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Corporate Climate Risk and Membership of Emission Trading Schemes

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ABSTRACT

Using a sample of 5364 firms from 65 countries, we demonstrate that membership in the scheme increases firm climate risk. Further analysis reveals that the positive impact of membership on climate risk is pronounced among firms in carbon-intensive industries. Our findings demonstrate that continental differences and legal origin could moderate or exacerbate the relationship between emission trading schemes (ETSs) and corporate climate risk. Similarly, the positive relationship between ETSs and corporate climate risk is only significant in the period after the Paris Agreement. This indicates that public interest in climate change discussions may have driven membership in the initiative rather than reflecting a real commitment to reducing carbon emissions. Additionally, we show that membership has short- to medium-term effects on corporate climate risk. Our results are robust to a battery of tests such as propensity score matching (PSM) and generalized method of moments (GMM).

JEL Classification: G10, G18, G32, G38, G39, Q50, Q54

1 | Introduction

Decades of emission-intensive industrial activities have resulted in anthropogenic climate change. This existential threat harbors far-reaching consequences for the planet, prompting grave alarm. Various mitigation strategies have been implemented at the national and multinational levels in response to this crisis and the persistent surge in emissions. Primary policy emphasis entails transitioning to a low-carbon economy and ultimately achieving net-zero emissions. Numerous diplomatic treaties have been ratified, climate policies enacted, and carbon trading markets established in select countries. A salient example is emission trading schemes (ETSs), which aims to curtail greenhouse gas (GHG) emissions through pricing mechanisms by imposing caps on aggregate industry emissions and allowing firms to trade allowances (Huang et al. 2022; Ren et al. 2022; Adamolekun 2024a, 2024b). The ETS framework, mandating participation from pollution-intensive firms predominantly in the energy and manufacturing sectors, has garnered substantial attention because of the considerable costs imposed on participant firms (Makridou et al. 2019). Critics argue that the scheme dampens firms' dedication and endeavors toward climate actions, thereby jeopardizing investments geared toward transitioning from nonrenewable energy sources to sustainable alternatives.

This study addresses critical concerns surrounding ETS and corporate climate risk (CCR) outcomes. Corporate climate risk captures corporate vulnerability to negative outcomes necessitated by adverse climate events' first-order or second-order effects (Adamolekun 2024a, 2024b; Sautner et al. 2023). In essence, it captures to what extent harmful climate events disrupt firms' operations. Corporate climate risk manifests in various forms. Physical risk is the first and perhaps most apparent form of CCR. This entails risk exposure associated with corporate losses linked to extreme weather events and changes in temperature or other climate patterns such as rainfall (Wang et al. 2022; Reboredo and Ugolini 2022; Sautner et al. 2023). The second manifestation-transitioning risk encompasses other secondary costs that arise from compliance and migration to climate-friendly or resistant processes (Wang et al. 2022; Reboredo and Ugolini 2022).

We empirically explore the extent to which ETS participation influences firms' climate change risks. We inquire whether ETS participation offers climate risk benefits and whether variations in geographical location, firm characteristics, and country-specific governance mechanisms account for the impacts of ETS participation on firms' risk exposure. To address these pivotal questions, we analyze an extensive global firm-level dataset. We deem this an indispensable examination, as the origins of climate change are attributed to industrial firms' GHG emissions (Rehman et al. 2021; Huang et al. 2022). Consequently, an empirical evaluation of the ETS as a policy solution is warranted. We draw upon the Porter hypothesis, which posits the advantageous effects of environmental regulations on firms' performance, and the stakeholder theory, premised on the notion that a firm's objectives should encompass value creation for shareholders and address the interests of other stakeholders (Freeman 1984; Jensen 2010). Additionally, we ground our proposition in legitimacy theory, which contends that businesses operate within society and must ensure their actions are perceived to yield positive societal impacts (Suchman 1995).

Society perceives the ramifications of firms' activities and maintains a social contract with the communities in which they operate (Boatright 2013). Consequently, the mounting global climate risks necessitate that firms undertake strategic decisions to mitigate the impacts of their operations (Altunbas et al. 2022; Margaret et al. 2023). By restricting firms' carbon emissions through pricing mechanisms, ETS provides a natural context for explaining the interplay between firms' environmental management practices and corporate climate outcomes. Concerns exist that carbon-intensive firms may exploit carbon leakage, wherein firms relocate production to jurisdictions with lax regulatory environments (Makridou et al. 2019; Koch and Mama 2019; Ren et al. 2022; Adamolekun et al. 2024). Consequently, the limitations imposed by the ETS are instrumental in explaining firms' emission mitigation commitments, particularly before and after the implementation of treaties such as the Paris Agreement.

