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Research article

Carbon markets and firms' perceived climate regulatory risk

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ABSTRACT

This study examines how involvement in emissions trading schemes (ETS) affects firm climate regulatory risks (FCRR) across 36 countries from 2003 to 2021. We find a positive link between ETS membership and FCRR. Furthermore, we investigate how governance structures and firm-specific factors influence this relationship. Our analysis indicates that factors such as financial constraints, CEO network size, CEO tenure, the number of independent directors, and board size can lessen the impact of ETS membership on FCRR. Conversely, higher corporate political risk, membership in carbon-intensive industries, and a greater number of co-opted board members intensify this effect. Early participation in the scheme appears to reduce the firms' climate regulatory risk, while subsequent withdrawal increases it. Notably, the influence of ETS on FCRR is mainly observed among firms operating in developed economies. Legislative shocks, such as the EU Climate and Energy Package, diminish the positive effect of the ETS on FCRR. Overall, our findings highlight the sensitivity of firm-level climate regulatory risk to strategic decisions regarding ETS participation and exit.

1. Introduction

Climate regulatory risk arises from changes in laws and regulations aimed at addressing climate change. Along with physical and technological risks, it constitutes one of the three principal forms of climate risk (Seltzer et al., 2022). Institutional investors increasingly acknowledge that corporate climate regulatory risk is a pressing facet of firm climate-change risk (Krueger et al., 2020). This risk manifests in diverse forms, impacting corporate earnings and operational costs (Karpoff et al., 2005). Furthermore, regulatory exposure affects firms' positions in capital markets, as evidenced by Seltzer et al. (2022), who demonstrate the significant impact of a firm's climate regulatory credentials on bond yield and credit rating. Similarly, Sakhel (2017) finds that firms are more concerned with the implications of climate regulatory risk than with physical or market-based climate risks. Importantly, exposure to regulatory risk may also hinder access to financing (Dang et al., 2025; Agyei-Boapeah et al., 2024).

Conceptually, it is important to distinguish between climate regulatory risk and climate policy uncertainty. While the former refers to the potential negative consequences of climate-related regulations and policies, the latter reflects the unpredictability surrounding such regulations and policies. Although an increase in climate policy uncertainty may increase climate regulatory risk, the two concepts differ in their causes, consequences, and measurement. First, climate regulatory risk is driven by the implementation or change of climate-related policies. In contrast, climate policy uncertainty is caused by various factors, including shifting public perceptions of climate risks, new climate-related data and technology, and exogenous shocks (e.g., oil price surges after conflicts and wars) (Berg et al., 2023). Consequently, regulatory risk may lead to numerous adverse effects (e.g., higher borrowing costs and limited financial access as previously discussed), while increasing climate policy uncertainty tends to deter investment decisions, such as lower returns and higher volatility in sustainable investments (Olasehinde-Williams et al., 2023), and reduce investment in energy sectors (Ren et al., 2022). In addition, their measurements also differ. Climate regulatory risk is typically assessed based on firm-level exposure to policy frameworks, which vary even within the same sector (Sautner et al., 2023). On the other hand, the climate policy uncertainty is often estimated using indices such as one developed by Gavriilidis (2021). It sheds light on the time variation of climate policy uncertainty for a given market. In this study, our focus is on firm-level climate regulatory risk (FCRR) rather than the macro-level climate policy uncertainty.

In response to climate risks, firms have adopted various mitigation

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strategies, including process emission reductions, changes in output, emissions trading, and combustion emission reduction (Cadez and Czerny, 2016). Among these, emissions trading schemes (ETS) have emerged as one of the most popular and widely adopted market-based mechanisms. Empirical evidence supports their effectiveness; for instance, Jung and Song (2023) show that ETS adoption has significantly reduced global carbon emissions across both post-industrial and pre-industrial economies. At the firm level, researchers have linked ETS participation to outcomes such as stock returns (Oestreich and Tsiakas, 2015), firm performance (Jia, 2023), productivity (Tang et al., 2023), green innovation (Zhou et al., 2023), green investment (Yang, 2023), R&D spending (Yu et al., 2023), debt financing (Huang et al., 2024), cash holdings (Sakariyahu et al., 2023), and dividend payouts (Zhu and Hou, 2022).

However, a growing body of literature highlights the adverse consequences of participation. For example, Yang (2023) finds that ETS membership can reduce corporate environmental investment. Other authors argue that ETSs may stimulate carbon leakages and ultimately encourage the pollution haven effect (De Beule et al., 2022). Complementing this view, Adamolekun et al. (2024) posit that members of ETSs emit more harmful gases than non-members. Ni et al. (2022) also reveal that ETS membership can lead to higher debt costs. Moreover, ETS participation may strain firm liquidity, prompting the need for larger cash reserves (Sakariyahu et al., 2023). Existing research also acknowledges the role and challenges of ETS in the context of the green transition, such as the deceleration of green innovation (Chen et al., 2021) or its positive impact on energy consumption and energy conservation in China (Hu et al., 2020).

Nonetheless, there is a notable gap in the literature exploring the impact of ETS memberships on FCRR. We argue that ETS participation would affect FCRR for two main reasons. First, the crucial connection between ETS and FCRR lies in the disclosure of climate-related information. ETS has been documented to enhance corporate environmental information disclosure (e.g., Li et al., 2023). Upon joining the ETS, firms face heightened pressure to disclose more climate-related information to avert negative consequences, such as government sanctions, elevated tax rates, litigation risk, or market risk (Adamolekun et al., 2024; Alshahrani et al., 2023; Bolton and Kacperczyk, 2021; Gong et al., 2021). In addition, there is a motivational aspect to enhance disclosure, creating an image of a "good citizen," a phenomenon commonly referred to as "greenwashing." (Ding et al., 2023). In essence, ETS membership makes a firm's exposure to climate risk more visible to the public. Therefore, we expect a positive association between ETS membership and FCRR.

Second, the financial implications of ETS participation can intensify regulatory risk. By design, ETS encourages firms to allocate more financial resources to long-term investments, such as capitalised and expense-based environmental protection initiatives (Zhang et al., 2020). However, these expenditures can strain cash flows in the short term. Additionally, participation often comes at a cost in capital markets. For example, Chapple et al. (2013) find that the stock markets react negatively to ETS announcements. They argue that investors assess the economic impact and the price of joining the ETS, which causes the market capitalisation of likely participants to shrink. Similarly, Ni et al. (2022) show that ETS membership increases penalised bond yield, reflecting greater perceived risk from the debt market. In short, joining ETS may affect a firm's financial health and amplify its exposure to regulatory scrutiny. This aligns with Sautner et al. (2023), who find that firm-level characteristics, such as managerial skills, financial constraints, and other firm-level characteristics, are key drivers of climate change exposure across firms, explaining about 70 % of the variation in firm climate change exposure. Taken together, these mechanisms suggest a positive relationship between ETS participation and FCRR.

