

Carbon Emission, Climate Change Awareness, and Firm Value: Empirical Evidence from Europe

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Abstract

This paper aims to investigate the effects of carbon emission levels and climate change awareness on firm value alongside the role of sustainability compensation incentives (SCI). Utilizing a panel data econometric model, which includes 4,804 firm-year observations of European firms across 30 countries and ten industry sectors from 2013 to 2023, the research reveals that high carbon emissions may face market sanctions on average for every additional thousand metric tons of emissions resulting in an average decrease of €625,000 in firm value. Conversely, strong climate change awareness positively correlates with firm value, as these firms often adopt effective strategies to capitalize on climate opportunities. The findings also find that sustainability compensation incentives (SCI) do not alleviate the negative impacts of carbon emissions as expected; instead, they may amplify these effects, highlighting the importance of stringent environmental regulations and disclosure standards for SCI effectiveness. The implications of these findings indicate that companies should incorporate climate metrics into their incentive mechanism plans and address emissions throughout the value chain, as this alignment can improve corporate sustainability and accountability. This study highlighted companies' need to align sustainability strategies with market expectations to enhance firm value and contribute to broader climate goals.

Keywords: carbon emission, climate change awareness, firm value, sustainability compensation incentives

1. INTRODUCTION

The European Commission and relevant organizations have recently emphasized the importance of nonfinancial disclosures, particularly on climate issues. Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014, which amends Directive 2013/34/EU, regulates the disclosure of non-financial information and diversity by several large companies and groups. Following a comprehensive public consultation process, Directive (EU) 2022/2464 on Corporate Sustainability Reporting Directive (CSRD) became effective on 5 January 2023. These regulations ensure that investors and stakeholders receive essential information to assess companies' impacts on society and the environment, as well as the financial risks and opportunities related to climate change and other sustainability issues. The adaptation process of companies during the transition to more stringent and standardized reporting practices is interesting to study to evaluate the effectiveness of this policy and its impact on company behavior and market value.

The increasing impacts of climate change, driven by rising greenhouse gas (GHG) emissions, emphasize the need to identify and evaluate climate change-related risks to economic activity. (Liu et al., 2024). Higher carbon emissions affect corporate cash flows due to future costs associated with compliance, abatement, regulation, and taxes that are not currently captured in market valuations of reported earnings and shareholders' equity (Griffin et al., 2017). Investors perceive high carbon emissions as an indicator that the company faces greater climate change-related risks (Matsumura et al., 2014). Aswani et al. (2024) stated that high carbon emissions could make a company's shares less attractive to investors who are averse to environmental risks, thereby reducing stock demand

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and lowering stock prices. Several studies, such as Matsumura et al. (2014) and Saka & Oshika (2014), found a negative impact of carbon emissions on firm value. However, more transparent disclosure of climate change impacts can improve corporate image and increase stock returns, as investors tend to reward companies that demonstrate a proactive attitude in managing environmental risks (Camilleri, 2018; Matsumura et al., 2014; Saka & Oshika, 2014). Thus, evidence implies that companies need to address climate-related risks to avoid lowering investor expectations and reducing market valuations.

However, Barth et al. (2001) stated that investors tend to ignore carbon emission level information when assessing a firm's value if the capital market views voluntarily disclosed carbon emissions as less reliable. In addition, there is a risk of bias and manipulation, where companies may present more favorable information to cover up higher actual emissions, which raises doubts about the accuracy of the data. Investors doubt their validity if an independent third party cannot verify carbon emission disclosures (Simnett et al., 2009). Moreover, investors often prioritize information that has a direct and clear impact on financial performance. If carbon emission disclosures are irrelevant or have no significant impact, investment analysis may ignore such information. As a result, investors may not consider them when assessing a firm's value, which can have a negative impact on the market's assessment of the company.

In addition to carbon emissions, corporate awareness of climate change is essential to identify related risks and opportunities. Climate change awareness refers to an individual or organization's understanding and attention to the impacts and risks generated by climate change. It includes knowledge of global warming, natural disasters, and the need to adapt and reduce greenhouse gas emissions. In the insurance industry context, Gatzert & Reichel (2022) stated that climate change awareness is essential because it can affect underwriting policies, products offered, and investment strategies. High awareness allows companies to better prepare for the challenges of climate change. Gatzert & Reichel (2022) also demonstrated that climate change awareness can boost company value within the insurance industry. Consequently, companies must develop strategies that ensure economic survival, benefit shareholders, and balance social and environmental considerations (Adger et al., 2018; Auerswald et al., 2018; Bosello et al., 2012; Galbreath et al., 2020; Gao et al., 2022; Ou-Yang et al., 2013; Rickards et al., 2014; Xu & Hyman, 2022).

Lack of climate change awareness among companies across industries can increase financial risk, reputational damage, and missed innovation opportunities. Companies that need to understand environmental risks may face high compliance costs, operational instability, and difficulties attracting and retaining talent. While studies have highlighted the impact of climate change in the insurance industry, such as those conducted by Gatzert & Reichel (2022), exploring climate change awareness in other sectors is essential. Therefore, the assessment of climate change awareness must go beyond the insurance industry to encompass various sectors, given the broad implications for sustainability and overall corporate value. This study aims to fill this gap by exploring climate change awareness across industries.

Our research aims to investigate whether investors place significant value on information about carbon emissions and climate change awareness. We examined the potential relationship between the level of emissions produced by companies, their corporate awareness of climate change risks, and firm value within European companies. Additionally, the study explores how sustainability compensation incentives (SCI) impact climate change awareness and carbon emissions on company value. Amid the challenges faced by sectors that are difficult to transition, such as oil and gas, aviation, and other heavy industries, companies must find and implement effective business models and organizational tools to meet their climate commitments. One innovative step that has emerged is linking executive compensation to climate performance. This incentive aims to align corporate strategy with management incentives. While climate-linked executive compensation alone cannot address all sustainability challenges, it conveys a positive message to investors, customers, suppliers, and employees about the company's commitment to future sustainability initiatives (Ritz, 2022).

We utilize value relevance research by Barth et al. (2001) and Matsumura et al. (2014) as a theoretical framework to evaluate whether carbon emission levels offer information that investors consider for firm valuation. We predict that if capital markets view carbon emissions as relevant for valuation and believe they are measured with sufficient reliability, carbon emission levels will have significant implications for market value (Barth et al., 2001). This study predicts that the company's market value will decrease as corporate emissions increase. Conversely, climate change awareness is expected to increase firm value. Such awareness often translates into proactive risk management and strategic opportunities that boost investor confidence. Next, the role of SCI will be explored, with the prediction that their impact on firm value may be more complex.

Results of this study show that capital markets actively integrate carbon emissions and climate change awareness in corporate valuation, with companies that do not report emissions transparently facing potential market sanctions. We find that the firm value decreases by average for every additional thousand metric tonnes of carbon emissions for a sample of European firms; the firm value decreases by €625,000¹. Moreover, significant climate change awareness is positively related to firm value, and firms with high awareness tend to adopt better strategies to capitalize on climate change opportunities. Although disclosure of carbon emissions may decrease firm value, it may be chosen for strategic reasons such as compliance and long-term benefits. This study finds that SCI does not reduce the negative impact of carbon emissions as expected; instead, it amplifies it and highlights that the effectiveness of SCI depends on strict environmental regulation and disclosure standards.

This research contributes significantly to understanding how climate change awareness and carbon emissions disclosure influence corporate valuation. It presents empirical evidence that capital markets actively integrate these factors into investment decisions, highlighting the critical importance of transparent carbon emissions disclosure. Using the Thompson Reuters database, this study extends the sample by using 4,804 firm-year observations across 30 countries and ten industry sectors (excluding the financial sector) from 2013 to 2023. To the best of our knowledge, this research has never been conducted before. By encompassing a diverse range of industries, the research enhances the generalizability of its findings, offering insights applicable across various sectors. It also provides actionable recommendations for corporate managers to align sustainability strategies with market expectations, advocating for integrating environmental performance into core business practices. Our findings suggest that nondisclosure of carbon emissions can be costly for firms and is associated with lower firm value, other things being equal. Furthermore, the study examines the role of SCI, revealing that these incentives may not effectively mitigate the adverse effects of emissions, thereby challenging existing assumptions and suggesting a need for more effective incentive mechanisms. This finding strengthens Ritz's (2022) analysis.

