPA's Greenhouse Gas Reporting Program (GHGRP) and EU Emission Trading Scheme (ETS), as they prescribe the strict adherence to specific accounting and reporting methods. Third, data stemming from corporate reports is more consistent than data generated from third-party estimations; however, consistency of third-party estimations increases significantly when Scopes 1 and 2 are combined. From these results, we derive several implications for academic research, corporate management, financial markets, data providers, and policymaking.

2 | LITERATURE REVIEW ON CCP DATA

Previous literature has covered firm-internal drivers, motivations, and efforts to account and disclose CCP data. The main drivers include regulatory pressures, firm reputation, greater transparency, risk mitigation, and improving financial performance (Busch & Hoffmann, 2011; Busch & Lewandowski, 2018; Damert, Paul, & Baumgartner, 2017; Hahn et al., 2015; Kolk, Levy, & Pinkse, 2008; Luo, Lan, & Tang, 2012; Reid & Toffel, 2009). The disclosure of CCP data "potentially reduces the principal-agent problem of asymmetric information by increasing transparency" (Hahn et al., 2015, p. 86). As such, companies disclose CCP data through voluntary channels—for example, sustainability reports or CDP—as a way to signal investors and other stakeholders of their superior firm performance (Clarkson, Li, Richardson, & Vasvari, 2008; Diaz-Rainey, Robertson, & Wilson, 2017). However, several issues remain pertaining to the quality of CCP data.

2.1 | The quality of CCP data

In an attempt to increase the quality of CCP data, the GHG Protocol was released over 15 years ago as a standardized framework in accounting and reporting GHG emissions in organizations, including entire operations and value chains (WRI/WBCSD, 2004). Since 2008, the CDP encourages all companies to use the GHG Protocol to increase comparability (CDP, 2017). However, the comprehensiveness and quality of CCP data remain a major issue to this day (Matisoff et al., 2013; Stanny, 2018).

Hummel and Schlick (2016) describe several desirable characteristics of data quality. These include verifiability, reliability, comparability, and consistency. In terms of data verifiability and reliability (i.e., the data are accurate, fair, and true), the literature has extensively covered how firms internally gather and report CCP data, for example, examining the drivers and motives to report according to guidelines, such as the Greenhouse Gas Protocol (Downie & Stubbs, 2013; Hahn et al., 2015; Schaltegger & Csutora, 2012). Hummel and Schlick (2016) discover an interesting finding when it comes to data reliability. The authors find that superior sustainability performers choose to disclose high-quality, timely sustainability reports, whereas poor sustainability performers disguise their true performance by releasing low-quality, less frequent reports (Hummel & Schlick, 2016). The latter finding was confirmed in a recent study showing how companies conceal information and employ various impression management strategies, including making excuses and delays, to hide poor performance (Talbot & Boiral, 2018).

The literature acknowledges the differences and limitations of CCP data comparability across firms. Andrew and Cortese (2011) examined different accounting methodologies from various reporting schemes, and concluded that CCP data will remain incomparable and ultimately unreliable for an unforeseeable future. Matisoff et al. (2013) studied the degree of data convergence in CDP from 2003 to 2010, examining trends in disclosure, transparency, and comparability of corporate carbon emission data over this period. They concluded as the amount of companies reporting increases, the comparability between disclosures increases in Scopes 1 and 2, but not in Scope 3. However, as more companies disclose CCP data, Matisoff et al. (2013) observed a decrease in the percentage of reports becoming available, hence less reliable for public scrutiny.

However, the consistency of CCP data between third-party providers has not been empirically investigated. Third-party data providers generate large datasets based on data from corporate reports and their own estimation methods. The latter approach is used primarily when company-reported data are not available. Thus, our first research question deals with the general level of consistency for CCP data between different third-party data providers.

2.2 | Mandatory and voluntary reporting schemes

Most companies report CCP data according to either mandatory or voluntary reporting schemes (Andrew & Cortese, 2011). Several regions and nations require energy-intensive companies to report annual carbon emissions of specific facilities according to a mandatory reporting scheme. For example, the European Union Emission Trading System (EU ETS) covers approximately 11,000 facilities, including large power stations and manufacturing plants, which cover around 45% of the GHG emissions in the European Union (EU Commission, 2018b). The U.S. Environmental Protection Agency (USEPA, 2018) requires facilities that emit more than 25,000 metric tons of CO₂-equivalent (CO₂e) emissions per year to disclose their annual emissions through the Greenhouse Gas Reporting Program (GHGRP). This program covers over 8,000 facilities and roughly 50% of the total U.S. emissions (USEPA, 2017).

Mandatory reporting schemes were established to monitor facility-level CCP data according to strict, formal rules for accounting and reporting (Perrault & Clark, 2010; Sullivan & Gouldson, 2012). Since these schemes consider carbon emissions at facility level, all covered emissions related to Scope 1. It can be assumed that emission data reported under a mandatory regulation is regarded as highly standardized and consistent. Nevertheless, it has been found that other aspects, such as reporting boundaries and emission factors, can be manipulated and, thus, may affect data comparability (Dragomir, 2012; Sullivan & Gouldson, 2012; Talbot & Boiral, 2018).

Beyond mandatory schemes, several voluntary carbon reporting initiatives have emerged. Voluntary reporting schemes have an advantage over mandatory reporting, as “voluntary disclosure programs like the CDP may allow firms to engage with stakeholders such as investors and employees more directly than mandatory reporting requirements and serve as a way to improve internal management of GHGs” (Matisoff et al., 2013, 297). Undoubtedly, the most successful voluntary initiative is the CDP (formerly the Carbon Disclosure Project) with more than 2,400 companies disclosing CCP data (CDP, 2017). Since 2003, the CDP collects data via an annual questionnaire from major corporations in various capital markets. Despite its success, several studies have raised concerns regarding the quality of data gathered and published by the CDP (CDP, 2010; Andrew & Cortese, 2011; Matisoff et al., 2013; Stanny, 2018).

The distinction between mandatory and voluntary reporting schemes is relevant in this article because they differ in scope and scheme. On the one hand, mandatory reporting schemes are stricter in terms of accounting methodology, but they are limited to direct emissions (Scope 1) and pertain to individual facilities (i.e., not entire firms). On the other hand, voluntary disclosures encourage companies to report both direct (Scope 1) as well as indirect emissions (Scopes 2 and 3). While such schemes encourage firms to report emissions for the entire firm and its value chain, they are much more lenient in accounting methodology, and this makes the comparability between firms difficult (Perrault & Clark, 2010). We explore the extent that mandatory and voluntary reporting schemes affect the consistency of CCP data between third-party providers.

2.3 | Third-party estimation methods

Although the number of firms disclosing their carbon emissions has increased over the years, many companies still do not report their carbon emissions. In those cases, third-party providers can use their own estimation methods to fill these data gaps. Such estimation methods are also essential in cases where investors and other stakeholders would like to assess the carbon footprint of supply chains since CCP data are typically scarce further along the supply chain.

The literature suggested three general approaches for estimation methods (Goldhammer, Busse, & Busch, 2017). First, a process analysis (PA) approach using primary and secondary production process data and the associated carbon emissions (Minx et al., 2009; Suh & Huppel, 2009; Wiedmann & Minx, 2008). This approach has been used extensively to estimate carbon footprints on a product level (Burkhardt, Heath, & Cohen, 2012; Dolan & Heath, 2012; Mazon, Mutton, Am Russell, & Keoleian, 2011) as well as on a firm level (Block et al., 2011; Gooding, 2012; Lee & Cheong, 2011). This approach is very detailed and requires a lot of specific information. At the same time, boundaries for proper calculation need to be established, which may result in a lack of completeness of the estimation (Minx et al., 2009; Suh & Huppel, 2009).

Second, input-output analysis (IOA) uses the input-output tables of national accounts to allocate the carbon emissions of the economy to smaller units on a sectoral basis. This approach has been applied to carbon footprint calculation at the firm level (Minx et al., 2009), for example, by ascribing emissions to individual firms according to their relative proportion of the firm's sales compared the sectors overall sales numbers. Assessing emissions per unit of turnover appears to be an appropriate frame of reference since it allows the most comparable analysis of individual CCP in the absence of any further company specific information. This method can be extended to a multi-regional input-output (MRIO) analysis (e.g., Lundie, Wiedmann, Welzel, & Busch, 2019). Therefore, MRIO analysis can also capture the Scope 3 emissions along the entire supply chain (Huang, Lenzen, Weber, Murray, & Matthews, 2009). The estimations resulting from MRIO analyses represent averages and do not consider firm specific aspects (Minx et al., 2009).

Third, hybrid approaches merge the strengths of both PA and IOA. They have been coined the state of the art for carbon footprinting (Wiedmann, 2009). The Norwegian “Klimakost” model is one example of a hybrid approach being applied to companies, municipalities and other organizations (Larsen, Solli, & Pettersena, 2012).

Third-party data providers combine and extend these approaches to estimate CCP data. ISS-Ethix estimates CCP data with the help of more than 800 sub-sector specific models, where every sub-sector is analyzed to identify emission predictors (ISS-Ethix Climate Solutions, 2019). MSCI ESG employs different estimation methods to determine CCP, for example, based on a company’s previous emission intensities (MSCI ESG Research, 2019). Sustainalytics uses more than 80 different estimation models to determine Scope 1 and 2 emissions, which are based on historical company data and non-linear regressions (Sustainalytics, 2019). The 80 different models are then calculated as average emissions per million USD revenue. Thomson Reuters ESG applies one of three different estimation methods to determine Scope 1 and 2 emissions in the following order, according to data availability: (a) previously reported emissions, (b) energy consumption, and (c) median emissions of industry or business sector (Thomson Reuters ESG, 2019). Finally, Trucost uses its own Extended Environmental Input–Output (EEIO) model based on industry-specific environmental impact data, and the flow of goods and services between economic sectors (Trucost ESG Analysis, 2019).

While the individual approaches differ, the third-party providers do share some commonalities in the estimation methods. Thomson Reuters ESG and Sustainalytics, for example, use similar business metrics to calculate industry average CCP data in the form of intensities and then convert those back to absolute emissions. ISS-Ethix and Trucost base their estimations on sector and country-specific models utilizing industry input–output tables. It appears that most third-party providers use industry-based methods over location-based methods. While various estimation methods can still yield different results, a high degree of consistency between third-party data estimations would be desirable. Thus, our third research question examines how consistent estimation methods are between third-party providers.

3 | METHOD

3.1 | Sample selection

In order to establish a representative sample, we selected third-party data providers based on two criteria. The first criterion is data type—data providers must offer company-wide CO₂e emission data in Scopes 1 and 2 as a minimum requirement, and if available, Scope 3 emissions. We excluded any data providers that only offered carbon scores or climate ratings to represent CCP information. The second criterion is data range—third-party providers must offer historical data for more than 5 years of same-firm data. Additionally, they should provide a global coverage of firms. We excluded any third-party data providers with only a few years of coverage, including those that have discontinued this service, as well as third-party providers focusing on a single country.

We derived a list of major third-party CCP data providers, including Bloomberg, CDP, ISS Ethix, MSCI, Sustainalytics, Thomson Reuters ESG, and Trucost. Table 1 shows the data type, timespan, coverage of companies having reported data, total company coverage, and additional details of each provider. We obtained this information through the providers’ websites and downloadable factsheets. When information was not available, we contacted the data providers directly, and asked them to provide supplemental information.

We matched CCP data from different providers for the same firm using the International Securities Identification Number (ISIN), resulting in a sample of 15,485 firms between 2005 and 2016. From this sample, we were able to draw firm–year observations where at least two providers can be compared: 50,793 observations (Scope 1), 50,609 observations (Scope 2), and 12,355 observations (Scope 3). The data correspond to the years of actual emissions. We calculated the pairwise Pearson correlation coefficient to analyze the strength of the relationship and thus the degree of consistency between two individual data providers. In addition, we also calculated the Spearman rank correlation coefficients, as they are less affected by potential outliers in the data.

In order to scrutinize the effects of mandatory emission reporting schemes, we utilized facility level carbon emissions as provided by the USEPA GHGRP and the EU ETS. We matched these facility emissions to their respective primary owners on a firm level. This allowed us to calculate aggregated facility emissions that are matched to one company. The USEPA GHGRP database provides information on the ownership structure of each facility through company names and the ownership percentage. Using these company names, we matched facilities to a single company ISIN. In cases where a facility has multiple owners, we considered the primary owner as the principal owner for our analysis. For the EU ETS, the World Carbon Market Database (WCMD, 2019) offers facility to company matching tables, including the ISINs. With the ISIN as the identifier, we were able to compare aggregated facility level emissions with CCP data from third party providers.

3.2 | Descriptive statistics and data handling

The descriptive statistics illustrate a heterogeneous picture for all emission scopes (see Table 2). Maximum values, means, and standard deviations vary substantially across providers for all scopes, pointing toward high levels of inconsistency. The large differences for maximum values made it

TABLE 1 Overview of data providers

Data provider	Data type	Timespan*	Coverage of reported data	Total coverage	Additional details
Bloomberg	CO ₂ e Scopes 1–3	2005–present	N.A.	~10,000 companies	Combines data from several sources.
CDP	CO ₂ e Scopes 1–3	2003–present	~2,000 companies	~2,000 companies	Relies on company reported data gathered through the CDP questionnaire; no estimations.
ISS Ethix	CO ₂ e Scopes 1–3	2005–present	~4,000 companies	~25,000 companies	Includes company reported data, third-party data and estimations. Additional forward-looking climate risk data provided.
MSCI	CO ₂ e Scopes 1–3	2008–present	~2,200 companies	~8,500 companies	Includes company reported data, third-party data and own estimations. MSCI Carbon Metrics® provides additional information.
Sustainalytics	CO ₂ e Scopes 1–2	2010–present	~2,000 companies	~11,000 companies	Includes company reported data, third-party data and own estimations. Carbon Solutions Suite® provides additional information.
Thomson Reuters	CO ₂ e Scopes 1–3	2002–present	~2,000 companies	~7,000 companies	Includes company reported data, third-party data and own estimations.
Trucost	CO ₂ e Scopes 1–3	2005–present	~1,800 companies	~14,000 companies	Includes company reported data, third-party data and own estimations. Estimation of Scope 3 emissions.

Note. Table 1 contains an overview of major CO₂e emission data providers. The information in this table is derived from the respective database documentation of each provider. The timespan corresponds to the years of emissions and not years of reports.

necessary to further investigate potential outliers. Since Pearson correlation coefficients are sensitive to extreme outliers, we manually investigated some of the extreme outliers, for example, 88,000,000,000 t CO₂e emissions indicated as the annual Scope 3 emissions of one company, which is more than the annual anthropogenic emissions. The additional analysis of the descriptive statistics in Table 2 led to the conclusion that the dataset had to be adjusted by removing severe outliers. To minimize the effect of potential errors in the data, we removed outliers by deleting 0.05% of the observations at the low and high end of the distribution for each provider. This adjusted dataset shows significantly higher correlations in all scopes and was used as a basis for further analyses.

Several data providers were not included in specific analyses due data availability reasons. ISS Ethix could not be included in many analyses, as they only offered combined Scope 1 and 2 data and estimated Scope 3 data. Sustainalytics was left out of Scope 3 analyses, as they do not provide Scope 3 data at all. Bloomberg does not reveal if the data stem from company reports or third-party estimates; therefore Bloomberg only included in general analyses (Bloomberg Finance L.P., 2019). The analyses for third-party estimated Scope 3 data was limited to two providers offering related data, ISS Ethix and Trucost.

TABLE 2 Descriptive statistics of Scopes 1, 2 and 3 t CO₂e emissions

Provider (Scope 1)	Observations	Min	Max	Mean	Std. Dev.
Bloomberg	11,688	.1	203,160,000	3,436,052	13,234,181
CDP	12,368	.1	461,661,074	3,745,308	15,776,920
MSCI	72,018	1	316,904,735	1,402,385	9,745,447
Sustainalytics	31,244	.2	571,928,834	1,947,869	12,496,509
Thomson Reuters	13,830	.014	603,242,000	4,057,620	15,628,072
Trucost	61,024	.01	1,313,968,524	2,068,556	12,584,346
Provider (Scope 2)		Min	Max	Mean	Std. Dev.
Bloomberg	11,459	.1	30,900,000	689,211	2,060,708
CDP	12,077	1.82	172,642,421	701,218	3,058,222
MSCI	72,266	1	2,464,659,522	260,294	9,223,938
Sustainalytics	31,327	1.82	29,184,916	298,464	1,117,465
Thomson Reuters	13,212	.108	265,643,000	772,442	3,319,742
Trucost	61,067	.16	210,544,206	272,636	1,389,614
Provider (Scope 3)		Min	Max	Mean	Std. Dev.
Bloomberg	7,060	1	917,117,000	10,293,090	58,544,006
CDP	6,868	.61	88,059,800,000	36,889,891	1,141,664,189
ISS Ethix	55,408	0	2,025,229,344	1,567,979	21,395,923
MSCI	8,860	1	5,967,000,000	14,057,086	112,160,780
Thomson Reuters	8,421	.2	1,112,720,049	11,867,324	62,246,568
Trucost	61,100	.41	663,034,435	1,459,358	6,375,612

Note. Table 2 shows the descriptive statistics of the data as it is available directly from each provider. No alterations to the data were made. All emissions are measured in metric tons.

4 | RESULTS

With respect to RQ1, the results show that Scope 1 data are highly consistent between most data providers with an average Pearson correlation coefficient of 0.97 and average Spearman correlation coefficient of 0.95. As shown in Table 3, a general pattern emerges: Scope 1 data are more consistent than Scope 2 data, and Scope 2 data are more consistent than Scope 3 data, where the biggest inconsistencies can be found. The Spearman rank correlations exhibit similar patterns for all our analyses and generally confirm that low Pearson correlation levels are not exclusively the result of individual outliers in the data.

Additionally, we investigated the development of consistency between third-party providers over time (compare Figure S1 in the Supporting Information). The general expectation would be that third-party data providers gain experience in gathering and processing CCP data over time. However, the overall data consistency fails to improve substantially. On the contrary, data on Scope 3 emissions became even less consistent over time.

In answering RQ2, we use facility-level emission data from the EPA GHGRP and EU ETS. Table 4 shows the percentage these aggregated facility emissions constitute of the total Scope 1 emissions of the matched company. The sample includes only U.S. and EU facilities, since GHGRP is under U.S. regulation and EU ETS is under European directives. Parent companies of these facilities can, however, originate from other countries and have multiple facilities not covered by these schemes. Aggregated facility-level emissions reported by companies through the USEPA GHGRP constitute on average between 33.01% and 41.74% of a company's total reported Scope 1 emissions. For companies reporting emissions under the EU ETS, aggregated facility-level emissions constitute between 39.38% and 49.36% of companies' total reported Scope 1 emissions. This analysis shows that mandatory reported data based on facility level provide little help in generating greater consistency of CCP data, since the mandatory reported data cover only a portion of a company's overall Scope 1 emission profile. For example, Enbridge, Inc. operates one of the world's largest crude oil pipeline networks in Canada and the United States. The CO₂e emissions stated in the sustainability report differs from what the company reports to the USEPA GHGRP for two reasons. First, the sustainability report includes global Scope 1 emissions, while the USEPA GHGRP report only covers U.S. facilities. Second, the calculation methods they used for the facilities covered by the EPA GHGRP is different than for the facilities outside of this regulation and facilities with less than 25,000 t CO₂e emissions annually (Enbridge Inc., 2017).

Given the results in Table 4, we expected a low consistency measured through correlation coefficients between aggregated facility level emissions and company Scope 1 emissions. The results in Table 5 confirm our expectations, and reveal that facility level emissions are not strongly correlated with companies' overall Scope 1 emissions. Facility emissions covered by mandatory reporting schemes are typically lower as the

TABLE 3 Adjusted CCP data

Scope 1	Bloomberg	CDP	MSCI	Sustainalytics	T. Reuters	Trucost
Bloomberg	1 (11,679)	0.9839* (5,482)	0.9795* (9,007)	0.9255* (5,964)	0.9901* (7,997)	0.9451* (9,405)
CDP	0.9924* (5,482)	1 (12,359)	0.9842* (9,200)	0.9877* (6,005)	0.9856* (7,456)	0.9562* (9,040)
MSCI	0.9912* (9,007)	0.9621* (9,200)	1 (71,989)	0.9013* (24,834)	0.9759* (10,720)	0.8899* (38,646)
Sustainalytics	0.9675* (5,964)	0.9726* (6,005)	0.9311* (24,834)	1 (31,216)	0.9218* (6,651)	0.8721* (20,967)
T. Reuters	0.9918* (7,997)	0.9746* (7,456)	0.9876* (10,720)	0.9637* (6,651)	1 (13,818)	0.9496* (11,623)
Trucost	0.9845* (9,405)	0.9598* (9,040)	0.9615* (38,646)	0.8860* (20,967)	0.9861* (11,623)	1 (6,0964)
Scope 2	Bloomberg	CDP	MSCI	Sustainalytics	T. Reuters	Trucost
Bloomberg	1 (11,449)	0.9778* (5,303)	0.9695* (8,859)	0.9242* (5,905)	0.9777* (7,784)	0.9234* (9,235)
CDP	0.9647* (5,303)	1 (12,066)	0.9768* (8,977)	0.9869* (5,858)	0.9805* (7,241)	0.9518* (8,828)
MSCI	0.9393* (8,859)	0.8715* (8,977)	1 (72,240)	0.9049* (24,958)	0.9626* (10,459)	0.8423* (38,817)
Sustainalytics	0.9022* (5,905)	0.9418* (5,858)	0.8780* (24,958)	1 (31,297)	0.9167* (6,601)	0.8566* (21,075)
T. Reuters	0.9208* (7,784)	0.9389* (7,241)	0.8675* (10,459)	0.7956* (6,601)	1 (13,200)	0.9251* (11,179)
Trucost	0.9092* (9,235)	0.9059* (8,828)	0.8444* (38,817)	0.8901* (21,075)	0.8232* (11,179)	1 (61,007)
Scope 3	Bloomberg	CDP	MSCI	T. Reuters	Trucost	
Bloomberg	1 (7,054)	0.8057* (3,038)	0.8868* (4,215)	0.9425* (4,870)	0.6638* (5,731)	
CDP	0.4137* (3,038)	1 (6,862)	0.8499* (4,597)	0.8049* (4,089)	0.5835* (5,321)	
MSCI	0.8963* (4,215)	0.4045* (4,597)	1 (8,856)	0.8923* (5,257)	0.6510* (7,517)	
T. Reuters	0.9864* (4,870)	0.3956* (4,089)	0.8907* (5,257)	1 (8,414)	0.6320* (7,121)	
Trucost	0.5924* (5,731)	0.2203* (5,321)	0.3813* (7,517)	0.5771* (7,121)	1 (61,040)	

Note. Table 3 shows the Pearson (lower left side) and Spearman (upper right side) correlation coefficients of our base sample which has been adjusted by removing the top and bottom 0.05% of observations.

* Indicates a significance level of $p < 0.01$, number of observations in parentheses.

companies' overall Scope 1 emissions. For many companies, a majority of their Scope 1 emissions are not subject to the regulations. Thus, we conclude, mandatory reporting schemes do not help improve CCP data consistency. However, exceptions can be found for certain industries or companies with numerous high-emitting facilities that are covered by the mandatory schemes. For example, the energy company RWE has most of its power plants covered within the EU ETS. RWE had in 2016 facility level emissions reported under the EU ETS of 139 million metric tons, while third-party providers reported Scope 1 emissions of 154 million metric tons (90% of their global Scope 1 emissions).

Next to mandatory schemes we investigate the extent of how voluntary reporting schemes affect the consistency of CCP data between third-party providers. To measure this properly, we first established a baseline by investigating the correlations of CCP data indicated as company-reported (Table 6). We found that company-reported data increased the overall correlation levels in Scopes 1 and 2. Moreover, Table 6 reveals

TABLE 4 Aggregated facility emissions of a firm compared to their reported Scope 1 emissions

Provider	EPA GHGRP		EU ETS	
	Obs.	% of Scope 1	Obs.	% of Scope 1
Bloomberg	1,043	33.14	847	39.38
CDP	1,093	33.01	936	42.80
MSCI	1,543	41.74	937	45.30
Sustainalytics	879	33.36	493	42.35
Thomson Reuters	1,155	35.86	995	42.81
Trucost	1,094	34.51	887	49.36

Note. Table 4 shows the facility level CO₂e emission data provided under the EPA GHGRP and the EU ETS, compared to the Scope 1 emission data from third party providers. For each provider, we show the share of emissions under the EPA GHGRP and the EU ETS of the total reported Scope 1 emissions.

TABLE 5 Correlation between aggregated facility emissions and Scope 1 emissions from data providers

		Bloomberg	CDP	MSCI	Sustain.	T. Reuters	Trucost
Facility GHGs – EPA GHGRP	Pearson correlation coefficients	0.5961* (1,154)	0.5728* (1,214)	0.6013* (2,995)	0.5636* (2,166)	0.5282* (1,323)	0.5940* (2,517)
	Spearman rank correlation coefficients	0.6445* (1,154)	0.6491* (1,214)	0.6312* (2,995)	0.6222* (2,166)	0.6134* (1,323)	0.5694* (2,517)
Facility GHGs – EU ETS	Pearson correlation coefficients	0.7254* (942)	0.7331* (1,040)	0.7227* (1,380)	0.7252* (726)	0.6979* (1,252)	0.7041* (1,657)
	Spearman rank correlation coefficients	0.7727* (942)	0.8023* (1,040)	0.7589* (1,380)	0.7871* (726)	0.7635* (1,252)	0.7759* (1,657)

Note. Table 5 shows the Pearson and Spearman correlation coefficients between the CO₂e emission data provided under the EPA GHGRP and the EU ETS and the third party providers in our study.

*Indicates a significance level of $p < 0.01$, number of observations in parentheses.

that the combination of Scopes 1 and 2 into a single data item also yields higher correlation levels compared to Scope 2 alone. Consistency in Scope 3 emissions does not improve with company-reported data when compared to the overall findings (Table 3), which again reveals how difficult it is to properly gather these data.

Next, we created a subsample of company-reported data only for firms included in the CDP database. The findings show opposite trends when compared to the results in Table 6. We detected lower correlations for Scopes 1 and 2. This suggests that reporting to the CDP can potentially cause further data inconsistency. One explanation for greater inconsistency may be related to different values presented as “company-reported data” (i.e., CDP and company reports), which providers have to choose. For example, in 2010, ConocoPhillips, the third-largest U.S. oil company, reported to the CDP emissions of 57,981,000 t CO₂e. Both TruCost and Bloomberg report this figure. At the same time, Thomson Reuters and MSCI must have relied on a different source of information in this case, since both report 26,618,645 t CO₂e in their databases. Upon further investigation, we found that Thomson Reuters and MSCI based their data from the company revised value of 26.6 million metric tons of CO₂e published in a later report (ConocoPhillips, 2011).