This paper addresses this gap by examining the relationship between ETS membership and firm FCRR using a global sample. We find that ETS membership is associated with higher FCRR. However, it is important to note that this result may capture firms' exposure to climate regulatory uncertainty rather than actual climate regulatory risk. In this effect, it may reflect the extent to which firms perceive they are exposed to inconsistency in climate regulation. Several factors, including financial constraints, CEO network size, CEO tenure, the number of independent directors, and board size, are found to mitigate the impact of ETS membership on FCRR. Conversely, factors such as corporate political risk, membership in carbon-intensive industries, and the number of co-opted board members exacerbate the relationship between ETS membership and FCRR. Notably, our results reveal that joining the scheme before the Paris Agreement reduces a firm's FCRR, while exiting the scheme increases it. The result also shows that the positive impact of ETS on FCRR is only pronounced among firms operating in developed nations. Finally, legislative policies, such as the EU Climate and Energy Package, could reduce the positive impact of the ETS on FCRR.

We contribute to the literature in several important ways. First, we employ the firm-level climate regulatory risk measure developed by Sautner et al. (2023) to provide new insights into the implications of corporate participation in the ETS. To the best of our knowledge, this is the first study to assess how ETS membership affects firm-level climate regulatory risk empirically. Second, our study extends the burgeoning conversations on the role and implications of ETS membership (Adamolekun et al., 2024; De Beule et al., 2022; Naegele and Zaklan, 2019). Third, we complement existing literature on corporate governance and the green transition (see, for instance, Luo and Tang, 2021) by identifying specific governance mechanisms that moderate the impact of ETS membership and FCRR. Finally, we provide a global perspective: while most of the existing literature is based on a single country, particularly China, we analyze firms across multiple countries and industries. This allows us to uncover the broader, cross-national implications of ETS participation and the role of institutional context in shaping climate risk exposure.

The remainder of the paper is structured as follows. Section 2 discusses the literature review, and Section 3 presents the methodology. In section 4, we discuss the findings. Section 5 concludes this study.

2. Literature review

2.1. Climate regulatory risk

Climate change poses a substantial threat to the world economy and human lives. Governments and policymakers worldwide continue to introduce new rules and regulations to combat climate change, including emission quotas, carbon taxes, fines, and lending restrictions for high-carbon-emitting producers. Those evolving legal and regulatory frameworks impose a significant risk on firms, known as the climate regulatory risk. A notable example is Volkswagen's record-breaking fine in 2017 for cheating on emission tests. Importantly, climate regulatory risk is not limited to carbon-intensive firms; it can also affect low-emission firms. For instance, the Bank of England (2023) has announced a review of its regulatory capital frameworks for banks and insurers to better account for climate risks. This may result in banks with greater exposure to climate-sensitive assets being required to hold more Tier 1 capital.

The significance of climate regulatory risk is widely recognised. Based on a sample in New Zealand, Bui and De Villiers' (2017) survey indicates that climate regulatory uncertainty is the primary constraint to carbon management accounting. Those interviewed in the survey are aware of the uncertainty surrounding climate policy and prefer a reactive rather than a proactive strategy to address the climate risks their organisations face. Krueger et al. (2020) focus on institutional investors and report that climate regulatory risk was considered the most significant risk among the three types of climate risk. Over half of participants (55 %) reported that this risk had materialised between 2017 and 2018. Similarly, Stroebel and Wurgler's (2021) survey is based on a large sample consisting of academics, professionals, and regulators. Their

Table 1
Variable Definition The table presents the definition of the main variables used in this study.

Variable	Definition
Firm climate regulatory risk (FCRR)	This variable captures corporate climate regulatory risk based on a bigram extracted from the transcript of earning calls (Sautner et al., 2023).
ETS	This is a variable that captures whether a firm is in an emission trading scheme or not.
Working Capital	This refers to the working capital of a corporation deflated by total assets.
CAPEX	This is the value of capital expenditure of a firm in a year.
R & D	This is the total value of money spent by a firm on research and development (R&D) divided by total assets.
RoA	This is the earnings before interest, tax, depreciation, and amortization (EBITDA) deflated by the total assets.
Industry Sales Growth	This captures a firm's sales growth adjusted by industry sales growth in a year.
Size	This is the natural logarithm of a firm's total assets.
Leverage	This refers to a firm's total debt deflated by total assets in a year.
Market to Book	Market-to-book (MTB) ratio is the market value of equity divided by the book value of equity.
Firm Political Risk	This is the value of a firm's political risk extracted from corporate earnings calls (Haslam et al., 2018).
Financial Constraint	This captures a firm's financial constraint using the KZ index.
Board Size	This is the natural log of the total number of board members.
Independent Director	This refers to the number of independent directors appointed by a firm.
Co-opted Board	This captures the number of directors appointed during the tenure of the CEO.
CEO Network	This measures the network reach of a firm's CEO.
CEO Time in Coy	This is the total number of years a CEO has spent in a company.
Carbon Intensity	This is a dummy variable that captures whether a firm is a member of a carbon-intensive industry.

results show that climate regulatory risk is the most concerning among climate-related risks over the next 5 years (2021–2026). In the long term, over the next 30 years (2021–2051), participants ranked climate regulatory risk as the second most important risk after physical risk.

There is a growing body of literature examining the impact of climate regulatory risk on firms. Several studies highlight the financial costs of climate regulatory risk. Kovacs et al. (2021) document that firms tend to increase leverage following a decline in climate regulatory risk, suggesting that firms adjust their capital structure in response to changes in climate regulatory risk. Seltzer et al. (2022) find that a higher level of climate regulatory risk is associated with a poorer bond rating and a wider bond yield spread, indicating an increased cost of debt financing. Focusing on equity valuation, Berkman et al. (2024) demonstrate that firm-specific climate risk, with a particular emphasis on regulatory risk, has an adverse effect on corporate market valuation. They also show that the disclosure of climate regulatory risk is limited, as less than half of their sample firms disclosed such information in 10-Ks.

Despite these costs, some studies highlight potential benefits associated with climate regulatory risk. Mueller and Sfrappini (2022) investigate the impact of climate regulatory risk on bank lending behaviour and find that European banks are more willing to lend to firms exposed to high climate regulatory risk. This may reflect a forward-looking perspective, anticipating future benefits if climate regulations are successfully implemented. Mbanyele et al. (2024) show that climate regulatory risk can lower labour investment inefficiency by imposing financial constraints and forcing management to adjust labour employment decisions in response. Firms are less likely to overinvest in labour in such circumstances. In line with this, Dang et al. (2025) demonstrate that climate regulations negatively affect access to finance

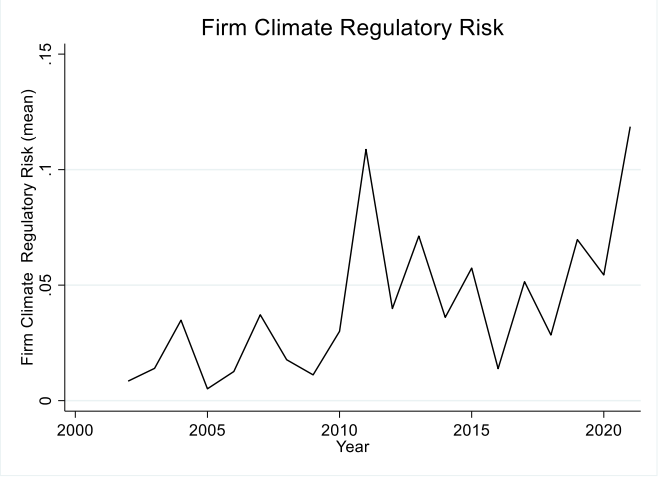

Fig. 1. Firm Climate Regulatory Risk Yearly
The plot presents the movement in firm climate regulatory risk year on year.