Additionally, the findings underscore the need for stronger regulations and supportive frameworks that promote sustainable practices, informing policymakers of critical actions to foster a low-carbon economy. The research identifies gaps for future investigation, particularly concerning the differentiation of regulatory environments and the types of sustainability incentives. Finally, by linking its findings to the Sustainable Development Goals (SDGs), particularly SDG 13, focused on climate action, this study emphasizes the broader significance of corporate sustainability efforts in achieving global climate targets. Overall, the research enhances our understanding of the interplay between carbon emissions, climate change awareness, and firm value, providing valuable insights for companies, investors, and policymakers.

This paper is organized as follows. First, it provides an overview of the study's background. The second section reviews theories and prior research on carbon emissions, climate change awareness, sustainability compensation incentives (SCI), firm value, and hypothesis development. Section 3 outlines the research methodology, while section 4 presents the results of the empirical testing along with a discussion. Section 5 discusses the conclusions, the analysis's limitations, and future research directions.

2. LITERATURE REVIEW

2.1. Theory and Previous Research

Carbon Emission and Firm Value

Natural resource-based (NRB) theory provides insight into how resource capacity can influence corporate actions (Hart, 1995). This theoretical framework means that companies face trade-offs that they must perform between various competing factors regarding climate change disclosures (Matsumura et al., 2014). Investors may desire detailed information about climate risks and disclosures, collecting, analyzing, and reporting. However, such information can be resource-intensive and costly for firms.

In Western settings, several studies have found that reducing carbon emissions could increase firm value (Griffin et al., 2017; Matsumura et al., 2014; Palea & Santhià, 2022). Griffin et al. (2017) analyzed carbon emission levels using data from the Carbon Disclosure Project (CDP) with samples from two economic environments, Canada and the United States. This study shows that greenhouse gas emission levels have a negative impact on stock prices, especially in the utilities, energy, and raw materials sectors. Investors in Canada and the US treat stocks as if higher emissions carry additional off-balance sheet liabilities that are not reflected in market valuations of reported earnings and shareholder equity. Higher emissions cause this negative relationship, which will drain more

¹ To provide context for this figure, it is worth noting that the net present value of €50 per metric tonne of carbon emissions, when continuously discounted at an 8 percent interest rate, equates to approximately €625 (that is, €625,000 per thousand metric tonnes of carbon emissions).

cash flow from the company in the form of higher future compliance, abatement, regulatory, and tax costs not already reflected in the market's assessments of reported earnings and shareholders' equity. This result confirms the findings of Matsumura et al. (2014) that high carbon emissions are vulnerable to corporate sustainability risks and legal sanctions such as fines and lawsuits. In addition, carbon emission issues are closely related to sustainability issues.

Similar results were obtained using data from European countries and Australia (Chapple et al., 2013; Clarkson et al., 2015), although Liesen et al. (2017) have no evidence that carbon emissions reduce portfolio returns. Liesen et al. (2017) argue that the information costs associated with disclosing and managing carbon emissions do not burden corporate financial resources. Furthermore, investors should not ignore carbon-related information and performance when making investment decisions. During the analysis period, financial markets also showed inefficiencies in pricing publicly available information related to carbon disclosure and performance. Implementing mandatory and standardized information on carbon performance is expected to improve market efficiency and result in more optimal capital allocation in the real economy. In an Asian setting, Han et al. (2022), using a sample of Taiwanese firms, found different results showing that firm value is positively associated with carbon emissions, contrasting with the findings of extant research. This finding emphasizes that the Taiwanese government does not do enough to promote reductions in carbon emissions. Therefore, this issue is of less concern to the public than it should be.

Climate Change Awareness and Firm Value

Carbon risk awareness is a company's ability to proactively identify key risks arising from carbon-related issues and consider their potential consequences (Jung et al., 2018). Climate change awareness in this study refers to how companies respond to climate change as a commercial risk and opportunity. This assessment is based on several critical criteria that reflect the company's involvement in and actions regarding climate change. Jung et al. (2018) stated that in the context of financing costs, firms with greater awareness of carbon risks can communicate more effectively with lenders about their carbon management strategies. This reduces information asymmetry and, in turn, may lower the carbon risk premium in debt costs. While this awareness is not the only necessary element, it is an important first step in carbon risk management. Companies that are aware of the risks they face are more likely to integrate these risks into their formal risk management systems, enabling them to address such issues before they develop into larger issues (Subramaniam et al., 2015). This approach allows them to maintain social legitimacy and reduce risk while improving their reputation (Antonini et al., 2021; Caby et al., 2020; Cong et al., 2020; Cosma et al., 2022; Galeone et al., 2023; Guo et al., 2022; Kılıç & Kuzey, 2019; Liesen, 2015; Lombardi et al., 2022; Luo et al., 2012; Nathalia & Setiawan, 2022; Park et al., 2023; Principale & Pizzi, 2023).

According to the NRB theory (Hart, 1995), a company's resources and capabilities are crucial for sustaining a competitive edge. Halady & Rao (2010) emphasize that focusing on the negative health impacts of climate change can raise individual awareness and encourage managers to implement more effective climate change campaigns. In this context, investing in resources to reduce carbon emissions is considered a strategic investment in capabilities essential for the company's future success. From political and economic theory perspectives, companies disclose climate-related information and adopt sustainability practices to foster positive relationships with governments, regulators, and other stakeholders. Addressing climate change is viewed as a strategic move to strengthen political and economic positioning, which helps companies achieve business objectives and maintain stability in an increasingly regulated environmental landscape (Cotter et al., 2011; Guo et al., 2022). Companies with strong environmental performance are more likely to openly disclose their carbon information to enhance their reputation with stakeholders (Shui et al., 2023).

Sustainability Compensation Incentives

Ritz (2022) stated that high-carbon companies face increasing pressure to align their corporate strategies with climate goals, such as extracting value from traditional high-carbon operations while shifting to greener technologies and investing in low-carbon initiatives to ensure long-term sustainability. Linking executive compensation to emission reductions in line with climate goals can increase the likelihood of achieving these commitments Ritz (2022). De Cesari & Ozkan (2015) stated that executive ownership and stock-based pay-performance sensitivity as a form of executive incentive are mechanisms to align managerial and shareholder interests. By making climate-related targets part of executive pay, companies can demonstrate their commitment to sustainability to stakeholders, enhance their reputation, and attract more investment. In an era of increasing environmental awareness, companies face demands to integrate sustainability principles into their business strategies. One emerging approach is providing sustainability compensation incentives, which are believed to influence company value significantly.

Agency theory posits that offering incentives can help mitigate conflicts between corporate managers and shareholders, motivating managers to exert greater effort. This, in turn, can lower agency costs, enhance cash flow and firm valuation, and decrease the cost of capital (Jensen & Meckling, 1976; Jensen & Meckling, 2012). SCI is crucial in driving substantial sustainability strategies and positively affecting corporate performance in the context of supportive regulations and policies to mitigate climate change impacts. By motivating executives to incorporate sustainability into their corporate strategies, SCI encourages the development and execution of initiatives to reduce carbon emissions and seize climate-related opportunities. Executives are more likely to implement strategies that enhance energy efficiency, reduce waste, and adopt eco-friendly technologies, which can result in long-term benefits, such as operational cost savings and improved corporate reputation among consumers and investors. Furthermore, SCI incentivizes executives to explore and capitalize on opportunities arising from climate change, such as entering green markets or investing in technologies that mitigate environmental impacts. This proactive approach helps companies manage climate-related risks, such as compliance with stringent environmental regulations and reputation management, ultimately enhancing overall company performance and value.