Finally, RQ3 focusses on the consistency levels of estimation methods between third-party providers. Only three data providers offer third-party estimations on individual Scopes 1 and 2 emissions—MSCI, Sustainalytics, and Trucost. Thomson Reuters and ISS Ethix provide only combined Scope 1 and 2 figures for estimations. Moreover, ISS Ethix and Trucost are the only providers estimating Scope 3 emissions.

The results in Table 7 illustrate that—not surprisingly—correlation levels between data providers are lower when using only third-party estimations for both Scope 1 and 2 emissions. For example, the Pearson correlations of Scope 1 emissions between MSCI and Sustainalytics decrease from 0.99 (company-reported) to 0.77 (third-party estimates) and from 0.98 (company-reported) to 0.69 (third-party estimates) for Scope 2 emissions. When combining Scopes 1 and 2, the correlation levels improve for third-party estimated data even though the underlying estimation models used by the data providers differ considerably. The two estimations for Scope 3 emissions yield inconsistent results. In this case, ~97% of observations differ by more than 10% between the two providers. These low correlations highlight the differences in third-party estimation results. An extreme example of this is the WH Group, the world’s largest pork producer, where TruCost estimates 39,839,717 and ISS 6,707,330 t CO₂e Scope 3 emissions in 2015.

TABLE 6 CCP data from company reports

Scope 1	CDP	MSCI	Sustainalytics	T. Reuters	Trucost	
CDP	1 (8,600)	0.9924* (8,597)	0.9980* (5,702)	0.9861* (7,281)	0.9856* (6,420)	
MSCI	0.9741* (8,597)	1 (15,945)	0.9927* (6,251)	0.9873* (6,351)	0.9855* (7,518)	
Sustainalytics	0.9996* (5,702)	0.9960* (6,351)	1 (7,503)	0.9815* (4,704)	0.9856* (5,697)	
T. Reuters	0.9744* (7,281)	0.9904* (9,239)	0.9915* (4,704)	1 (12,677)	0.9820* (6,267)	
Trucost	0.9637* (6,420)	0.9901* (7,518)	0.9959* (4,697)	0.9897* (6,267)	1 (11,761)	
Scope 2	CDP	MSCI	Sustainalytics	T. Reuters	Trucost	
CDP	1 (8,376)	0.9860* (8,368)	0.9960* (5,598)	0.9803* (7,076)	0.9714* (6,213)	
MSCI	0.9287* (8,368)	1 (15,365)	0.9854* (6,396)	0.9812* (9,068)	0.9746* (7,302)	
Sustainalytics	0.9979* (5,598)	0.9860* (6,396)	1 (5,486)	0.9757* (4,679)	0.9796* (4,729)	
T. Reuters	0.9388* (7,076)	0.9106* (9,086)	0.9265* (4,679)	1 (6,089)	0.9688* (6,084)	
Trucost	0.9109* (6,213)	0.9548* (7,302)	0.9894* (4,729)	0.9087* (6,084)	1 (7,980)	
Scope 1+2	CDP	ISS	MSCI	Sustainalytics	T. Reuters	Trucost
CDP	1 (11,737)	0.9915* (7,068)	0.9928* (8,220)	0.9986* (5,495)	0.9805* (8,113)	0.9905* (6,138)
ISS	0.9947* (7,068)	1 (14,818)	0.9901* (8,806)	0.9886* (6,707)	0.9774* (8,815)	0.9860* (6,438)
MSCI	0.9734* (8,220)	0.9937* (8,806)	1 (14,904)	0.9922* (6,279)	0.9817* (10,427)	0.9920* (7,207)
Sustainalytics	0.9996* (5,495)	0.9942* (6,707)	0.9973* (6,279)	1 (7,461)	0.9769* (5,438)	0.9897* (4,682)
T. Reuters	0.9382* (8,113)	0.9234* (8,815)	0.9434* (10,427)	0.9075* (5,438)	1 (18,408)	0.9815* (7,944)
Trucost	0.9684* (6,138)	0.9940* (6,438)	0.9953* (7,207)	0.9957* (4,682)	0.9440* (7,944)	1 (11,710)
Scope 3	CDP	MSCI	T. Reuters	Trucost		
CDP	1 (6,862)	0.8499* (4,597)	0.8049* (4,089)	0.5891* (4,142)		
MSCI	0.4045* (4,597)	1 (8,856)	0.8923* (5,257)	0.6632* (4,963)		
T. Reuters	0.3956* (4,089)	0.8907* (5,257)	1 (8,414)	0.6399* (4,453)		
Trucost	0.2146* (4,142)	0.4277* (4,963)	0.6088 (4,453)	1 (11,796)		

Note. Table 6 shows the Pearson (lower left side) and Spearman (upper right side) correlation coefficients between third party data providers. The data included in this table is limited to those observations that were clearly identified as originating from company reports by the provider.

* Indicates a significance level of $p < 0.01$, number of observations in parentheses.

TABLE 7 CCP data from third-party estimations

Scope 1	MSCI	Sustainalytics	Trucost		
MSCI	1 (23,880)	0.8754* (15,562)	0.8443* (23,865)		
Sustainalytics	0.7704* (15,526)	1 (15,581)	0.8326* (13,358)		
Trucost	0.8744* (23,865)	0.7536* (13,358)	1 (23,961)		
Scope 2	MSCI	Sustainalytics	Trucost		
MSCI	1 (24,178)	0.8804* (15,872)	0.7752* (24,160)		
Sustainalytics	0.6909* (15,872)	1 (15,881)	0.8086* (13,357)		
Trucost	0.5648* (24,160)	0.6385* (13,357)	1 (24,175)		
Scope 1+2	ISS	MSCI	Sustainalytics	T. Reuters	Trucost
ISS	1 (26,679)	0.8435* (26,574)	0.8838* (18,006)	0.8362* (9,169)	0.8095* (20,610)
MSCI	0.5366* (26,574)	1 (26,585)	0.8993* (15,401)	0.8557* (11,743)	0.8618* (23,615)
Sustainalytics	0.7097* (18,006)	0.7720* (15,401)	1 (13,373)	0.8808* (7,480)	0.8687* (13,342)
T. Reuters	0.6008* (9,169)	0.7601* (11,743)	0.7295* (7,480)	1 (13,223)	0.8361* (13,196)
Trucost	0.7574* (20,610)	0.8759* (23,615)	0.7571* (13,342)	0.6952* (13,196)	1 (41,520)
Scope 3	ISS	Trucost			
ISS	1 (20,467)	0.1421* (20,451)			
Trucost	0.1591* (20,451)	1 (20,645)			

Note. Table 7 shows the Pearson (lower left side) and Spearman (upper right side) correlation coefficients between third party data providers. The data included in this table is limited to those observations that were clearly identified as originating from estimations by the provider.

*Indicates a significance level of $p < 0.01$, number of observations in parentheses.

5 | DISCUSSION

The findings are important along three dimensions—scope, scheme, and source. According to scope, we observe as the complexity of carbon accounting increases from direct emissions (Scope 1) to indirect emissions (Scope 2 and 3), the consistency of CCP data between third-party providers decreases. The higher levels of data consistency in Scopes 1 and 2 is most likely a consequence of investors' requests for more transparent disclosure in these areas (Sullivan & Gouldson, 2012). Thus, it seems essential to engage further in promoting and requesting firms to follow a standardized approach, even in the more complex Scope 3 realm (Matisoff et al., 2013).

According to reporting scheme, mandatory reporting schemes provide little benefit in generating higher consistency of CCP. Since these reporting schemes are based on facility-level data, they deliver an incomplete picture of companies' overall Scope 1 emissions. CCP data stemming from mandatory reporting schemes, including the USEPA GHGRP and EU ETS, cover between 33% and 49% of firms' Scope 1 carbon emissions. Additionally, CCP data stemming from voluntary reporting schemes do not improve data consistency. If firms report different values through different reporting channels, this creates further inconsistency. This is in line with previous research findings that the use of different data sources, that is, CDP and sustainability reports, leads to higher levels of inconsistency (Depoers, Jeanjean, & Jérôme, 2016; Perrault & Clark, 2010).

With respect to source, the consistency of third-party estimated data is lower when compared to data stemming from company reports. However, the combination of estimated data for Scope 1 and 2 emissions provides a surprising result of higher consistency. This outcome illustrates

that the applied estimation methods can improve consistency to a certain extent. The biggest inconsistencies emerge for Scope 3 emissions—for both company reported as well as estimated data. More importantly, third-party providers do not provide transparent coverage of the categories of Scope 3 emissions. Thus, transparency of the Scope 3 sources will become important as more companies set reduction goals along supply chains according to science-based targets (Rekker, Humphrey, & O'Brien, 2019).

These findings reveal two points for further discussion: (a) the value of fostering consistency and (b) the significance of third-party estimation methods. Fostering CCP data consistency is important for several reasons. First, consistent CCP data are a necessary requirement for a range of stakeholders in order to measure, analyze, and compare CCP data between firms and over time. Achieving high levels of CCP data consistency should ultimately create a “level playing field between firms and across industries” (Bowen & Wittneben, 2011, p. 1029). Second, consistent CCP data are the foundation for thorough stress tests for banks and investors considering CCP data in investment decisions. For example, the TCFD (2017) has developed recommendations for climate-related financial disclosures for a better understanding of related financial risks. However, the TCFD (2017, p. 1) stresses the lack of consistent CCP data “hinders investors and others from considering climate-related issues in their asset valuation and allocation processes”. Third, as more countries and regions implement carbon taxes and emission trading schemes, CCP data—notably beyond the already covered facility level data—will become more important from a financial perspective. Thus, fostering consistent CCP data covering all three emission scopes is essential for accurately assessing the business risks and opportunities in pathways toward decarbonization (Griffin et al., 2017; Stanny & Ely, 2008).

Third-party estimations play an important role in the CCP data context, as data providers fill in data gaps when companies do not or only partially report emission data themselves. This is especially the case for companies that are not listed on stock exchanges, covering a majority of small and medium-sized enterprises (Bradford & Fraser, 2008). As such, third-party estimations will continue to play a significant role. However, at the same time, the data based on estimations is another source for inconsistency. First, third-party estimation methods vary between and within each provider (e.g., Thomson Reuters applies one of three different estimation methods depending on data availability). This explains why the results of third-party estimations are rather inconsistent. Second, the underlying assumptions and estimation rules are not fully disclosed in a transparent manner. This explains why it remains challenging from an outsider's perspective to determine the reasons for the prevailing inconsistency in full detail. Notably, it remains not clear what data providers do and do not include in their Scope 3 estimations.

Most data providers use estimations based on input–output analyses. The advantage for third-party providers is that the data are publically available and user-friendly (Huang et al., 2009). However, the clear disadvantage is that results remains an estimate based on industry or sector averages, that is, you cannot detect the good performers from the laggards within any given sector (Minx et al., 2009). Process analysis could mitigate this issue; however, it requires a lot of company and process-specific information, and thus, it is likely to play rather a minor role for data providers who need to handle huge amounts of data points. In sum, third-party estimates make CCP data more comprehensive and wide-ranging, closing data gaps specifically regarding supply chains and small and medium-sized enterprises (Comas Martí & Seifert, 2013). It appears very likely that stakeholders will have to rely on third-party estimated data in the coming years. In terms of data consistency, we derive two implications: First, data providers should use a combination of the most reliable estimation methods—according to data availability. Second, providers should disclose in more detail how the estimations are conducted.

6 | CONCLUSION

These results on the consistency of CCP data between third-party providers are relevant for future research, corporate management, financial markets, data providers as well as policymaking. First, academic researchers must be mindful of the consistency of CCP data for future research settings, as it can significantly affect the results. We would advise researchers to apply three practicable steps to increase the consistency of CCP data in future studies. First, extreme outliers should be examined to see if they are errors or actual outliers. For example, a company using renewable energy may have zero Scope 1 emissions—so the provided data are indeed an outlier but nevertheless correct and, thus, should be included. Second, scholars should repeat their analyses for data sets with and without outliers. The results show whether the outliers make a difference and to which scale they affect the results. The third step is to carefully select the source of CCP data, not just focusing on emission scopes, but also considering the differences of corporate-reported data and third-party estimation methods. If researchers are able to distinguish the two sources of data, we would suggest reporting the results in different models. For example, one model could cover for the entire sample and one model could cover only the company-reported data as a robustness check. Furthermore, future research could test the correlations of third-party estimated CCP data between the provider amounts and the maximum industry adjusted amount, also known as the Engaged Tracking amounts. The Engaged Tracking data (ET Carbon Dataset) has been used in several recent studies (Belkhir & Elmeligi, 2019; Jackson & Belkhir, 2018).

Second, corporate management should avoid situations where different CCP data are communicated or presented externally. Management should be very careful to check the consistencies in the CCP data, including the CDP and their own sustainability reports. The tolerated latitude of carbon accounting discourages consistent data are reflected in the inconsistencies between third-party data providers. Furthermore, companies should be aware of the release of CCP data based on third-party estimation methods, notably in the Scope 3 context. Managers could start

gathering and disclosing Scope 3 emissions on their own as well as become more involved in improving standards for related estimation methods. They should join in a wider discourse on transparency and clarity of CCP data, especially what are the most consistent approaches for all scopes. Furthermore, with respect to Scope 3 emissions, it would be desirable to develop mutually agreed minimum standards. In sum, data consistency in Scope 3 would particularly benefit from a universally accepted standardization. Eventually, extending the scope of coverage to include small companies would also benefit from user-friendly accounting tools and reporting standards for these firms (Bradford & Fraser, 2008).

Third, our results point toward a challenge for a key player in the future decarbonization process, financial markets. On the one hand, CCP data are becoming increasingly relevant for investment appraisals (Depoers et al., 2016; Matsumura et al., 2014; Reid & Toffel, 2009). On the other hand, the consistency of data is not guaranteed, and could be hindering adequate analyses and assessments. Investors should engage firms to follow a standardized approach accordingly. Moreover, it is important to further raise the awareness in financial markets that capturing climate risks in investment portfolios must go beyond pure carbon footprints. Ex-post data about carbon performance on its own typically does not reveal any information for future risks. Further information about individual assets—such as their carbon dependency, decarbonizing options, and adaptation-related exposures—is required (Diaz-Rainey et al., 2017). Thus, carbon footprints are an essential step of a holistic climate risk management approach within investment appraisals.

Fourth, data providers should increase the transparency about their own estimation methods. We are aware that further standardization is not the most likely way forward regarding third-party estimation methods. It is well known that different estimation methods inherently yield different and, thus, inconsistent results. As our analysis shows, the correlation results for combined Scope 1 and 2 emissions for third-party estimated data do not diverge too greatly from reported data. As such, estimating CCP appears to be a promising way to close related data gaps. However, the data provider could help by increasing transparency of the details of their estimation methods. For example, data providers could indicate to which extend and in which cases they use sector-averages to infer firm-level emissions. Thus, investors can decide which third-party estimation methods they find most adequate and reliable. Eventually, the argument to move beyond publicly listed firms is also valid in the estimation context: phasing in estimations for firms other than large listed corporations will be an important step in order to pave the way for an economy-wide decarbonization.

Fifth, the findings of this article are also relevant for policymakers. For example, the recently released “Action Plan: Financing Sustainable Growth” of the EU Commission (2018a) seeks to reorient capital flows toward sustainable investment and manage financial risks stemming from climate change. It intends to develop sustainability benchmarks, which is only possible with a sound and standardized methodology to calculate carbon footprints. Furthermore, risks associated with climate change shall play an important role. All these ambitious efforts require high quality CCP data. This article illustrates some current shortcomings and severe challenges ahead.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ORCID

Timo Busch  <https://orcid.org/0000-0001-6405-5252>

Matthew Johnson  <https://orcid.org/0000-0001-6491-2082>

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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Paper 2

Re-examining the firm value effect of carbon emissions.

Re-examining the firm value effect of carbon emissions

Abstract

This study investigates the impact of carbon emissions on firm value, emphasizing the significance of accurate emission data for financial valuation. With climate change advancing, stakeholders are increasingly focusing on firms' carbon emissions as a measure of sustainability. This paper extends the existing literature by evaluating the accuracy and potential biases of carbon emission estimation models and their implications for firm valuation. Using a comprehensive dataset of US firms from the Asset4 database, covering the period from 2014 to 2020, the study evaluates different estimation methods against actual reported emissions to determine their precision and reliability in capturing firm-value effects. Findings show a negative relationship between carbon emissions and firm value, consistent with prior research. Importantly, the results underline the necessity of distinguishing between Scope 1 and Scope 2 emissions, showing that Scope 2 emissions incur a higher penalty on firm value, suggesting a greater potential for mitigation through cleaner energy sources. The study also addresses the challenge of incomplete emissions data in corporate disclosures and evaluates the effectiveness of different estimation approaches. While estimation models are essential for filling data gaps, they vary significantly in terms of accuracy and bias. The performance of these models suggests a need for ongoing refinement to enhance their predictive power and reliability.

Keywords: carbon emissions, firm value, data consistency, carbon emission estimation, climate change, industrial ecology

1 Introduction

Corporate carbon emissions data is increasingly important and is key for firms aiming to reduce emissions and essential for regulators to develop effective climate policies. However, not all firms consistently disclose their emissions, leading capital markets, policymakers, and researchers to rely on carbon emission estimation models to understand non-reporting firms' emissions. This paper investigates the accuracy and potential bias of different models used to estimate carbon emissions and the implications for their firm-value effect. Governments have started regulating carbon emissions and setting targets to curb climate change. The EU's goal of becoming "Net Zero" by 2050 is part of the European Green Deal, and 24 US states and the District of Columbia have adopted specific emission reduction targets (Center for Climate and Energy Solutions, 2022). These policy targets, combined with emission trading schemes like the European Emission Trading System (EU ETS) and the California Cap-and-Trade Program, require accurate emission data from the sectors and firms covered, usually gathered through the systems themselves. Additionally, considerations for extending policies require carbon emission information, either voluntarily reported or estimated by data providers like Refinitiv, to identify areas warranting future regulatory interventions. Furthermore, accurate carbon emission information is vital for capital markets. Studies have shown that firm value decreases by \$39 to \$212 per additional ton of carbon emissions (Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023), depending on the study's timeframe and Scope. Factors influencing this effect include stakeholder pressure, increased capital costs for less carbon-intensive technologies, and potential liabilities from fines or regulatory interventions. Carbon emission information is also important for researchers investigating the impact of firms' emissions. This information is gathered through voluntary disclosure platforms like the Carbon Disclosure Project (CDP), corporate reports or filings for the Securities and Exchange Commission (SEC), or required disclosures under government regulations like the EU ETS or the Greenhouse Gas Reporting Program (GHGRP) in the US. Data providers like

Refinitiv collect this information and estimate emissions for non-reporting firms. Busch et al. (2020) found high consistency in reported data regardless of the data provider, but the accuracy of estimated data varies, with Pearson correlations between different providers' estimates for total emissions (Scope 1 + Scope 2) ranging from 0.54 to 0.88. These variations likely result from the estimation models used by providers. For example, sector-based averages yield high correlations but not necessarily accurate measures on the firm level. Most data providers do not publish detailed, replicable methods for estimating firm-level carbon emissions, making accuracy evaluation challenging.

This study uses two replicable estimation methods to investigate their accuracy and implications for firm valuation models that include carbon emissions as a dependent variable. The results contribute to the literature in several ways. First, as active carbon emission management gains importance, the explanatory power of the emission estimation model from Griffin et al. (2017) decreases over time. Second, insights into the accuracy and coverage performance of different carbon emission estimation models are provided. Third, while confirming previous findings on the firm-value effect of carbon emissions in general, the study highlights the importance of differentiating between Scope 1 and Scope 2 emissions. It shows that the firm value effect is stronger for Scope 2 emissions and that firms with high Scope 1 (Scope 2) emissions but comparatively low Scope 2 (Scope 1) emissions suffer an additional penalty in firm value for their Scope 1 (Scope 2) emissions.

2 Background

Over the years, discussions about firms' influence on the environment and its financial implications have evolved from asking whether it "pays to be green" (Hart & Ahuja, 1996) to asking under what circumstances it pays to be green (King & Lenox, 2001). Initially, environmental activities focused on "win-win" cases, like waste reduction programs that increased operational efficiency. Carbon emissions, however, present a unique challenge since

they have no intrinsic value and are mostly a byproduct of cheap energy. Despite the significant issue of climate change they cause, the incentive for firms to reduce carbon emissions often comes from stakeholder engagement, environmental regulation, and public pressure rather than direct financial benefits. To create financial incentives for firms to reduce emissions, mechanisms like carbon taxes and emission trading systems are implemented. These measures have made carbon emissions financially relevant for firms, leading to various studies investigating the firm-value relevance of carbon emissions. Matsumura et al. (2014) found that capital markets incorporate voluntary carbon emission disclosures into firm valuations as part of their risk profile. Clarkson et al. (2015) noted that market-value effects are based on emissions exceeding freely allocated allowances under the EU ETS. Griffin et al. (2017) concluded that voluntarily disclosed carbon emission information is as value-relevant as estimated emissions. Ott and Schiemann (2023) distinguished between expected and unexpected carbon emissions, finding market value relevance for expected emissions regardless of assurance, with unexpected emissions being more relevant when assurance is present.

These studies, are based on data from the early stages of carbon disclosures. For example, Matsumura et al. (2014) used voluntary disclosures from S&P500 firms between 2006 and 2009, and Clarkson et al. (2015) relied on data from the EU ETS for the same period. Griffin et al. (2017) use CDP data between 2006 and 2012 for S&P500 firms and Ott and Schiemann (2023) CDP data between 2006 and 2014 for S&P500 firms in carbon intensive industries. Since then, these sources have undergone significant changes. The EU ETS has expanded to include additional sectors, and the CDP questionnaire has become more comprehensive, increasing firm coverage. Moreover, the allocation of emission allowances in the EU ETS has shifted from free allocation to auctioning, with steadily increasing carbon prices. This shift suggests a greater value relevance of carbon emissions. Policy developments like the Paris

Accord (2015), the US Inflation Reduction Act, and the EU Green New Deal further emphasize the importance of environmental responsibility in firms' risk profiles. Spandel et al. (2020) found that investors differentiate between material and immaterial aspects of environmental responsibility, indicating the need for differentiation in the relevance of emissions between Scopes. For instance, in California, emissions are priced under the Cap and Trade Program, affecting Scope 1 emissions directly. Additionally, Griffin et al. (2017) and Ott and Schiemann (2023) rely on carbon emission estimations, whose varying results from different providers (Busch et al., 2020) create uncertainty about the implications for firm-value relevance. Studies investigating firm-value effects (Clarkson et al., 2015; Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023) have historically used combined measures of Scope 1 and Scope 2 emissions. However, regulatory developments and policy targets for emission reductions have increased the availability of self-reported carbon emission data and their materiality to firms. For instance, Han et al. (2022) found a positive firm-value effect of carbon emissions in Taiwan, cautioning against broad generalizations of firm-value effects. This underscores the need to revisit the firm-value effects literature, particularly regarding different carbon emission estimation models and their implications on firm-value models like that of Matsumura et al. (2014). Furthermore, differentiating emissions by Scope (i.e., Scope 1, Scope 2, combination of Scope 1 & 2) in estimation models and their firm-value effects is crucial. While earlier studies provided foundational insights, recent developments in environmental regulation, carbon pricing, and policy changes necessitate a re-evaluation of the firm-value relevance of carbon emissions. The shift from voluntary to more regulated carbon disclosures, the differentiation between emission Scopes, and the increasing materiality of carbon emissions to firms call for updated research to reflect these changes accurately.

3 Data and Research Design

First, I collect data for all US firms from the Asset4 database for the years 2014 until 2020. This database contains firm-level financial and non-financial information from Refinitiv for listed firms. The initial sample contains 20,797 firm-year observations. The financial sector is then excluded, since the unique characteristics of financial firms in terms of emissions could potentially skew results (Delmas et al., 2015). This step removes 3,815 observations, leading to a sample of 16,982 firm-year observations. All continuous variables were winsorized at the 1%-level to mitigate the effect of outliers in the data.

Carbon emission estimation models

From this sample I estimate carbon emissions using two different approaches. First, I replicate the carbon emission estimation methodology as it is documented by Refinitiv (Refinitiv, 2021). For the CO₂-Model the first step is to take the latest available carbon emission data of a firm and divide it by that year's number of employees. Step two takes this factor and multiplies it with the number of employees for the year that is estimated. Step three repeats the process with net sales instead of number of employees. The average of the two resulting numbers is the firm's emission estimate for the year. The Median-Model follows a similar procedure. In the first step the median ratio of emissions to employees is calculated for all firms belonging to the same industry (according to the Thomson Reuters Business Classification (TRBC)). The TRBC has the highest level of detail at the 8-digit level and includes larger parts of an industry as it moves up to a 2-digit sector level. If fewer than ten firms are present for the purpose of calculating the first step, the TRBC-level is moved up until more than ten firms are available. The second step is to multiply the number of employees for the firm that is estimated with the median ratio of its industry. The third step repeats the process with net sales instead of number of employees. The fourth step is to take the average of the two results as the estimate for the firm. Notably, Refinitiv combines the estimation results from the CO₂-Model, the Median-

Model, and the Energy-Model (which is not replicated in this study due to the limited data available) into a single estimated emissions variable. The detailed documentation (Refinitiv, 2021) that makes it possible to replicate Refinitiv's estimations also allows to estimate emissions of firms that have reported them and thus benchmark the results against existing reported data.

Second, I replicate the carbon emission estimation model used by Griffin et al. (2017) which is based on a regression model. The model considers logged total revenue (\logRevenue), logged capital expenditure (\logCapex), logged gross property plant and equipment to depreciation expense (\logPPEPD), logged intangibles (\logIntan), gross margin ($GMAR$), leverage (LEV) and an industry dummy variable on logged carbon emissions (\logScope) as reported by Refinitiv. The resulting coefficients are then used to predict the carbon emissions for a given firm year. The emission estimations were conducted for Scope 1 emissions and Scope 2 emissions, separately, and for the combined total emissions (the sum of Scope 1 and Scope 2), where \logScope represents the respective emission scope.

$$\begin{aligned} \logScope_{i,t} = & \beta_0 + \beta_1 \logRevenue_{i,t} + \beta_2 \logCapex_{i,t} + \beta_3 \logPPEPD_{i,t} + \beta_4 \logIntan_{i,t} \\ & + \beta_5 GMAR_{i,t} + \beta_6 LEV_{i,t} + \varepsilon_{i,t} \end{aligned}$$

I then compare the different emission estimation results to reported emissions from Refinitiv. These and all following analyses are based on the sample from 2014 to 2020. First, a potential bias in the data is investigated by calculating the difference in means between estimated and reported data and then testing their significance using a two-tailed t-test. Second, to test the predictive ability of the different estimation models, I calculate the difference in deciles of the distribution for reported and estimated data. This test shows how many firms fall into the same decile in the estimated data compared to reported data.