Various studies have documented the dual benefits of ETS on firms' performance and the environment. Recent research demonstrates that ETS participation enhances corporate and green innovation, diminishes business pollutants such as carbon dioxide and GHG, and improves firms' carbon transparency and cost-effectiveness (Wei et al. 2021; Huang et al. 2022). According to Fan (2018), businesses can fulfill ETS regulatory requirements by assessing their emissions output and utilizing low-carbon technologies to decrease emissions or trading quotas. In addition, participating in ETS introduces external corporate control through data disclosure, incentivizes technology adoption, impacts innovation, reduces societal carbon emissions, and allows firms to minimize climate risks while addressing societal challenges through quality corporate governance (Chen et al. 2022).

Previous literature, however, reveals several consequences for firms' ETS membership. Emission credit prices experience volatility because of supply and demand changes, energy market fluctuations (Ji et al. 2018), and environmental and macroeconomic risk events (Wei et al. 2022). Therefore, ETS can incentivize firms to outsource polluting activities to jurisdictions with lax regulations (Naegele and Zaklan 2019). If emission quotas are lenient or overallocated, firms may purchase credits instead of investing in emissions reductions, prolonging stakeholder climate risk exposure. In addition to inherent climate-related operation risk, ETS member firms also face increased regulatory risk as investments in technologies and processes adhering to current regulations may become obsolete if regulations change, raising compliance costs.

This study adds to the literature on climate change and carbon pricing by examining the effect of ETS participation on corporate climate change risk exposure using a broader cross-country firm-level dataset than previous studies (Huang et al. 2018; Makridou et al. 2019; Huang et al. 2022; Hossain et al. 2023). Our sample period spans 2002–2021, covering periods before and after the Paris Agreement, and includes about 32,752 firm-year observations from 65 countries. We use firm-level climate risk as the dependent variable, employing data from Sautner et al. (2020), and utilize propensity score matching (PSM) and system GMM methodologies to assess the robustness of our findings.

Our baseline results suggest that ETS participation is associated with increases in firms' future climate risk exposure. This finding is counterintuitive and contradicts the fundamental objective of the ETS. As a result, we perform a series of supplementary analyses on the data to explore potential variations in our initial findings. First, we examine whether ETS participation influences CCR depending on firms' carbon intensities. Our motivation to consider firms' carbon intensity primarily stems from the hypothesis that variations in emission levels may be crucial to firms' climate-related actions. We find ETS participation increases climate risk exposure for carbon-intensive firms but find insignificant effects for non–carbon-intensive firms.

Next, we categorize firms by location, investigate whether the effects of ETS participation may differ across continents, and assess the role of countries' legal origins. Considering the occurrence of carbon leakage, which is associated with stringent environmental regulations, we posit that continental, country-specific, and institutional factors may influence the impact of ETS participation on firms' climate risk outcomes. Our results underscore considerable continental disparities in firms' climate risk exposure. In particular, we observe a statistically significant positive effect of ETS membership on climate risk exposure for African and European firms. Conversely, our analysis reveals no significant impact on firms in South America, North America, and Asia. With respect to the legal framework of countries, our findings indicate a positive influence of emission trading on the risk exposure of firms in civil law countries while unveiling an insignificant effect for firms in common law countries. Further, ETS effects on climate risk were more pronounced after the Paris Agreement, and lag–lead analysis indicates that ETS effects may take up to 5 years to manifest, particularly for asset-heavy firms.

Our study contributes to the literature on climate change, ETS, and firms' risk exposure, complementing existing knowledge and providing valuable insights for stakeholders in carbon markets. First, existing research indicates that studies on firms' corporate actions have predominantly focused on their financial performance (see Huang et al. 2018; Makridou et al. 2019; Hossain et al. 2023). Prior studies that have sought to examine CCR have relied on firm carbon emissions level as a proxy (see, e.g., Nguyen and Phan 2020; Bose et al. 2021; Altunbas et al. 2022). We diverge from this approach and adopt firms' risk exposure as a proxy, a novel perspective recently developed by Sautner et al. (2020). Unlike prior studies, our adopted measure of CCR encapsulates a wide range of climate challenges beyond the emission of GHGs. Second, our study augments the extensive body of knowledge on ETSs by investigating the impact of membership on firms' risk outcomes. To the best of our knowledge, ours is the first study to explore carbon markets through the lens of firms' risk exposure. We examine both linear and lag–lead effects, identifying a significant positive impact, particularly for carbon-intensive firms. As such, our findings resonate with similar studies examining ETS and their effects on firm performance (see Makridou et al. 2019; Pan et al. 2022; Sakariyahu et al. 2023). From a theoretical standpoint, the finding that ETS participation has varied impacts on firms depending on their carbon intensity aligns with the propositions of Porter's hypothesis, which emphasizes the benefits of environmental regulations.