2.2 Hypothesis Development

NRB theory emphasizes the importance of evaluating company value in light of the cost-benefit trade-offs associated with resource allocation for carbon emission reduction (Hart, 1995). Companies that fail to incorporate climate change risks into their business strategies, such as by not investing in renewable energy, often face lower market value expectations from investors. Investors may perceive companies that need to proactively address their environmental impacts as having reduced future potential or sustainability. Increased regulatory costs, including carbon taxes, compliance expenditures, and reputational risks, can diminish a company's investment appeal and market value. Moreover, high carbon emissions are often linked to elevated operational costs and challenges in maintaining technological efficiency and environmentally friendly practices. Consequently, firms with poor environmental performance, such as high carbon emissions, generally experience reduced corporate value due to increased investment risks and higher capital costs.

Capital markets frequently evaluate companies based on climate change-related risks and opportunities, leading to higher risk profiles for firms with substantial carbon emissions. As Giannarakis et al. (2017) and Matsumura et al. (2014) noted, carbon emissions significantly contribute to climate change. Matsumura et al. (2014) also found that companies' values decline when they disclose high carbon emission levels, reflecting the capital market's negative perception of such firms. High greenhouse gas emissions can adversely affect a company's future cash flows, as highlighted by Griffin et al. (2017). Firms with substantial carbon emissions often incur additional costs for regulatory compliance, emissions reductions, and environmental impact-related expenses. This hypothesis posits that elevated carbon emissions signal significant financial risks, decreasing firm value.

H1: Companies with higher carbon emissions are likely to have a lower firm value

According to NRB theory (Hart, 1995), companies that fail to integrate climate change risks into their business strategies—such as by investing in renewable energy—risk a decrease in value due to lower market expectations. These companies may face increased operating costs, reputational risks, and potential losses from stringent environmental regulations. Jung et al. (2018) found that firms demonstrating awareness of carbon risks, such as responding to CDP surveys, can mitigate these financial penalties, making negligible impacts on their debt costs. In contrast, companies with high climate change awareness often take proactive steps to integrate risks and opportunities into their strategies, including investments in clean technologies and sustainable practices. This result mitigates climate-related risks and enhances their attractiveness to investors, consumers, and stakeholders. Gatzert & Reichel (2022) also show that large European insurance companies exhibit greater awareness of climate change risks and opportunities than their U.S. counterparts, which positively impacts their value, as shown by Tobin's Q analysis. Firms that recognize and effectively manage their carbon risks are better positioned to prepare for future losses and identify resource efficiency opportunities, leading to improved financial performance. Consequently, investors tend to favor companies demonstrating heightened climate change awareness, as these firms are better equipped to manage environmental risks, attract investment, and capitalize on innovation. As a result, firm value increases alongside a positive reputation and enhanced adaptability to regulatory and market changes.

This study argues that companies with a higher awareness of climate change are better equipped to integrate these risks into their operational strategies (Subramaniam et al., 2015), leading to improved risk management and reduced financial uncertainty. Companies aware of the risks and opportunities of climate change can better prepare mitigation and adaptation actions to anticipate potential losses in the future. Apart from that, companies can also

identify opportunities for climate change through resource efficiency that will bring benefits in the future. Climate change awareness can also help companies respond more effectively to regulatory and market changes, improving financial performance and company value. Thus, investors will tend to value companies that demonstrate a heightened awareness of the risks and opportunities of climate change, as these companies often have a better ability to manage environmental risks, attract greater investment, and exploit opportunities for efficiency and innovation. As a result, the firm value can increase, along with a built positive reputation and a better ability to adapt to regulations and changes in market dynamics.

H2: Companies with higher climate change awareness are likely to have a higher firm value

Several authors, including Ji (2015) and Haque (2017), highlight the importance of sustainable executive compensation policies that encourage executives to adopt a long-term social and environmental perspective. This approach focuses on improving environmental performance. In this context, compensation policies are designed to discourage managerial decisions that could result in fines or penalties for the company. However, there are other dimensions, such as social issues and corporate governance, where negative actions are not directly punished financially, but poor performance can damage the company's image or reputation. Consequently, to achieve non-financial goals, environmental, social, and governance (ESG)-based compensation policies can effectively motivate employees to achieve sustainable goals beyond just financial results (Haque, 2017). Companies implementing sustainability compensation incentives tend to increase their overall value while changing the impact of carbon emissions and climate change awareness on company performance.

By aligning executive pay with sustainability goals, companies signal their commitment to environmental management, which can enhance their reputation and attract investors (Ritz, 2022). This strategic alignment motivates management to prioritize sustainable practices and reduces the negative impacts associated with carbon emissions. Companies provide sustainability-related compensation incentives, which can encourage managers to behave more responsibly in managing carbon emissions. In addition, corporate awareness of climate change can be triggered and strengthened by implementing sustainability compensation incentives. When companies provide these incentives, management feels more compelled to integrate sustainability practices into their strategies. With the incentives, they may be more motivated to find innovative ways to manage carbon emissions and pay attention to the environmental impacts of their business decisions. These incentives serve as a tool to encourage more responsible behavior and help build a proactive corporate culture to address climate change risks. Thus, even if the awareness comes from within the company, incentives can strengthen and accelerate the process of learning and adopting better practices. It also shows investors that the company is serious about addressing environmental challenges, which can increase the firm value in the eyes of stakeholders.

H3a: Companies that provide sustainability compensation incentives are likely to weaken the influence of carbon emissions on firm value.

H3b: Companies that provide sustainability compensation incentives are likely to strengthen the influence of climate change awareness on firm value.

3. RESEARCH METHOD

3.1 Data and Sample Selection

This research examines the influence of carbon emissions and climate change awareness on company value. Furthermore, the researchers expanded the test by testing whether the impact of sustainability compensation incentives influenced this relationship. The research sample was selected based on the following criteria: 1) public companies domiciled in Europe; 2) companies not located in conflict-affected countries; 3) companies with complete data availability; 4) does not include companies from the financial industry classified by the GICS (Global Industry Classification Standard) industry. With these criteria, we obtained a sample of 4,804 companies from 30 European countries with unbalanced panel data characteristics. Table 1 Panel A presents the sample selection process in detail. The research data was sourced from the Thomson Reuters Dataset. Table 1 details the distribution of firm-year observations, with Panel B presenting the breakdown by country and Panel C providing the distribution by industry and year.

Table 1. Panel A: Sample Selection Process

Selection criteria	Observations
Initial observations	71,181
Excluded:	
Company in country with missing data	(66,377)
Company is located in a conflict-ridden country	(2,442)
Final observations	4,804

Table 1. Panel B. Sample Distribution by Country

No.	Country	Freq.	%	Cum	No.	Country	Freq.	%	Cum
1	Austria	113	2.35	2.35	16	Isle of Man	1	0.02	39.95
2	Belgium	104	2.16	4.52	17	Italy	167	3.48	43.43
3	Cyprus	3	0.06	4.58	18	Jersey	6	0.12	43.55
4	Czech Republic	2	0.04	4.62	19	Lithuania	1	0.02	43.57
5	Denmark	143	2.98	7.60	20	Luxembourg	74	1.54	45.11
6	Faroe Islands	4	0.08	7.68	21	Monaco	4	0.08	45.19
7	Finland	190	3.96	11.64	22	Netherlands	209	4.35	49.54
8	France	608	12.66	24.29	23	Norway	145	3.02	52.56
9	Germany	551	11.47	35.76	24	Poland	32	0.67	53.23
10	Gibraltar	4	0.08	35.85	25	Portugal	75	1.56	54.79
11	Greece	47	0.98	36.82	26	Romania	6	0.12	54.91
12	Guernsey	2	0.04	36.87	27	Spain	245	5.10	60.01
13	Hungary	21	0.44	37.30	28	Sweden	441	9.18	69.19
14	Iceland	1	0.02	37.32	29	Switzerland	264	5.50	74.69
15	Ireland; Republic of	125	2.60	39.93	30	United Kingdom	1,216	25.31	100
Total									4,804

Note: Table 1 Panel B presents the distribution of the sample based on Country Listed in Thompson Reuters. We randomly selected observations with available data and no missing values. We intentionally excluded some conflict-ridden countries (such as, Ukraine and Russia)

Table 1. Panel C. Sample Distribution by Industry Sector and Year of Observation.