Firm value effect of carbon emissions

In a second step I draw on the firm valuation model that Matsumura et al. (2014) have adopted and extended from commonly used balance sheet valuation models (Barth & McNichols, 1994; Campbell et al., 2003). In their analysis, they hypothesize that the market value (*MV*) of a firm is dependent on its carbon emissions (*GHG*), total assets (*ASSETS*), total liabilities (*LIAB*) and operating income (*OPINC*). In this model the expected direction of the effects of each independent variable on market value are negative for carbon emissions, positive for total assets, negative for total liabilities and positive for operating income. Following Matsumura et al. (2014) I also use unscaled dependent and independent variables. I use this model as a basis to investigate the effects that different measures of carbon emissions, reported and estimated, have on a commonly used and referenced model that connects firms' value with their carbon emissions.

$$MV_{i,t} = \beta_0 + \beta_1 GHG_{i,t} + \beta_2 ASSETS_{i,t} + \beta_3 LIAB_{i,t} + OPINC_{i,t} + \varepsilon_{i,t}$$

The *GHG* variable represents the reported emissions from Refinitiv, the estimated emissions according to Griffin et al. (2017) and the estimated emissions based on the Refinitiv methodology.

4 Results

Estimation models

Panel A of Table 1 shows the descriptive statistics for the data used in the replication of the Griffin et al. (2017) model. Notably, more than half of the firms in this sample do not report any intangible assets in Refinitiv. Panel B shows the adjusted R^2 of the estimation used to predict emissions with the Griffin et al. (2017) model. The results for the model's explanatory power shown in Panel B are similar to the results obtained by Griffin et al. (2017) and lie between 0.511 and 0.865 depending on year and emission scope. However, a steady decline in explanatory power is observable for Scope 1, Scope 2 and total emissions from 2014 to 2020. Panel C shows the results of a paired, two-tailed t-test of the differences in means between the

reported data and estimated data. Griffin et al. (2017) employed the same test in their study but compared logged emissions and found no significant difference in the logged means of firms' reported emissions and their own estimated emissions. The advantage of using logarithmically scaled variables is that changes are symmetrical. Employing the same approach, I also find no statistically or economically significant differences (these results are not reported). However, as shown in Panel C, taking the absolute values reveals a significant bias in the estimated data. The Griffin et al. (2017) emission models and the Refinitiv Median-Model all underestimate emissions compared to reported data. The Griffin et al. (2017) Scope 1 results show a difference in means of around 1.6 million tons of carbon emissions, or almost 50% less emissions than reported. For Scope 2 and total emissions the differences are also around 30-40%. The Refinitiv Median-Model shows a difference of around 30% in means for total emissions. The exception in this comparison is the Refinitiv CO₂-Model that shows only a 4% difference in means between estimated and reported total emissions and slightly overestimates firms' emissions. Since the difference in means could be driven by extreme values, I also compare the difference in medians and find that less substantial, showing a difference of around 10% (20%) for the Griffin et al. (2017) Scope 1 (Scope 2) model. For the Scope 1+2 model, however, the difference is still substantial at around 65% fewer emissions than reported. Unlike the Griffin et al. (2017) models, the Refinitiv models all slightly overestimate median emissions by around 5-10%. Overall, the Griffin et al. (2017) model underestimated median and mean emissions, the Refinitiv CO₂-Model slightly overestimates median and mean emissions and the Refinitiv Median-Model overestimates median emissions, but underestimates mean emissions. The significance in these differences could also be driven by extreme values, thus in addition to a T-test, I also report the results of a Wilcoxon signed-rank test that also show a significant difference. Panel D shows the results of an analysis of the predictive power for the different estimation models. Each estimated emission variable is split into deciles, as well as the respective reported emission variables. I then compare each pair of estimated and reported

emissions and calculate, how many observations fall into the same or adjacent decile in the estimated and reported data. For each estimation method, around a quarter of the estimated emissions fall into the same or adjacent decile as in the reported data. The exception is the CO₂-Model from Refinitiv, which estimates emissions to be in the same or adjacent decile 87% of the time for combined Scope 1 and 2 emissions and 99% or 97% of the time respectively for Scope 1 and Scope 2 emissions estimated separately. It shows an average difference in the decile between estimated and reported data of -0.073 (0.071 and 0.083 for Scope 1 and Scope 2), whereas the other estimation models show an average difference between -2.693 and -2.959. Compared with the analyses of logarithmic carbon emissions' bias and predictive ability in Griffin et al. (2017) I find a consistent underestimation of carbon emission data for absolute emissions, except when using the Refinitiv CO₂-Model.

Insert Table 1 about here.

One explanation for these differences lies in the approach of the different estimation models. The regression-based model by Griffin et al. (2017) uses logarithmic values and is thus not affected by extreme values in the data that could distort results. However, a non-parametric test confirms the significant differences in means. Similarly, the Median-Model from Refinitiv is also unaffected by extreme values in the distribution. If extreme outliers were the drivers for the major difference in means between reported and estimated data shown in Panel C of Table 1, the majority of firms should still appear in the same or adjacent decile in the distribution of reported and estimated data. Since 75% of firms fall in a different decile in the estimated data compared to the reported, a systematic difference must be assumed that is not driven by extreme outliers. This could be explained by the increasing importance for firms to actively manage their emissions. As carbon management strategies are implemented, the deviation from the amount of emissions one could expect (Ott & Schiemann, 2023) as a function of e.g. firm size or asset age, output or asset age increases and the estimation model captures fewer of the

influential factors for firm emissions. This perspective is also consistent with the steady decline in explanatory power the Griffin et al. (2017) model exhibits, shown in Panel B of Table 1.

Firm value effect

Table 2 shows the descriptive statistics of the data used in the firm value model. It is the nature of estimated data that they are meant to increase the universe of available observations. At the same time different estimation approaches require a diverse range of available data (e.g., the Griffin et al. (2017) model requires a range of financial data of a firm, while Refinitiv's approaches only require firms' sales, number of employees and, possibly, previous emissions). Thus, the number of observations varies for each scope and estimation model. Note that the economic variables are reported at their maximum number of observations used in the firm valuation model and in thousand USD. Previous studies of the firm value effect of carbon emissions were focused on large cap indices like the S&P 500 (Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023), while I focus on the largest number of observations obtainable. Thus, the means for both economic and carbon emission data tend to be smaller than in comparable studies due to the number of smaller firms in the sample. When looking at the number of observations contained in the firm value model, the limiting factor is the availability of carbon emission information, which can be alleviated through estimations. In this sample, the reported Scope 1+2 emissions from Refinitiv are available for 3,171 firm-years, while estimated data from the CO₂-Model is only available for 3,116 firm-years (if estimations are calculated for all firms where it is possible, not just those that did not report emissions in a given year). This is likely caused by the CO₂-Model estimation approach. The nature of the model only allows estimations for firms that have reported emissions in the past and only with a lag of at least one year. Since firms that started reporting emissions rarely stop or show gaps in their reporting, the number of additional observations generated with the CO₂-Model is limited.

Insert Table 2 about here.

Table 3 shows the results for the estimated firm value effect of carbon emissions. This replication of the model used in Matsumura et al. (2014) yields similar results for total carbon emissions (*Reported Scope 1+2* in column (3)). Where Matsumura et al. (2014) estimate a decrease in firm value of around 212,000 USD, I find a decrease of around 158,000 USD per additional ton of carbon emissions. Similarly, the control variables show the expected direction in their influence on firm value with *Total Assets* and *Operating Income* being positively associated with firm value and *Total Liabilities* negatively associated. Differences in the firm value effect of carbon emissions appear when separating emissions into Scope 1 and 2 and when looking at different estimated data. The estimated emissions from the model used in Griffin et al. (2017) do not yield significant results for Scope 1 (column(4)), Scope 2 (column(5)) or total emissions (column(6)). The Refinitiv estimation methods yield significant results with the CO2-Model (column(7)) showing a coefficient (-0.164) similar to the reported data and the findings reported by Matsumura et al. (2014). The Median-Model yields a significantly higher coefficient at -0.515 which means a penalty in firm value of 515,000 USD per ton of total carbon emissions. The reason the coefficient of the Median-Model is higher than that of the CO2-Model is likely of a more technical nature. Taking into account the bias in the estimated data from Table 1 into account, where the Median-Model underestimates carbon emissions by around 30%, one would expect to see each ton of carbon emissions to have a higher impact on firm value if the estimated and reported emissions are still strongly correlated (Busch et al., 2020).

Previous work has already shown the importance of differentiation between emission types, for example relative or absolute emissions (Bauckloh et al., 2023) or Scope 1 and 2 emissions (Ott & Schiemann, 2023). An additional analysis of the differentiation between Scope 1 and Scope 2 emissions in Table 3 (columns (1) and (2)) yields an interesting finding. Where Scope 1

emissions alone have a similar impact compared to total emissions at 154,000 USD penalty per ton of carbon emissions, Scope 2 emissions show a much higher penalty of 696,000 USD per ton. Bauckloh et al. (2023) have already shown that US firms, which are subject to the Greenhouse Gas Reporting Protocol (GHGRP) still appear to be unable to fundamentally disconnect their economic activities from their carbon emissions. From this perspective, it makes sense for capital markets to award a higher penalty to Scope 2 emissions than to Scope 1 emissions. Scope 1 emissions are defined as directly resulting from the firms' activities and are thus closely linked to their profits. Scope 2 emissions on the other hand are defined as resulting from purchased power and heat and can thus feasibly be reduced without affecting firms' economic activities, as long as there are sufficient green energy providers available. These results are qualitatively and quantitatively robust to a subsample of only large cap firms (the largest 50% of firms in the sample based on their total assets), such as has been used in previous studies (Griffin et al., 2017; Matsumura et al., 2014; Ott & Schiemann, 2023).

Insert Table 3 about here.

Additionally, investors also differentiate between material and immaterial sustainability-related topics with regards to their importance to the firm they want to evaluate. In a study by Spandel et al. (2020) the authors utilize the release of standards by the Sustainability Accounting Standards Board (SASB) on which areas of sustainability are particularly important for a sector. Firms that are scored worse in the areas of sustainability that were identified as critical for their industry by the SASB showed a negative impact on firm value following the release of their sector's standards. Similarly, in terms of carbon emissions, firms also face different challenges. Assuming that particularly high emissions in Scope 1 or Scope 2 indicate that this is the main challenge for a firm in terms of emission reductions would mean that these emissions should consequently exhibit a higher firm value penalty. An analysis of a sub-sample consisting of firms that are in the 5th to 10th percentile for Scope 1 emissions and in the 1st to 5th percentile

for Scope 2 emissions of the available reported data, meaning high Scope 1 and low Scope 2 emissions, shows that in this instance the market value penalty for Scope 1 emissions is 562,000 USD per ton of carbon emissions while there is no significant penalty for Scope 2 emissions (Table 4 Panel B Columns (1) and (2)). If the largest source of a firm's emissions are Scope 2 emissions, the market value penalty for those emissions is 2,953,000 USD while Scope 1 emissions are not significantly penalized (Table 4 Panel B Columns (3) and (4)). Additionally, the results from the descriptive statistics show that the distributions for these two sub-samples are right skewed for Market Value and emission scopes. For the sample of low Scope 1 and high Scope 2 emissions, the Market Value mean is around two times the median and similarly the Reported Scope 2 mean is two times the median. For the sub-sample with high Scope 1 emissions and low Scope 2 emissions, however, the Market Value mean is around two times the median while the Reported Scope 1 mean is almost 15 times the median. This suggests that while Scope 1 emissions play a (very) significant role for some firms, Scope 2 emissions play a considerable role for a lot of firms. From these results, it appears that the market value penalty for carbon emissions depends on total emissions. But the extent of the penalty can vary substantially, based on the main source of a firm's carbon emissions, and how expensive it is to reduce these emissions. The largest penalties per ton of emissions are consequently awarded to firms whose main source of carbon emissions are indirect emissions. The results for the remaining sample without the firms investigated in Table 4 corresponds to the results from Table 3 (Columns (1) and (2)) in terms of significance, coefficient size and direction of effect.

Insert Table 4 about here.

5 Discussion

The results of this study provide several interesting implications. First, regarding the accuracy of carbon emission estimation methods, the estimation model used by Griffin et al. (2017) explains a large proportion of the variance within the model, with an *R*-squared between 0.865

and 0.709 for the year 2014, depending on scope. However, the explanatory power decreases over time to an *R*-squared of between 0.652 and 0.548 in 2020. As carbon emissions become increasingly important and carry with them regulatory risks and in some cases direct cost in the form of carbon emission allowances under an emission trading system, they are likely more actively managed by firms. Thus, carbon emission estimation models may benefit from including additional metrics that capture firms' active management of their emissions. Furthermore, it appears that estimation methods based on average or median values like the model by Griffin et al. (2017) and the Median-Model from Refinitiv produce results, which systematically underestimate emissions. This is especially worrying as the reported emissions these estimations are based on are likely already containing underreporting firms (Hoepner & Rogelj, 2021). Future research should carefully consider if estimated emissions are required for an analysis and what the possible implications for their results are.

Second, there are trade-offs to consider for different estimation methods. For example, the Refinitiv CO₂-Model and Median-Model both produce substantially more overall observations than the Griffin et al. (2017) model. However, the CO₂-Model relies on the earliest previously available emissions for a firm to estimate the following years' emissions. Since not many firms start reporting their emissions and then cease to report again, a lot of those observations generated are also available as reported emissions. The Median-Model is based on industry medians and thus is much more efficient at estimating emissions for non-reporting firms. Thus if the goal of including estimated emissions is to reduce a sample bias by extending the range of firms covered, because the assumption is that only certain firms, for example particularly good performers, reported their emissions, then using a model like the Refinitiv Median-Model or the Griffin et al. (2017) model could be advised, since they produce more observations in addition to what is available in reported data. If the goal is to increase the number of available observations to produce more robust results, then filling gaps using the CO₂-Model approach may be more appropriate. Indeed, the firm-specific relationship between emissions, revenue

and number of employees in the CO₂-Model appears to be quite strong as the large number of accurate estimations suggest (87%) and the model could be adjusted to not only estimate emissions based on last previous reported data but to also generate estimations for earlier years before reporting started, based on the first reported emission data when filling data gaps. In general, trade-offs due to the nature of different estimation models are worth considering – the higher the complexity of the estimation model, the lower the potential number of estimations that can be generated, which may, however, be more accurate. The complexity of an estimation model also affects the number of additional observations generated beyond what is available as reported data.

Third, the distinction between emission scope is important when considering the firm value effect of carbon emissions. Scope 1 and Scope 2 emissions are connected differently to firms' activities. For industries such as cement manufacturing or chemicals, direct emissions are the main source of emissions, and these emissions are directly connected to their business activities. Other sectors primary source of emissions is a result of purchased energy (e.g., IT sector). The results from Table 3 show that the firm value effect of emissions varies from 154,000 USD per ton of Scope 1 emissions to 696,000 USD per ton of Scope 2 emissions, using the reported data for the full sample of US firms. If emissions are directly caused by firms' activities and the reduction of emissions could only be achieved cost-effectively by reducing these activities, then a lower market value penalty for Scope 1 emissions is justified. During the period of this study, in the US the main regulatory interventions regarding Scope 1 emissions are the California Cap and Trade Program and the GHGRP. Allowance prices in the California Cap and Trade Program between 2014 and 2020 have slowly risen from around 12 to 17 USD (California Cap and Trade Program, 2023), which is far from the price of between 50 and 250 USD that economists believe is necessary to incentivize firms to start reducing their emissions (Reuters, 2021). A comparably low firm value penalty for Scope 1 emissions therefore reflects the state of regulatory risk and pressure for US firms. On the other hand, Scope 2 emissions are not directly caused by firms'

activities. Firms could reduce their Scope 2 emissions simply by substituting emission intensive energy sources with clean energy. More importantly, Scope 2 emissions are connected to energy prices directly, regardless of additional carbon emission regulation. Improvements in energy efficiency that help save on electricity lead to reductions of Scope 2 emissions and decrease expenses for purchased energy. This can directly affect firms' bottom lines by reducing costs. In line with this argument, the additional analysis in Table 4 Panel B shows that firms with low Scope 1 emissions but high Scope 2 emissions are showing the highest firm value penalty of 2,953,000 USD but are not significantly scrutinized for their Scope 1 emissions. Firms with high Scope 1 emissions and low Scope 2 emissions are equally showing a firm value penalty of 562,000 USD for their Scope 1 emissions but no significant penalty for their Scope 2 emissions. This also fits previous findings by Spandel et al. (2020) that capital markets are able to identify the material areas of environmental performance for a firm and evaluate their respective performance accordingly. These findings suggest that the firm value effect of carbon emissions is affected by the level of materiality of the emission scope for a given firm. Furthermore, the market value effects may also depend on the price attached to the emissions. Future research into the firm value effect of Scope 2 emissions regarding energy price levels may reveal novel insights.

6 Conclusion

This study contributes to the ongoing discourse surrounding the impact of carbon emissions on firm value. The findings emphasize the important role of accurate carbon emissions data, derived both from reported figures and estimation models, in understanding their consequences on firm value. These analyses support previous findings by Clarkson et al. (2015) and Matsumura et al. (2014), that increased carbon emissions are correlated with a reduction in firm value. They also highlight the importance of distinguishing between Scope 1 and Scope 2 emissions in the estimation and reporting processes. The analysis revealed a more substantial

firm value penalty for Scope 2 emissions, which could be attributed to their indirect nature and the potential for firms to switch to greener energy sources. This distinction aligns with the findings of Ott & Schiemann (2023), who suggest that distinct types of emissions carry different weight in financial evaluations due to varying levels of materiality and regulatory impact. Moreover, the study highlights the need for robust estimation models to bridge gaps in emissions reporting and the need to carefully consider the estimation methods used by data providers when constructing datasets for future analyses. Finally, the distinction between Scope 1 and Scope 2 emissions reveals, that good firm performance in one scope does not protect from firm value penalty as a consequence of particularly bad performance in the other scope. Capital markets appear to be able to recognize the problematic emission scope performance of firms and price them accordingly. As the regulatory landscape evolves and the economic implications of emissions become more pronounced, this study offers valuable insights for policymakers, investors, and corporate managers. By enhancing the understanding of the link between carbon emissions and firm value, we can foster more informed decision-making that supports the transition towards a low carbon economy.

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Table 1.**Panel A. Descriptive statistics for the CO2 emission estimation model used by Griffin et al. (2017).**

	N	mean	sd	min	max	p5	p50	p95
<i>ln_scope1</i>	1764	11.893	2.970	3.504	18.184	6.937	11.873	16.786
<i>ln_scope2</i>	1732	12.039	1.975	6.111	16.022	8.563	12.211	15.151
<i>ln_scope12</i>	2006	12.932	2.299	7.462	18.365	9.162	12.883	16.847
<i>ln_revenue</i>	2006	22.539	1.311	17.968	25.114	20.346	22.558	25.114
<i>ln_capex</i>	2006	19.660	1.583	13.501	22.366	17.020	19.713	22.366
<i>ln_ppedp</i>	2006	2.911	0.619	1.101	5.017	2.062	2.865	3.853
<i>ln_intan</i>	2006	2.159	6.380	0.000	23.679	0.000	0.000	21.264
<i>gmar</i>	2006	0.405	0.251	-0.528	0.999	0.075	0.383	0.845
<i>lev</i>	2006	0.293	0.209	0.000	3.852	0.015	0.277	0.584

Panel B. Explanatory power of the Griffin et al. (2017) estimation model.

Adjusted R²	2014	2015	2016	2017	2018	2019	2020
<i>ln_scope1</i>	0.865	0.777	0.761	0.754	0.691	0.725	0.632
No. Obs. (cumulative)	121	272	460	687	971	1344	1802
<i>ln_scope2</i>	0.709	0.684	0.600	0.547	0.511	0.550	0.548
No. Obs. (cumulative)	119	263	439	656	929	1290	1742
<i>ln_scope12</i>	0.819	0.758	0.753	0.710	0.684	0.723	0.652
No. Obs. (cumulative)	138	314	519	774	1091	1498	2002

Panel C. Test of bias.

	Obs.	Median	Median difference	Mean	SD	T-test p-value	Wilcoxon p-value
Reported Scope 1	1,805	152	-	3,500	10,469	-	-
Griffin Scope 1	1,805	138	14	1,875	4,621	0.000	0.000
Reported Scope 2	1,745	199	-	751	1,492	-	-
Griffin Scope 2	1,745	165	34	446	674	0.000	0.000
Reported Scope 1+2	2,006	393	-	3,903	10,978	-	-
Griffin Scope 1+2	2,006	151	242	2,477	6,698	0.000	0.000
Reported Scope 1+2	4,530	620	-	5,845	15,027	-	-
CO2-Model Scope 1+2	4,530	654	-34	6,050	15,343	0.000	0.000
Reported Scope 1+2	5,224	501	-	5,340	14,289	-	-
Median-Model Scope 1+2	5,224	552	-51	3,861	8,756	0.000	0.000
Reported Scope 1	3,879	210	-	4,925	13,150	-	-
CO2-Model Scope1	3,879	218	-8	5,196	13,907	0.000	0.000
Reported Scope 1	4,517	163	-	4,443	12,454	-	-
Median-Model Scope1	4,517	185	-22	4,370	12,473	0.570	0.000
Reported Scope 2	3,678	265	-	902	1,658	-	-
CO2-Model Scope2	3,678	281	-16	938	1,708	0.000	0.000
Reported Scope 2	4,260	224	-	800	1,531	-	-
Median-Model Scope2	4,260	231	-7	645	1,282	0.000	0.000

Panel D. Predictive ability of the different estimation models.

	Obs.	Neighbouring Obs.	Percentage	Mean difference
Estimated Scope 1	1,805	476	26	-2.693
Estimated Scope 2	1,745	445	26	-2.959
Estimated Scope 1+2	2,006	488	24	-2.909
CO2-Model Scope 1+2	3,946	3,433	87	-0.073
Median-Model Scope 1+2	4,575	1,214	27	-2.737
CO2-Model Scope 1	3,879	3,839	99	0.071
Median-Model Scope 1	4,517	1,261	28	-2.514
CO2-Model Scope 2	3,678	3,562	97	0.083
Median-Model Scope 2	4,260	1,026	24	-2.931

Table 1. Panel A shows the descriptive statistics of the data used in replicating the CO2 emission estimation model of Griffin et al. (2017).

Panel B shows a test of the explanatory power for each scope of emissions by year.

Panel C shows a test of bias in the estimations following Griffin et al. (2017). The mean and difference in means between each estimated carbon emission variable and the respective reported data is shown, as well as the significance of the difference estimated in a two-tailed t-test. Median, median difference, mean and standard deviation are reported in 1,000 tCO₂e.

Panel D shows the predictive ability of each emission estimation model following Griffin et al. (2017). For each estimated and reported emission variable the decile is calculated and the number of observations in an estimated emission variable that fall into the same or adjacent decile compared to the reported emissions are shown.

Table 2. Descriptive Statistics of the Firm Value Model

	N	Mean	SD	p5	Median	p95
Market Value	11,027	11,252,397.426	25,700,107.662	147,592.525	2,290,174.014	55,830,579.645
Total Assets	11,027	9,168,306.567	24,593,963.584	83,724.000	1,639,384.000	42,877,000.000
Total Liabilities	11,027	6,084,038.686	17,164,774.887	17,262.160	878,105.000	30,413,000.000
Operating Income	11,027	2,147,810.955	5,414,012.494	0.000	433,086.031	10,247,999.000
Reported Scope 1	2,757	3,709,871.087	11,195,604.923	1,258.000	124,633.000	24,950,000.000
Reported Scope 2	2,709	749,592.535	1,485,515.235	6,280.000	196,581.000	3,800,000.000
Reported Scope 1+2	3,171	4,354,101.515	12,505,858.593	11,613.000	381,952.000	26,800,000.000
Estimated Scope 1	6,888	587,021.279	2,609,804.639	20.207	6,985.835	2,052,068.750
Estimated Scope 2	6,888	168,315.203	438,009.192	580.919	24,272.635	954,114.063
Estimated Scope 1+2	6,888	184,007.268	572,225.488	580.919	24,272.635	954,114.063
CO2-Model Scope 1+2	3,116	4,707,614.805	13,070,910.872	15,654.912	413,872.984	28,649,144.000
Median-Model Scope 1+2	11,027	1,078,076.894	4,595,935.837	440.283	47,386.219	3,898,187.750
CO2-Model Scope 1	2,809	4,126,596.055	12,707,757.476	1,564.074	143,600.000	26,059,464.000
Median-Model Scope 1	11,025	1,115,839.922	6,202,469.676	113.152	11,297.896	3,222,356.500
CO2-Model Scope 2	2,713	790,141.811	1,537,782.551	8,695.439	220,276.750	3,816,690.750
Median-Model Scope 2	11,027	218,806.820	706,843.574	230.388	29,967.191	1,068,249.750

Table 2 shows the descriptive statistics of the data used in the firm value model based on Matsumura et al. (2014). Market Value, Total Assets, Total Liabilities and Operating Income are stated in \$1,000.

Table 3. Firm Value Effect of Carbon Emissions.

Panel A. Regression results of the firm-value model using reported emission data.

	Reported Scope 1	Reported Scope 2	Reported Scope 1+2
Reported Scope 1	-0.154*** (0.042)		
Reported Scope 2		-0.696** (0.353)	
Reported Scope 1+2			-0.158*** (0.033)
Total Assets	0.409*** (0.077)	0.404*** (0.076)	0.435*** (0.076)
Total Liabilities	-0.302*** (0.095)	-0.299*** (0.094)	-0.303*** (0.095)
Operating Income	3.015*** (0.170)	3.027*** (0.172)	2.972*** (0.168)
Constant	2,975,520.773*** (510,220.724)	3,188,825.398*** (546,314.429)	2,835,049.219*** (442,824.171)
Industry dummy	Yes	Yes	Yes
Observations	2,757	2,709	3,171
R-squared	0.717	0.716	0.724

Panel B. Regression results of the firm-value model using estimated emission data.