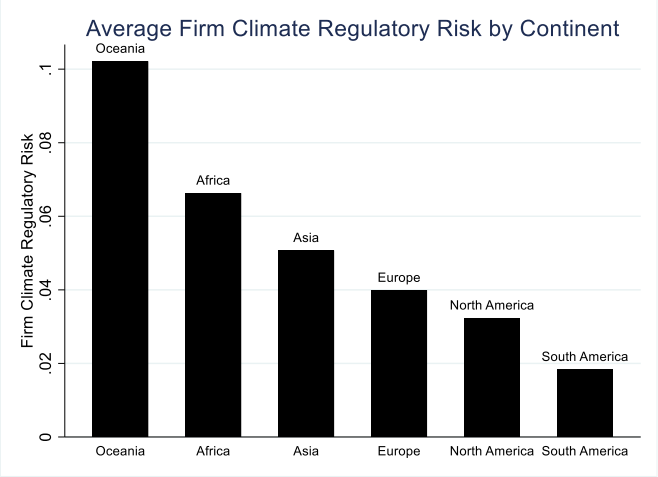

Fig. 2. Firm Climate Regulatory Risk by Continent
The bar chart presents the average firm climate regulatory risk at the continent level.

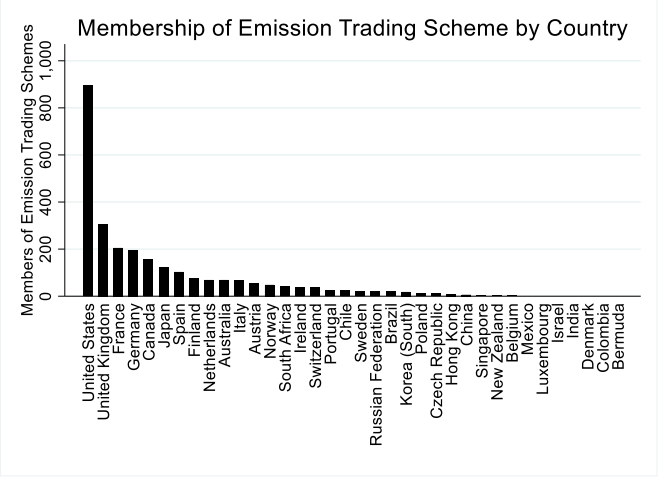

Fig. 3. Membership of ETS by Country
The chart reports the membership of Emission Trading Schemes at the country level.

Table 2
Baseline regression.

	(1)	(2)	(3)
Emission Trading	0.0490***	0.0471***	0.0241***
	(6.04)	(5.48)	(2.75)
Size		0.0066***	0.0062***
		(2.91)	(2.00)
Leverage		0.0343**	0.0162
		(1.83)	(0.88)
ROA		0.0172	0.0176
		(0.57)	(0.58)
Market to Book		−0.0014	0.0013
		(-0.58)	(0.54)
Industry Sales Growth		−0.0000	0.0000
		(-0.00)	(0.15)
Working Capital		−0.0161	0.0423**
		(-0.74)	(1.94)
Capex		0.0258	−0.0656
		(0.38)	(-0.94)
R&D		−0.0003	−0.0001
		(-0.76)	(-0.26)
Constant	0.0300***	−0.1287***	−0.0580
	(7.37)	(-2.40)	(-0.77)
Industry Effect	No	No	Yes
Year Effect	No	No	Yes
Country Effect	No	No	Yes
Observations	16,289	15,270	15,270
Adjusted R Squared	0.008	0.010	0.062

This table presents the baseline fixed effect regression that examines the relationship between ETS membership and FCCR. Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 %, respectively. T stats are reported in parentheses.

for firms in the manufacturing industry.

2.2. Emission trading scheme (ETS)

In recent years, emission trading schemes have gained increasing attention as a key market-based tool for combating climate change. A substantial body of research has focused on the effectiveness of ETS in improving carbon performance, particularly in reducing CO_2 emissions (e.g., Bayer and Aklin, 2020; Chen and Lin, 2021; Jiang et al., 2024; Zhang et al., 2020). The majority of these studies provide consistent evidence that ETS significantly reduces carbon emissions.

Our study is mainly linked to two strands of the ETS literature. The first focuses on the value relevance of ETS participation. However, findings in this area remain mixed. For example, early research by Chapple et al. (2013) document an adverse market reaction to proposed ETS membership for Australian firms. In line with these findings, Dewaelheyns et al. (2023) demonstrate value destruction for European firms following the introduction of Phase III of the EU ETS. Park et al. (2024) also find that participation in ETS significantly reduces the firm value among listed companies in South Korea. In contrast to those studies, Tang et al. (2022) present evidence from China showing that the market value of listed firms increases upon joining an ETS. They argue that such value creation is through three channels: the single effect of the carbon price, increased innovation activities, and improved carbon disclosure. Yu et al. (2023b) echo Tang et al. (2022)'s findings and address the positive role of ETS in driving innovation, which in turn enhances the firm value of Chinese corporations.

A second strand of research examines the risk implications of ETS, with substantial evidence supporting the view that ETS participation increases firm-level risk. Huang et al. (2024) investigate the impact of a firm's participation in ETS on its debt financing. They document a positive relationship between the cost of debt and membership in ETS. They argue that lenders perceive the cost of participation in ETS to outweigh the benefit. Focusing on the risk of financial distress, Lambertides and Tsouknidis's (2024) findings suggest that the EU ETS imposes a significant financial burden on regulated firms, thereby increasing their risk of distress. Chen et al. (2024) further show that acquiring firms are reluctant to take over target firms in countries with ETS implementation. Post-performance deteriorates when targets are subject to ETS. These findings highlight growing concerns around the financial and strategic risks associated with firms' participation in ETS.

3. Data and methodology

3.1. Data

To empirically examine our hypotheses, we collect firm-level data on ETS membership from Refinitiv Eikon. Our proxy for corporate climate regulatory risk relies on the work of Sautner et al. (2023). To be more specific, this measure captures the frequency with which bigrams associated with corporate climate regulatory shocks are mentioned in proximity to terms like "risk" or "uncertainty" during earnings call transcripts (Sautner et al., 2023). This proxy offers several advantages. First, it leverages voluntary information discussions from earnings calls, thereby reflecting not only management's concern but also the perception of the market and stakeholders. Second, it captures meaningful cross-sectional variation of regulatory risk across countries, sectors, and individual firms. A possible explanation is that firms' idiosyncratic exposure to climate change would lead to economically meaningful heterogeneity. Third, the robustness of this measure has been validated using a range of alternative approaches, including manual auditing and keyword adjustments.

However, this proxy for climate regulatory risk is not without limitations. First, it relies on voluntary information disclosure in earnings calls; various external and internal factors may influence the extent and nature of the disclosed information. For instance, prior studies have shown that government ownership (Giannarakis et al., 2018), environmental shareholder activism (Flammer et al., 2021), institutional investors (Ilhan et al., 2023), and firm size and performance volatility (Bratten and Cheng, 2025) can shape disclosure practices. Furthermore, disclosure incentives may be distorted by strategic motives, including greenwashing (Wedari et al., 2021) and CEO equity compensation (Luo et al., 2021). Therefore, the information disclosed in earnings calls may not fully reflect firms' actual level of regulatory risk exposure. Despite these concerns, this measure has been widely adopted in the literature, including in several top-tier studies (e.g., Sautner et al., 2023; Li et al., 2024), which supports its empirical validity.