Industry Sector Code	YEAR											Total
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
[10]	38	39	34	30	24	21	21	20	21	21	20	289
[15]	90	84	76	70	45	45	38	35	34	33	36	586
[20]	210	184	161	153	118	82	69	65	73	70	62	1247
[25]	129	110	90	71	60	38	36	34	31	30	31	660
[30]	67	67	59	53	38	34	31	28	27	22	22	448
[35]	53	51	40	37	26	24	18	18	17	19	20	323
[45]	55	49	34	28	17	14	11	12	13	13	12	258
[50]	52	48	42	37	29	24	21	21	21	19	21	335
[55]	40	33	36	34	26	30	28	22	22	22	26	319
[60]	61	62	51	41	37	23	18	13	14	11	8	339
Total	795	727	623	554	420	335	291	268	273	260	258	4804

Note: Table 1 Panel C presents the sample distribution based on GICS (Global Industry Classification Standards) is available in Thompson Reuters during the observation period. The two-digit sector code used is: “[10] Energy Equipment & Services, Oil, Gas & Consumable Fuels; [15] Chemicals, Construction Materials, Containers & Packaging, Metals & Mining, and Paper & Forest Products; [20] Aerospace & Defense, Building Products, Construction & Engineering, Electrical Equipment, Industrial Conglomerates, Machinery, Trading Companies & Distributors, Commercial Services & Supplies, Professional Services, Air Freight & Logistics, Passenger Airlines, Marine Transportation, Ground Transportation, and Transportation Infrastructure; [25] Automobile Components, Automobiles, Household Durables, Leisure Products, Textiles, Apparel & Luxury Goods, Hotels, Restaurants & Leisure, Diversified Consumer Services, Distributors, Broadline Retail, and Specialty Retail; [30] Consumer Staples Distribution & Retail, Beverages, Food Products, Tobacco, Household Products, and Personal Care Products; [35] Health Care Equipment & Supplies, Health Care Providers & Services, Health Care Technology, Biotechnology, Pharmaceuticals, and Life Sciences Tools & Services; [45] IT Services, Software, Communications Equipment, Technology Hardware, Storage & Peripherals, Electronic Equipment, Instruments & Components, Semiconductors & Semiconductor Equipment; [50] Diversified Telecommunication Services, Wireless Telecommunication Services, Media, Entertainment and Interactive Media & Services; [55] Electric Utilities, Gas Utilities, Multi-Utilities, Water Utilities, Independent Power and Renewable Electricity Producers; [60] Diversified REITs, Industrial REITs, Hotel & Resort REITs, Office REITs, Health Care REITs, Residential REITs, Retail REITs, Specialized REITs, and Real Estate Management & Development.”

3.2 Hypotheses Testing

We formulated equation (1) to test hypotheses, which was estimated using OLS regression with several testing modifications involving industry, year, and country fixed effects. This study also analyzed companies' decisions to give sustainability compensation incentives in order to examine their influence on firm value (hypotheses 3a and 3b)

$$\begin{aligned} TOBINSQ_{jt} = & \alpha + \beta_1 CE_{jt} + \beta_2 CCA_{jt} + \beta_3 SCI_{jt} + \beta_4 CE * SCI_{jt} + \beta_5 CCE * SCI_{jt} + \beta_6 ROA_{jt} + \beta_7 DER_{jt} \\ & + \beta_8 BVS_{jt} + \beta_9 Industry\ Fixed\ Effect_{jt} + \beta_{10} Year\ Fixed\ Effect_{jt} \\ & + \beta_{10} Country\ Fixed\ Effect_{jt} \\ & + \varepsilon_{jt} \end{aligned} \quad ..Equation (1)$$

This research uses TOBINSQ to represent firm value. Company value is one of the benchmarks for investors when viewing the company's long-term financial performance (Scott, 2017). The proxy used by researchers to measure company value is Tobins'Q. This proxy refers to research by Li et al. (2016), Gatzert & Reichel (2022), and Sharma et al. (2023). Tobins'Q was introduced by Tobin (1969). Tobin (1969) stated that the concept of Tobin's Q integrates monetary theory with general equilibrium theory to measure and predict investment decisions. Tobin's Q is designed to estimate or project expected future earnings on company profits that are not too sensitive to strategic manipulation of accounting profits (Dechow, 2023). This proxy was chosen because it is based on the definition of company value used in this research, and this measure is particularly appropriate for the context of European firms. Using Tobin's Q as a proxy for company value in European firms is beneficial due to its integration of market and book values, which provides a comprehensive investment assessment. Strict financial reporting regulations in Europe enhance the accuracy of these values, making Tobin's Q a reliable measure for long-term performance. Additionally, its insensitivity to accounting manipulation ensures integrity in financial reporting, focusing on stable projections of future earnings relevant in competitive markets.

CE shows carbon emissions, which describes thousands of tons of carbon emissions. CCA (Climate Change Awareness) shows the extent to which a company recognizes and responds to climate change as a commercial risk and opportunity. This assessment is based on several criteria that reflect a company's involvement and actions on climate change. This research uses the moderating variable SCI (Sustainability Compensation Incentive) using a dummy variable, one if the company has a policy to incentivize executives related to sustainability actions, while 0 otherwise. All data for this research were obtained from the Thomson Reuters database.

This research uses several control variables, namely ROA (Return on Assets), DER (Debt to Equity Ratio), and BVS (Book Value of Share). ROA was chosen since it is an essential indicator of a company's operational efficiency and profitability. It can influence the analysis results by showing how effectively the company utilizes its assets to generate profits. Several studies that use Return on Assets (ROA) are Girella et al. (2019) and Kılıç & Kuzey (2019). This study chooses to use ROA as a proxy for profitability because it measures a company's net income as a percentage of total assets, providing a clear picture of its efficiency in using its assets to generate profits Kılıç & Kuzey (2019). This proxy is relevant because emission management often requires investment in infrastructure and better environmental practices, which are directly related to using a company's assets (Girella et al., 2019). Thus, researchers consider ROA more appropriate than other proxies because it is more holistic and representative in evaluating the relationship between profitability and climate change disclosure.

DER is included to control the impact of capital structure on financial risk and company leverage, which can influence the relationship between independent variables and company value. Leverage measures the proportion of debt to equity and can affect disclosure decisions because companies with high debt levels face higher capital costs if they are not transparent. Companies with high leverage are usually more motivated to improve disclosure quality to reduce debt costs and financial risk. Previous research (Matsumura et al., 2014) shows that companies with higher leverage provide higher-quality disclosures.

BVS, as an indicator of corporate valuation, is added to consider the book value of shares in market valuation, ensuring that the effect of this valuation variable does not interfere with the analysis of the main relationships. By controlling these variables, the research aims to separate the influence of financial performance, capital structure, and market valuation so that the analysis results are more accurate and representative in assessing the impact of carbon emissions and climate change awareness on company value.

Researchers also conducted additional analysis by dividing the research sample period into two: first, the 2013-2015 period, which was the period before the implementation of the SDGs, and second, the 2016-2023 period, after the publication of the Task Force on Climate-related Financial Disclosures (TCFD) framework. This breakdown was carried out to evaluate the impact of different sustainability disclosure regulations and standards on the relationship between carbon emissions, climate change awareness, and corporate value. By comparing these two periods, researchers aim to identify whether stricter policies and more detailed reporting standards, such as the TCFD, affect the effectiveness of sustainability compensation incentives and increase their impact on company value. This analysis allows for a more in-depth assessment of how changes in environmental regulations and policies affect emissions disclosures and corporate performance and provides insight into corporate responses to sustainability policies as they evolve over time.