	Griffin Scope 1	Griffin Scope 2	Griffin Scope 1+2	CO2-Model Scope 1+2	Median-Model Scope 1+2	CO2-Model Scope 1	Median-Model Scope 1	CO2-Model Scope 2	Median-Model Scope 2
Griffin Scope 1	-0.133 (0.135)								
Griffin Scope 2		0.684 (1.217)							
Griffin Scope 1+2			-0.064						

			(0.106)							
CO2-Model Scope 1+2				-0.164***						
				(0.034)						
Median-Model Scope 1+2					-0.516***					
					(0.060)					
CO2-Model Scope 1						-0.164***				
						(0.037)				
Median-Model Scope 1							-0.361***			
							(0.040)			
CO2-Model Scope 2								-0.893***		
								(0.343)		
Median-Model Scope 2									-1.789***	
									(0.418)	
Total Assets	0.685***	0.667***	0.683***	0.443***	0.610***	0.428***	0.615***	0.422***	0.617***	
	(0.108)	(0.108)	(0.108)	(0.077)	(0.078)	(0.079)	(0.078)	(0.079)	(0.079)	(0.079)
Total Liabilities	-0.608***	-0.603***	-0.607***	-0.304***	-0.451***	-0.295***	-0.456***	-0.292***	-0.464***	
	(0.136)	(0.136)	(0.136)	(0.095)	(0.103)	(0.095)	(0.103)	(0.095)	(0.103)	(0.103)
Operating Income	3.071***	3.081***	3.072***	2.926***	2.973***	2.910***	2.934***	2.951***	2.961***	
	(0.219)	(0.216)	(0.219)	(0.166)	(0.150)	(0.172)	(0.151)	(0.176)	(0.153)	(0.153)
Constant	1,606,773.957	1,132,567.448	1,546,082.028	3,478,912.712	1,672,551.814	3,467,898.650	1,351,041.845	4,030,841.799	1,955,844.242	
	***	**	***	***	***	***	***	***	***	***
	(356,003.473)	(560,718.084)	(371,331.748)	(473,138.254)	(243,559.774)	(532,475.400)	(242,488.110)	(578,156.686)	(270,994.205)	
Industry dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,888	6,888	6,888	3,116	11,027	2,809	11,025	2,713	11,027	
R-squared	0.726	0.726	0.726	0.722	0.741	0.715	0.741	0.713	0.737	

Table 3 Panel A shows the results of the firm value model based on Matsumura et al. (2014) using reported carbon emission data.

Table 3 Panel B shows the results of the firm value model based on Matsumura et al. (2014) using carbon emission data obtained through different estimation methods.

Coefficients are reported in million USD.

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

Table 4. Additional Analysis of Firms with High/Low Scope 1 and Scope 2 Emissions
Panel A. Descriptive statistics for firms with high/low scope 1 and scope 2 emissions.

Firms with high scope 1 emissions and low scope 2 emissions.

	N	Mean	SD	p5	p50	p95
Market Value	460	18,494,494.082	29,814,488.146	641,019.215	7,786,983.980	97,792,127.154
Reported Scope 1	440	3,775,853.888	10,491,630.949	87,752.000	244,610.000	19,197,842.000
Reported Scope 2	460	108,856.486	71,886.001	4,134.500	108,105.000	221,872.500
Total Assets	460	15,730,745.317	20,655,500.053	983,947.500	7,921,707.500	53,257,500.000
Total Liabilities	460	11,132,797.467	15,223,200.494	471,750.000	5,657,816.500	42,147,414.000
Operating Income	460	3,279,250.562	4,568,247.285	118,292.000	1,722,525.500	15,520,500.000

Firms with low scope 1 emissions and high scope 2 emissions.

	N	Mean	SD	p5	p50	p95
Market Value	517	37,650,634.153	47,461,249.559	1,955,154.921	15,715,605.247	147,863,000.000
Reported Scope 1	517	72,849.608	47,531.750	7,037.000	66,686.000	159,104.000
Reported Scope 2	499	516,168.714	682,347.698	146,143.000	274,782.000	1,925,390.000
Total Assets	517	31,773,281.630	46,697,382.429	2,356,000.000	13,669,936.000	137,851,000.000
Total Liabilities	517	20,513,802.913	32,005,854.983	1,373,709.000	8,741,200.000	94,389,000.000
Operating Income	517	7,537,256.817	10,551,456.801	290,095.000	2,857,999.750	37,160,000.000

Panel B. Regression results for firms with high/low scope 1 and scope 2 emissions.

	(1)	(2)	(3)	(4)
	<i>High Scope 1; low Scope 2</i>		<i>Low Scope 1; high Scope 2</i>	
Reported Scope 1	-0.562***		18.78	
	-0.166		-24.706	
Reported Scope 2		-5.344		-2.953*
		-12.235		-2.086
Total Assets	0.753***	0.737**	0.257	0.315*
	-0.282	-0.305	-0.158	-0.166
Total Liabilities	-0.379	-0.619	-0.325**	-0.375***
	-0.41	-0.401	-0.129	-0.137
Operating Income	3.663***	3.951***	3.566***	3.500***
	-0.719	-0.737	-0.52	-0.527
Constant	639,248.18	1,381,449.33	-981,788.53	2,203,408.913*
	-574,170.94	-1,371,705.18	-2,452,192.96	-1,296,029.84
Industry dummy	Yes	Yes	Yes	Yes
Observations	440	460	517	499
R-squared	0.730	0.715	0.755	0.753

Table 4 Panel A shows the descriptive statistics for a sub-sample of firms that are characterized by high/low scope 1/scope 2 emissions.

Table 4 Panel B shows the regression results of one-tailed test for a sub-sample of firms that are characterized by high scope 1 emissions and low scope 2 emissions (columns (1) and (2)) or low scope 1 emissions and high scope 2 emissions (columns (3) and (4)). Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Paper 3

Under Pressure? The Link Between Mandatory Climate Reporting and Firms' Carbon Performance.

Under Pressure? The Link Between Mandatory Climate Reporting and Firms' Carbon Performance

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Tobias Bauckloh¹, Christian Klein², Thomas Pioch^{3,*} ,
and Frank Schiemann^{3,*} 

Abstract

We examine whether and how mandatory climate reporting leads to changes in firms' carbon emissions. Drawing on legitimacy theory and using a difference-in-differences design, we assess the effect of the Greenhouse Gas Reporting Program (GHGRP), introduced by the Environmental Protection Agency (EPA) in 2010, on the carbon performance defined as carbon intensity and absolute carbon emissions of affected firms. We find that firms affected by the GHGRP improve their carbon intensity significantly more than unaffected firms after the introduction of the GHGRP, but not their absolute carbon emissions. The results are robust to changes in the difference-in-differences design. Overall, our study contributes to research on mandatory climate reporting by assessing the GHGRP's suitability to generate a real sustainable change in firms' operations and reduce their negative impact on our climate.

Keywords

carbon performance, mandatory reporting, legitimacy theory, sustainable change

Introduction

Firms experience increasing pressure to report on their carbon risks, strategies, and emissions (Eccles et al., 2011; Reid & Toffel, 2009). In this context, voluntary climate reporting initiatives such as the CDP (formerly: Carbon Disclosure Project) have emerged, which rely on the cooperation of firms. Although firms are major contributors to global carbon emissions and should act transparently and responsibly (Klettner et al., 2014), regulators can intervene when firms are not transparent about their commitment to national and international climate goals. To this end, national and international mandatory climate reporting regimes have been established (e.g., the Greenhouse Gas Reporting Program [GHGRP]). Comyns (2016) shows that reporting quality and quantity increase under mandatory climate reporting regimes, such as the European Union Emissions Trading System (EU ETS). Whether and how the reporting of carbon emission data

¹Universität zu Köln, Germany

²Universität Kassel, Germany

³Universität Hamburg, Germany

*Both authors are now affiliated to Otto-Friedrich-Universität Bamberg, Germany.

Corresponding Author:

Thomas Pioch, Faculty of Business, Economics and Social Sciences, Universität Hamburg, Rentzelstraße 7, 20146 Hamburg, Germany.

Email: thomas.pioch@uni-hamburg.de

also leads to a real sustainable change within firms in the form of reduced carbon emissions is still being discussed (Downar et al., 2021; Haque & Ntim, 2018; Jouvenot & Krueger, 2020; Qian & Schaltegger, 2017; Tomar, 2019). We contribute to this discussion from a legitimacy theory perspective by assessing the effect of a mandatory climate reporting regime on the carbon performance (operationalized as both, carbon intensity and absolute carbon emissions) of affected firms, operating in the country with the second-highest carbon emissions, the United States).

During the United Nations Framework Conference on Climate Change (UNFCCC, 2015) in Paris in November and December 2015, 197 parties agreed to the goal of limiting the rise in global temperature to significantly below 2°C (preferably 1.5°C) compared with the preindustrial level. This goal requires tremendous efforts to reduce carbon emissions in the public as well as the private sector. According to a special report by the Intergovernmental Panel on Climate Change (IPCC), the remaining carbon budget for a 66% likelihood of limiting global warming to 1.5°C amounts to 420 GtCO₂, and about 580 GtCO₂ for a 50% likelihood (Rogelj et al., 2018). In other words, carbon neutrality must be reached in about 20 years (66% chance) or 30 years (50% chance), respectively. Given the serious consequences that are expected in a scenario of unmitigated climate change (Steffen et al., 2018), the international consensus is that all parties that contribute to it have a responsibility to mitigate their carbon emissions (World Commission on the Ethics of Scientific Knowledge and Technology, 2010) and that real sustainable change is required. Thus, environmental corporate social responsibility (CSR) such as carbon emissions management has become an important aspect of societal expectations toward firms (Flammer, 2013). The increasing political and societal awareness of the serious consequences of climate change led to a growing number of regulations directly aimed at decreasing carbon emissions. Examples include the introduction of carbon taxes (e.g., Norway and Switzerland), climate-friendly mobility concepts (e.g., lowering the VAT rate on train tickets in Germany), and emissions trading systems (e.g., the EU ETS).

Drawing on legitimacy theory, we analyze whether and how a mandatory climate reporting regime, which aims at improving carbon transparency, is related to subsequent firm carbon performance improvements. Given a rising societal awareness of the consequences of climate change, mandatory reporting and the public disclosure of emissions can lead to firms being exposed to increasing societal expectations to improve their carbon performance (e.g., Deegan, 2002; Dowling & Pfeffer, 1975). Firms respond to such expectations to ensure their legitimacy, that is, their “license to operate” (Newson & Deegan, 2002). Therefore, mandatory climate reporting can trigger substantial firm carbon performance improvements.

The Environmental Protection Agency’s (EPA) GHGRP provides a unique setting to test this assumption. This mandatory climate reporting regime mandates firms to report emissions from facilities that emit 25,000 metric tons or more of carbon dioxide equivalent per year in the United States (EPA, 2020). It covers direct carbon emitters, suppliers of fossil fuel and industrial gas as well as facilities that store carbon dioxide underground for sequestration or other reasons. Certain industries such as the agricultural industry are exempt from the GHGRP. Carbon emissions are reported at the facility level annually. The EPA verifies the collected data by themselves and subsequently publishes it on its website. The aim of the GHGRP is to better understand the sources of carbon emissions in the United States and to support the development of further regulations to reduce emissions. Failure to comply with the GHGRP is considered a violation of the Clean Air Act and carries with it a fine of up to US\$45,268 per day (EPA, 2021a, 2021b). The EPA (2020) estimates that the facilities covered by the GHGRP are responsible for approximately 50% of the total U.S. carbon emissions. In contrast to the EU ETS, the GHGRP is not connected to a carbon emission reduction program and pricing mechanism. Consequently, improvements in carbon performance subsequent to the introduction of the GHGRP may be directly attributable to the mandatory reporting effect, and results are not distorted by carbon pricing effects.

Covering the period from 2007 to 2016, we apply a difference-in-differences design to estimate the effect of the GHGRP on the carbon performance of affected firms after its introduction

in 2010. Our results show that while there were no significant differences in the development of the carbon performance between firms affected by the GHGRP and unaffected firms prior to the introduction of the GHGRP, subsequent to its introduction affected firms show a stronger improvement in their carbon intensity. This observation is robust to changes in the difference-in-differences design and the sample composition. However, the analysis of absolute carbon emissions reveals a surprising result: Firms affected by the GHGRP did not reduce their absolute emissions as strongly as unaffected firms after the introduction of the GHGRP. Overall, our study provides evidence that the effect of the introduction of a mandatory climate reporting regulation is limited to improvements in firms' carbon intensity (meaning improvements in the efficiency of firms' carbon emission producing operations). That means a mandatory climate reporting regime, such as the GHGRP, can provide necessary incentives to limiting firms' contribution to climate change, but is not sufficient by itself to reach national or international climate goals.

The contributions of our study are fourfold. First, we add to the strand of literature that discusses *whether* climate reporting has implications on the carbon performance of reporting firms. Existing studies mainly focus on the effects of voluntary climate reporting (Haque & Ntim, 2018; Qian & Schaltegger, 2017), of mandatory climate reporting on firms' aggregated facility emissions falling under a certain regulation (Downar et al., 2021; Matisoff, 2013; Tomar, 2019) and of mandatory climate reporting on global firm carbon performance in a country with an existing carbon pricing scheme (Jouvenot & Krueger, 2020). We extend this scope by analyzing the impact of the introduction of a mandatory climate reporting regime on the global carbon performance of firms operating in a country without a national carbon pricing scheme. The extension to the global firm carbon performance is important because an analysis based on facility emissions that fall under a certain regulation cannot capture whether firms' shift emissions to unregulated facilities (i.e., in the case of the GHGRP, facilities in the United States that do not fall under the GHGRP as well as facilities outside of the United States). Moreover, a carbon pricing scheme may distort the effects of the mandatory climate reporting regime. Second, we contribute to the question *how* mandatory climate reporting might induce a real sustainable change in firms' operations. Drawing on and adding to legitimacy theory, we provide insight into how mandatory disclosure regimes can lead to different real outcomes compared with voluntary disclosures. Research argues that voluntary environmental reporting is used for impression management purposes to ensure firms' legitimacy without substantially changing their operations (Archel et al., 2009; Deegan, 2002; Delgado-Márquez et al., 2017; Haffar & Searcy, 2020; Kraft, 2018; O'Donovan, 2002). Under a mandatory climate reporting regime, substantial changes in firms' carbon emissions can be triggered, because opportunities for impression management are much more limited than under voluntary disclosure. Third, we provide new insights into the important differentiation of carbon intensity and absolute carbon emissions (Busch & Hoffmann, 2011). Although the studies by Downar et al. (2021), Jouvenot and Krueger (2020), and Tomar (2019) find improvements in both carbon performance variables, we obtain opposite results for the two variables, which underlines the need for more detailed investigations of the relationship between carbon intensity and absolute carbon emissions. Fourth, knowledge about the influence of climate policies on firms' carbon performance and the mechanisms of improvement is essential for the future design of policies toward a low carbon economy. Previous studies have focused on carbon taxes or ETS that are similar to the GHGRP in reporting requirements but connected to a carbon price (Bel & Joseph, 2015; Haites, 2018), or consider only emissions from electricity generation in a specific region (Murray & Maniloff, 2015). Current developments in CSR reporting are moving in the direction of mandatory reporting regimes, for example, the Corporate Sustainability Reporting Directive (CSRD) in the EU, the Large Employer Emergency Financing Facility (LEEFF) in Canada, or the Business Responsibility Report (BRSR) by the Security and Exchange Board of India. We show that in the case of the GHGRP, the introduction of a mandatory reporting regime that focuses on carbon emissions has limited but nevertheless positive

implications on firms' carbon performance, contributing to the discussion whether and how the reporting of nonfinancial information can materialize into a real outcome (de Bakker et al., 2020).

The remainder of this article is structured as follows. In "Theoretical Background, Related Literature, and Hypothesis Development" Section, we present the theoretical background, related literature and derive our hypothesis. "Research Design" section describes our research design. "Empirical Results" section presents the results of our empirical tests and is followed by a detailed discussion in "Discussion" Section. "Conclusion" section concludes our study.

Theoretical Background, Related Literature, and Hypothesis Development

Theoretical Background

Legitimacy theory describes firms as part of a broader social system, that is, the society (e.g., Deegan, 2002). Firms can only survive when society considers their operations legitimate. Suchman (1995) defines legitimacy as "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions" (p. 574). In other words, firms are considered legitimate if their activities do not violate the rules and values of the society (Dowling & Pfeffer, 1975). According to Deegan (2002), legitimacy is necessary for a firm's survival for two main reasons. First, legitimate firms have better access to critical resources, such as human and financial capital. Second, illegitimate firms could be confronted with various forms of retribution which threatens their ability to survive (e.g., loss of sales or fines). Consequently, firms try to align their operations with the (changing) rules and values of society to ensure their legitimacy, which is seen as a "license to operate" (Newson & Deegan, 2002).

Environmental legitimacy refers to the perception that a firm's environmental performance is congruent with society's rules and values. In this context, climate change has become an important issue. The growing concern about the speed and consequences of global warming as documented by the IPCC (Rogelj et al., 2018) has led to regulatory measures (e.g., the EU ETS) and rising public attention. The contribution of private firms to climate change is an important aspect in this debate (Carbon Disclosure Project [CDP], 2017). Although the United States have a mixed history of climate policy, failing to ratify the Kyoto Protocol and withdrawing from the Paris Climate Accord, climate change is a legitimacy issue for firms in the United States. Twenty-four U.S. states and the District of Columbia have established their own carbon emission reduction targets (Center for Climate and Energy Solutions, 2021). Firms also need to consider public opinion to maintain legitimacy and in the United States, 75% of survey respondents support the idea to "Regulate CO₂ as a pollutant," 70% think that "Corporations should do more to address global warming" and 60% believe "The President should do more to address global warming" and these opinions have not changed significantly since 2010 (Marlon et al., 2020). In 2008, Barack Obama's campaign also had a strong focus on climate change issues and emission reductions (Broder, 2008).

According to Dowling and Pfeffer (1975), there are three distinct approaches for firms to gain and maintain (environmental) legitimacy: first, the firm can adapt its structure by changing its goals, methods of operations and output. Legitimacy concerning a firm's structure is referred to as institutional legitimacy (Deegan, 2019). Second, the firm can try to manipulate society's norms and values through communication so that its practices appear legitimate. Finally, the firm can attempt, again through communication, to become associated with symbols or values, which appear congruent with the society's norms and values. The latter two strategies are often referred to as strategic legitimacy or impression management since they aim at changing stakeholders' perception of the firm without changing its operations (Deegan, 2019).

Related Literature and Hypothesis Development

Research has shown the examples of strategic legitimacy through the use of voluntary environmental reporting and impression management (Archel et al., 2009; Deegan, 2002; Delgado-Márquez et al., 2017; Haffar & Searcy, 2020; Kraft, 2018; O'Donovan, 2002). Some empirical studies show that poorer environmental performers are more likely to disclose nonfinancial information voluntarily to legitimize their poor performance (Cho et al., 2012; Cho & Patten, 2007; Patten, 2002). Specifically focusing on climate reporting, results are contradictory. Although Qian and Schaltegger (2017) and Siddique et al. (2021) suggest a positive relationship between carbon disclosure and carbon performance, Haque and Ntim (2018) find that firms adopting voluntary reporting guidelines, such as the guidelines from the Global Reporting Initiative (GRI), are more likely to implement carbon reduction measures, but do not improve carbon performance. Consistently, Belkhir et al. (2017) and Bernard et al. (2015) find no correlation between GRI reporting and firms' carbon emissions. We are investigating whether the introduction of mandatory reporting leads to real changes in firms' carbon performance, as in this scenario firms are no longer able to use reporting as an impression management tool.

Although several mandatory climate reporting regimes were implemented in recent years, investigations of their effect on firms' carbon performance are scarce (Hahn et al., 2015). Tang and Demeritt (2018) explore the rationales for and impacts of carbon reporting by means of a systematic documentary analysis and semi-structured interviews. They find that carbon reporting has an influence on internal operations and the public image of firms but less on firms' carbon performance. Downar et al. (2021) show for a sample of 24 firms headquartered in the United Kingdom that the introduction of the U.K. Companies Act 2006 (Strategic Report and Director's Report) Regulations 2013 led to an improvement in the firm carbon performance. However, Downar et al. (2021) focus on facility emissions falling under a certain regulation, not on firms' global direct emissions. Therefore, they do not control for a possible shift of emissions to facilities that operate outside of regulation. The same holds for Matisoff (2013) and Tomar (2019), who investigate the effects of different U.S. state-level mandatory climate reporting regimes (Matisoff, 2013) and the GHGRP (Tomar, 2019) and find no (Matisoff, 2013) and a positive (Tomar, 2019) effect on carbon performance. Moreover, in the setting of Downar et al. (2021), a carbon pricing mechanism, the EU ETS, already exist prior to the introduction of the new regulation, which makes it difficult to disentangle the effects of the mandatory reporting regime and the carbon pricing mechanism on carbon performance. The same applies to Jouvenot and Krueger (2020), who investigate the effect of the U.K. Companies Act on global firm-level GHG emissions.

Our study differs from these previous studies by assessing the effect of the introduction of a mandatory climate reporting regime on firms' global carbon intensity and absolute carbon emissions without the additional effects of a comprehensive carbon pricing scheme. This is necessary to derive implications for legitimacy theory, which assumes that firms adapt their operations (i.e., at least improve their carbon intensity) to meet societal values besides being motivated by regulatory pressure. Consequently, conclusions regarding legitimacy theory are limited for most of the aforementioned studies, because they are conducted in a setting with a carbon pricing scheme (e.g., the EU ETS).

In our setting, we argue that the collection and disclosure of carbon emission data through public institutions as well as easy and free access to the data might improve the trustworthiness of the data and enable society to surveil the development of firms' carbon performance. This leads to enhanced societal pressure on firms to improve their carbon performance.

Based on the arguments above, we formulate the following hypothesis:

Hypothesis 1 (H1): Firms affected by the GHGRP will improve their carbon performance subsequent to the introduction of the reporting regime to a greater extent than unaffected firms.

Research Design

Sample

We collect data from different sources for our analysis. We obtain carbon emission data from Trucost and cover the time period from 2007 to 2016. Trucost is a specialized provider of firm-level environmental information, which employs an “environmentally extended input-output” model that differentiates environmental impacts of 464 business activities to estimate emissions of nonreporting entities. Theoretically, in a voluntary carbon reporting environment, firms could make the choice to disclose their carbon emissions dependent on how well they perform. That means, firms which already have a good carbon performance or are on their way to achieve it will be more likely to disclose their emissions voluntarily, especially prior to the disclosure mandate. Firms with lackluster performance are more likely not to disclose. This would introduce a bias toward good carbon performers in our dataset and would make it more difficult to identify improvements in carbon performance. By using Trucost carbon emission data and including carbon emission estimations for nonreporting firms, we mitigate this bias. Busch et al. (2022b) show that the reliability and consistency of Trucost estimated Scope 1 emissions are similar to actual reported Scope 1 emissions. In addition, the inclusion of these estimations allows us to investigate carbon emissions before the respective firms started reporting or the mandatory regulation (i.e., the GHGRP) was introduced. This increases our overall sample size and helps reducing missing observations of nonreporting firms. Thus, the Trucost data are well suited as a base for our measures of carbon performance.

We exclude firms from the financial industry in our analysis, since these firms typically do not face issues in dealing with Scope 1 emissions and the unique characteristics of financial firms can skew results (Delmas et al., 2015). This leads to an initial sample of 1,458 U.S. firms with 8,017 firm-year observations. We then identify firms that own and operate facilities falling under the GHGRP by collecting facility information through the EPA Facility Level Information on Greenhouse Gases Tool (FLIGHT) and hand-match the International Securities Identification Number (ISIN) for each firm that is listed in the FLIGHT as a facility owner. In cases where a facility is not 100% owned by a single firm, we identify the firm owning the largest share as the principal owner. Using the ISIN, we then combine the carbon emission data from Trucost with the facility ownership information from the FLIGHT system. This allows us to split our full sample into a treatment sample of firms that own facilities subject to the GHGRP (i.e., regulated firms) and a control sample of firms that do not own such facilities (i.e., unregulated firms). The treatment sample contains 263 firms with 1,910 firm-year observations and the control sample 1,195 firms with 6,107 firm-year observations. We combine these carbon emission data with financial information from Refinitiv Datastream. Due to data availability, we arrive at a final sample of 1,454 firms and 7,961 firm-year observations. We winsorize all continuous variables in our analysis at the highest and lowest 1% level to curb the effect of potential outliers in the data.

Variables

In our analyses, the dependent variable is carbon performance. We operationalize this variable as a process-based measure, carbon intensity (*Scope 1 Intensity*), and as an outcome-based measure, absolute total emissions (*Log Scope 1*). *Scope 1 Intensity* is calculated as Scope 1 emissions (in metric tons) divided by total assets (in US\$1,000). It captures firms' efforts to

reduce carbon emissions in their operations, while controlling whether firms are expanding/reducing their operations (Busch et al., 2022a). The measure of intensity based on total assets captures the overall efficiency in firms' operations; however, it does not account for fluctuations (e.g., a "bad year" where sales decreased but assets remain unchanged). *Log Scope 1* is measured as the logarithm of a firm's total Scope 1 emissions. Taking the natural logarithm allows for better comparison between firms, since, for example, firms with high emission can also reduce their emissions more in absolute terms. In contrast to process-based measures, outcome-based measures like *Log Scope 1* are often not able to fully capture managerial efforts aimed at reducing carbon emissions, since they disregard changes in the amount of firms' operations (Busch & Hoffmann, 2011). However, absolute emissions are an important factor when it comes to evaluating any policy aimed at addressing climate change. Emission intensity and absolute emissions are thus complementary measures of firm carbon performance.

Both dependent variables, *Scope 1 Intensity* and *Log Scope 1*, build on the emissions targeted by the GHGRP, which are Scope 1 (direct) emissions. Although Scope 2 and 3 (indirect) emissions are important in certain industries, they are under the reporting firms' discretion to a much lesser degree than Scope 1 emissions and instead depend on other external factors, like energy prices or the availability of renewable energy providers in the reporting firms region. Therefore, we only focus on emissions that are directly affected by the regulation (i.e., Scope 1 emissions). Firms' total Scope 1 emissions are a good basis for our analysis because they are not affected if firms shift production (and, thereby, carbon emissions) from facilities falling under the GHGRP to other facilities (these can be facilities within the United States, which do not reach the threshold value of the GHGRP, or facilities outside the United States). Moreover, carbon emission data on facility level are only available after the GHGRP introduction, while firms' Scope 1 emissions are already available before the introduction. This enables us to measure changes in facility-based emissions around the GHGRP introduction. In our sample, direct facility-level emissions constitute the main portion of firms' Scope 1 emissions. On average, Trucost Scope 1 emissions of sample firms regulated by the GHGRP consist of 80% facility-level emissions, which are covered by the GHGRP and 20% other emissions (i.e., outside the GHGRP).