In addition to climate risk data, we collect other firm-level financial and operational data from Worldscope. The final dataset spans the period from 2003 to 2021 and includes firms from 36 countries. To ensure consistency and reliability in our analysis, we only include firms with at least 10 years of data. Further details on data distribution and country coverage are provided in Appendix A.

3.2. Empirical method

To test our hypothesis, we estimate the following regression equation:

$$Reg_{i,t} = \alpha + \beta ETS_{i,t} + \beta' Cont'_{i,t} + \lambda_c + \varrho_j + \mu_t + u_{i,t} \quad (1)$$

where $Reg_{i,t}$ denotes the regulatory risk of firm i in year t. $ETS_{i,t}$ captures whether a firm is a member of an ETS at year t or not. The vector $Cont'_{i,t}$ encompasses control variables. The terms λ_c, ϱ_j and μ_t represent country, industry, and year effects, respectively, and $u_{i,t}$ refers to the error term. Our choice of control variables was motivated by recent studies in the area that have sought to address similar issues (see for instance, Adamolekun et al., 2024; De Beule et al., 2022; Hu et al., 2020; Naegele and Zaklan, 2019; Ni et al., 2022; Sakariyahu et al., 2023; Yang, 2023). We provide more details of our variables in Table 1.

To further strengthen the robustness of our analysis and mitigate potential concerns regarding selection bias and endogeneity, we employ

Table 3
ETS membership, country differences and firm regulatory risk.

	USA	UK	Australia	Canada	France	Germany	Japan	Switzerland
Emission Trading	0.0421***	0.0102	0.0197***	0.0134	0.0282***	0.0258***	0.0270***	0.0248***
	(3.82)	(1.10)	(2.22)	(1.48)	(3.12)	(2.87)	(3.01)	(2.80)
USA	−0.0810***							
	(-3.87)							
Emission Trading # USA	−0.0442***							
	(-2.66)							
UK		−0.0813***						
		(-3.55)						
Emission Trading # UK		0.1107***						
		(4.54)						
AUS			0.0595***					
			(2.65)					
Emission Trading # AUS			0.1626***					
			(3.28)					
CN				−0.0835***				
				(-3.31)				
Emission Trading # CN				0.1689***				
				(5.03)				
FRA					−0.0672***			
					(-2.50)			
Emission Trading # FRA					−0.0576**			
					(-1.85)			
GER						−0.0493		
						(-1.54)		
Emission Trading # GER						−0.0298		
						(-0.82)		
JP							−0.0843***	
							(-2.09)	
Emission Trading # JP							−0.0659	
							(-1.55)	
SWZ								−0.0730***
								(-2.22)
Emission Trading # SWZ								−0.0334
								(-0.57)
Size	0.0062***	0.0062***	0.0063***	0.0065***	0.0063***	0.0062***	0.0061***	0.0062***
	(2.02)	(2.00)	(2.03)	(2.10)	(2.02)	(2.00)	(1.97)	(2.00)
Leverage	0.0158	0.0169	0.0159	0.0132	0.0166	0.0161	0.0161	0.0162
	(0.86)	(0.92)	(0.86)	(0.72)	(0.90)	(0.87)	(0.87)	(0.88)
ROA	0.0182	0.0180	0.0181	0.0157	0.0172	0.0180	0.0172	0.0175
	(0.60)	(0.59)	(0.60)	(0.52)	(0.57)	(0.59)	(0.57)	(0.58)
Market to Book	0.0014	0.0014	0.0013	0.0013	0.0014	0.0013	0.0014	0.0013
	(0.56)	(0.58)	(0.53)	(0.53)	(0.55)	(0.53)	(0.55)	(0.54)
Industry Sales Growth	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.15)	(0.15)	(0.15)	(0.14)	(0.15)	(0.15)	(0.15)	(0.15)
Working Capital	0.0415**	0.0425**	0.0416**	0.0431***	0.0429***	0.0423**	0.0417**	0.0421**
	(1.91)	(1.96)	(1.91)	(1.99)	(1.97)	(1.94)	(1.91)	(1.93)
Capex	−0.0616	−0.0699	−0.0630	−0.0607	−0.0658	−0.0662	−0.0661	−0.0662
	(-0.88)	(-1.00)	(-0.90)	(-0.87)	(-0.94)	(-0.94)	(-0.94)	(-0.94)
R&D	−0.0001	−0.0002	−0.0001	−0.0002	−0.0001	−0.0001	−0.0001	−0.0001
	(-0.21)	(-0.30)	(-0.27)	(-0.28)	(-0.25)	(-0.26)	(-0.24)	(-0.26)
Constant	−0.0638	−0.0540	−0.1489***	−0.0598	−0.0595	−0.0573	−0.0561	−0.0575
	(-0.85)	(-0.72)	(-2.00)	(-0.80)	(-0.79)	(-0.76)	(-0.75)	(-0.77)
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	15,270	15,270	15,270	15,270	15,270	15,270	15,270	15,270
Adj R Squared	0.063	0.064	0.063	0.064	0.062	0.062	0.062	0.062

This Table presents the result of splitting our sample of firms into various countries.Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 %, respectively. The T stats of the regression analysis are reported in parentheses.

a propensity score matching (PSM) model specified as follows:

$$D_i = \alpha + \varphi X_i + \varepsilon_i \quad (2)$$

This model matches treated observations (members of ETS - i.e., $D_i = 1$) with untreated counterparts (non-members of ETS - i.e., $D_i = 0$) based on the highest propensity scores. This strategy aims to address concerns relating to asymptotic biases. The predictor variables considered include size, leverage, return on assets (RoA), sales growth, market-to-book ratio, working capital, capital expenditures (CAPEX), and research and development (R&D).

4. Discussion and findings

4.1. Main findings

Fig. 1 depicts the time trend in firm climate regulatory risk (FCRR). The plot indicates significant spikes in firm climate regulatory risk after 2010 and 2020. Put together, spikes coincide with periods of increased investor attention to climate risk (Aliano et al., 2023).

In Fig. 2, we compare average firm climate regulatory risk across continents. The chart reveals that firms in Oceania, Africa, and Asia appear to face higher levels of climate regulatory risk. Notably, these regions appear to be more exposed to climate disasters (Eckstein and

Table 4
ETS membership, corporate governance, and firm climate regulatory risk.