4. RESULT AND DISCUSSION

4.1 Descriptive Statistics

Table 2 reports the descriptive statistics for all variables used in this research based on a sample size of N = 4,804. The variable TOBINSQ is employed to represent firm value, where a score exceeding one indicates that the company's market value is higher than the market price of its shares. The mean value of TOBINSQ is 1.789, suggesting that, on average, the market value of firms exceeds their share price. The TOBINSQ ratio ranges from a minimum of 0.273 to a maximum of 63.919, highlighting significant variability in firm valuation. The variable CE (Carbon Emission) is measured in millions of tons and encompasses total carbon dioxide (CO₂) and CO₂ equivalent emissions, following the guidelines of the GHG Protocol. These emissions include various greenhouse gases such as CO₂, methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorinated compounds (PFCs), sulfur hexafluoride (SF₆), and nitrogen trifluoride (NF₃). Descriptive statistics for CE reveal a mean emission level of 4.232 million tons. This result indicates a generally moderate average carbon emission across firms, though there is considerable variability, with some firms exhibiting substantially higher emissions. Climate Change Awareness (CCA) shows a mean value of 74.979, with a minimum of 51.350 and a maximum of 94.920. This range indicates a broad spectrum of climate change awareness among firms, with substantial variation in how companies perceive and address climate change risks and opportunities. For the SCI variable, the analysis indicates whether executive compensation is linked to achieving targets related to sustainability. A value of 1 denotes that such incentives are in place and vice versa. This variable provides insight into how compensation structures may align with sustainability goals and corporate responsibility.

Table 2. Descriptive Statistics

	N	Minimum	Maximum	Mean	Median	StdDev
Dependent Variables						
TOBINSQ	4,804	0.273	63.919	1.789	1.332	1.883
Independent Variables						
CE	4,804	1.00e-05	194.800	4.232	0.202	15.941
CCA	4,804	51.350	94.920	74.978	42.883	8.863
SCI	4,804	0.000	1.000	0.510	1.000	0.499
Control Variables						
ROA	4,804	-0.340	1.980	0.057	0.050	0.072
DER	4,804	0.01	42.070	1.137	0.720	2.006
BVS	4,804	1.800	6.666	3.402	3.555	0.519

Note: This table presents summary statistics for all variables comprising 4,804 firm-year observations in 30 European countries from 2014 – 2023.

Table 3 presents the Pearson Correlation matrix for the study's variables. Most variables appear to be correlated, and only a few do not. Table 3 provides a comprehensive overview of the pairwise correlations between each variable, offering insights into their linear relationships. Positive values indicate a direct relationship, where increases in one variable are associated with increases in another, while negative values suggest an inverse relationship. Correlations close to 1 or -1 signify strong relationships, whereas those near 0 imply weak associations. The matrix reveals several significant correlations. Notably, Tobin's Q (TOBINSQ) shows a strong positive correlation with Return on Assets (ROA) (0.7050), indicating that firms with higher market valuations tend to have better asset efficiency. Climate Change Awareness (CCA) is moderately positively correlated with TOBINSQ (0.1478), suggesting that greater climate change awareness is associated with higher firm valuation. However, this relationship is statistically significant at a lower threshold ($p < 0.10$). CE and SCI show weak and statistically insignificant correlations with firm value and performance metrics.

Additionally, Total Assets (ASSET) exhibits a very high positive correlation with Total Liabilities (LIAB) (0.9581), highlighting a strong relationship between a firm's asset base and its liability levels. DER and ROE correlations are relatively weak, indicating limited impact on financial performance measures. While some relationships are statistically significant, many correlations are weak or insignificant, suggesting that the associations between environmental and financial metrics are complex and require further investigation.

Table 3. Pearson Correlations

	[1] TOBINSQ	[2] CE	[3] CCA	[4] SCI	[5] ROA	[6] ASSET	[7] LIAB	[8] DER	[9] ROE	[10] BVS
[1]	1.0000									
[2]	-0.0932	1.0000								
[3]	0.1478	-0.1244	1.0000							
[4]	-0.0269	0.00692	-0.2649	1.000						
[5]	0.7050	-0.0633	0.1216	-0.0225	1.0000					
[6]	0.0359	-0.1185	0.0006	-0.0101	0.0077	1.0000				
[7]	0.0453	-0.1144	-0.0006	-0.0161	0.0156	0.9581	1.0000			
[9]	0.2196	0.0255	0.0644	-0.0055	0.3735	0.0217	0.0260	1.0000		
[9]	-0.0692	-0.0165	-0.0579	-0.0044	-0.1870	-0.0072	0.0015	-0.1992	1.0000	
[10]	0.0489	-0.1760	0.0066	-0.0559	0.0069	0.7973	0.8053	0.0036	0.0128	1.0000

Coefficients in bold are significant at $p < 0.10$

Coefficients in plain text are not significant $p > 0.10$

N= 4,804 firm-year observations in 30 European countries from 2013 – 2023.

For variable definition see Appendix.

4.2 Main Result and Discussion

Tables 4a and 4b present the results of the fixed effects regression (Equation 1). Table 4a includes fixed effects by industry, country, and year (column 1), as well as fixed effects by year separation (columns 2 and 3). This year's split aims to analyze several significant events that may occur during the sample period to assess the response to them. For example, we investigated whether companies showed higher commitment to achieving goal 13 of the SDGs, namely addressing climate change, before the publication of the SDG Index (2013–2015) and how this influenced the increase in company value from an investor perspective. Subsequently, we assess fluctuations in company value during the period following the SDG Index publication and throughout the TCFD Framework implementation from 2016 to 2023. This period is particularly significant as it marks increased regulatory pressure and the adoption of sustainability reporting standards. By evaluating company value fluctuations during this time, we can explore the impact of sustainability regulations and policies on market responses to various sustainability initiatives. This comprehensive analysis sheds light on how companies adapt to and capitalize on sustainability trends and offers insights into the broader implications for investor behavior and firm valuation in an evolving regulatory landscape.

Table 4a. Fixed-Effect Regression Result

Dependent Variable:	Full Period		2013 – 2015		2016-2023	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coeff.	T-stas.	Coeff.	T-stas.	Coeff.	T-stas.
	<i>Firm Value obtained from TOBINSQ</i>					
CE	-1.695** (0.023)	-2.27	-3.590 (0.508)	-0.66	-2.462*** (0.000)	-4.33
CCA	0.0099*** (0.000)	4.34	0.060*** (0.000)	5.53	0.0101*** (0.000)	3.56
SCI	0.045 (0.221)	1.23	0.088 (0.445)	0.76	0.064** (0.004)	2.02
ROA	18.480*** (0.000)	68.00	19.519*** (0.000)	48.24	15.358*** (0.000)	46.28
DER	-0.058** (0.050)	-1.96	0.059** (0.045)	-2.01	0.038*** (0.000)	3.67
BVS	0.0625*** (0.000)	3.86	0.031 (0.869)	0.17	0.123*** (0.001)	3.36
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-0.876 (0.000)	-3.92	-2.278 (0.000)	-3.05	3.051 (0.000)	4.82
F	824.64		440.60		342.85	
r2	0.5092		0.5537		0.4388	
r2_a	0.5086		0.5524		0.4375	
N	4,804		2,166		2,638	

The t statistics in parentheses indicate significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The Relationship Between Carbon Emission and Firm Value

The results from Table 4a show that companies with high CE have a negative effect on company value with a t-value (1)= 2.27 ($p < 0.05$). Thus, the result of this test indicates that H1 is supported. These results are consistent with the findings of Chapple et al. (2013), Matsumura et al. (2014), Clarkson et al. (2015), Griffin et al. (2017), and Palea & Santhià (2022). Griffin et al. (2017) show that high greenhouse gas (GHG) emissions can be considered an additional risk not directly reflected in the company's financial statements, such as income and equity. Although the company may appear financially healthy, the potential future costs due to regulation, compliance, or higher taxes due to high carbon emissions can reduce the firm value. In other words, companies with high emissions may face additional costs in the future, which can harm their current value.