In our analysis, we investigate the effect of the GHGRP introduction on U.S. firms' carbon performance through a difference-in-differences estimation. With the introduction of the GHGRP in 2010 (i.e., the treatment), it became evident to firms that the data collected by the EPA would eventually be made public, and thus reporting high emissions might threaten a firm's legitimacy. Accordingly, we analyze effects following the treatment by creating a dummy variable *Post*. The variable takes the value of 0 for years before the treatment in 2010 and the value of 1 starting with the treatment year. We use a dummy variable *Treat* to capture firms affected by the GHGRP. *Treat* takes the value of 0 for firms that are not directly affected by the GHGRP (i.e., firms which do not own regulated facilities) and the value of 1 for firms that own regulated facilities and are thus directly affected. The interaction of *Post* with the *Treat* variable allows us to measure the difference in the carbon performance development between affected and unaffected firms after the treatment. For further analyses, we also create a subsample where treatment and control firms are limited to industries characterized by a high-emission intensity in the following sectors: Oil & Gas (ICB 0001), Basic Materials (ICB 1000), Industrials (ICB 2000), and Utilities (ICB 7000).

We also control for several other factors that could explain firms' carbon performance. The amount of property, plant, and equipment (PPE) indicates the extent to which a firm relies on physical production assets in its business. We measure *PPE Intensity* as the ratio of the net value of PPE to total assets. A high *PPE Intensity* indicates that a firm relies more heavily on physical production processes, which typically causes more carbon emissions compared with a firm, for example, from the service industry, which requires less PPE in its production

Table 1. Industry Composition of Samples.

	Number of unique firms	Full sample	Treatment sample	Control sample
Oil and gas	100	8.33 (633)	23.63 (447)	3.56 (216)
Basic materials	88	6.38 (508)	16.81 (318)	3.13 (190)
Industrials	360	25.10 (1,998)	16.97 (321)	27.63 (1,677)
Consumer goods	175	11.96 (952)	13.85 (262)	11.37 (690)
Health care	213	11.37 (905)	3.49 (66)	13.82 (839)
Consumer services	240	17.55 (1,397)	2.06 (39)	22.38 (1,358)
Telecommunications	18	1.32 (105)	0.53 (10)	1.57 (95)
Utilities	61	5.53 (440)	16.81 (318)	2.01 (122)
Technology	199	12.47 (993)	5.87 (111)	14.53 (822)
Sum	1,454	100 (7,961)	100 (1,892)	100 (6,069)

Note. Table 1 contains the industry composition as percentages for the full sample, the treatment sample, and the control sample. The number of firm-year observations is written in parentheses.

processes (Trinks et al., 2020). Therefore, we expect *PPE Intensity* to be positively correlated with carbon intensity and absolute carbon emissions. We use a firm's total assets as an indicator of firm size (variable *Total Assets*, denominated in billion US\$), which we expect to be negatively related to carbon intensity, because larger firms can have efficiency gains due to economies of scale (Clarkson et al., 2008) and positively correlated with absolute carbon emissions. We control for risk, operationalized as *Leverage* and calculated as the total long-term debt to common equity ratio. The reporting of carbon emissions is an essential indicator for a firm's environmental performance and the legitimacy of its ongoing operations in which debt-holders are particularly interested (Dhaliwal et al., 2014). Thus, we expect a positive correlation between leverage and carbon performance. Finally, we control for firms' profitability measured as the ratio of income before extraordinary items and total assets (*ROA*) (Barth et al., 2017), since profitable firms have more opportunities and resources available to implement measures to improve their carbon performance. This variable also controls for negative events, like a sharp decline in a firm's profitability (e.g., due to a sudden decrease on a firm's net sales).

Table 1 shows the industry distribution in percent of our sample. The treatment sample (i.e., firms that own regulated facilities) shows more firms from industries with a high-emission intensity (specifically Oil and gas, Basic materials, and Utilities) compared with the control sample (i.e., firms that do not own regulated facilities). This is unsurprising because the GHGRP targets specific high-emission facilities which are typically found in these industries. Although firms in other industries also started addressing the issue of carbon emissions before 2010 (e.g., Dell in 2002; Goldman Sachs in 2006; Nike in 2008 or Pfizer in 2002), a treatment sample consisting of more high-emission firms may introduce a bias because these firms could be more motivated to reduce emissions due to greater public attention.

Model and Measurement

We test our hypothesis through a difference-in-differences analysis, where *Post* identifies the pretreatment and treatment period and *Treat* captures whether a firm is affected by the GHGRP. Therefore, our regression model has the following form:

$$Scope\ 1\ intensity_{i,t} = \beta_0 + \beta_1 Post_t + \beta_2 Treat_i + \beta_3 Post_t * Treat_i + \beta_n \begin{pmatrix} PPE\ Intensity_{i,t} \\ Total\ Assets_{i,t} \\ Leverage_{i,t} \\ ROA_{i,t} \end{pmatrix} + \varepsilon_{i,t}.$$

We employ an ordinary least squares (OLS) regression with firm-clustered standard errors. The clustered standard errors help account for within-cluster correlation and heteroscedasticity (Gow et al., 2010; Petersen, 2009). We also test the parallel trend assumption that is underlying the difference-in-differences estimation method. We follow Chen et al. (2018) and apply a timing approach where we substitute our interaction term ($Post * Treat$) with timing variables, $year-1$ and $year+1$, which we individually interact with our treatment indicator to track the effect of the regulation over time compared with the benchmark year 2010. If the introduction of the regulation and the publication of carbon emission data have a causal effect on carbon performance, we should not see significant effects before each respective treatment. We test the parallel trend immediately around the introduction of the regulation to exclude other events that could influence firms' carbon performance. For example, the 2008 oil price drop or the release of the new IPCC Assessment Report in 2014 can influence firms and industries to different degrees and direct more attention toward the issue of climate change. Such events could potentially introduce confounding factors.

Empirical Results

Descriptive Statistics

Panel 1 of Table 2 shows the descriptive statistics of all the variables in our model after winsorizing at the highest and lowest 1% level. In the full sample, on average, firms have carbon emissions of 0.139t per 1,000 US\$ in total assets and value their total assets at 13.7 billion US\$. This translates to roughly two million tons of carbon emissions per year ($0.139 * 13.7$). They also own, on average, 0.295 US\$ in PPE per US\$ of total assets. In the sample comparison between regulated and unregulated firms, we find that carbon emissions (*Log Scope 1*) are higher in the treatment sample than in the control sample. *Scope 1 Intensity* is also higher in the treatment sample (an average of 0.361t of carbon emissions per 1,000 US\$ in total assets) compared with the control sample (an average of 0.070t of carbon emissions per 1,000 US\$ in total assets). The Industry Classification Benchmark (ICB) classifies listed firms according to their main source of revenue. Table 1 highlights the industry composition and the predominant industries of our U.S. treatment sample (i.e., the regulated firms). When comparing the full sample with our sample of firms in high-emission industries, we see that on average firms in the high-emission industries sample have a higher *Scope 1 Intensity* than the full sample (0.219t of carbon emissions per 1,000 US\$ in total assets compared with 0.139t in the full sample) but perform better than the sample of only firms regulated by the GHGRP. Although firms in the high-emission industries sample show similar *Total Assets* as the full sample firms, their *PPE Intensity* is substantially larger. Furthermore, more than 5% of firm-year observations have a leverage of 0.

Panel 2 of Table 2 also shows the Pearson correlation coefficients of our variables. Although all coefficients are significant at $p < .01$, the correlation coefficients are typically low. Even the highest coefficient values (correlation of *Log Scope 1* and *Scope 1 Intensity*; *Log Scope 1* and *PPE intensity*) do not exceed 0.6. Therefore, we do not expect issues with multicollinearity.

Base Analysis

The results of our base analysis, presented in Table 3, are in line with our hypothesis. Column (1) shows a significantly negative coefficient for the interaction term $Post * Treat$ (coefficient: 0.079;

Table 2. Descriptive Statistics and Correlations.**Panel 1**

Full sample

Variable	N	M	SD	p5	p50	p95
<i>Log Scope I</i>	7,961	11.437	2.491	7.651	11.212	16.224
<i>Scope I intensity</i>	7,961	0.139	0.384	0.001	0.020	0.821
<i>PPE intensity</i>	7,961	0.295	0.249	0.028	0.208	0.801
<i>Total assets</i>	7,961	13.735	32.869	0.370	4.091	52.985
<i>Leverage</i>	7,961	0.791	1.703	0.000	0.467	3.390
<i>ROA</i>	7,961	0.042	0.113	-0.127	0.051	0.169

Treatment sample

Variable	N	M	SD	p5	p50	p95
<i>Log Scope I</i>	1,892	13.875	2.118	10.600	13.783	17.557
<i>Scope I intensity</i>	1,892	0.361	0.575	0.006	0.106	1.594
<i>PPE intensity</i>	1,892	0.487	0.249	0.108	0.484	0.877
<i>Total assets</i>	1,892	26.675	52.545	1.060	9.945	109.892
<i>Leverage</i>	1,892	1.037	1.642	0.000	0.699	3.455
<i>ROA</i>	1,892	0.030	0.112	-0.124	0.038	0.143

Control sample

Variable	N	M	SD	p5	p50	p95
<i>Log Scope I</i>	6,069	10.677	2.076	7.386	10.600	14.220
<i>Scope I intensity</i>	6,069	0.070	0.265	0.001	0.015	0.220
<i>PPE intensity</i>	6,069	0.235	0.217	0.022	0.156	0.739
<i>Total assets</i>	6,069	9.701	22.099	0.307	3.117	40.865
<i>Leverage</i>	6,069	0.714	1.715	0.000	0.397	3.352
<i>ROA</i>	6,069	0.046	0.113	-0.129	0.055	0.174

High-emission industries sample

Variable	N	M	SD	p5	p50	p95
<i>Log Scope I</i>	4,561	12.295	2.404	8.815	11.962	16.802
<i>Scope I intensity</i>	4,561	0.219	0.481	0.003	0.038	1.242
<i>PPE intensity</i>	4,561	0.348	0.268	0.034	0.254	0.850
<i>Total assets</i>	4,561	13.387	32.613	0.526	4.368	48.575
<i>Leverage</i>	4,561	0.858	1.586	0.000	0.564	3.226
<i>ROA</i>	4,561	0.046	0.093	-0.075	0.050	0.158

Panel 2

Correlation coefficients

Variable	<i>Log Scope I</i>	<i>Scope I Intensity</i>	<i>PPE Intensity</i>	<i>Total Assets</i>	<i>Leverage</i>	<i>ROA</i>
<i>Log Scope I</i>	1					
<i>Scope I intensity</i>	0.5741*	1				
<i>PPE intensity</i>	0.5316*	0.3567*	1			

(continued)

Table 2. (continued)**Panel 2**

Correlation coefficients

Variable	<i>Log Scope 1</i>	<i>Scope 1 Intensity</i>	<i>PPE Intensity</i>	<i>Total Assets</i>	<i>Leverage</i>	<i>ROA</i>
<i>Total assets</i>	0.3535*	0.0475*	0.0635*	1		
<i>Leverage</i>	0.1124*	0.0446*	0.1233*	0.0573*	1	
<i>ROA</i>	0.1022*	-0.0362*	-0.0716*	0.0500*	-0.0759*	1

Note. Panel 1 of Table 2 contains the descriptive statistics of the full sample as well as the subsamples of only regulated firms, only unregulated firms and only firms in high-emission industries. Note that *Total Assets* is denominated in billion US\$. PPE = property, plant, and equipment.

Panel 2 of Table 2 presents the Pearson correlation coefficients for the full sample ($N = 7,961$), with *denoting a significance level of $p < .01$.

$p < .01$). That means, after the introduction of the GHGRP in 2010, firms in the treatment sample improve their carbon intensity significantly more than firms in the control sample. In addition, *Post* is also significantly negative (-0.017 ; $p < .1$) indicating that all firms improved their carbon intensity to some degree. This result also means that firms in the treatment sample reported a total change of *Scope 1 Intensity* of -0.096 after the GHGRP introduction ($0.017-0.079$). More specifically, based on the average *Scope 1 Intensity* for treatment firms in the pretreatment period (0.427),¹ the total reduction of *Scope 1 Intensity* translates into an improvement in carbon intensity of around 22.5% ($0.096/0.427$), while the improvement attributable to being affected by the GHGRP still amounts to around 18.5% ($0.079/0.427$).

We also investigate whether the introduction of the GHGRP had an effect on firms' absolute carbon emissions. The idea behind introducing legislation on firm carbon emissions is to counteract and prevent climate change. Achieving this goal requires an absolute reduction of carbon emissions. In Table 3, Column (3), *Post* has a significantly negative coefficient (-0.567 , $p < .01$) for *Log Scope 1*, which means that control firms have 43.3% less emissions in the posttreatment period on average than in the pretreatment period.² *Post**Treat** is significantly positive (0.252 , $p < .01$) indicating that treatment firms reduced their emissions significantly less than control firms, that is, $28.7\% = \exp(0.252) - 1$. More specifically, treatment firms decreased their absolute emissions following the GHGRP introduction by only 14.6% ($-43.3\% + 28.7\%$) compared with the 43.3% reduction of control firms. Note, while the reductions seem large at first, they represent the average improvement during the treatment period (2010–2016). Therefore, the effects on absolute carbon emissions are contrary to those by Jouvenot and Krueger (2020), who find a 12.19% reduction in global Scope 1 emissions relative to a control group during a treatment period from 2013 to 2016. This observation might be attributable to differences in the experimental settings, because in the study of Jouvenot and Krueger (2020), the carbon pricing scheme of the EU ETS might provide an additional incentive to reduce carbon emissions. For our sample of firms in high-emission industries, we find a similar treatment effect in the *Post**Treat** interaction term as in our full sample (-0.073 , $p < .10$). The total change in *Scope 1 Intensity* for treatment firms in this subsample was -0.143 ($-0.070-0.073$) and the total change in *Log Scope 1* is -18.9% , that is, $\exp(-0.613) - 1 + \exp(0.238) - 1$.

For our control variables, we see that firms with a higher *PPE Intensity* have a significantly higher carbon intensity and significantly higher absolute emissions. Our base analysis is also tested for parallel trends. Results are presented in Columns (2), (4), (6), and (8), showing no significant effects before or after the respective treatment year (variables: *Year-1**Treat** and *Year+1**Treat**). We, therefore, conclude that our results indeed measure the hypothesized event

Table 3. Regression Results of the Base Analysis Using the Full Sample and the High-Emission Industries Sample.

Carbon performance indicator	Full sample				High-emission industries sample			
	Scope 1 Intensity (1)	Log Scope 1 (2)	Scope 1 Intensity (3)	Log Scope 1 (4)	Scope 1 Intensity (5)	Log Scope 1 (6)	Scope 1 Intensity (7)	Log Scope 1 (8)
<i>Post*Treat</i>	-0.079*** (0.028)		0.252*** (0.097)	-0.179 (0.173)	-0.073* (0.041)	0.050 (0.063)	0.238*	-0.175 (0.236)
<i>Year-1*Treat</i>		0.050 (0.034)		-0.150 (0.171)		-0.003 (0.062)		-0.133 (0.234)
<i>Year+1*Treat</i>		0.018 (0.034)						
Post	-0.017* (0.009)		-0.567*** (0.054)		-0.070*** (0.024)		-0.613*** (0.086)	
Treat	0.248*** (0.054)	0.185*** (0.011)	1.753*** (0.174)	1.982*** (0.057)	0.234*** (0.089)	0.179*** (0.021)	1.360*** (0.257)	1.583*** (0.080)
<i>Year-1</i>		0.004 (0.018)		0.426*** (0.091)		0.037 (0.041)		0.457*** (0.154)
<i>Year+1</i>		0.004 (0.018)		0.338*** (0.090)		0.031 (0.041)		0.367** (0.153)
<i>PPE intensity</i>	0.411*** (0.060)	0.411*** (0.018)	3.733*** (0.262)	3.752*** (0.089)	0.447*** (0.095)	0.447*** (0.034)	3.240*** (0.390)	3.253*** (0.129)
<i>Total assets</i>	-0.000 (0.000)	-0.000 (0.000)	0.000*** (0.000)	0.000*** (0.000)	0.000 (0.000)	0.000 (0.000)	0.000*** (0.000)	0.000*** (0.000)
<i>Leverage</i>	-0.001 (0.005)	-0.001 (0.002)	0.054** (0.022)	0.053*** (0.012)	0.007 (0.013)	0.006 (0.005)	0.062 (0.045)	0.058*** (0.020)
<i>ROA</i>	-0.019 (0.046)	-0.014 (0.035)	3.026*** (0.299)	3.058*** (0.178)	0.129 (0.140)	0.165* (0.091)	1.894*** (0.528)	2.052*** (0.341)
Constant	-0.010 (0.013)	-0.024*** (0.007)	9.896*** (0.096)	9.386*** (0.035)	0.055 (0.034)	-0.007 (0.016)	10.677*** (0.149)	10.123*** (0.062)
Observations	7,961	7,961	7,961	7,961	3,609	3,609	3,609	3,609
R ²	0.166	0.163	0.496	0.496	0.136	0.130	0.473	0.468
Firms	1,454	1,454	1,454	1,454	609	609	609	609
Cluster	Firm	—	Firm	—	Firm	—	Firm	—

Note. Table 3 presents the regression results of our base analysis with *Scope 1 Intensity* and *Log Scope 1* as the dependent variables for our full sample and our high-emission industries sample. Columns (1)–(4) contain regression models based on the full sample and Columns (5)–(8) contain regression models based on the high-emission industries sample. PPE = property, plant, and equipment.

Standard errors are in parentheses.

* $p < .1$. ** $p < .05$. *** $p < .01$.

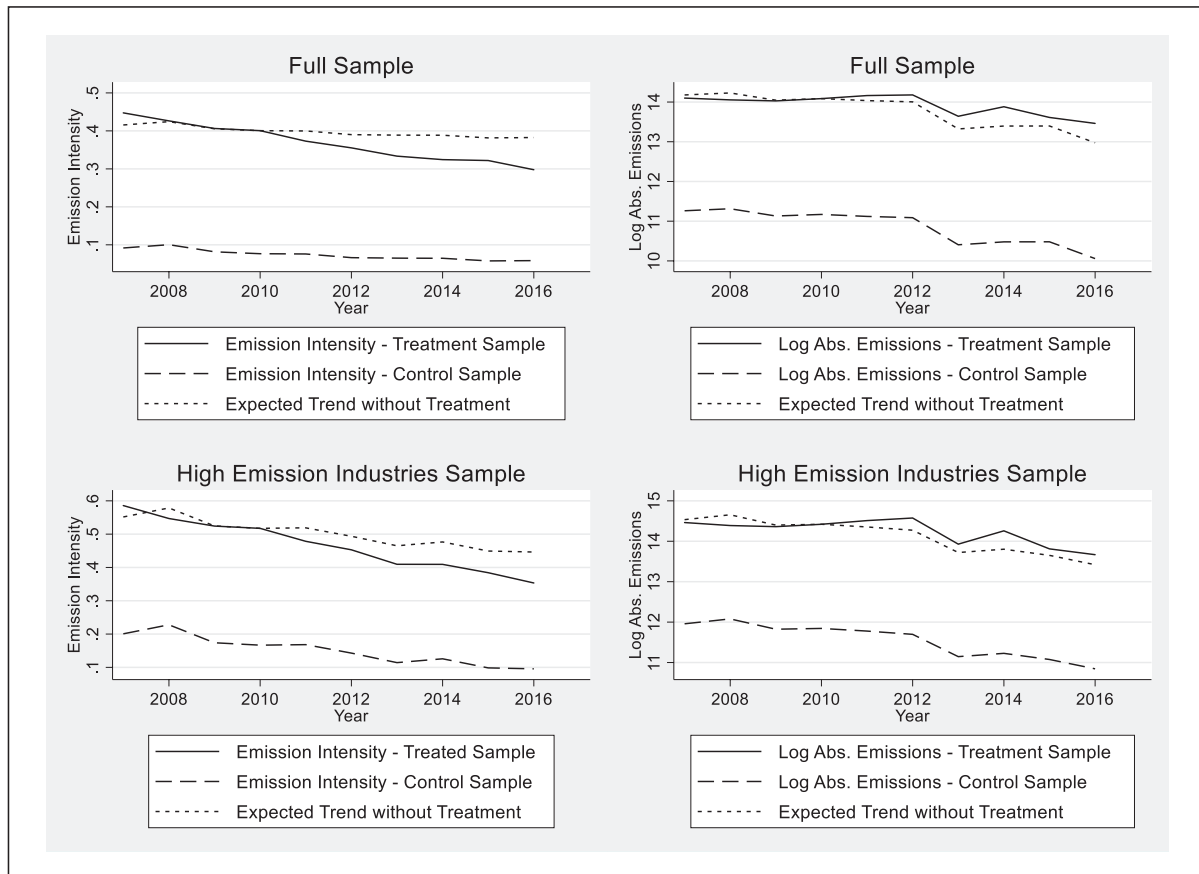


Figure 1. Graphic Representation of the Parallel Trend Assumption.

Note. Figure 1 presents the parallel trends of treatment and control firms before the introduction of the Greenhouse Gas Reporting Program (GHGRP) and the divergence afterwards for our full sample and our sample of firms from high-emission industries. The left column shows the results for emission intensity and the right column shows the results for log absolute emissions.

and its effect on carbon performance. This can also be observed in a graphical representation of the parallel trends in emission intensity (Figure 1). The continuous line represents the treatment firms and the dashed line the control firms. The dotted line shows the expected development of emissions if the treatment did not have any influence on the treatment firms and the parallel trend continued after the treatment.

Overall, we interpret the results as an indication that firms forced to disclose their facility-level emissions to the EPA perceive this requirement as a potentially legitimacy-threatening issue to which they respond with substantial efforts to improve carbon intensity. Therefore, the mandated disclosures can play a role in motivating firms to assume responsibility to mitigate their carbon emissions (World Commission on the Ethics of Scientific Knowledge and Technology, 2010). Our findings show that a mandate to disclose carbon emissions—even if it is restricted to the facility level—improves firm-level carbon intensity, but at the same time reduces the motivation to decrease absolute carbon emission. This is in line with studies showing that the relation between disclosure and carbon performance is not consistently confirmed by empirical literature (Belkhir et al., 2017; Bernard et al., 2015).

Furthermore, our results for carbon intensity are in line with studies confirming carbon performance improvements based on facility emissions falling under a mandatory disclosure regulation (Downar et al., 2021; Tomar, 2019). But we show that such improvements are not consistent across different definitions of carbon performance (i.e., intensity measures vs. absolute measures) on a global carbon emission level and in the absence of a national carbon pricing scheme.

Additional Analyses

First, in the U.S. setting, we compare firms directly affected by the GHGRP with firms that are not affected. The GHGRP focuses on firms in high carbon-emitting industries, and despite our efforts to create a comparable sample using only high-emitting industries, the results could also be affected by other events in the same years, which affected the carbon performance of the treatment firms more than the carbon performance of the control firms. For example, from 2009 to 2010, the oil price increased considerably. Therefore, our first additional analysis focuses on a comparison of the treatment firms within the United States with firms outside the United States, which have similar characteristics to the treatment firms. We use firms from the EU, which are affected by the EU ETS, for comparison, because the EU ETS focuses on similar firms (i.e., high-emitting firms). Indeed, both regulations are similar in their focus on facilities with emissions above an annual threshold of 25,000 metric tons. However, the EU ETS is connected to a price on carbon and it was introduced in 2005. That means, comparable EU firms do not undergo significant changes in EU ETS regulation between 2009 and 2010 because they have already undergone these changes. Early opportunities for carbon emission reductions would have been realized a while ago and firms under the EU ETS have had several years of experience with the regulation and reporting at the time the GHGRP was introduced in the United States. Since we can thus expect that firms in the EU are on a stable trajectory in terms of carbon emissions and should not show sudden reactions, they are a suitable control group for U.S. firms that face a new regulation.

We gather information about firms affected by the EU ETS similarly to those affected by the GHGRP. We collect the facility-level carbon emission data from the database Carbon Market Data and use the database's matching of facilities to firms and additionally add ISIN identifiers manually, where they are missing. Afterward, we use the same model as in our previous analysis to calculate the difference-in-differences between U.S. and EU firms that are subject to a mandatory reporting regime. We also collect monthly carbon price information from the European Energy Exchange and calculate annual average EU ETS allowance prices, which we use as an additional control variable (*ETS Allowance Price*).

Table 4 shows results of the US-EU difference in difference model. Column (1) presents a significant coefficient for *Post*Treat* (-0.141 ; $p < .01$), indicating that U.S. firms improve their carbon intensity significantly more than their European counterparts after the GHGRP was introduced. This is consistent with our expected effect of the GHGRP regulation. Although EU firms could have experienced earlier opportunities to reduce emissions after the introduction of the EU ETS, these effects should no longer play a role in 2010. This is also what we find empirically. Although firms affected by the EU ETS show a better carbon intensity compared with GHGRP firms (0.259 vs. 0.427) and lower average emission levels (6.76m tCO₂e vs. 7.12m tCO₂e) before 2010, after the GHGRP introduction, U.S. firms caught up and improved carbon intensity to 0.339 and average emissions 6.20m tCO₂e (these figures are not reported in the tables of this study). This might seem to be a surprising result at first, because the EU regulation affects the same industries and has an additional carbon price attached to it. However, we do not see a significant effect from the allowance price in our regression analysis, which is consistent with the common assessment that the early phases of the EU ETS failed to incentivize investments in emission-reducing measures, due to an oversupply of emission allowances and thus too low allowance prices (Edenhofer et al., 2017). In fact, during our sample period, the average allowance price fluctuated around 10€ per metric ton of carbon emissions, with 12.65€ in 2009 and 16.28€ in 2010.

Although the EU and U.S. firms affected by their respective regulation can be expected to be very similar, the setting is not ideal for a difference-in-differences analysis because our control firms (EU firms) are not free of any treatment (they just received the treatment much earlier).

Table 4. Regression Results of the Comparison Between the United States and the EU and the United States and the Rest of the World.