	(1)	(2)	(3)	(4)	(5)
Emission Trading	0.0707***	0.0409**	0.0344***	0.0461***	−0.0214
	(3.85)	(1.89)	(2.37)	(3.55)	(-1.29)
Independent directors	0.0020***				
	(2.51)				
Emission Trading # independent directors	−0.0038***				
	(-2.94)				
Board tenure		−0.0012			
		(-1.06)			
Emission Trading # Board tenure		−0.0026			
		(-0.86)			
CEO Time in Coy			0.0000		
			(0.12)		
Emission Trading # CEO Time in Coy			−0.0008		
			(-0.98)		
CEO Network Size				0.0000	
				(1.54)	
Emission Trading # CEO Network size				−0.0000***	
				(-2.71)	
Co-opted directors					0.0064
					(0.57)
Emission Trading # Co-opted directors					0.0919***
Size	0.0039	0.0061**	0.0045	0.0043	0.0046
	(1.19)	(1.96)	(1.47)	(1.31)	(1.42)
Leverage	0.0168	0.015	0.0145	0.0149	0.0182
	(0.92)	(0.85)	(0.78)	(0.78)	(0.93)
ROA	0.0183	0.0200	0.0060	0.0089	0.0021
	(0.60)	(0.66)	(0.19)	(0.28)	(0.06)
Market to Book	0.0010	0.0014	0.0017	0.0017	0.0016
	(0.40)	(0.56)	(0.69)	(0.68)	(0.62)
Industry Sales Growth	0.0000	0.0000	0.0000	0.0000	0.0000
	(0.15)	(0.14)	(0.14)	(0.14)	(0.13)
Working Capital	0.0447***	0.0442***	0.0257	0.0286	0.0308
	(2.05)	(2.02)	(1.17)	(1.26)	(1.34)
Capex	−0.0570	−0.0642	−0.0829	−0.0753	−0.0635
	(-0.81)	(-0.92)	(-1.13)	(-0.99)	(-0.82)
R&D	−0.0001	−0.0001	−0.0000	−0.0000	−0.0000
	(-0.21)	(-0.23)	(-0.03)	(-0.00)	(-0.08)
Constant	−0.0275	−0.0501	−0.0106	−0.0095	−0.0219
	(-0.35)	(-0.67)	(-0.14)	(-0.12)	(-0.28)
Industry Effect	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes
Country Effect	Yes	Yes	Yes	Yes	Yes
Observations	15,266	15,270	13,097	12,891	12,721
Adj R Squared	0.063	0.062	0.063	0.064	0.065

This Table presents the regression analysis that examines the relationship between ETS membership firm corporate governance and FCCR.Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 % respectively. We report the T stats of the regression analysis in parentheses.

Kreft, 2020; Global Climate Risk Index, 2021, 2023).

Fig. 3 provides a visual representation of corporate ETS membership by country. The data reveals a significant representation of firms from the USA, UK, France, Germany, Canada, and Japan in carbon markets. At the same time, ETSs are less prevalent among firms in India, Colombia, Denmark, and Bermuda.

In Table 2, we present our baseline regression results. The first column reports the result of the entire sample without controls. Columns 2 and 3 present our regression results after introducing control variables, year, country, and industry effects. Across all model specifications, ETS membership is positively and significantly associated with FCRR. These findings suggest that joining an emissions trading scheme increases firms' exposure to climate-related regulatory risk. One potential explanation for the result is that joining emissions trading schemes forces new joiners to disclose more information (Li et al., 2023). However, this information flow could be detrimental to firms in terms of regulatory exposure. Furthermore, membership in ETS could place a firm under more scrutiny, which would amplify the negative impact of any potential regulatory misbehaviour. The results of the analysis deepen the understanding of prior studies in the literature, which suggest that more carbon disclosures could be beneficial to firms (see, for example, Matthews et al., 2024).

Nonetheless, it is important to underline that the findings may reflect corporate exposure to climate regulatory uncertainty rather than risk. Firm membership in emissions trading schemes may expose firms to climate regulatory uncertainty. Therefore, a significant portion of the risk exposure may be tied to the regulatory uncertainty of their membership rather than actual climate risk exposure.

Next, in a subsample analysis, we explore how countrywide differences may influence these results. As shown in Table 3, we find that ETS membership is associated with a decrease in FCRR for firms in the USA and France. In contrast, Australia, the UK, and Canada have a positive impact of ETS on FCCR. The findings may also reflect the level of climate regulatory uncertainty inherent in the aforementioned countries. Firms in countries with more advanced and concerted climate regulatory structures may face heightened levels of climate regulatory uncertainty (Kwabi et al., 2025). For firms in Germany, Japan, and Switzerland, the impact of ETS on FCCR is insignificant. These findings highlight the role of institutional and contextual differences in shaping the outcomes of emissions trading schemes. Other non-tangible factors, such as culture and national consensus on climate change, could shape outcomes from participating in emissions trading schemes.

Overall, these results in some regards align with a subset of the emission trading literature that has questioned the effectiveness of the

Table 5
ETS membership, unique firm features, and corporate climate regulatory risk.

	(1)	(2)	(3)	(4)
Emission Trading	0.0254***	0.0359***	−0.0070	−0.0010
	(2.53)	(2.69)	(-0.63)	(-0.07)
Fin Constraint	0.0011			
	(0.16)			
Emission Trading # Fin Constraint	−0.0043			
	(-0.27)			
Growth Opp		−0.0448		
		(-0.62)		
Emission Trading # Growth Opp		−0.2255		
		(-1.17)		
Political Risk			0.0001***	
			(3.28)	
Emission Trading # Political Risk			0.0002***	
			(4.50)	
Carbon Intensive				0.0331
				(1.31)
Emission Trading # Carbon Intensive				0.0426***
				(2.54)
Size	0.0062***	0.0063***	0.0056**	0.0063***
	(2.00)	(2.04)	(1.83)	(2.02)
Leverage	0.0161	0.0160	0.0180	0.0168
	(0.88)	(0.87)	(0.98)	(0.91)
ROA	0.0180	0.0175	0.0218	0.0186
	(0.59)	(0.58)	(0.72)	(0.61)
Market to Book	0.0013	0.0014	0.0013	0.0013
	(0.54)	(0.55)	(0.51)	(0.54)
Industry Sales Growth	0.0000	0.0000	0.0000	0.0000
	(0.15)	(0.14)	(0.13)	(0.14)
Working Capital	0.0423**	0.0425**	0.0416**	0.0397**
	(1.94)	(1.95)	(1.92)	(1.82)
Capex	−0.0659	0.0000	−0.0540	−0.0622
	(-0.94)	(.)	(-0.77)	(-0.89)
R&D	−0.0001	−0.0002	−0.0001	−0.0002
	(-0.27)	(-0.32)	(-0.26)	(-0.30)
Constant	−0.0594	−0.0620	−0.0551	−0.0994
	(-0.78)	(-0.82)	(-0.74)	(-1.24)
Industry Effect	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes
Country Effect	Yes	Yes	Yes	Yes
Observations	15,270	15,270	15,226	15,270
Adj	0.062	0.062	0.066	0.062

This Table presents the regression analysis that examines the relationship between ETS membership, unique firm features and FCCR. Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 % respectively. We report the T stats of the regression analysis in parentheses.

schemes and complement studies that have advocated restructuring existing schemes (Adamolekun, 2024; Naegele and Zaklan, 2019). However, this result also questions the assertion that emissions trading schemes are ineffective. It implies that scheme deliverables vary across countries, thus suggesting that soft factors, such as context and culture, are important considerations.

Table 4 explores the moderating role of corporate governance in shaping outcomes from ETS membership. Our results indicate that firms with a higher proportion of independent directors on their boards derive more favourable FCRR outcomes from ETS membership. Similarly, firms led by CEOs with extensive networks or longer tenures within the firm appear to capitalise on membership benefits. Conversely, firms with a substantial portion of their boards appointed during the tenure of the CEO do not appear to harness the benefits of ETS membership for FCRR fully. Taken together, these findings suggest that the corporate governance structure can be strategically leveraged to enhance outcomes from corporate climate actions. Our study corroborates the growing literature

Table 7
Exogenous Shock-EU climate and energy package.