Additionally, companies with high carbon emissions risk facing a decline in reputation with consumers and investors, further deteriorating the market's perception of their value (Matsumura et al., 2014; Saka & Oshika, 2014). Investors tend to reduce their assessments of companies deemed unsustainable or facing reputational risks related to their environmental impact. High carbon emissions reflect operational and compliance risks and affect investors' perceptions of a company's long-term sustainability and growth potential, ultimately reducing the company's market value. These results are consistent with research (Matsumura et al., 2014). Saka & Oshika (2014) stated that negative market valuation of companies with high carbon emissions may be due to reputational impacts and future regulatory risks. Aswani et al. (2024) stated that a company's carbon emissions can influence the stock returns received by investors. When a company has high levels of carbon emissions, investors who care about environmental impacts tend to avoid the company's shares. When many investors choose to avoid stocks from industries with high carbon emissions, demand for them decreases, which can cause share prices to fall below their intrinsic value. As a result, demand for these shares decreases, causing share prices to fall. This decline in share prices directly reduces the company's market value because its market value is usually reflected in its share price. However, other studies found that disclosing their carbon management practices enhances market value. Companies that transparently disclose their efforts in managing carbon emissions tend to have a higher market value (Matsumura et al., 2014; Saka & Oshika, 2014), and this is a signal that the company is more reliable in managing carbon risk and has lower risk, so lenders are willing to provide loans with lower interest rates (Jung et al., 2018). This positive effect of disclosure becomes more pronounced when companies have a high volume of carbon emissions. In this context, disclosing information regarding carbon management practices increases transparency. It helps companies with high emissions increase their market value by showing that they proactively manage their environmental impacts.

The Relationship Between Climate Change Awareness and Firm Value

Building on these results, the study next examines the impact of CCA on company value to assess how companies' efforts in mitigating and adapting to climate change risks affect their market valuation. While the previous findings indicate that high carbon emissions are negatively associated with market value and that disclosing carbon management practices can improve market value, further analysis is needed to understand the effects of climate change awareness. This research explores how a company's awareness of climate change influences its market value, focusing on the measures taken for mitigation and adaptation. The aim is to provide deeper insights into how proactive climate risk management can impact market assessments and whether climate change awareness is an additional indicator in evaluating a company's market value.

CCA is proven to increase company value with a t-value (1)= 4.34 ($p < 0.01$). Thus, awareness of climate change reduces risks, increases efficiency, and creates significant and sustainable added value for companies (H2 is supported). Aligned with Gatzert & Reichel (2022), this evidence captures the impact of company value from various industries. NRB theory posits that companies that manage natural resources sustainably can create competitive advantages. In this context, a heightened awareness of climate change is an essential capability that enables companies to manage environmental risks, improve operational efficiency, and innovate with environmentally friendly technologies. Companies that acknowledge climate change as a risk are more likely to develop innovative products or services designed to mitigate these risks and adapt their business models. This proactive approach helps overcome potential threats and allows firms to capitalize on emerging market opportunities related to climate change. These companies can improve operational efficiency and enhance their market reputation by integrating climate considerations into their product development and strategic planning. Consequently, investors view these firms more favorably, as their forward-thinking strategies and risk management capabilities contribute to higher future cash flows and sustainable value creation. Thus, the research supports the notion that awareness of climate change and the consequent adaptation and innovation play a crucial role in boosting company value.

Additionally, companies that demonstrate a commitment to sustainability can improve their reputation in the eyes of investors and stakeholders, which contributes to increasing their market value. Companies aware of climate change risks are better equipped to implement effective strategies that ultimately increase their value in the market (Subramaniam et al., 2015). Jung et al. (2018) showed that awareness of carbon risks can reduce financial penalties, thereby minimizing their impact on debt costs. Investors often prefer companies that demonstrate high awareness of climate change, as these companies are perceived as being better able to manage environmental risks, attract investment, and capitalize on innovation opportunities. Thus, investors can also make predictions about future cash flows more accurately since companies have a more comprehensive consideration of future risks realized through mitigation actions for climate change.

Additional Analysis

Further analysis was carried out on the breakdown of the 2013-2015 and 2016-2023 periods to determine the event response. For example, whether the sub-sample period before the SDG index (2013 - 2015) and during the SDG index period (2016-2023) or the implementation of the TCFD affects corporate climate change management, which impacts corporate value. Table 4a accommodates the above questions, which we test using a regression analysis with fixed effects. Our findings provide a good opportunity to get a complete picture throughout the study. First, in column 2, in the period 2013 to 2015, the relationship between carbon emissions and corporate value is not found to be significant (t-value (2) = -0.66 and $p > 0.01$), indicating that investors may have paid less attention to environmental issues at that time. However, in column 3, from 2016 to 2023, a significant negative impact of carbon emissions on corporate value is observed (t-value (3) = -4.33 and $p < 0.01$). Implementing a stricter regulatory framework and international agreements to combat climate change may have caused investors' increased sensitivity to carbon emissions in recent years. As a result, the full sample analysis from 2013 to 2023 reveals that carbon emissions are associated with a decline in firm value, reflecting a broader market shift toward prioritizing sustainable business practices and the financial implications of environmental performance.

Furthermore, unlike carbon emissions, where there is no evidence of a decline in firm value in 2013-2015, climate change awareness appears to have a consistent effect across all periods (column 1, column 2, and column 3). The authors argue that investors viewed carbon emissions as a less significant risk prior to the introduction of the SDGs index (a framework that guides countries to formulate sustainable development policies and strategies) and the TCFD Recommendations (guidelines for a more climate-responsive financial system, which encourages greater action to mitigate and adapt to climate change). Market sentiment may prioritize other financial metrics over carbon emissions, focusing on profitability, growth potential, or general market conditions. Furthermore, Matsumura et al. (2014) argue that carbon emissions meet the definition of an externality. There is uncertainty about the extent to which firms will be required to internalize the costs of their carbon emissions in the future. Firms may not fully internalize the environmental costs of their activities. Additionally, companies might be able to transfer the expenses associated with their carbon emissions to their customers and/or supply chain partners. Thus, this uncertainty creates an opportunity for companies to not fully bear these costs, which can prevent carbon emissions from significantly impacting their market valuation. If companies can pass these costs on to consumers or supply chain partners, the firm value may remain stable, even in the face of stricter regulations in the future. Meanwhile, in climate change awareness, this study argues that awareness is a form of company commitment in responding to climate change issues that can improve reputation and attract investors. By showing awareness of the risks and opportunities related to climate change, companies can increase their market value and adapt to increasingly stringent regulations and increasingly environmentally conscious consumer preferences. Subramaniam et al. (2015) emphasize the importance of awareness of climate change risks in a company's operational strategy. This theoretical framework makes climate change awareness essential in assessing a firm value in a competitive market.

Table 4a also shows that the control variables ROA and BVS used in this study have a positive effect, and DER has a negative effect on company value. The positive influence of ROA means that companies with high efficiency in generating profits from their assets tend to have a higher market value because investors see these companies as more profitable and efficient. Likewise, a high BVS, which measures the ratio between the book value of equity and the market value of equity, indicates that investors consider companies with a higher market value than their book value more valuable. On the other hand, a high DER indicates that the company has a large proportion of debt compared to its equity. The negative influence of DER indicates that investors perceive companies with high levels of debt as riskier, which can reduce the market value of these companies. Thus, these results indicate that asset efficiency and high relative book value contribute positively to company value, while high debt can reduce the firm value in the market.

Moderating Effect of Sustainability Compensation Incentives

Hypothesis H3a expects that sustainability compensation incentives will reduce the negative impact of carbon emissions on firm value. However, the results that show a larger coefficient in absolute value with t value (1) = -3.15 ($p < 0.001$) compared to $t = -2.27$ ($p\text{-value} < 0.05$) (See Table 4b) after moderation indicate that sustainability compensation incentives strengthen the impact negative carbon emissions on company value, not weakening or reducing it (H3a is not supported). In other words, companies that implement sustainability incentives experience a greater decline in company value due to carbon emissions than companies that do not have such incentives. Investors may doubt the credibility of incentives if they are seen as merely symbolic efforts or greenwashing so that the negative impact of carbon emissions remains strong. A company's internal motivation to reduce carbon emissions may be less intense if incentives are not deeply integrated into the company's strategy, and crisis or change situations may reduce the incentives' effectiveness. Thus, sustainability compensation incentives may not be enough to reduce the negative impact of carbon emissions on firm value.