Lastly, we believe our study offers crucial policy insights to stakeholders in the carbon market. The findings presented in this paper can provide managers with essential information regarding planning and investing in sustainable projects while acknowledging the effects on their corporate outcomes. Firms can strengthen their reputation as ethical and progressive by actively managing their emissions and engaging in ETS. This can increase brand value, draw in eco-conscious investors, and increase customer loyalty. As the corporate and policy spheres become increasingly climate-conscious, our study also delivers valuable guidance to investors interested in eco-friendly businesses. In light of carbon leakage, we argue that our research can benefit governments and policymakers by guiding their environmental regulations and understanding the implications of such policies for firms.

The remainder of the paper is organized as follows: The next section delves into existing studies in the literature and presents the study's hypotheses. A discussion of the methodology and the empirical findings follow this. Finally, the paper concludes with policy recommendations and suggestions for future research.

2 | Theoretical Framework, Empirical Review, and Hypotheses Development

2.1 | Theoretical Framework

This study utilizes a diverse theoretical framework, combining stakeholder legitimacy, Porter's hypothesis, and institutional theories to gain a thorough and nuanced comprehension of the research aims. These theories are crucial because they offer complementary insights into companies' climate risk, participation in ETSs, and societal effects. By combining various theoretical approaches, this paper provides a comprehensive examination of how joining the ETS can help reduce the adverse effects of climate change. This approach enables a detailed analysis of the factors influencing ETS membership, which is in line with the new scholarly focus on using many theoretical frameworks to study intricate corporate social phenomena.

From a theoretical standpoint, there are numerous arguments for the adoption of carbon trading schemes. *Porter's hypothesis* (PH) serves as the primary foundation for various theoretical assertions. It contends that the introduction of environmental regulations can stimulate innovation among firms, which in turn fosters increased competition and improved environmental performance (Porter 1991; Porter and Linde 1995). Essentially, PH suggests that, through the impact of environmental regulations, businesses may be incentivized to engage in innovative activities that can offset some or all of the additional costs related to innovation, thereby enhancing the company's performance and competitiveness. The theory also opines that environmental regulation (ER) is critical for firms' environmental performance as well as business performance. It asserts that well-designed and strict environmental regulation stimulates innovation that not only reduces the total costs of doing business but also offsets the costs of compliance (Porter and Linde 1995). There is a general consensus in the literature that the standards imposed by environmental regulations on firms' activities come with additional costs and risks that may affect firms' performance (Palmer et al. 1995; Ambec and Barla 2002; Cerin 2006). These standards include cap-trade-emission allowance, environment taxes, and technology standards, among others. Accordingly, climate resilience expenses due to changes in the supply chain, production disruption, and increased premiums, among others, are many of the high costs to firms, especially those exposed to physical climate risks.

Proponents of PH contend that ER acts as a hedge against these risks by creating new incentives that shape the rate and direction of businesses through innovation, which can bring competitive advantages and enhance performance (Murty et al. 2006; Ambec et al. 2013). Nevertheless, these costs divert the capital required for productive activities (Ambec et al. 2013), thus challenging the efficacy of PH for business. Indeed, PH is a win-win opportunity for firms inclined toward providing climate solutions (Murty et al. 2006). One strategy to address the effects of regulatory risks involves limiting carbon emissions, an approach further supported by the ETS.

Moreover, proponents of *legitimacy theory* posit that firms must be seen as legitimate by their stakeholders, including customers, employees, investors, and society at large. Such a social license is instrumental to the long-term viability and success of the business. In the context of carbon emissions, companies must take measures to address environmental pollution and demonstrate a commitment to sustainability to maintain social legitimacy (Luo 2019). Social perceptions of the firm contributing to environmental degradation can lead to reputational damage, regulatory costs, and, ultimately, a loss of legitimacy

(Choi et al. 2013). Therefore, seen through the lens of legitimacy theory, firms have social incentives to implement sustainability reporting frameworks, engage with stakeholders, and support or advocate for environmental policies and action on climate change, especially when their sustainability performance is low. Consequently, firms are socially indebted and must take steps to fulfill this social contract should they desire to maintain their legitimacy status. In pursuit of maintaining their legitimacy status, firms may take action to greenwash their operations. At both ends of the spectrum (i.e., the genuine pursuit of legitimacy in society or merely taking actions to be perceived as legitimate), joining an ETS is a plausible action a firm should take.