	United States/EU		United States/rest of the world	
	(1)	(2)	(3)	(4)
<i>Post</i> × <i>Treat</i>	-0.141*** (0.041)		-0.062* (0.033)	
<i>Year-1</i> × <i>Treat</i>		0.118*** (0.030)		0.069*** (0.027)
<i>Year+1</i> × <i>Treat</i>		-0.037 (0.040)		0.015 (0.025)
<i>Post</i>	0.047 (0.031)		-0.041** (0.019)	
<i>Treat</i>	-0.022 (0.080)	-0.167** (0.077)	-0.202*** (0.060)	-0.256*** (0.047)
<i>Year-1</i>		-0.062*** (0.022)		0.000 (0.016)
<i>Year+1</i>		0.047 (0.036)		-0.018 (0.015)
<i>ETS allowance price</i>	0.001 (0.002)	-0.002 (0.002)		
<i>PPE intensity</i>	0.853*** (0.138)	0.850*** (0.137)	1.222*** (0.106)	1.221*** (0.106)
<i>Total assets</i>	-0.000* (0.000)	-0.000* (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
<i>Leverage</i>	-0.010 (0.015)	-0.011 (0.015)	0.024* (0.013)	0.023* (0.013)
<i>ROA</i>	0.479*** (0.175)	0.490*** (0.177)	0.913*** (0.215)	0.935*** (0.217)
Constant	0.048 (0.068)	0.118* (0.066)	0.012 (0.041)	-0.016 (0.039)
Observations	2,908	2,908	7,710	7,710
R ²	0.111	0.108	0.144	0.143
Firms	371	371	1,096	1,096
Cluster	Firm	—	Firm	—

Note. Table 4 presents the regression results of the comparison United States/EU and United States /rest of the world with *Scope 1 Intensity* as the dependent variable and the treatment year 2010 (*Post*) in all regression models. In the United States–EU comparison, *Treat* identifies firms that fall under the GHGRP or the EU ETS regulation. In the United States –rest of the world comparison, *Treat* identifies U.S. firms that fall under the GHGRP and the worst emitters in certain high-emission industries in the rest of the world. Column (1) shows the results of the comparison between U.S. and EU firms and Column (3) shows the results of the comparison between U.S. firms and firms in the rest of the world, excluding the EU. Columns (2) and (4) contain the respective parallel trend tests. ETS = Emissions Trading System; EU = European Union; PPE = property, plant, and equipment. Standard errors are in parentheses.

* $p < .1$. ** $p < .05$. *** $p < .01$.

Therefore, we add a second analysis, and compare U.S. firms affected by GHGRP to high carbon-emitting firms located in the rest of the world which are not affected by the GHGRP. We use the same identification strategy as in our high-emission industries subsample. Thus, we identify firms that should operate similar facilities to their U.S. counterparts in the most emission-intensive industries. We then proceed, as previously, by conducting a difference-in-differences analysis, including a test for parallel trends. Results in Table 4, Column (3), contain a significantly negative coefficient for *Post* × *Treat* (-0.062 ; $p < .01$), meaning that U.S. firms improved their carbon intensity significantly more than similar firms outside the United States. This finding further confirms our base analysis results and supports the notion that mandatory climate reporting is an effective tool to improve firm carbon intensity.

We also perform a number of additional robustness tests. First, when there are concerns that the treatment sample is not randomly selected, which typically is the case in real world settings, propensity score matching can be used to make the treatment and control samples more comparable regarding the observable variables (Chen et al., 2018). By matching treatment with control firms using the variables from our base analysis, we generate a sample that allows us to compare firms, which are similar in their emissions and firm characteristics in the pretreatment period (2009) but differ in whether they are affected by the GHGRP. Applying an OLS regression model to the propensity score-matched sample leads to qualitatively similar results as our base analysis.

Second, we apply a fixed effects regression model with firm-clustered standard errors, which helps control for omitted variable bias. Firm fixed effects allow us to control for unobserved firm-specific characteristics, whereas year fixed effects control for overall time series effects like additional confounding events. The fixed effects models confirm our initial hypothesis tests. Third, we test a specification of our base model without control variables to see if our results hold. Fourth, we test our base model using the Huber–White sandwich estimators, which are robust to heteroscedasticity (White, 1980). Fifth, we also use both, metric tons of Scope 1 emissions and Scope 1 intensity, calculated as the ratio of Scope 1 emissions to PPE and the ratio of Scope 1 emissions to sales, as alternative dependent variables for our base model. Sixth, we test our parallel trend assumptions for all analyses using different variations of placebo years and estimation methods. Finally, we limit our sample period to the years directly surrounding the introduction of the GHGRP in 2010 (sample limited to 2008–2012). All of these tests show qualitatively similar results to our base analysis.

Discussion

In case of voluntary environmental reporting, extensive literature has argued that it could be used for impression management purposes to gain or maintain (strategic) legitimacy (Archel et al., 2009; Deegan, 2002; Delgado-Márquez et al., 2017; Haffar & Searcy, 2020; Kraft, 2018; O'Donovan, 2002). Consequently, firms may disclose their environmental performance to manipulate society to obtain its support and approval because it is often easier to manage a reputation than to make real sustainability improvements (Dowling & Pfeffer, 1975; Lyon & Maxwell, 2011; Neu et al., 1998). In line with that, some studies find that poorer environmental performers are more likely to disclose nonfinancial information voluntarily to legitimize their poor performance (Cho et al., 2012; Cho & Patten, 2007; Patten, 2002) and that voluntary carbon reporting is not followed by improvements in carbon performance (Belkhir et al., 2017; Bernard et al., 2015; Haque & Ntim, 2018). Some researchers even argue that voluntary reporting might negatively affect social progress, that is, firms' sustainability performance (Deegan, 2019). Our study cannot fully confirm this observation for mandatory carbon reporting. Although the smaller reduction in absolute carbon emissions suggests that firms required to report under the GHGRP are reducing their efforts to decrease absolute emissions, the results also show increasing efforts to improve carbon intensity. It appears that firms do not or cannot use mandatory reporting entirely as an impression management tool. This could be due to the fact that, in contrast to voluntary reporting, the mandatory reporting under the GHGRP does not allow firms discretion in the selection of data to be reported and in its presentation, which would be necessary in the context of impression management and strategic legitimacy (Deegan, 2019). Firms can no longer control the “story” under the GHGRP, because the data are made available to the public in a standardized form on the EPA website. Without the opportunity to manipulate society, to communicate a certain carbon performance to the outside, firms are forced to increase at least certain aspects of carbon performance to act in accordance with society's expectations.

The success of the Toxic Release Inventory (TRI) in the United States confirms this reasoning and serves as anecdotal evidence of the effect of an environmental reporting regulation. Since its implementation in 1988, the TRI tracks the management of certain toxic chemicals that may pose a threat to the environment (EPA, 2019). U.S. facilities in different industries must annually report how much of each chemical they release into the environment or manage through recycling, energy recovery, and treatment. The reporting is mandatory when the use of these chemicals exceeds established levels. Currently, the TRI covers more than 650 different toxic chemicals. In 1995, 7 years after its implementation, the release of covered chemicals declined by 45% (Fung & O'Rourke, 2000). In their assessment of the TRI, Fung and O'Rourke (2000) attribute its success, among other things, to the possibility for citizens to inform themselves about toxic

chemical releases and the resulting public pressure on polluting firms. Both, the TRI and the GHGRP, are pure mandatory reporting regimes, in the sense that they are not explicitly linked to any reduction programs.

A key feature of our study is the use of two measures of carbon performance, namely carbon intensity and absolute carbon emissions. The advantage of process-based measures (carbon intensity) over absolute measures (absolute carbon emissions) is that the former take into account changes in the scale of firms' operations and thus capture the efficiency of operations while the latter do not (Busch & Hoffmann, 2011). Our results confirm that firms affected by the GHGRP improve their carbon intensity more than firms in the control sample. As argued above, this indicates that the introduction of the GHGRP motivates real changes in the efficiency of operations. However, at the same time, we find a significantly smaller percentage reduction in absolute carbon emissions for reporting firms compared with nonreporting firms. At first sight, this may be a consequence of increasing business operations. However, we address this issue through a number of control variables such as PPE intensity, firm size, leverage, and profitability. Alternatively, firms with high carbon emissions might be able to show impressive absolute emission reductions, which are still relatively smaller than for firms with lower carbon emissions. For example, a firm with 10 million tons of yearly Scope 1 emissions reports a decrease of an impressive 500,000 tons, which would mean a 5% decrease. At the same time, a firm with one million tons of yearly Scope 1 emissions reports a decrease of 90,000 tons, which would amount to a 9% decrease.³ Therefore, the reporting scheme might increase the motivation to report large absolute emission reductions, but it might not extend to also achieve large relative improvements. Considering that especially for carbon-intensive sectors entirely decoupling carbon emissions from business activities is often difficult, firms might deem it sufficient to show at least some improvements to secure their legitimacy (e.g., Haberl et al., 2020). Therefore, our study emphasizes the importance to consider both types of variables, intensity and absolute measures, when evaluating a legislative measure to address climate change. However, while absolute emissions show firms' progress toward reaching the overall important goal of net zero emissions, carbon intensity shows their progress on the transition toward this target. In the short term, it is thus not necessarily negative if firms with improving carbon intensity, at the same time, show no improvements in total emissions. This could mean that their business is growing, crowding out competitors with inferior carbon intensity, thus contributing to the overall reduction of a given sector's emissions.

Future research could provide additional insights into the discrepancy between intensity and absolute emission measures. For example, future research might analyze how firms approach carbon emission reduction efforts through improving operational efficiency, outsourcing, offsetting, or adapting business models and how these in turn affect absolute emissions and emission intensity. It may also prove useful to explore how society's expectations are perceived by firms in the United States and what repercussions are expected or experienced for noncompliance. The GHGRP provides firms in the United States with a standardized framework by which they can compare their own carbon performance with that of their peers. Whether this information could lead to firms reducing their emission reduction efforts because the urgency to act is actually lower than anticipated could be explored in a future study.

Conclusion

We analyzed whether and how the introduction of a mandatory climate reporting regime leads to improvements in firms' carbon performance. A reason for firms to improve carbon performance might be the need to secure legitimacy, given the public disclosure of carbon emission data and increasing societal expectations that firms limit their contribution to climate change. In our setting, we use the GHGRP, which was introduced in 2010. We find that the carbon intensity of U.S.

firms affected by the GHGRP improved significantly more than the carbon intensity of unaffected U.S. firms. At the same time, regulated U.S. firms reduced their absolute carbon emissions less than unregulated U.S. firms. These seemingly contradictory results may be worth further exploration. Although we control for several possible explanations, such as changes in firm size, leverage or profitability, there may be additional unobserved differences, like specific firm-level differences in the ability to decouple emissions from production. However, a mandatory reporting regulation leads to real sustainable change in firms' operations and can be a stepping stone for further regulation. The detailed emission information of the GHGRP, including location, could create pressure, particularly from U.S. states that have set individual emission reduction targets, like California, which in 2018 passed legislation toward achieving carbon neutrality by 2045 (Executive Department, State of California, 2018) or New Mexico, which in 2019 committed to reducing carbon emissions by 45% below 2005 levels (Executive Office, State of New Mexico, 2019).

To achieve any climate goals, firms must improve their carbon performance including their absolute emissions. Tomar (2019) has shown that individual facilities reduce their absolute carbon emissions subsequent to the GHGRP introduction, because managers in these facilities learn and profit from experience of surrounding businesses in terms of carbon management. Our results suggest that carbon management experience from individual facilities can translate to improvements in the efficiency of operations throughout the entire firm and decrease carbon intensity. However, results for absolute carbon emissions suggest that learnings from individual facilities on how to decrease carbon emissions do not enable firms to fundamentally disconnect their business growth from the amount of absolute emissions.

Our study and its results contribute to research in four ways. First, we add to the discussion *whether* climate reporting has implications on firms' carbon performance. Literature on voluntary climate reporting identifies either no or limited effects on firms' carbon performance (Haque & Ntim, 2018; Qian & Schaltegger, 2017). Existing studies of the effect of mandatory climate reporting focus on firms' aggregated facility emissions falling under a certain regulation (Downar et al., 2021; Matisoff, 2013; Tomar, 2019) or on the global carbon performance of firms headquartered in a country with an existing carbon pricing scheme (Jouvenot & Krueger, 2020). We contribute to this literature by showing that the introduction of a mandatory climate reporting regime has a positive impact on the global carbon intensity of firms headquartered in a country without a national carbon pricing scheme. Second, we explain *how* mandatory climate reporting might lead to a sustainable change in firms' operations, drawing on and contributing to legitimacy theory. We argue that, opposed to voluntary reporting, under mandatory reporting firms cannot rely on strategic legitimacy and impression management, but are motivated to show real changes in firms' operational efficiency (institutional legitimacy) leading to an improved carbon intensity. Third, we provide new insights into the important firm-level distinction between carbon intensity and absolute carbon emissions. Downar et al. (2021) and Tomar (2019) find improvements for both carbon intensity and absolute carbon emissions calculated based on firms' aggregated facility emissions falling under a mandatory climate reporting regulation. However, we show that this is not the case when carbon intensity and absolute carbon emissions are calculated based on firms' global emissions. Although firms in our sample reduce their absolute carbon emissions after the GHGRP introduction on average, regulated firms do so to a lesser degree than unregulated firms. The same is true when only looking at high-emission industries. The reduction of absolute emissions is an essential measure for firms because it relates to the remaining global carbon emission budget that is left, according to the IPCC assessments, to have a chance of staying below 1.5°C global warming. Thus, the reduction of the overall carbon emissions in the economy is key to mitigate climate change. In the short term, firms with superior carbon intensity can contribute by crowding out competitors with inferior carbon performance, but in the long term, most likely, reductions in absolute emissions will be required. Although

Aragón-Correa et al. (2020) argue that mandatory regulation typically has a strong positive effect on firms' sustainability performance, it is important to consider the specific nature of the climate change problem. Due to the finite nature of the remaining carbon budget to remain under 1.5°C or 2°C a positive change in individual firms' carbon intensity may be a step in the right direction but is in itself not enough to solve the problem. Fourth, we add to the literature about the effectiveness of policy designs aimed toward a low carbon economy (Bel & Joseph, 2015; Haites, 2018; Murray & Maniloff, 2015). We show that mandatory climate reporting contributes directly to improved carbon performance and, therefore, deserves political consideration. Thereby, we also contribute to previous literature on the real effect of mandatory disclosure (Chen et al., 2018; Christensen et al., 2017). Although previous literature shows significant improvements in firms' sustainability performance after the introduction of respective disclosure mandates, our results also show that such improvements cannot be expected across the board. Given the current international development toward more mandated disclosures, such as the CSRD in the European Union, the LEEFF, or the requirement to disclose a BRSR by the Security and Exchange Board of India, future research can build on many opportunities to analyze the effectiveness of different systems in safeguarding capital markets and improving firms' sustainability performance.

Some limitations of our research design are worth mentioning because they highlight the potential for further research, and they emphasize careful interpretation of our results. The nature of a mandatory climate reporting regime is to target high-emitting facilities. Thereby, our sample is not based on a random assignment of firms to the treatment and control samples. That means, as in many real-world cases, we cannot create a perfect experimental setting. However, we address this issue through a number of control variables, the propensity score matching, and additional analyses to the best extent possible. With a general tendency toward more climate reporting, there are more opportunities to analyze the effectiveness of mandatory climate reporting regimes in different institutional contexts. In addition, due to the nature of our setting, there is no information about firms, which do not voluntarily report firm-level carbon emissions. We rely on estimates from Trucost for these firms. Therefore, if Trucost's estimation process is systematically flawed, this would affect our results. However, according to Busch et al. (2022b), the consistency and reliability of estimated emissions are not significantly different from reported carbon emission data. Furthermore, due to the nature of the GHGRP and its focus on facility-level emissions, we have used Scope 1 emissions to measure carbon performance. Although Scope 1 emissions, especially in high-emission industries, are an important factor in combatting climate change, the implications we draw do not necessarily hold true to the same extent for Scope 2 and Scope 3 emissions. Especially, Scope 3 emissions are, however, another key factor to achieve climate goals.

Further research can analyze whether mandatory climate reporting regimes affect the negative firm value effect of carbon emissions (Grewal et al., 2019; Griffin et al., 2017; Matsumura et al., 2014). Moreover, our research is focused on the GHGRP, a regulation specific to the United States and only targeting certain high-emission facilities. Therefore, our results do not necessarily translate to other regulatory settings. Future research can address whether other regulatory settings or current policy developments, such as the EU taxonomy on sustainable activities, can better motivate firms to identify critical processes to improve their absolute carbon emissions in alignment with Paris Climate Accord. Considering our somewhat surprising results that the GHGRP does not motivate regulated firms to reduce their absolute carbon emissions proportionally more than unregulated firms, future research can also analyze the underlying reasons. For example, it remains unclear why firms can improve their carbon intensity but are unable to disconnect their operations from absolute carbon emissions. Finally, while this study focuses on *whether* and *how* mandatory climate reporting has implications on firms' carbon performance, further knowledge about the causal chain that connects mandatory nonfinancial disclosure to

sustainability-related outcomes, and how managers adapt their behaviors and transform organizational policies, practices, and procedures is needed (Wickert & Risi, 2019).

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ORCID iDs

Thomas Pioch  <https://orcid.org/0000-0003-1019-6759>

Frank Schiemann  <https://orcid.org/0000-0002-7817-7792>

Notes

1. Unreported results.
2. Please note that due to the log transformation of the outcome variable *Log Scope 1*, the *Post*Treat* coefficient must be exponentiated for correct interpretation, that is, $\exp(-0.567) - 1 = -0.433 = -43.3\%$.
3. Such a scenario is not unlikely in our setting, because the treatment firms have on average substantially higher carbon emissions than the control firms (see Table 2).

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Author Biographies

Tobias Bauckloh is an Assistant Professor at the University of Cologne. He received his Ph.D. from the University of Kassel. His research focus is on the contribution of sustainable investments to solve societal challenges, the impact of sustainability on the performance of investments and regulations to promote sustainability in the investment process.

Christian Klein is a Professor at the University of Kassel. He received his Ph.D. at the University of Augsburg. His research focus is on private and institutional sustainable investors, sustainability on the capital market and financial and sustainability performance of sustainable investments.

Thomas Pioch is a Ph.D. candidate at the University of Bamberg. His research focus is on corporate carbon emission disclosure regulation, reporting accuracy and motivation of firms to reduce their carbon footprint.

Frank Schiemann is a Professor at the University of Bamberg. He received his Ph.D. at the University of Dresden. His research focus is on sustainability reporting and accounting, development and consequences of (mandated) corporate climate-related reporting and materiality in the context of sustainability disclosures.

Paper 4

What drives carbon-reducing investments? A vignette experiment on managers' decision making at the intersection of institutional-, organizational-, and individual-level factors.

RESEARCH ARTICLE OPEN ACCESS

What Drives Carbon-Reducing Investments? A Vignette Experiment on Managers' Decision-Making From a Multilevel Perspective

Rüdiger Hahn¹  | Thomas Pioch²  | Daniel Reimsbach^{3,4}  | Frank Schiemann² 

¹Faculty of Business Administration and Economics, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany | ²Faculty of Social Sciences, Economics and Business Administration, University of Bamberg, Bamberg, Germany | ³Faculty of Business Administration and Economics, University of Paderborn, Paderborn, Germany | ⁴Faculty of Management, Radboud Universiteit, Nijmegen, Netherlands

Correspondence: Frank Schiemann (frank.schiemann@uni-bamberg.de)

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ABSTRACT

Our study aims to shed light on the factors that drive managers' sustainability-related decision-making. We take a multilevel perspective, analyzing individual-, organizational-, and institutional-level factors, which allows us to present a coherent account of a complex environment of influential factors. Based on an explorative vignette experiment with professional managers in a setting related to carbon-reducing investments, we find that certain individual-level factors, such as managers' biospheric orientation or a strong belief in business ethics, are associated with higher carbon-reducing investments. However, these individual-level factors do not alter the overall influence of organizational- and institutional-level factors. The financial impact of carbon-reducing investments—at the organizational level—as well as the number of carbon-conscious investors and the regulatory disclosure regime in which a firm operates—at the institutional level—significantly drive managers' investment decisions. We find only a few instances in which specific factor combinations are decision-relevant. These findings have important implications for research and policymaking with regard to improving corporate sustainability in general and particularly reducing corporate carbon emissions.

1 | Introduction

The enduring debate between structure and agency (Cardinale 2018; Harmon, Haack, and Roulet 2019)—whether individual managers' actions or broader organizational and institutional constraints shape decision-making—has profound implications for understanding managerial behavior. This dichotomy, central to general management literature, has increasingly entered sustainability management research, where the tension between personal values and systemic pressures becomes especially pronounced (Glavas 2016; Gond et al. 2017). Our study contributes to this discourse, exploring

how individual, organizational, and institutional factors collectively influence managers' sustainability-related decisions. By addressing these intertwined levels, we aim to illuminate how carbon-reducing investments, a pressing challenge for corporate leaders, are shaped by both the freedom and the constraints managers navigate.

At the individual level, personal values, beliefs (Glavas 2016; Gond et al. 2017; Lülfs and Hahn 2014), and risk preferences (Hossain, Saadi, and Amin 2023; Slawinski et al. 2017) shape managers' actions, often requiring alignment with broader organizational goals. Organizational factors, such as the

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financial viability of sustainability projects (e.g., Griffin, Lont, and Sun 2017; Matsumura, Prakash, and Vera-Muñoz 2014), current sustainability performance (e.g., Trumpp and Guenther 2017; Yang, Zhu, and Albitar 2024), and management tools (e.g., Ott and Endrikat 2022; Yong et al. 2020), can either enable or constrain sustainable investments. Meanwhile, institutional pressures, including investor expectations and regulatory requirements, further shape managerial decisions (e.g., Durand, Hawn, and Ioannou 2019; Mittelbach-Hörmanseder, Hummel, and Rammerstorfer 2021).

Although prior research has provided important insights into these levels individually, less attention has been paid to their simultaneous and interactive effects. A simultaneous investigation would help to identify the relative importance of these factors and how they may interact with one another. Although the need for multilevel research is well acknowledged (Athanasopoulou and Selsky 2015; Felin, Foss, and Ployhart 2015), the literature offers limited approaches and insights in this regard (for an exception, see Muller and Kolk 2010). This is particularly important because the embedded nature of the different levels (Harmon, Haack, and Roulet 2019) influencing managerial decision-making suggests potential interactions or dependencies. Managers operate in an organizational context that shapes their decision-making, whereas both managers and organizations are embedded in an institutional context that further influences behavior (Athanasopoulou and Selsky 2015). Furthermore, although individual-level factors in managerial decision-making have gained increasing attention within the “microfoundations movement” (Felin, Foss, and Ployhart 2015) in management research (Glavas 2016; Gond et al. 2017), concerns persist that this area remains underexplored (Boone et al. 2022). Especially from a broader sustainability management research perspective, there have been recent calls to bring “values back in” (Risi et al. 2022) and to explore why managers, and consequently firms, act more or less sustainably. To address these shortcomings, our study seeks to answer the following research question: *How do individual, organizational-, and institutional-level factors drive managers' sustainability-related decision-making?*

To give our study a concrete setting, we examine decision-making related to carbon-reducing investments. Reducing carbon emissions is one of the most urgent societal imperatives of our times (Howard-Grenville et al. 2014), and this responsibility falls heavily on the corporate sector. Ultimately, it is managers who must decide whether to invest in carbon-reducing initiatives (He et al. 2022), making it crucial to understand the factors that drive these decisions. Thus, the decision to invest in carbon reduction serves as an ideal case to investigate how managers' sustainability-related decision-making may be influenced by factors at different levels.

In considering the factors that influence managerial decision-making, we examine whether individual-level factors, such as personal values, beliefs, and risk preferences, impact managers' investment decisions, and the extent to which these factors interact with institutional and organizational factors. For methodological and content-related reasons, we focus on five factors at the organizational and institutional levels: relative carbon performance, the financial impact of an investment, and incentive system design (organizational level), as well as

investor orientation and carbon disclosure regime (institutional level). Given the potentially vast interactions across these three levels, we employ an exploratory research approach to answer the research question, as existing knowledge on these interactions is limited. To this end, we conducted a vignette experiment (also referred to as a “factorial survey experiment”; see Liebe, Bartczak, and Meyerhoff 2017) with professional managers as respondents.

Our multilevel analysis reveals that certain individual-level factors, such as a biospheric orientation or a strong belief in business ethics, clearly influence managers' decision-making. However, they do not significantly alter the overall influence of organizational- and institutional-level factors. In our study, the most important factors for managers' decision-making are the financial impact of carbon-reducing investments at the organizational level and the number of carbon-conscious investors in a firm and the regulatory disclosure regime in which the firm operates at the institutional level.

Our study makes several contributions. Theoretically, it engages with and connects to the microfoundations movement in strategy and organization theory (Felin, Foss, and Ployhart 2015) and the ongoing debate regarding the primacy of structure versus agency in explaining economic outcomes (Cardinale 2018). Reflecting on developments in these fields over the last decade, our multilevel approach acknowledges that “(...) giving any primacy to a level is an empirical question” (Felin, Foss, and Ployhart 2015, 587). Empirically, our exploratory approach thus considers influential factors across multiple levels, thereby extending previous research that has often focused on a single level of analysis. In particular, the inclusion of individual-level factors addresses recent calls in the literature (e.g., Risi et al. 2022) and provides insights on the role and importance of managerial characteristics in sustainability-related decision-making while accounting for organizational and institutional factors. Given the carbon-related context of our study, the findings also directly contribute to and inform ongoing policy discussions. Our results indicate that policy initiatives aimed at educating investors about companies' climate impact—such as the EU regulation on Sustainability-Related Disclosures in the Financial Services Sector (SFDR, EU 2019/2088) or the European Green Bond Standard (EUGBS, EU 2023/2631), as well as policies aimed at increasing carbon prices and initiatives to mandate climate-related disclosures, is likely to be effective in motivating managers to actively reduce their companies' climate impacts.

2 | Factors Influencing Managers' Decision-Making

The extant literature has analyzed and discussed various factors at the individual, organizational, and institutional levels, which potentially influence managers' decisions to invest in sustainable activities. In the following, we highlight the most significant and commonly discussed factors identified in the literature and outline our expectations regarding their relations to sustainable investments in general, and carbon-reducing investments in particular. Additionally, the embedded nature of the individual, organizational, and institutional levels suggests that factors from different levels interact with each other (Boone et al. 2022;

Harmon, Haack, and Roulet 2019). However, we deliberately do not formulate hypotheses because the many potential (and unexplored) interaction effects make such an approach unfeasible. Instead, we highlight the exploratory nature of our study, especially regarding how factors on different levels interact.