Table 4b. Regression Result -Moderating Effect

	Full Period		2013 – 2015		2016-2023	
	(1)	(2)	(3)	(4)	(5)	(6)
	Coeff.	T-stas.	Coeff.	T-stas.	Coeff.	T-stas.
<i>Dependent Variable:</i>	<i>Firm Value obtained from TOBINSQ</i>					
CE*SCI	-4.526*** (0.002)	-3.15	-0.781 (0.776)	-0.28	-1.270** (0.010)	-2.59
CCA*SCI	-0.0002 (0.583)	-0.09	-0.0012 (0.446)	-0.76	0.0011** (0.013)	2.50
ROA	18.480*** (0.000)	68.00	19.519*** (0.000)	48.24	15.358*** (0.000)	46.28
DER	-0.058** (0.050)	-1.96	0.059** (0.045)	-2.01	0.038*** (0.000)	3.67
BVS	0.0625*** (0.000)	3.86	0.031 (0.869)	0.17	0.123*** (0.001)	3.36
Industry Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Country Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
_cons	-0.876 (0.000)	-3.92	-2.278 (0.000)	-3.05	3.051 (0.000)	4.82
F	824.64		440.60		342.85	
r2	0.5092		0.5537		0.4388	
r2_a	0.5086		0.5524		0.4375	
N	4,804		2,166		2,638	

*The t statistics in parentheses indicate significance at * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

The following result tests hypothesis H3b, which states that companies that provide SCI tend to increase company value and strengthen the influence of climate change awareness (CCA) on company value. Data analysis shows that in the entire period (2013-2023), hypothesis H3b is not supported significantly. After being moderated by SCI, the coefficient for the interaction (CCA*SCI) becomes -0.0002, with a t-value (1) -0.09 and a p-value > 0.05 . The statistical results indicate that SCI has no effect in strengthening or changing the positive impact of climate change awareness on firm value. However, from 2016 to 2023, the coefficient for the interaction became 0.0011, with a t-value (3)= 2.5 and a p-value < 0.05 , indicating a significant positive relationship between climate change awareness and firm value when moderated by SCI. These results show that in this period, SCI began to have a positive impact, indicating that companies that implement sustainability incentives can effectively utilize their awareness of climate change to increase firm value. These results indicate that increasingly tightening environmental regulations and sustainability disclosure standards, such as the SDG Index and TCFD Framework, increase the effectiveness of sustainability compensation incentives in moderating the relationship between CCA and firm value. In contrast, in the 2013-2015 period, regulations have yet to be fully implemented, and companies may have yet to respond to these regulations effectively. The study reveals that SCI can significantly enhance the link between climate change awareness and firm value, particularly as regulations become stricter and investor awareness increases. However, the effectiveness of these incentives appears to be more apparent in the period following the strengthening of sustainability regulations and disclosure standards.

Agency theory explains that providing incentives can help reduce conflicts between corporate managers and shareholders and motivate managers to work harder. This theoretical framework, in turn, can reduce agency costs, increase cash flow and corporate valuation, and lower the cost of capital (Jensen & Meckling, 1976; Jensen &

Meckling, 2012). However, carbon reduction initiatives require long-term investments that do not provide immediate financial returns. In this context, executives with a self-interested attitude may be reluctant to pursue such large-scale investments (Liao et al., 2015).

Similar to previous studies, such as Baraibar-Diez et al. (2019), Baraibar-Diez et al. (2019) revealed that Sustainable Executive Compensation (SEC) has no significant impact on CSR performance. Fabrizi et al. (2014) also found that monetary incentives that align CEO and shareholder interests have a negative impact on CSR initiatives, including in the context of carbon emissions and climate change awareness. Incentives focusing on short-term performance, such as bonuses and stock prices, may encourage CEOs to prioritize immediate financial results, ignoring investments needed to reduce carbon emissions and raise awareness of climate change. On the other hand, non-monetary incentives, such as attention to the CEO's career and positional power, may encourage executives to consider the company's and stakeholders' long-term interests, including environmental impacts. These results suggest that executive incentive designs need to be more holistic, integrating non-monetary factors to encourage commitment to sustainability and social responsibility rather than focusing solely on short-term financial gains so that companies can address carbon emissions and climate change awareness issues more effectively.

Furthermore, these results support Ritz (2022), who states that companies need to consider integrating climate metrics into short-term and long-term incentive plans. Ritz (2022) states that one of the main challenges is determining whether incentives should be based on emissions resulting from the company's production or cover the entire value chain. Incentive design principles tend to lean toward the first approach, but strategic considerations increasingly favor the second approach. As the ability to measure emissions across the value chain increases, more holistic incentives will become more attractive.

4.3 Sensitivity Analysis

To assess the robustness of our primary findings, we conducted a sensitivity analysis using a method similar to that employed by Matsumura et al. (2014). This analysis examines the relationship between variations in firm value, changes explicitly in Tobin's Q ($\Delta TOBINSQ_{jt}$), and variations in carbon emissions (ΔCE_{jt}).

In addition, to control for potential bias of correlated omitted variables, we include proxies for Asset ($ASSET_{jt}$), Liability ($LIAB_{jt}$), and Return on Equity (ROE_{jt}). Natural logarithm of total assets was also used in previous studies such as Girella et al. (2019) as a factor influencing companies' integrated reporting disclosure of corporate climate change practices (Amran & Haniffa, 2011; Eleftheriadis & Anagnostopoulou, 2015), and carbon emissions (Dutta & Dutta, 2021; Matsumura et al., 2014). Companies with large total assets can invest in managing climate change risks and opportunities. This result aligns with the NRB theory (Hart, 1995) and the theory of proprietary costs (Girella et al., 2019; Prado-Lorenzo et al., 2009). In addition, large companies with large assets tend to have more attention from regulators and investors regarding environmental issues. Conversely, companies with high levels of debt may result in greater financial risk, which may affect investors' perception of firm value. By accounting for liabilities, the analysis can control for potential bias arising from unmeasured variables, ensuring that the relationship between carbon emissions and firm value can be analyzed more accurately. This helps identify whether the negative impact of carbon emissions on firm value is due to internal factors (such as liabilities) or is a direct effect of the emissions themselves. ROE can influence investors' perceptions of firm value; companies with high ROE are often perceived as more attractive, even with high carbon emissions. By including ROE, analyses can control for variables that may affect the relationship between carbon emissions and firm value, helping to identify whether changes in firm value are caused by carbon emissions themselves or by the firm's financial performance as measured by ROE. The model applied in this sensitivity analysis is articulated as follows:

$$\Delta TOBINSQ_{jt} = \beta_0 + \beta_1 \Delta CE_{jt} + \beta_2 BVS_{jt} + \beta_3 ASSET_{jt} + \beta_4 LIAB_{jt} + \beta_5 ROE_{jt} + \varepsilon_{jt} \quad .. Equation (2)$$

The sensitivity analysis results corroborate our primary finding that an increase in carbon emissions is associated with a decline in firm value. The coefficient for the change in carbon emissions (ΔCE) is -6.339, with a t-value of -3.04 and a p-value < 0.05, demonstrating high statistical significance and alignment with our main results. This decrease in firm value in response to rising carbon emissions reflects a negative assessment by the capital market regarding the growing environmental impact. These findings reinforce the understanding that higher carbon emissions lead to a reduction in firm value, consistent with the primary results indicating a negative relationship between carbon emissions and firm value. Additionally, this sensitivity analysis provides further evidence that the adverse effect of carbon emissions on firm value is robust and unaffected by variations in model specifications.