	(1)
	Corporate Regulatory Risk
ATET	
ETS & EU Climate and Energy Package	−0.0361*
	(-1.81)
Controls	
Size	0.0028
	(0.21)
Leverage	0.0183
	(0.29)
ROA	0.0398
	(0.76)
Market to Book	0.0012
	(0.27)
Industry Sales Growth	−0.0001
	(-0.67)
Working Capital	0.0818
	(1.30)
Capex	0.0717
	(0.44)
R&D	0.0095
	(1.23)
Constant	−0.0582
	(-0.18)
Country Effect	Yes
Industry Effect	Yes
Year Effect	Yes
Observations	4,879

The table reports the result of the difference in difference in differences (DDD) regression. ATET refers to the after-treatment effect on the treated. Details of variable definition are provided in Table 1 t statistics are reported in parentheses. *, **, and *** refers to significance level at less than 10 %, 5 %, and 1 % respectively.

Table 6
The impact of first joiners and exiting of ETS on firm regulatory risk.

	Panel A: Year of Joining		Panel B: Exiting the Scheme		
	Before the Paris Agreement	Paris Agreement	Year 1	Year 2	Year 5
ETS	0.0464***	0.0538***			
	(4.22)	(3.71)			
Year of Joining	−0.0462***	−0.0405***			
	(-3.40)	(-2.61)			
Exiting from ETS			0.0194**	0.0311***	0.0446***
			(1.95)	(3.06)	(3.63)
Constant	−0.0291	−0.0292	−0.0166	−0.0505	−0.0011
	(-0.39)	(-0.39)	(-0.21)	(-0.63)	(-0.01)
Control	Yes	Yes	Yes	Yes	Yes
Industry Effect	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes
Country Effect	Yes	Yes	Yes	Yes	Yes
Observations	15,034	15,034	13,715	12,616	9,557
Adj_R^2	6 %	6 %	6 %	6 %	7 %

Notes: *** & **** denote significance levels below 10 % and 5 %, respectively; t stats are reported in parentheses.*

Table 8
ETS, firm regulatory risk emerging market.

	(1)	(2)
	Developed Market	Emerging Market
Emission Trading	0.0256***	−0.0125
	(2.87)	(-0.25)
Size	0.0067***	−0.0071
	(2.09)	(-0.39)
Leverage	0.0190	−0.0565
	(1.02)	(-0.44)
ROA	0.0166	−0.2666
	(0.55)	(-0.25)
Market to Book	0.0014	0.0144
	(0.57)	(0.47)
Industry Sales Growth	0.0000	0.1035
	(0.15)	(1.45)
Working Capital	0.0459***	−0.0566
	(2.06)	(-0.45)
Capex	−0.0727	0.2966
	(-1.02)	(0.67)
R&D	0.0004	−0.0001
	(0.12)	(-0.20)
Constant	−0.0671	−0.0067
	(-0.87)	(-0.01)
Industry Effect	Yes	Yes
Year Effect	Yes	Yes
Country Effect	Yes	Yes
Observations	14,542	728
Adj	0.057	0.143

This Table presents the regression analysis that examines the relationship between ETS membership and FCCR across firms from emerging markets and developing markets. Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 % respectively. We report the T-statistics of the regression analysis in parentheses.

that advocates the role of corporate governance in the green transition (Luo and Tang, 2021). The findings shed light on the role of firm corporate governance structure, managerial skill, and expertise in the green transition.

Next, we report the results of how certain firm-level features affect the relationship between ETS membership and FCRR in Table 5. Interestingly, financial constraints and the degree of firms' growth opportunities do not significantly alter this relationship. In addition, we examine how FCRR deliverables from ETS membership are affected by firm political risk and industry carbon intensity. The motivation for considering this route of enquiry is that prior risk exposure of such firms could dictate outcomes from climate actions. For instance, the negative regulatory risk impact of membership may be more pronounced among firms with a history of inappropriate conduct. Accordingly, we consider two categories of risk: operational risk, which can be inferred from a firm's industry, and political risk, proxied by a firm's interactions with the government. Our findings confirm that firm political risk and industry carbon intensity can significantly shape how firms experience climate-related regulatory pressure under ETS frameworks. This aligns with the view that corporate political risk can reveal the severity of climate-related vulnerabilities (Afsar Basha et al., 2023).

Furthermore, we examine the impact of remaining in or exiting emissions trading schemes on FCRR. We engage this line of enquiry because potential results from this analysis are particularly valuable in terms of policy for relevant stakeholders. We report the results of this investigation in Table 6. Panel A of Table 6 reports the results of investigating the impact of the year of joining an ETS on FCRR. Using the inception of the Paris Agreement and the year it came into effect as a reference point, we examine the outcome. The findings indicate that firms that joined the scheme before 2013 (i.e., prior to the commencement of discussions on the Paris Agreement) experienced a reduction in FCRR, suggesting the potential benefits of early adoption in this scheme. Taken together, our findings suggest that firms that joined the scheme before 2017 improved their climate regulatory risk. However, counterparts that joined the scheme after 2017 did not reap such benefits.

Panel B of Table 6 examines the impact of exiting the scheme on FCRR. The results suggest that exiting an ETS increases FCRR, even up to 5 years after exiting, implying more severe consequences for exiting than remaining. This implies that although there are significant regulatory consequences of remaining in the scheme, the costs of exiting the scheme do outweigh the regulatory costs of remaining in it.

The nature of the relationship between FCRR and ETS membership may be contingent upon the degree of effectiveness of institutions in the countries where firms operate. Developed nations may have more mature institutions, whereas those in emerging and developing countries may be less advanced and less equipped to address the regulatory challenges of ETS. Accordingly, we test this hypothesis by splitting our sample into developed and emerging countries. We report the result of

Table 9
Propensity score matching.

Panel A: Treatment and Control Comparison

Variable	Category	Treated	Control	% Bias	% Reduction	*t*-Test
Size	Unmatched	24.23	22.78	84.2	94 %	41.56
	Matched	24.23	24.32	−5.2		−1.61
Leverage	Unmatched	0.30	0.27	15	65 %	6.39
	Matched	0.30	0.30	−5.3		−2.18
RoA	Unmatched	0.05	0.06	−10.1	81 %	−4.25
	Matched	0.05	0.05	2		0.74
MTB	Unmatched	0.96	1.50	−41.7	96 %	−17.14
	Matched	0.96	0.94	1.8		0.82
Sales Growth	Unmatched	−0.03	0.31	−1.4	96 %	−0.51
	Matched	−0.03	−0.02	−0.1		−1.66
WCAP	Unmatched	0.07	0.14	−43.2	89 %	−17.97
	Matched	0.07	0.06	4.7		2.07
CAPEX	Unmatched	0.06	0.05	15	84 %	6.34
	Matched	0.05	0.06	−2.4		−0.87
R&D	Unmatched	0.85	0.30	7.5	43 %	3.43
	Matched	0.86	0.55	4.3		1.38

Panel B: Propensity Score Estimation

Variable	**Category**	**Control**	**Difference**	**S.E.**	**T-Stat**
FCRR	Unmatched	2.6 %	7.4 %	0.7 %	10.81
	ATT	6.6 %	3.4 %	1.8 %	1.84

The Table presents the result of the propensity score matching (PSM). Panel A reports the mean comparison while panel B presents the post-matching estimation. ATT refers to the average treatment effect on the treated.