We identified a set of individual-level factors relating to managers' personal values, beliefs, and risk preferences; organizational-level factors (i.e., relative carbon performance, financial impact, and incentive system); and institutional-level factors (i.e., investor orientation and disclosure regime). Table 1 provides an overview of the different levels and factors, the related literature, and exemplary links to theories. Finally, we list the expected (isolated) direction in which the factors affect managers' decisions to invest in sustainable activities. The list of factors is not exhaustive but instead focuses on a set of important and well-researched factors with the aim of providing a suitable starting point for an exploratory analysis. Furthermore, the nature of our methodological approach (i.e., a vignette experiment, as detailed in the following section) warrants a focus on a smaller set of factors.

Regarding individual-level factors, a rich body of literature has explored how personal values, beliefs, and risk preferences impact managers' decisions to invest in sustainable activities (e.g., Boone et al. 2022; Gond et al. 2017; Hafenbrädl and Waeger 2017; Hossain, Saadi, and Amin 2023). Chin, Hambrick, and Treviño (2013), for example, showed that conservative-leaning CEOs in the United States invest less in sustainable activities and only do so when financial performance allows it, whereas liberal CEOs invest more and do so with less regard for financial performance. Hossain, Saadi, and Amin (2023) show that the risk-aversion of CEOs can lead to environmental degradation, especially in the form of higher carbon emissions. In general, moral or prosocial motives and a sustainable value orientation have been identified as important drivers of managers' sustainable behaviors (Gond et al. 2017; Lülfs and Hahn 2014). Consequently, we identified managers' personal values, beliefs, and risk preferences as individual-level factors that potentially play a role in their decisions to invest in carbon emission reductions. We expect that more altruistic and environmentally conscious managers with lower degrees of risk aversion tend to decide in favor of higher carbon-reducing investments.

Focusing on the organizational level, an important factor influencing managers' decisions about sustainable investments can be the current sustainability performance of a firm relative to its peers. Literature links higher carbon emissions to lower firm value (Clarkson et al. 2015; Griffin, Lont, and Sun 2017; Matsumura, Prakash, and Vera-Muñoz 2014; Ott and Schiemann 2023), which suggests that carbon-reducing investments increase firm value. Firms with poor sustainability performance might thus be able to realize stronger improvements in their sustainability performance with the same investment (i.e., by picking low-hanging fruit) compared to firms with an already superior sustainability performance. The resulting *inverse* U-shaped relationship between sustainability performance and profitability is empirically reported by Misani and Pogutz (2015) and Lopatta, Canitz, and Tideman (2022). However, specifically on the issue of carbon performance, Trumpp and Guenther (2017) and Lewandowski (2017) show that firms with

lower levels of carbon performance experience a negative association between carbon and financial performance, whereas a positive relation has been documented for firms with high-level carbon performance. This U-shaped relation is emblematic of the “too little of a good thing” effect. Accordingly, although it seems prudent for managers to evaluate their firm's position in terms of carbon performance relative to that of their peers, it is unclear whether better or worse carbon performance ultimately motivates carbon-reducing investments. Thus, we do not formulate an expectation about the direction of this influence.

On the organizational level, carbon-reducing investment decisions are determined by whether and how quickly investment expenditures pay off financially—due to either decreased costs (e.g., cost savings under emission trading regimes with high carbon prices) or increased sales (e.g., reputational effects of improved carbon performance). The discussion on the financial benefits of environmentally responsible corporate behavior has evolved over time from the question of whether it pays to be green (Hart and Ahuja 1996; Stefan and Paul 2008) to the question of *when* it pays to be green (Albertini 2013; Dixon-Fowler et al. 2013; Hoang et al. 2020). Thus, the time horizon of potential financial benefits seems to play an important role. Consequently, we expect that the financial benefits of carbon-reducing investments are positively associated with managers' respective investment decisions and even more so if those benefits materialize in the short term.

The third organizational-level factor that we identified refers to how carbon performance is integrated into firms' incentive systems. Previous literature has discussed how incentive systems potentially influence managers' sustainable behavior (Renwick, Redman, and Maguire 2013; Yuriev et al. 2018). Incentive systems aim to align managers' objectives with the firm's goals and are based on rewards. Such systems can support a sustainability-related climate in a company through tangible measures, such as bonus payments or other monetary benefits (Cohen et al. 2023; Derchi, Davila, and Oyon 2023; Eccles, Ioannou, and Serafeim 2014). Such reward systems are considered a potentially powerful intervention, and empirical research has shown that integrating sustainability aspects into incentive systems fosters sustainability performance in general (Ott and Endrikat 2022; Velte 2016) and carbon performance in particular (Haque 2017). Accordingly, we identified firms' incentive system design, in which compensation is either based exclusively on financial performance or partly on carbon performance, as another potential factor influencing managers' decisions to invest in carbon emission reductions. We expect that an incentive system that is partly based on carbon performance increases managers' carbon-reducing investments.

Regarding institutional factors, there is ample evidence that institutional investors, just as retail investors, increasingly focus on sustainability-related issues when allocating their funds (Kerber and Jessop 2021; de Villiers, Cho, Turner, and Scarpa 2023) and managers likely adjust their sustainability-related investment behavior to the expectations of their investors. Beyond the normative considerations of retail investors (Cahan, Chen, and Chen 2017; Hong and Kacperczyk 2009), professional investors also experience regulatory pressure to become more transparent with regard to sustainability-related impacts and risks of

TABLE 1 | Overview of factors potentially influencing carbon-reducing investments.

Level	Factor	Related papers	Potential theory connection	Expected direction
Individual	Personal values and beliefs	Boone et al. 2022; Chin, Hambrick, and Treviño 2013; Gond et al. 2017; Hafenbrädl and Waeger 2017; Lülfs and Hahn 2014	Behavioral	Managers with stronger altruistic characters and who are more environmentally conscious tend to invest more in carbon-reducing activities.
Institutional	Risk preference	Hossain, Saadi, and Amin 2023; Slawinski et al. 2017	Behavioral	Managers with higher degrees of uncertainty avoidance tend to invest less in carbon-reducing activities.
	Investor orientation	Cahan, Chen, and Chen 2017; Dhaliwal et al. 2011; Hong and Kacperczyk 2009; Kerber and Jessop 2021	Agency, decision usefulness, signaling	Stronger carbon investor orientation can motivate carbon-reducing investments.
Organizational	Disclosure regime	Bauckloh et al. 2022; Downar et al. 2021; Jouvenot and Krueger 2020; Tomar 2023	Disclosure, institutional, legitimacy	(Stricter) Disclosure mandates increase carbon-reducing investments.
	Relative carbon performance	Clarkson et al. 2015; Griffin, Lont, and Sun 2017; Matsumura, Prakash, and Vera-Muñoz 2014; Misani and Pogutz 2015; Ott and Schiemann 2023; Trumpp and Guenther 2017	Legitimacy, signaling, stakeholder	Influence seems likely, but its direction is unclear.
	Financial impact	Albertini 2013; Dixon-Fowler et al. 2013; Hart and Ahuja 1996; Hoang et al. 2020; Stefan and Paul 2008	Agency, financial economics	Managers increase carbon-reducing investments if these investments lead to positive financial returns in the foreseeable future.
	Incentive system	Derchi, Davila, and Oyon 2023; Eccles, Ioannou, and Serafeim 2014; Haque 2017; Ott and Endrikat 2022; Renwick, Redman, and Maguire 2013; Yuriev et al. 2018; Velte 2016	Agency, behavioral, financial economics	Incentive systems, which integrate carbon performance, lead to more carbon-reducing investments.

their investments (for the European Union, see, e.g., the SFDR and the EUGBS). Consequently, they may pass on such pressure by demanding sustainability disclosures and, eventually, sustainability performance improvements from their investees (Dhaliwal et al. 2011). We thus expect that a stronger investor orientation toward climate-related issues will positively influence managers' decisions to invest in carbon emission reduction activities.

Furthermore, we identified the regulatory environment in which firms and their managers operate as another important institutional factor. Public demand for corporate transparency about sustainability performance has increased over the years and emanates from several sources. In the carbon context, numerous countries have established carbon emission-reporting schemes that mandate firms to report their carbon emissions on the facility level (e.g., Greenhouse Gas Reporting Program in the United States¹ or the EU ETS²) or on the firm level (e.g., the Companies Act 2006 [Strategic Report and Directors' Report] Regulations 2013 in the United Kingdom). Additional voluntary disclosure of firms' carbon emission and other climate-related information was encouraged by organizations such as the CDP and TCFD, and further developments on sustainability- and climate-related disclosures are manifold (e.g., the Corporate Sustainability Reporting Directive, CSRD, in the EU; climate-related disclosure standards from the ISSB; and proposals on climate-related disclosures from the SEC). Accordingly, managers face pressure directly from standards and regulations. When comparing voluntary and mandatory initiatives, voluntary reporting has often been accused of serving as a tool for impression management (i.e., to gain or safeguard legitimacy) without significantly changing firms' process structures (Deegan 2002; Delgado-Márquez, Pedauga, and Cordón-Pozo 2017; Haffar and Searcy 2020) and without leading to positive tangible outcomes (Haque and Ntim 2018; Qian and Schaltegger 2017). Mandatory carbon emission disclosure regimes, however, have been linked to improved sustainability performance in affected firms (Bauckloh et al. 2022; Christensen, Hail, and Leuz 2021; Downar et al. 2021; Fiechter, Hitz, and Lehmann 2022; Jouvenot and Krueger 2020; Tomar 2023). We thus identified the specific type of disclosure regulation environment as an institutional factor that potentially influences managers' decision to invest in carbon emission reductions. We expect that managers perceive increased institutional pressures in a mandatory disclosure regime and act accordingly (Christensen, Hail, and Leuz 2021) so that (stricter) disclosure mandates increase sustainable investments.

In sum, we account for managers' personal values, beliefs, and risk preferences as individual-level factors, firms' carbon performance, the financial impact of the investment, and the incentive system as organizational factors, and investor orientation and the regulatory environment as institutional factors. As described above, these factors have been studied individually in previous research. However, the complexity of the different factors on different levels that managers face (T. Hahn et al. 2014) warrants a simultaneous investigation to identify the relative importance of the various factors as well as how they potentially interact. Thus far, the literature has offered scarce insights in this regard. Muller and Kolk (2010), for example, gave some consideration to the simultaneous extrinsic and intrinsic

motivations of managers to engage in sustainability activities from an international trade perspective. They found that both trade-related pressure and management commitment to sustainability increased firms' sustainability performance levels. Adding to this initial evidence, we employ a vignette experiment that allows for the simultaneous inclusion of individual-, organizational-, and institutional-level factors. This enables us to identify the decisive factors that lead to substantive action in terms of carbon emission reduction.

3 | Materials and Methods

3.1 | Vignette Experiment as a Research Approach

We employ a vignette experiment to explore which of the abovementioned factors influence managers' carbon-reducing investment decisions. Vignette experiments, also referred to as "factorial survey experiments" (Liebe, Bartczak, and Meyerhoff 2017), have their roots in sociological research (Wallander 2009), but the method has also become popular in business studies (Aguinis and Bradley 2014; Oll et al. 2018). Vignette experiments aim to uncover and understand the implicit judgments, preferences, and behaviors of individuals in decision-making processes (Aguinis and Bradley 2014; Auspurg, Hinz, and Sauer 2017). For this purpose, participants are confronted with "vignettes," "that is, carefully designed descriptions of hypothetical people, social situations, or scenarios" (Oll et al. 2018, 27). The vignettes differ from each other in a discrete number of attributes (or factors), the values of which are manipulated (Auspurg and Jäckle 2017). This manipulation results in a potentially large number of different vignette versions, representing the "vignette population" or "vignette universe" (Alexander and Becker 1978). Participants judge a predefined number of vignette versions through an evaluation task. After completing the evaluation task, participants typically provide respondent-specific information analogous to a traditional survey. This setup allows conclusions to be drawn about the respondents' preferences in the decision-making process (Jasso 2006; Rossi and Anderson 1982).

The systematic variation of the attributes within the vignette allows researchers to determine and separate the causal influence of each individual attribute. Including respondent-specific information in the analysis enables scholars to investigate "(a) the elements of information used to form judgments, (b) the weight of each of these factors, and (c) how different subgroups of the respondents agree on (a) and (b)" (Martin 2012, 525). In sum, a vignette experiment is perfectly suited to capture our exploratory research context as it allows for "complex evaluative judgments, which are grounded on a multitude of different factors that the respondents might not even be able to make explicit" (Oll et al. 2018, 33). In the following section, we describe the specific design of the vignette experiment employed to answer our research question.

3.2 | Design of the Vignette Experiment

For the experimental design, we followed best-practice recommendations from research in business studies (Aguinis and

Bradley 2014; Oll et al. 2018) and adjacent disciplines. The participants in the online vignette experiment first accessed introductory notes asking them to assume the role of a manager in a multinational capital market-oriented company in the manufacturing industry and stating that carbon emissions are an inevitable part of the company's business model. The participants were then confronted with the vignettes. Each vignette described a different scenario combining five attributes with different attribute levels. We chose the attributes and their levels in line with the considerations and prior evidence as presented above. Table 2 displays all attributes and attribute levels (two to three each).

As the first attribute, we focused on *investor orientation* and included information on the number (small or large) of the company's investors who considered corporate carbon emission information in their decision-making. This attribute accounted for the potential influence of the company's investor base. The second attribute captured the *relative carbon performance* and ranked the company among its sector peers in terms of current carbon performance (among the best or worst 30%). The third attribute (*financial impact*) specified the potential financial bottom-line effects of carbon emission-reducing investments (no significant effect or a positive effect within either 1 or 5 years). The fourth attribute (*incentive system*) captured the potential effects of bonus payments (bonus payments exclusively determined by financial aspects or partly determined by corporate carbon performance). Finally, the fifth attribute (*disclosure regime*) specified the company's carbon disclosure obligations as part of its annual reporting (entirely voluntary, mandated, or mandated reporting on carbon emission reduction strategies in different global warming scenarios).

Regarding the number of attributes, Auspurg and Hinz (2015) suggest a midlevel complexity of 7 (± 2) to avoid overburden of respondents with too many attributes as well as boredom of respondents due to only few attributes (similar Auspurg, Hinz, and Liebig 2009; Auspurg et al. 2010; Rooks et al. 2000). Due to the general complexity of an investment decision, we deliberately opted for the lower boundary and chose five attributes. As smaller vignette universes "allow a more precise estimation of parameter values" (Auspurg and Hinz 2015, 19), we also limited the number of levels per attribute as much as possible. Having a balanced number of either two or three levels per attribute also helps to avoid a potential number-of-levels effect (Auspurg and Hinz 2015; Wittink, Krishnamurthi, and Nutter 1982). This was possible in our case as it still allowed us to construct realistic vignettes. All possible attribute-level combinations amount to 72 ($2 \times 2 \times 3 \times 2 \times 3$) different vignettes, representing the complete vignette universe. Figure 1 depicts one of the 72 vignettes as an example and illustrates the readability of the vignettes. The universe contained no illogical or implausible cases so that no vignette had to be excluded.

For a comparably low number of attributes (in our case five), Auspurg and Hinz (2015) recommend using only a few vignettes per responded to prevent boredom and fatigue due to limited variation between the vignettes, which could affect the reliability and validity of the vignette experiment (Aguinis and Bradley 2014; Auspurg and Jäckle 2017; Karren and Barringer 2002). Each respondent was thus consecutively confronted with eight vignettes that were randomly drawn without replacement from the 72 vignettes of the complete vignette universe. We opted for a random sample as the most resource-efficient and thus feasible approach for us. With eight vignettes

TABLE 2 | Attributes and attribute levels.

Label	Attributes	Attribute levels
Investor orientation	A "____" of your company's investors use corporate carbon emission information in their decision-making.	1. small number 2. large number
Relative carbon performance	Your company is currently ranked among the "____" in its sector regarding corporate carbon performance.	1. best 30% 2. worst 30%
Financial impact	Investments in carbon emission-reducing measures will have "__ (1/2) __" effect on your financial bottom line "__ (a/b) __."	1. no significant 2. a positive a) within the next year b) within the next 5 years
Incentive system	Your personal bonus payments are "_____."	1. partly determined by your company's carbon performance 2. exclusively determined by your company's financial performance
Disclosure regime	In its annual report, your company "_____."	1. can voluntarily disclose carbon emission information 2. is legally required to disclosure carbon emission information 3. is legally required to disclose carbon emission reduction strategies in different global warming scenarios

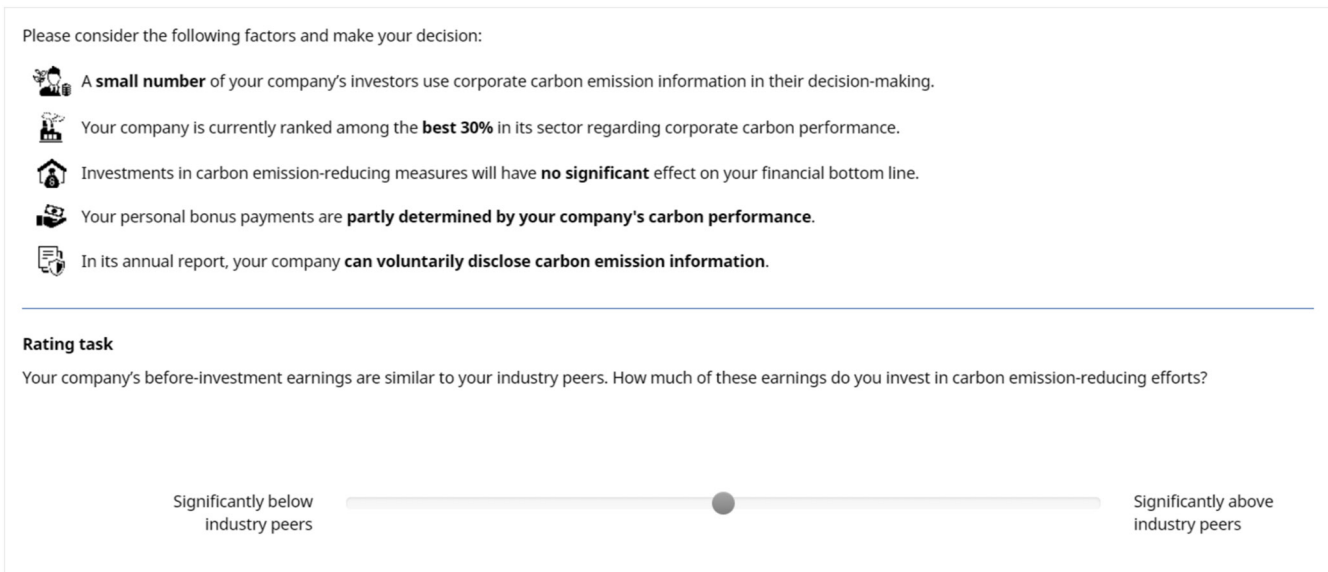


FIGURE 1 | Sample vignette.

per participant, we stayed well below the maximum recommended number of 20 suggested by Lauder (2002).

The participants had to respond to each vignette with a rating task. For this purpose, they were first informed that the company's before-investment earnings were similar to those of their industry peers. Then, they used a slider to indicate what proportion of their company's pre-investment earnings they would invest in carbon emission-reducing measures (see Figure 1). The slider could be freely set on a scale between the endpoints "significantly below industry peers" and "significantly above industry peers." The slider was centered by default, representing investments in carbon emission-reducing measures at the level of the peers' investments. The rating task was repeated for all eight vignettes.

Individual-level information on managers' personal values, beliefs, and risk preferences was gathered through a postexperimental questionnaire. Personal values and beliefs were queried using the Environmental Portrait Value Questionnaire (E-PVQ) by Bouman, Steg, and Kiers (2018), which allows the measurement of the personal values proven to underlie and predict individuals' environmental beliefs and behaviors. The E-PVQ measures values with a total of 17 items in four categories: *biospheric* (concern for the environment), *altruistic* (concern for others), *hedonic* (concern for pleasure and comfort), and *egoistic* (concern for personal resources). Additionally, we asked the respondents two questions about their opinions on businesses' ethical responsibilities (*business ethics*). In order to capture risk preferences, we followed Sharma (2010) and inquired about the participants' tendency to avoid risk (*risk aversion*) and their ambiguity tolerance (*uncertainty avoidance*). Additionally, we asked participants to provide sociodemographic information, such as age, gender, nationality, working experience in years, industry sector affiliation, and whether their job profile included budgetary responsibility. We use sociodemographic information as control variables in our analyses. Each of the measurements mentioned in this paragraph was captured on a seven-point Likert scale. Appendix A presents the complete E-PVQ and

the questions for *business ethics*, *risk aversion*, and *uncertainty avoidance*.

3.3 | Sample and Descriptive Statistics

The vignette experiment was administered online to gain access to a sufficiently large pool of professional managers with several years of work experience. The invitation was distributed through various channels, such as the business network LinkedIn, newsletter mailing lists, or personal contacts. The respective link only granted access to the experiment once to reduce the risk of sampling biases. After completing the questionnaire, the participants could choose between two reward options for their participation: participation in a raffle for one of five €25 Amazon vouchers (in this case, an email address had to be provided but was kept separate from the answers and deleted after the raffle) or offsetting of 100-kg carbon emissions through a nonprofit organization.

A total of 102 professional managers completed the experiment. However, not all participants gave a complete set of judgments for all eight vignettes and/or answered the postexperimental questionnaire in full. In sum, we collected observations from 85 participants who completed the eight judgments and answered all the individual-level questions, leading to a sample of 639 observations. This large number of vignette observations helps to mitigate any potential weaknesses of random sampling. Auspurg and Hinz (2015) argue that, in practical setting, at least 200 vignettes are necessary to obtain efficient samples via random sampling. With more than three times this number, we err on the side of caution.

We also created two additional dummy variables, *gender_dummy* and *age_dummy*, which equaled 1 if the question was answered, and 0, otherwise. This procedure allowed us to control for gender and age while keeping observations of the participants in our sample who did not answer the age- and gender-related questions. Table 3 provides the descriptive statistics of the sample.

TABLE 3 | Descriptive statistics of our sample.

Panel 1—Investment decisions and overview of respondents								
Variable	N	Mean	SD	Min.	Max.	p5	p50	p95
<i>Investment</i>	639	71.313	22.980	0.000	100.000	23.000	74.000	100.000
<i>Experience</i>	85	8.288	5.288	1.000	29.000	1.000	7.000	18.000
<i>Gender</i>	N	Female	Male	No answer				
	85	22	60	3				
<i>Budget</i>		Yes	No					
	85	59	26					
<i>Reward</i>		Offset	Raffle					
	85	76	9					
<i>Age</i>		Mean	Min.	Max.	No answer			
	85	37.802	21	57	14			
Panel 2—Individual-level factors.								
Variable	N	Mean	SD	Min.	Max.	p5	p50	p95
<i>Biospheric</i>	85	5.803	1.015	2.000	7.000	4.000	6.000	7.000
<i>Altruistic</i>	85	5.986	0.740	3.800	7.000	4.600	6.000	7.000
<i>Hedonic</i>	85	5.387	0.942	3.000	7.000	4.000	5.333	7.000
<i>Egoistic</i>	85	4.220	0.983	2.000	7.000	2.600	4.400	5.800
<i>Risk aversion</i>	85	3.248	1.106	1.000	6.750	1.500	3.250	4.750
<i>Uncertainty avoidance</i>	85	2.977	1.183	1.000	6.000	1.250	3.000	5.250
<i>Business ethics</i>	85	5.945	1.134	2.000	7.000	3.500	6.000	7.000

Panel 1 shows the respondents' average age of 37.8 years (16.5% of respondents did not answer this question). Furthermore, 70% of the respondents were male, 26% were female, and 4% did not answer this question. In addition, 69% indicated that they had budget responsibilities in their job, and the average work experience in the respondents' current field of work was 8.3 years. In sum, the average participant in our sample was a middle-aged person with significant work experience and thus exactly a person who would typically engage in the decisions we included in our experiment.

Panel 1 also shows the average proportion of the company's pre-investment earnings that the participants chose to invest in carbon emission-reducing measures. Given that the slider that the participants used to make their investment decisions was set to the center by default (i.e., at a value of 50, representing an investment similar to that of their industry peers), the reported average *investment* value of 71.31 shows that overall, the participants tended to invest more of their company's pre-investment earnings than their firm's industry peers. Panel 2 of Table 3 shows the descriptive statistics regarding the personal values, beliefs, and risk preferences of the participants in our sample, indicating relatively high scores for biospheric and altruistic orientation and, to a lesser extent, also for egoistic and hedonistic values. Furthermore, on average, the respondents believed that

the responsibilities of businesses extend beyond pure financial responsibilities. Risk aversion and concern about uncertainties were at the medium level.

4 | Results

Each participant provided eight investment-related decisions based on eight vignettes. The answers are thus clustered at the participant level, resulting in potentially biased standard errors (Snijders and Bosker 2012; Wallander 2009). We therefore employed a multilevel regression model, taking into account the data's hierarchical structure (Sauer et al. 2011) to avoid biased results. The results of our multilevel regression model approach are reported in Table 4.

Columns (1)–(5) of Table 4 present the effect of the measured individual-level variables (*biospheric*, *altruistic*, *hedonic*, *egoistic*, *business ethics*, *risk aversion*, and *uncertainty avoidance*), each of the manipulated attributes individually, and control variables (*age*, *gender*, *experience*, *budget responsibility*, and *reward choice*). Column (6) shows the results of the full model, estimating the effects of all the manipulated attributes on the institutional and organizational levels simultaneously with the effects of the individual-level variables.

TABLE 4 | Base analyses of all the attributes and control variables.