4.4 Robustness Test

In addition, we carried out robustness testing using PBV (*Price-to-book Ratio*) as other firm value measurements.

$$\begin{aligned} PBV_{jt} = & \alpha + \beta_1 CE_{jt} + \beta_2 CCA_{jt} + \beta_3 SCI_{jt} + \beta_4 CE * SCI_{jt} + \beta_5 CCE * SCI_{jt} + \beta_6 ROA_{jt} + \beta_7 DER_{jt} \\ & + \beta_8 BVS_{jt} + \beta_9 Industry\ Fixed\ Effect_{jt} + \beta_{10} Year\ Fixed\ Effect_{jt} \\ & + \beta_{10} Country\ Fixed\ Effect_{jt} \\ & + \varepsilon_{jt} \end{aligned} \quad ..Equation (3)$$

The results of this analysis reinforce our primary findings regarding the impact of carbon emissions on firm value. Specifically, examining Price-to-Book Value (PBV) ratios confirms that higher carbon emissions are linked to lower PBV ratios. This result indicates that investors view carbon emissions negatively when evaluating firm value. The coefficients from this analysis (results not shown) support the conclusion that increased carbon emissions adversely affect firm value, irrespective of the valuation metric employed. These results further reinforce the robustness and validity of the negative correlation between carbon emissions and firm value, corroborating the consistency of our main findings.

5. CONCLUSION

This research investigates whether investors value the information contained in carbon emissions and climate change awareness. Specifically, it also further tests the influence of sustainability compensation incentives in this relationship. Using the Thompson Reuters database, this study extends the sample by using 4,804 firm-year observations across 30 countries and ten industry sectors (excluding the financial sector) from 2013 to 2023.

This research finds that capital markets actively integrate carbon emissions and climate change awareness into company valuations. These results indicate that investors and market analysts incorporate information about a company's carbon emissions into their evaluation of company value. Companies that do not report their carbon emissions transparently face the potential for additional sanctions from the market, reflecting increasing concerns over environmental impacts and compliance with related regulations. The research results show that corporate climate change awareness positively relates to corporate value. In addition, this research also concludes that companies that demonstrate a high level of awareness of climate change tend to adopt better strategies in dealing with risks and exploiting opportunities arising from climate change, increasing their market value. These results are consistent with previous findings (Gatzert & Reichel, 2022), which show that proactive companies in managing environmental issues can strengthen their reputation and attract greater investment. This research provides broader insights because it covers a variety of industries, thus strengthening the results with more comprehensive coverage. This research adds to our understanding of how capital markets value carbon emissions disclosure and provides new insights into the consequences of carbon emissions disclosure and measures on firm value. These findings are essential for companies to understand that transparency in carbon emission disclosure is a regulatory obligation and directly influences their market assessment and performance. This study found that for every additional thousand metric tons of carbon emissions, company value fell by an average of €625,000. Although disclosing carbon emissions may reduce a firm's value in capital markets, companies may still choose to do so for broader strategic reasons, including regulatory compliance, stakeholder pressure, and the potential long-term benefits of transparency and risk management. The decision to disclose carbon emissions is often part of a broader sustainability strategy and consideration of the long-term impact on a company's reputation and sustainability.

The analysis shows that SCI do not function as expected in reducing the impact of carbon emissions on firm value, nor do they effectively enhance the relationship between climate change awareness and firm value. SCI negatively affects carbon emissions because investors view these incentives as unconvincing symbolic efforts. Although incentives are given to encourage sustainable practices, the impact of high carbon emissions already poses significant risks that can burden cash flow. Assuming the company does not make substantial emission reductions, in that case, the incentives given can instead be symbolic efforts or greenwashing, where the company appears to be trying to show a commitment to sustainability without actual actions that can reduce negative impacts. This condition can worsen investor perceptions of the company's management, decreasing the firm's overall value.

The results of this research open up further research related to climate change disclosure. Will it affect firm value if companies disclose climate-related risks and opportunities based on IFRS S2 Climate-related Disclosures? If company disclosures indicate that the magnitude of climate risks is greater than climate opportunities, will it also be negatively reacted to by investors? The development of this research extends the findings of Matsumura et al. (2014) that companies that transparently disclose their efforts in managing carbon emissions tend to have a higher

market value (Matsumura et al., 2014; Saka & Oshika, 2014), and this is a signal that the company is more reliable in managing carbon risk and has lower risk, so lenders are willing to provide loans with lower interest rates (Jung et al., 2018). These findings also emphasize that the effectiveness of SCI is highly dependent on strict environmental regulations and disclosure standards. A more in-depth analysis of how regulations and market perceptions of carbon emissions evolve and how these factors influence firm value is needed. These results open up future research.

Given the positive (negative) relationship between climate change awareness (carbon emissions) and firm value, companies must proactively align their sustainability strategies with market expectations. Corporate managers are encouraged to integrate sustainability into their core business strategies, ensuring environmental performance is central to decision-making. This integration can involve setting ambitious but achievable targets for carbon reduction, investing in cleaner technologies, and increasing transparency through regular sustainability reporting. For policymakers, our findings underscore the importance of developing and enforcing regulations that encourage sustainable practices. Creating a framework that supports companies in transitioning to low-carbon operations, such as tax breaks for sustainable investments or penalties for excessive emissions—can foster a more favorable business environment.

Additionally, executive incentive designs need to be more holistic, integrating non-monetary factors to encourage commitment to sustainability and social responsibility rather than focusing solely on short-term financial gains so that companies can more effectively address carbon emissions and climate change awareness issues. Encouraging collaboration between the private sector and environmental organizations may help businesses adopt best practices in sustainability. By aligning corporate strategies with investors' and regulators' expectations, companies can mitigate risks associated with carbon emissions and enhance their long-term value and reputation in the market.

The limitation of this study lies in the fact that the researcher did not capture whether the company is from a country that requires or does not require sustainability disclosure. Further research can specifically distinguish these regulatory aspects. This study can be developed by exploring the influence of carbon emission disclosure and climate change awareness by distinguishing regulations in developed and developing countries, government regimes, and socio-culture. The implications of these findings suggest that companies need to design incentive mechanisms that effectively integrate incentives with the company's long-term strategy. However, this study is limited to assessing the existence or absence of sustainability compensation incentive (SCI) policies for executives rather than exploring the types or incentive mechanisms implemented, both monetary and non-monetary. Therefore, further research is needed to explore the relationship between incentive types and their impacts on sustainability decisions and firm value. Thus, future research can provide deeper insights into how different incentives influence executive behavior in managing climate change-related risks and opportunities.

The findings of this study have broader significance in the context of global efforts to combat climate change, particularly regarding the Sustainable Development Goals (SDGs). By showing that investors increasingly consider carbon emissions disclosure and climate awareness in assessing firm value, this study supports SDG 13, which focuses on climate action. Transparency in emissions reporting helps companies comply with regulations and enhances their reputation in the market, which can encourage greater investment and support sustainable economic growth. Furthermore, the results of this study highlight the need for a more holistic incentive design to encourage sustainability practices so that companies can contribute to achieving global climate targets and reduce the negative impact of carbon emissions. By embracing transparency and responsibility, companies can strengthen their position in addressing environmental challenges while also having a positive impact on communities and stakeholders as a whole.

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Appendix

Table. Variable Definitions

Variable Name	Variable	Measurement	Sources
Dependent Variables			
Firm Value	TOBINSQ	is obtained from the market value (= total outstanding shares multiplied by share price at the end of the year) plus total book value of liabilities divided by total book value of assets.	Thompson Reuters
	PBV (Price-to-Book Value)	is calculated by dividing the market price per share by the book value per share.	Thompson Reuters
Independent Variables			
Carbon Emission	CE	denotes carbon emissions in millions of tons	Thompson Reuters
Climate Change Awareness	CCA	is calculated from the extent to which companies recognize and respond to climate change as a commercial risk and opportunity. This assessment is based on several key criteria that reflect a company's involvement and actions on climate change.	Thompson Reuters
Moderating Variables			
Sustainability Compensation Incentive	SCI	is defined as 1 if the senior executive's compensation linked to Sustainability targets and 0 otherwise	Thompson Reuters
Control Variables			
Return on Asset	ROA	is calculated as net income after taxes divided by total asset	Thompson Reuters
Debt to Equity Ratio	DER	is calculated as total liabilities divided by total equity	Thompson Reuters
Book Value Per Share	BVS	is total equity divided by total common shares outstanding at the end of the period.	Thompson Reuters
Firm Size	ASSET	is calculated as total assets	
Liabilitas	LIAB	is calculated as total liabilities	Thompson Reuters
Return on Equity	ROE	is calculated as net income after taxes divided by total equity	Thompson Reuters