Table 10
Robustness test - country controls.

	(1)
	Corporate Regulatory Risk
Emission Trading	0.0233***
	(2.82)
Size	0.0067***
	(2.37)
Leverage	0.0071
	(0.41)
ROA	0.0140
	(0.48)
Market to Book	0.0016
	(0.66)
Industry Sales Growth	0.0000
	(0.10)
Working Capital	0.0332**
	(1.66)
Capex	−0.0372
	(-0.59)
R&D	−0.0009
	(-0.29)
CO2 emissions (kg per PPP $ of GDP)	−0.3506**
	(-1.87)
GDP per capita	−0.0000***
	(-2.93)
GNI growth	−0.0017
	(-0.77)
Corruption	−0.0031
	(-0.10)
Government Efficiency	−0.0267
	(-0.70)
Regulatory Quality	0.0574
	(1.62)
Rule of Law	0.0312
	(0.51)
HHI	0.0815
	(0.29)
Climate Vulnerability Index	−0.4070
	(-0.39)
Constant	0.0508
	(0.14)
Industry Effect	Yes
Year Effect	Yes
Country Dummy	Yes
Observations	13,099
Adjusted R^2	0.060

This Table presents the regression analysis that examines the relationship between ETS membership, country features, and FCCR. Details of variable definition are provided in Table 1. ** & *** indicate significance levels below 10 % and 5 % respectively. We report the T-statistics of the regression analysis in parentheses.

this test in Table 7. The findings from this analysis reveal that the positive association between FCRR is only pronounced among firms in developed markets. This supports the idea that conceptual differences exist in how sustainable initiatives are designed and implemented between emerging and developed nations, which could influence their effectiveness (Dögl and Behnam, 2015).

Therefore, the differing results for the impact of ETS on FCRR in developed and emerging markets are not surprising. The prior literature highlights the differences between ETS in developed and emerging markets, emphasising issues such as market liquidity, price signal effect, and incentives/monitoring function (Zhou et al., 2020; Kukah et al., 2025). Those differences in ETS may affect the FCRR differently across markets, as their impacts on the cost of capital (e.g., Chapple et al., 2013; Xu et al., 2025) and information disclosure (e.g., Hossain and Farooque, 2019) vary.

The EU Climate and Energy Package became the key legislation for reaching the EU's clean energy goals by 2020. The legislation is often referred to as the "20-20-20" and had three principal goals: a 20 % reduction in greenhouse gas emissions compared to 1990 levels, a 20 % increase in efficient energy use, and a 20 % increase in energy generation from renewable sources (Böhringer and Keller, 2011). The policy took effect in 2009. In our empirical design, we adopt the legislation as an exogenous shock for EU firms. Accordingly, we restrict our sample to EU firms and specify a difference-in-differences regression, which we report in Table 8. The test findings reveal that the shock resulted in a decrease in FCRR. We argue that the benefits of joining ETSs largely explain the adverse effect. Member firms of the emission trading scheme are less severely exposed to climate regulations that would be exacerbated by new policies, such as the phasing out of free allowances and the carbon border adjustment mechanism (CBAM) (Stefano, 2022). In comparison to non-members, scheme members would be better protected from increased compliance costs and ensuing market volatility resulting from the market stability reserve (Stefano, 2022).

4.2. Robustness test

For an added dimension of rigour, we specify a PSM model according to Equation (2). We report the results in Table 9. Panel A of Table 9 presents the pre-estimation test results. The pre-estimation test indicates that the propensity score matching effectively reduced pre-estimation bias. In panel B of Table 9, we report the results of the post-PSM regression estimation. The findings confirm the view that membership of ETS is positively associated with firm climate regulatory risk. Taken together, even after matching member firms (treated) with similar non-members (non-treated), we find support for the argument that membership in emissions trading schemes exacerbates a firm's climate regulatory risk.

In a further test, reported in Table 10, we examine whether and how country-level factors influence the relationship between ETS and FCRR. In the revised model, similar to Adamolekun et al. (2024, 2025), we account for factors such as CO2 emissions per capita, GDP per capita, GNI growth, corruption, Government efficiency, regulatory quality, rule of law, HHI, and climate vulnerability index. Despite the introduction of these factors, we consistently report results in line with our baseline analysis.

In the final test employing a structural equation model (SEM), we explore the role and effect of mediating variables on the relationship between FCRR and ETS. In panel A of Table 11, we examine the direct impact of ETS on FCRR. Panel B of Table 11 presents the indirect effects of ETS on FCRR, while Panel C of Table 11 reports the total effects. In summary, the results indicate a direct relationship between ETS and FCRR.

5. Conclusion

Motivated by the growing call for more decisive corporate climate action, this study examines whether emissions trading schemes help mitigate firms' climate regulatory risk. Our examination indicates that membership in the scheme increases corporate climate regulatory risk. Moreover, we observe that various factors, including corporate governance structures and firm-specific features, can either exacerbate or mitigate the impact of ETS on firms' climate regulatory risk. On a positive note, we find that firms that join the scheme early reduce their climate regulatory risk, while those that exit the scheme increase such risk. The result also shows that the positive effect of ETS on FCRR is mainly evident among firms in developed countries. Policies such as the EU Climate and Energy Package may diminish the positive influence of the ETS on FCRR.

Our results provide policy guidance to firms, investors, and the government. The findings shed more light on the potential implications of taking climate action. In particular, we demonstrate that such actions may incur significant initial costs. Nonetheless, implementing a robust corporate governance structure and leveraging exceptional CEO features could mitigate the negative impacts of joining such schemes. For investors clamouring for more climate action from firms, we demonstrate

Table 11
Robustness test – SEM.

Panel A: Direct effects

Structural: Carbon Intensive					Co-opted **Board**				
	Coefficient	Standard Error	Z	P-value		Coefficient	Standard Error	Z	P-value
Emission Trading	0.185	0.012	15.32	0.000	Size	0.002	0.002	1.36	0.174
Size	−0.029	0.003	−9.43	0.000	Leverage	−0.024	0.014	−1.7	0.09
Leverage	0.019	0.025	0.77	0.44	RoA	−0.022	0.028	−0.78	0.438
RoA	−0.050	0.047	−1.06	0.29	MTB	0.010	0.002	5.06	0
MTB	−0.072	0.003	−21.83	0.000	Sales Growth	0.000	0.000	1.07	0.287
Sales Growth	0.000	0.000	−1.79	0.073					
Working Capital	−0.113	0.027	−4.14	0.000					
CAPEX	1.943	0.089	21.76	0.000					
R & D	−0.002	0.001	−3.57	0.000					

Regulatory Risk

	Coefficient	Standard Error	Z	P-value
Carbon Intensive	0.054	0.006	8.88	0.000
Co-opted	0.026	0.010	2.55	0.011
Emission Trading	0.053	0.008	6.32	0.000
Size	0.008	0.002	3.69	0.000
Leverage	0.029	0.017	1.74	0.082
RoA	−0.007	0.032	−0.22	0.827
MTB	0.000	0.002	−0.15	0.878
Sales Growth	0.000	0.000	−0.03	0.974
Working Capital	−0.030	0.019	−1.58	0.114
CAPEX	0.027	0.062	0.43	0.667
R & D	0.000	0.000	−0.8	0.425