	Relative carbon performance	Financial impact	Incentive system	Investor orientation	Disclosure regime	Full model
Variables	(1)	(2)	(3)	(4)	(5)	(6)
<i>Biospheric</i>	3.710** (1.773)	3.668** (1.735)	3.642** (1.771)	3.791** (1.780)	3.810** (1.757)	3.896** (1.735)
<i>Altruistic</i>	2.579 (2.555)	2.121 (2.496)	2.558 (2.551)	2.333 (2.564)	2.429 (2.530)	1.790 (2.493)
<i>Hedonic</i>	0.849 (1.692)	1.320 (1.654)	0.799 (1.690)	0.977 (1.698)	0.815 (1.676)	1.345 (1.653)
<i>Egoistic</i>	-0.805 (1.700)	-1.589 (1.665)	-0.846 (1.699)	-1.110 (1.708)	-0.802 (1.684)	-1.986 (1.664)
<i>Business ethics</i>	2.720* (1.462)	3.072** (1.429)	2.756* (1.461)	2.888** (1.468)	2.759* (1.448)	3.254** (1.428)
<i>Risk aversion</i>	3.743** (1.771)	3.444** (1.732)	3.622** (1.769)	3.454* (1.778)	3.721** (1.752)	3.154* (1.732)
<i>Uncertainty avoidance</i>	0.807 (1.708)	0.646 (1.670)	0.936 (1.707)	1.032 (1.714)	0.754 (1.691)	0.712 (1.670)
<i>Relative carbon performance</i>	-1.402 (1.429)					-1.368 (1.269)
<i>Financial impact 5years</i>		11.850***				11.908***
<i>Financial impact 1year</i>		(1.652)				(1.596)
<i>Incentive system</i>		16.819*** (1.634)				17.226*** (1.582)
<i>Investor orientation</i>			-1.936 (1.455)			-2.009 (1.293)
<i>Disclosure Regime_1</i>				6.901*** (1.424)		7.041*** (1.288)
<i>Disclosure Regime_2</i>					3.267* (1.783)	
<i>Disclosure Regime_combined</i>					2.773 (1.791)	3.725*** (1.383)
<i>Age</i>	0.323 (0.329)	0.208 (0.322)	0.325 (0.329)	0.326 (0.330)	0.302 (0.326)	0.177 (0.322)
<i>Age_dummy</i>	-10.673 (13.292)	-5.105 (13.004)	-10.937 (13.278)	-10.127 (13.343)	-10.024 (13.165)	-3.709 (12.993)

(Continues)

TABLE 4 | (Continued)

Variables	Relative carbon performance (1)	Financial impact (2)	Incentive system (3)	Investor orientation (4)	Disclosure regime (5)	Full model (6)
<i>Gender</i>	5.044 (3.699)	5.797 (3.619)	4.860 (3.696)	4.169 (3.717)	4.991 (3.663)	4.760 (3.620)
<i>Gender_dummy</i>	-6.797 (11.471)	-11.544 (11.233)	-6.064 (11.467)	-5.894 (11.520)	-6.526 (11.355)	-10.107 (11.234)
<i>Experience</i>	-0.467 (0.375)	-0.343 (0.366)	-0.474 (0.374)	-0.489 (0.376)	-0.478 (0.371)	-0.376 (0.366)
<i>Budget responsibility</i>	0.510 (3.638)	-0.399 (3.557)	0.330 (3.636)	0.064 (3.653)	0.498 (3.603)	-1.128 (3.556)
<i>Reward choice</i>	6.074 (5.345)	4.245 (5.232)	6.090 (5.339)	5.909 (5.366)	5.742 (5.295)	3.342 (5.232)
<i>Constant</i>	-2.337 (20.719)	-5.651 (20.237)	-1.214 (20.728)	-4.591 (20.786)	-4.228 (20.528)	-6.079 (20.256)
Observations	639	639	639	639	639	639
Number of groups	85	85	85	85	85	85

Notes: Table 4 presents the results of our base analyses. Columns (1)–(5) contain the results of each individual attribute estimation, including control variables. Column (6) shows the results of the full model, including all the attributes and control variables. Standard errors in parentheses.

*** $p < 0.01$,

** $p < 0.05$,

* $p < 0.1$.

Regarding the managers' personal values, beliefs, and risk preferences, Columns (1)–(6) consistently show that a positive *bio-spheric* attitude, a belief in *business ethics*, and a high level of *risk aversion* are positively related to a manager's carbon-reducing investments. All of these main effects are robust throughout our different analyses in terms of both effect size and significance. None of the other personal values, beliefs, and risk preferences attain significance.

Focusing on organizational-level factors, carbon-reducing investments are higher when they have a positive *financial impact*. As shown in Column (2), when the financial benefits materialize within 5 years, the investments are 11.850 points higher ($p < 0.01$), and in cases in which the financial benefit materializes within 1 year, investments are 16.819 points higher ($p < 0.01$) than in the absence of positive effects on the firm's financial bottom line. However, *relative carbon performance* and *incentive system* are not significantly related to carbon-reducing investment decisions. The results remain robust in the full model as shown in Column (6).

For institutional-level factors, *investor orientation* shows significant coefficients. As reported in Column (4), we find that managers' carbon-reducing investments are, on average, 6.901 points higher ($p < 0.01$) when firms have a large number of investors who incorporate carbon emission information into their decision-making on investments compared with the investments

of managers whose firms have a small number of these investors. The *disclosure regime* also affects managers' carbon-reducing investments. When faced with the legal requirement to disclose climate-related information (*Disclosure Regime_1*), investments are 3.267 points higher ($p < 0.1$; Column [5]) than investments in a voluntary disclosure regime. At the same time, mandatory forward-looking reporting of reduction strategies (*Disclosure Regime_2*) does not seem to impact the investment decision despite a positive (but insignificant; $p > 0.1$) coefficient. For our further analyses, we combined these two attribute levels into one binary variable: *disclosure regime combined* ("0" for voluntary disclosure regimes and "1" for mandatory disclosure regimes). In Column (6), we see a positive and significant coefficient of 3.725 ($p < 0.01$).

Table 5 reports a set of interaction analyses among organizational- and institutional-level factors while accounting for the individual-level factors. We report a reduced set of five interactions that we believe to be the most relevant. We also tested all the other combinations of the five factors, but all were statistically insignificant. In general, the results for the five attributes and for personal values, beliefs, and risk preferences are consistent with the results of our baseline analyses in Table 4. Regarding the interaction effects, we report two positive and significant interactions, indicating an additional strengthening effect on managers' investments that comes with specific combinations of manipulated attributes.

TABLE 5 | Analyses of interactions between attributes.

Variables	Investor orientation and relative carbon performance	Financial impact and incentive system	Investor orientation and disclosure regime	Relative carbon performance and disclosure regime
	(1)	(2)	(3)	(4)
<i>Biospheric</i>	3.878** (1.741)	3.921** (1.747)	3.899** (1.736)	3.886** (1.737)
<i>Altruistic</i>	1.966 (2.503)	1.824 (2.510)	1.803 (2.495)	1.815 (2.496)
<i>Hedonic</i>	1.404 (1.659)	1.315 (1.664)	1.358 (1.655)	1.346 (1.654)
<i>Egoistic</i>	-2.077 (1.671)	-2.053 (1.676)	-1.970 (1.667)	-1.951 (1.667)
<i>Business ethics</i>	3.178** (1.433)	3.158** (1.438)	3.251** (1.429)	3.258** (1.429)
<i>Risk aversion</i>	3.252* (1.739)	3.050* (1.744)	3.150* (1.733)	3.146* (1.734)
<i>Uncertainty avoidance</i>	0.652 (1.677)	0.839 (1.683)	0.723 (1.672)	0.707 (1.672)
<i>Investor orientation</i>	3.738** (1.771)	7.128*** (1.284)	7.429*** (2.246)	7.016*** (1.288)
<i>Relative carbon performance</i>	-4.730*** (1.771)	-1.457 (1.259)	-1.372 (1.269)	-0.171 (2.241)
<i>Financial impact 5 years</i>	12.022*** (1.586)	9.399*** (2.275)	11.911*** (1.596)	11.916*** (1.596)
<i>Financial impact 1 year</i>	17.209*** (1.571)	12.502*** (2.282)	17.234*** (1.582)	17.162*** (1.584)
<i>Incentive system</i>	-1.774 (1.287)	-6.669*** (2.281)	-2.014 (1.293)	-1.987 (1.293)
<i>Disclosure Regime_combined</i>	3.752*** (1.374)	3.594*** (1.374)	4.003** (1.911)	4.613** (1.947)
<i>Interact: Investor orientation *Relative carbon performance</i>	6.856*** (2.540)			
<i>Interact: Financial impact 5 years *Incentive system</i>		4.624 (3.174)		
<i>Interact: Financial impact 1 year *Incentive system</i>		9.046*** (3.175)		
<i>Interact: Investor orientation *Disclosure Regime_combined</i>			-0.579 (2.743)	

(Continues)

TABLE 5 | (Continued)

Variables	Investor orientation and relative carbon performance (1)	Financial impact and incentive system (2)	Investor orientation and disclosure regime (3)	Relative carbon performance and disclosure regime (4)
Interact: <i>Relative carbon performance*Disclosure Regime_combined</i>				-1.798 (2.773)
<i>Age</i>	0.184 (0.323)	0.162 (0.324)	0.179 (0.322)	0.176 (0.322)
<i>Age_dummy</i>	-3.992 (13.041)	-3.100 (13.083)	-3.760 (13.001)	-3.630 (13.007)
<i>Gender</i>	4.466 (3.635)	4.911 (3.646)	4.782 (3.623)	4.786 (3.624)
<i>Gender_dummy</i>	-9.884 (11.277)	-10.233 (11.315)	-10.162 (11.242)	-10.398 (11.255)
<i>Experience</i>	-0.374 (0.367)	-0.344 (0.369)	-0.378 (0.366)	-0.372 (0.366)
<i>Budget responsibility</i>	-1.395 (3.570)	-0.899 (3.581)	-1.123 (3.558)	-1.095 (3.560)
<i>Reward choice</i>	3.025 (5.253)	3.408 (5.271)	3.354 (5.235)	3.484 (5.242)
Constant	-4.333 (20.337)	-3.676 (20.411)	-6.499 (20.363)	-6.907 (20.318)
Observations	639	639	639	639
Number of groups	85	85	85	85

Note: Table 5 presents the results of our four interaction analyses. Columns (1)–(4) show the results of the simultaneous estimation of all the attributes and four specific interactions as indicated in the column title. The estimations also contain control variables. Standard errors in parentheses.

*** $p < 0.01$,

** $p < 0.05$,

* $p < 0.1$.

First, we found an additional positive effect of 6.856 points ($p < 0.01$) for the combination of poor carbon performance and a large number of investors who consider carbon information. This means that a manager confronted with a large number of investors focusing on climate-related issues and poor carbon performance increases emission-reducing investments by 5.864 points ($3.738 - 4.730 + 6.856$) compared to a manager faced with a small number of investors focusing on climate-related issues and good carbon performance.

Second, we find an additional positive effect of 9.046 points ($p < 0.01$) when the firm's incentive system partly considers its carbon performance alongside its financial performance when, at the same time, carbon-reducing investments positively affect the firm's financial bottom line within 1 year. This means that a manager faced with an investment project with a positive financial impact within 1 year and an incentive system that considers nonfinancial alongside financial performance will increase the amount of carbon-reducing investments by 14.879

points ($12.502 - 6.669 + 9.046$) compared to managers facing investment opportunities with longer term financial impacts and incentive systems that only consider financial performance. However, we found no significant interaction effect of a mandatory disclosure regime combined with either a large number of carbon-conscious investors or poor relative carbon performance. In other words, the effect of a mandatory disclosure regime on managers' carbon-reducing investments is relatively stable across firms with an inferior or superior carbon performance and across firms with a strong or weak investor orientation toward climate change.

Finally, we interacted the answers to each of the individual-level questions on values, beliefs, and risk preferences with each organizational- and institutional-level factor. Table 6 summarizes the results of these interactions with the direction of the coefficient and the significance. We found a significant effect for five separate interactions in total. However, due to the large number of tests (35) that we performed and given the required level

TABLE 6 | Interactions between individual-level factors and vignette attributes.

	Investor orientation	Relative carbon performance	Financial impact	Incentive system	Disclosure regime
Biospheric	−*	−	−*	−	+
Altruistic	+	−	−	+	−
Hedonic	−	−*	+	+	−
Egoistic	−	−	−	+	−
Business ethics	+	+	−	−	+
Risk	+	+	−	−	−
Uncertainty	−	+	−	−	+

Note: Table 6 contains the results of our analyses of interactions between managers' personal values, beliefs, and risk preferences and organizational- and institutional-level factors. We show the coefficient direction with + and −.

*Significance level of at least $p < 0.1$.

of $p < 0.1$, we cannot rule out the possibility that these results are mostly driven by Type 2 errors. This is emphasized by the fact that no clear pattern of significant results exists. Significant results were found for separate cases stretched over four out of seven personal values, beliefs, and risk preferences (biospheric, hedonic, egoistic, and uncertainty) and over four out of five attributes (investor orientation, relative carbon performance, financial impact, and incentive system). Accordingly, we conclude that personal values, beliefs, and risk preferences do not strongly interact with institutional- and organizational-level factors.

5 | Discussion

Two relevant shortcomings in the literature on sustainability-related managerial decision-making motivated this study: The still underexplored role of individual-level factors and the fact that institutional-, organizational-, and individual-level factors have mostly been studied separately in the past, despite contextual complexity that warrants simultaneous investigation. Consequently, this study explored a variety of factors and how they interact in shaping managers' decisions in the context of a potential investment in carbon emission-reducing measures. As part of our experimental design, we exposed our professional participants to different scenarios through vignettes. These vignettes included five manipulated factors on the organizational and institutional levels that previous literature has (separately) linked to managerial decision-making in the realm of climate change. To account for individual-level factors, we measured managers' personal values, beliefs, and risk preferences. Our results show that the most important factors for managers' decision-making were the number of carbon-conscious investors in a firm, the financial impact of carbon-reducing investments, and the regulatory nonfinancial disclosure regime in which a firm operates. The firm's initial carbon performance relative to its peers and the design of managers' incentive systems were not significantly factored into the decision-making in our setting. These findings are robust across different personal values, beliefs, and risk preferences of managers. In the following, we theoretically reflect upon those findings, and we discuss potential implications for corporate practice and policymaking.

5.1 | Theoretical Reflections

For a long time, there have been competing positions on the role and existence of managerial agency (Cardinale 2018). Proponents of such an agency perspective argue that organizational actions and performance are to a certain extent reflections of managerial attributes. In other words, differences in managerial attributes would allow to explain heterogeneity in firm-level outcomes. Others, however, argue that managerial attributes do not really matter because managers are primarily constrained by their organizational and/or institutional structure. Such a deterministic view would thus give primacy to structure over agency. However, as Cardinale (2018, 132) argues, "... institutional theory seems to be converging toward the view that both agency and structure matter." Our findings support that view.³

Considering the underexplored role of individual-level factors, our findings support the agency perspective with evidence that managers' personal values, beliefs, and risk preferences indeed play an important role in shaping their sustainability-related actions (Bouman et al. 2020; Muller and Kolk 2010). In our setting, a positive attitude toward the biosphere, a strong belief in business ethics, and a high level of risk aversion explain a higher likelihood of managers' decisions to invest in carbon emission reductions. These findings support the notion that corporate carbon emission reductions will be easier to achieve if the responsible managers' values, beliefs, and risk preferences match the idea of fighting against climate change (Boone et al. 2022). Notably, we found no or, at best, only sparse and weak evidence for interactions among these individual-level factors with the organizational- and institutional-level factors in our setting. In other words, managers' personal values, beliefs, and risk preferences are robust drivers of their decisions to invest in carbon emission-reducing measures, regardless of the organizational or institutional structure the decision-making is embedded in.

However, considering the (separate) influence of factors at the organizational and institutional levels, several of our findings also speak to the importance of structure in decision-making, thus also confirming and complementing previous findings in the literature. This applies to our findings on the

influence of the financial impact of carbon-reducing investments (Albertini 2013; Dixon-Fowler et al. 2013; Hart and Ahuja 1996; Hoang et al. 2020; Stefan and Paul 2008), the number of carbon-conscious investors (Cahan, Chen, and Chen 2017; Dhaliwal et al. 2011; Hong and Kacperczyk 2009; Kerber and Jessop 2021), and the regulatory carbon disclosure regime in which a firm operates (Bauckloh et al. 2022; Downar et al. 2021; Fiechter, Hitz, and Lehmann 2022; Jouvenot and Krueger 2020; Tomar 2023). For these factors, the direction of the influence is also in line with our expectations, as summarized in Table 1, and further serves as evidence supporting the structure-dominated theories mentioned therein.

It is noteworthy though that not all the structural factors in our vignette study show a significant relation with the carbon-reducing investment decisions. Namely, the organizational-level factors of relative carbon performance and incentive system are insignificant and, accordingly, do not fully support the conclusions of the previous empirical literature, but they are nevertheless (theoretically) plausible in the setting of our experiment. First, previous empirical studies have indicated that an incentive system that rewards nonfinancial performance leads to improved nonfinancial outcomes (Baraibar-Diez, Odriozola, and Fernández Sánchez 2019; Ott and Endrikat 2022). However, we did not find support for such an effect. This might be due to managers' uncertainty regarding the personal financial returns they could gain through the incentive system. Even if an investment in carbon reduction measures is financially rewarded by the compensation scheme (i.e., by linking compensation partly to carbon performance), an overall negative effect on the personal financial reward could still prevail, for example, in cases when the carbon reduction measures have no immediate positive or even a negative (short-term) financial impact. Usually, financial performance continues to be a dominant element of managerial incentive schemes, even if nonfinancial measures are included, which implies that managers seem to be reluctant to invest in carbon-reducing efforts if they do not see (short-term) positive financial impacts.

Second, we find no evidence for the influence of relative carbon performance on managerial decision-making in our setting. Although we refrained from formulating an expectation regarding the direction of this influence, this finding contrasts nonetheless with our expectation that an influence (of any direction) exists, as we discussed above and highlighted in Table 1. However, previous literature has reported different non-linear directions for this relationship. For example, some scholars argue and demonstrate that for the worst carbon performers in a sector, carbon-reducing investments might negatively affect financial profitability (Clarkson et al. 2011), especially if such efforts are only driven by compliance or regulatory requirements (King and Lenox 2002; Lankoski 2008), whereas others show that carbon emissions in general are negatively related to firm value (Griffin, Lont, and Sun 2017; Matsumura, Prakash, and Vera-Muñoz 2014). Accordingly, the overall insignificant results might be due to managers' different reactions to relative carbon performance. However, the inconsistency in prior literature could also stem from different frame conditions that previous research did not or could not control for. Indeed, we found that managers of firms with inferior carbon performance

invested significantly more in carbon emission-reducing efforts in our experiment under the condition that the number of carbon-conscious investors was high. Accordingly, investor orientation toward carbon emission reduction seems to provide a sufficiently strong motivation for managers of firms with inferior carbon performance to invest in carbon emission-reducing efforts.

We can corroborate these findings with arguments based on sociopolitical theories (e.g., Delgado-Márquez, Pedauga, and Cerdón-Pozo 2017) suggesting that poorly performing firms do not necessarily invest more resources in emission reduction. Only when external pressures increase and, thus, legitimacy is at risk, do managers seem to act. This interaction between an organizational-level factor (relative carbon performance) and an institutional-level factor (investor orientation) supports our claim that a simultaneous investigation of factors on different levels is warranted. Further support for this claim is provided by our finding of a significant interaction effect between a firm's incentive system design and short-term financial impact as two organizational-level factors. If managers were partially rewarded for carbon performance and were more certain about the short-term positive financial impact of such an investment, they invested significantly more in carbon emission reductions. The uncertainty about the financial impact of carbon-reducing investments might thus contribute to managers' focus on short-term pressures instead of long-term goals. This reasoning is also in line with the literature on managerial decision-making in complex situations (Kleinknecht et al. 2020).

Overall, we find clear support for three influential factors at the organizational and institutional levels (i.e., investor orientation, financial impact of carbon-reducing investments, and regulatory disclosure regime) and no empirical support for two further factors (i.e., relative carbon performance and incentive system). However, we show that the latter two factors are important as well because they interact with some of the aforementioned influential factors. The complexity of different institutional pressures and organizational characteristics in the realm of carbon reduction investments thus indeed warrants a simultaneous investigation, and we strongly encourage future research in this and related areas to account for this structural complexity in research approaches. Interestingly, however, our results do not show that the individual level, via managers' personal values, beliefs, and risk preferences, warrants such a simultaneous approach. The individual level instead seems to 'act' on its own. Picking up then beforementioned notion that "(...) giving any primacy to a level is an empirical question" (Felin, Foss, and Ployhart 2015), we thus argue that primacy might not exist and that both structure and agency matter. However, although managerial agency seems to exist independently of structure, different structural levels seem to be interdependent. We encourage future research to further challenge this finding or to find similar evidence in related areas.

5.2 | Practical Implications

Governments and other regulators are currently implementing new and adjusting existing regulations with the aim of decreasing carbon emissions. The results of our study directly connect to

and inform ongoing policy discussions. First, we found evidence that investor preferences can create real effects. This supports policy developments aimed at informing investors about the climate impact of companies, such as the SFDR (EU 2019/2088) or the EUGBS (EU 2023/2631).

Second, our finding that the financial impact of carbon-reducing investments plays a strong role in managers' decision-making supports the notion that high carbon prices can lead to increased corporate carbon reduction efforts.

Third, our findings indicate that mandating climate-related disclosures has a positive impact on carbon-reducing investments. This adds, for example, to the findings on the positive effects of the mandatory disclosure of carbon emissions (Bauckloh et al. 2022; Downar et al. 2021). Our empirical insights support the recent push toward mandated climate-related or sustainability-related disclosure as a policy tool. Although the results of our study do not allow for a specific evaluation of different initiatives (e.g., by the EU CSRD and the ISSB), they support the general idea of mandating carbon disclosure.

Fourth, the positive impact of mandating carbon disclosure materialized independently of all the other factors analyzed in our study, indicating an absence of adverse effects. We therefore conclude that mandatory carbon disclosure can also be a good complement to a variety of different sustainable finance regulations. In this vein, our results also hint at potentially reinforcing the mechanisms of some regulations. More specifically, if investors' orientation toward corporate climate impacts increases (e.g., due to the SFDR or the EUGBS), especially companies with high carbon emissions (i.e., poor carbon performance) might be incentivized to invest more in emission reduction efforts. Furthermore, higher carbon prices could lead to increased carbon-reducing investments, especially for firms that connect carbon performance measures to their incentive systems. Overall, our study provides evidence that policy efforts in the area of sustainable finance can have real carbon-reducing effects.

Finally, and beyond policy considerations, our findings on individual-level factors show that personal values, beliefs, and risk preferences have an impact on managers' carbon-reducing investment decisions but at the same time do not strongly interact with other factors. Accordingly, a "value screening" of existing or future managerial staff could thus be a useful human resources task for all firms in different settings that aim to reduce their carbon footprint.

6 | Conclusion

This study provided important insights into the key factors that shape managers' sustainability-related decision-making. We acknowledge, however, that the findings of our study need to be considered in light of its limitations. The results of the E-PVQ as part of the postexperimental questionnaire produced what could be considered an empirical anomaly: Our participants scored relatively high on both altruism and egoism, which goes against theoretical reasoning. However, prior work relying on the E-PVQ (Bouman, Steg, and Kiers 2018; Steg et al. 2014)

shows that it is not uncommon to observe a positive or nonsignificant negative correlation between these two characteristics. Nevertheless, all this work could suffer from carry-over effects, in our case from emphasizing the carbon context in the vignettes which might have primed participants when answering the postexperimental questionnaires. Further limitations relate to the applied vignette experiment method. For example, designs such as ours specifically aim to achieve internal validity, which might come at the cost of external validity (R. Hahn et al. 2021). Most importantly, to avoid confounding factors and to limit the participants' cognitive effort, the number of included and manipulated factors at the institutional and organizational levels was limited to five. Although these factors were carefully selected based on prior academic literature and topical regulatory developments, other factors might well have been included. For example, team-level factors were not considered in our setting mainly due to methodological reasons, although they might represent important drivers in the decision-making process (e.g., Harmon, Haack, and Roulet 2019). We encourage future research to explore relations between these and other levels and to analyze further factors at the organizational (e.g., whether sustainability is anchored in a company's mission, vision, or policies) and institutional levels (e.g., the level of pressure by stakeholders other than investors) and how, together with personal values, beliefs, and risk preferences, they influence managerial decision-making.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

¹ See <https://www.epa.gov/ghgreporting>.

² See https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en.

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Appendix A

Portrait Value Questionnaire (How Much Is This Person Like You?)

Biospheric	Not like me at all		Somewhat like me			Very much like me	
It is important to [him/her] to prevent environmental pollution.	0	0	0	0	0	0	0
It is important to [him/her] to protect the environment.	0	0	0	0	0	0	0
It is important to [him/her] to respect nature.	0	0	0	0	0	0	0
It is important to [him/her] to be in unity with nature.	0	0	0	0	0	0	0
Altruistic	Not like me at all		Somewhat like me			Very much like me	
It is important to [him/her] that every person has equal opportunities.	0	0	0	0	0	0	0
It is important to [him/her] to take care of those who are worse off.	0	0	0	0	0	0	0
It is important to [him/her] that every person is treated justly.	0	0	0	0	0	0	0
It is important to [him/her] that there is no war or conflict.	0	0	0	0	0	0	0
It is important to [him/her] to be helpful to others.	0	0	0	0	0	0	0
Hedonic	Not like me at all		Somewhat like me			Very much like me	
It is important to [him/her] to have fun.	0	0	0	0	0	0	0
It is important to [him/her] to enjoy the life's pleasures.	0	0	0	0	0	0	0
It is important to [him/her] to do things [he/she] enjoys.	0	0	0	0	0	0	0
Egoistic	Not like me at all		Somewhat like me			Very much like me	
It is important to [him/her] to have control over others' actions.	0	0	0	0	0	0	0
It is important to [him/her] to have authority over others.	0	0	0	0	0	0	0
It is important to [him/her] to be influential.	0	0	0	0	0	0	0
It is important to [him/her] to have money and possessions.	0	0	0	0	0	0	0
It is important to [him/her] to work hard and be ambitious.	0	0	0	0	0	0	0
Business ethics question business ethics	I strongly disagree		I neither agree nor disagree			I strongly agree	
Business has a social responsibility beyond making a profit.	0	0	0	0	0	0	0
The ethics and social responsibility of a firm are essential to its long-term profitability.	0	0	0	0	0	0	0
Risk Preferences Questionnaire.							
Risk aversion	I strongly disagree		I neither agree nor disagree			I strongly agree	
I tend to avoid talking to strangers.	0	0	0	0	0	0	0
I prefer a routine way of life to an unpredictable one full of change.	0	0	0	0	0	0	0
I would not describe myself as a risk-taker.	0	0	0	0	0	0	0
I do not like taking too many chances to avoid making a mistake.	0	0	0	0	0	0	0
Uncertainty avoidance	I strongly disagree		I neither agree nor disagree			I strongly agree	
I find it difficult to function without clear directions and instructions.	0	0	0	0	0	0	0
I prefer specific instructions to broad guidelines.	0	0	0	0	0	0	0
I tend to get anxious easily when I do not know an outcome.	0	0	0	0	0	0	0
I feel stressful when I cannot predict consequences.	0	0	0	0	0	0	0