Panel B: Indirect effects

Structural: Carbon Intensive					Co-opted **Board**				
	Coefficient	Standard Error	Z	P-value		Coefficient	Standard Error	Z	P-value
Emission Trading	0	(no path)			Size	0	(no path)		
Size	0	(no path)			Leverage	0	(no path)		
Leverage	0	(no path)			RoA	0	(no path)		
RoA	0	(no path)			MTB	0	(no path)		
MTB	0	(no path)			Sales Growth	0	(no path)		
Sales Growth	0	(no path)							
Working Capital	0	(no path)							
CAPEX	0	(no path)							
R & D	0	(no path)							

Regulatory Risk

	Coefficient	Standard Error	Z	P-value
Carbon Intensive	0	(no path)		
Co-opted	0	(no path)		
Emission Trading	0.010	0.001	7.68	0.000
Size	−0.002	0.000	−6.08	0.000
Leverage	0.000	0.001	0.29	0.773
RoA	−0.003	0.003	−1.22	0.223
MTB	−0.004	0.000	−7.46	0.000
Sales Growth	0.000	0.000	−1.39	0.164
Working Capital	−0.006	0.002	−3.75	0.000
CAPEX	0.104	0.013	8.22	0.000
R & D	0.000	0.000	−3.31	0.001

Panel C: Total effects

Structural: Carbon Intensive					Co-opted **Board**				
	Coefficient	Standard Error	Z	P-value		Coefficient	Standard Error	Z	P-value
Emission Trading	0.185	0.012	15.32	0	Size	0.002	0.002	1.36	0.174
Size	−0.029	0.003	−9.43	0	Leverage	−0.024	0.014	−1.7	0.09
Leverage	0.019	0.025	0.77	0.44	RoA	−0.022	0.028	−0.78	0.438
RoA	−0.050	0.047	−1.06	0.29	MTB	0.010	0.002	5.06	0
MTB	−0.072	0.003	−21.83	0	Sales Growth	0.000	0.000	1.07	0.287
Sales Growth	0.000	0.000	−1.79	0.073					
Working Capital	−0.113	0.027	−4.14	0					
CAPEX	1.943	0.089	21.76	0					
R & D	−0.002	0.001	−3.57	0					

Regulatory Risk

	Coefficient	Standard Error	Z	P-value
Carbon Intensive	0.054	0.006	8.88	0
Co-opted	0.026	0.010	2.55	0.011
Emission Trading	0.063	0.008	7.56	0
Size	0.006	0.002	2.98	0.003

(*continued on next page*)

Table 11 (*continued*)

Panel C: Total effects					
Structural: Carbon Intensive					Co-opted **Board**
	Leverage	0.030	0.017	1.76	0.079
	RoA	−0.010	0.032	−0.32	0.75
	MTB	−0.004	0.002	−1.76	0.079
	Sales Growth	0.000	0.000	−0.15	0.882
	Working Capital	−0.036	0.019	−1.9	0.057
	CAPEX	0.131	0.061	2.14	0.032
	R & D	0.000	0.000	−1.08	0.282

The panel reports the results of the total effects of the structural equation model. P-values, standard errors and Z statistics are reported.

that some climate actions, such as ETSs, may have unintended consequences. Lastly, governments need to identify potential incentives for joining ETSs, as the current form may not provide sufficient motivation for new joiners.

We acknowledge several limitations in interpreting our findings. First, our proxy for climate regulatory risk is derived from voluntary disclosures made during the earnings call, which are not subject to mandatory reporting. As such, managers retain considerable discretion over whether and how much information to disclose, influenced by factors such as demand from institutional shareholders (Ilhan et al., 2023) or concerns about firm value (Vestrelli et al., 2024). Therefore, our proxy may not necessarily reflect the real level of climate risk the firm is facing, potentially weakening its reliability. In 2024, the US Securities and Exchange Commission (SEC) proposed a new regulation to enhance the mandatory disclosure for climate-related risk. However, these were withdrawn in early 2025 following legal challenges amid rising political opposition to the ESG agenda. Should such regulations be implemented in the future, the reliability of disclosure-based proxies, such as the one employed in this study, would improve, as standardized reporting would encourage transparency and reduce the scope of managerial discretion to conceal risk communication. Second, while firm-level climate regulatory risk is conceptually distinct from climate policy uncertainty, the two are related. For instance, heightened climate policy uncertainty can suppress firms' investments in green technologies (Hu et al., 2023), which are essential for building and enhancing climate resilience (Gao et al., 2024). Therefore, in the period of an increasing climate policy uncertainty, the positive relation between participating in ETS and firm-level climate risk may be further strengthened. Future research could explore the interplay between climate policy uncertainty and firm-level climate risk to provide deeper insights into how these forces jointly shape corporate outcomes.

CRediT authorship contribution statement

Gbenga Adamolekun: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Hao Li:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Bing Xu:** Writing – review & editing, Writing – original draft, Conceptualization.

Data statement

The Data used for this study will be made available upon reasonable request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Data Distribution

	Panel A: Country Distribution			Panel B: Year Distribution		
	Country	Frequency	Per cent	Year	Frequency	Per cent
1	Australia	412	2.53	2002	254	1.56
2	Austria	74	0.45	2003	325	2
3	Belgium	57	0.35	2004	447	2.74
4	Bermuda	55	0.34	2005	566	3.47
5	Brazil	93	0.57	2006	587	3.6
6	Canada	932	5.72	2007	660	4.05
7	Chile	34	0.21	2008	777	4.77
8	China	67	0.41	2009	842	5.17
9	Colombia	11	0.07	2010	962	5.91
10	Czech Republic	11	0.07	2011	1028	6.31
11	Denmark	73	0.45	2012	1094	6.72
12	Finland	135	0.83	2013	1063	6.53
13	France	785	4.82	2014	1031	6.33
14	Germany	477	2.93	2015	996	6.11
15	Hong Kong	98	0.6	2016	988	6.07
16	India	212	1.3	2017	980	6.02
17	Ireland	218	1.34	2018	1005	6.17
18	Israel	33	0.2	2019	987	6.06
19	Italy	141	0.87	2020	943	5.79
20	Japan	310	1.9	2021	754	4.63
21	Korea (South)	31	0.19	**Total**	**16,289**	**100**
22	Luxembourg	27	0.17			
23	Mexico	34	0.21			
24	Netherlands	324	1.99			

(*continued on next page*)

(*continued*)

	Panel A: Country Distribution			Panel B: Year Distribution		
	Country	Frequency	Per cent	Year	Frequency	Per cent
25	New Zealand	33	0.2			
26	Norway	154	0.95			
27	Poland	11	0.07			
28	Portugal	56	0.34			
29	Russian Federation	102	0.63			
30	Singapore	34	0.21			
31	South Africa	162	0.99			
32	Spain	278	1.71			
33	Sweden	87	0.53			
34	Switzerland	301	1.85			
35	United Kingdom	1774	10.89			
36	United States	8653	53.12			
	Total	**16,289**	**100**			

Panel A summarizes the distribution of observations across countries, and Panel B reports the distribution across years.

Data availability

Data will be made available on request.

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