Another theoretical perspective comes from the *stakeholder theory*, which advances the notion of how stakeholder interests can drive corporate strategic decisions (Donaldson and Preston 1995). The theory relates to how the interests of individuals or groups can impact the actions of an organization (Freeman 1984), suggesting an interaction between the interests of stakeholders and firm value creation. This further corroborates the position of the legitimacy theory. Noticeable changes in the climate have resulted in businesses facing demands through stakeholder activism to undertake strategic changes in their operations to impact society positively (Liesen et al. 2017). The need for firms to incorporate environmental considerations in business decisions to signal a commitment to protecting the environment further advances the position of the stakeholder theory. Although firm commitment to carbon reduction strategies can enhance investment prospects, firm reputation, and social performance (Jo and Harjoto 2012; Delmas et al. 2015), overlooking the importance of environmental and social performance can result in compliance and financing costs (Jung et al. 2018). Engaging in emission reduction strategies or trading carbon credits through ETS membership can enhance firm environmental practices in response to stakeholder interest.

Institutional theory is also a valuable framework for understanding how CCR and membership in ETSs are connected. According to this theory, firms are impacted by the regulations and standards of their operating environment (Choi et al. 2013). Companies may, therefore, participate in ETS as a result of pressures exerted by industry standards, professional groups, or social expectations. Being involved in ETS can be perceived as a sign of ethical conduct, which can decrease reputational risk and connect with broader corporate social responsibility objectives (Luo 2019). In addition, governments and regulatory agencies may enforce regulations or provide incentives that encourage firms to adopt ETS. Companies may also choose to participate in these schemes as a means of managing their climate risks due to the potential for regulatory penalties or the necessity to adhere to environmental standards. They may also choose to participate in ETS due to the involvement of their peers or competitors. This motivation could stem from a desire to avoid being viewed as falling behind in sustainable practices or to embrace what is widely regarded as the most effective approach in the business (Choi et al. 2013). By employing institutional theory, we investigate how institutional factors could influence the choices made by firms to participate in ETS as a means of mitigating climate-related risks.

2.2 | Empirical Review

Climate change has emerged as the primary theme of the 21st century, with growing concerns about its impact on the environment and society. It is now widely recognized that anthropogenic GHG emissions, primarily from burning fossil fuels, are the primary cause of global warming and climate change. In this context, businesses have been identified as one of the key emitters of GHG and face significant climate-related risks (IPCC 2013). Corporate climate risks can pose both challenges and opportunities for businesses. On the one hand, climate change poses significant risks to businesses, such as droughts, floods, wildfires, and other extreme weather and climate-related events that have the potential to disrupt supply chains, damage key infrastructure and facilities, and ultimately increase operational costs and reduce profit margins. On the other hand, businesses that take relevant steps to minimize the negative impact of their activities on the climate, decrease their climate risk levels, align with social and environmental concerns, and promote corporate sustainability can reap various benefits such as increased share returns, higher customer satisfaction, and a lower cost of capital (Berg et al. 2022). Although various factors, including regulatory shifts, physical modifications, technological innovations, financial consequences, and reputation, influence corporate reactions to climate change, it is mainly regulatory reforms that drive companies to seek novel approaches to reduce climate pollution (Williamson et al. 2006).

In addressing corporate exposure to climate risk, firms and stakeholders have turned to carbon mitigation schemes like ETSs. A myriad of studies have examined the effect of ETSs on macroeconomic factors, carbon emission, and price bubbles, among others. However, studies that directly link ETS and CCRs are relatively scarce. For instance, Chapple et al. (2013) examined the effect of ETS on the market valuation of listed firms in Australia and found that the Australian ETS has a significant impact on the capital market, most especially on carbon-intensive firms. Similarly, Yang et al. (2016) also assessed companies' awareness and perceptions of ETS in China and observed that most companies in China participate in the ETS to enhance their social reputations as well as improve government ties but not to reduce GHG emissions. Contrastingly, using a difference in difference (DID) approach, Löschel et al. (2019) investigate the impact of European Union (EU) ETS on the economic performance of the manufacturing firms in Germany and demonstrate that EU ETS has no significant effect on the carbon emission reduction efficiency of the manufacturing industry. However, further analysis employing nearest-neighbour matching suggests that the EU-ETS improves the carbon emission reduction efficiency of the regulated firms during the first compliance period.

Although these studies provide valuable insights into ETS's macroeconomic and market effects, there remains a gap in the literature about the direct relationship between ETS participation and CCRs. Specifically, there is a lack of consensus on whether ETS membership mitigates or exacerbates these risks. For instance, although some studies suggest that ETS can incentivize firms to reduce emissions and innovate, thereby reducing climate risks, others indicate that compliance costs, market volatility, and the potential for superficial adherence (greenwashing) could increase a firm's exposure to climate risks. This inconsistency in the literature points to a need for further research that directly addresses how ETS participation impacts CCRs, particularly in different regulatory and market contexts.

2.3 | Hypothesis Development

Building on the theoretical literature, one of the key decisions businesses can take to signal a commitment to the shift toward more sustainable business practices is joining an ETS. Under the current regulatory framework, ETS serves as one of the primary policy instruments for incentivizing the reduction of corporate GHG emissions. Membership in an ETS provides firms with an economic and regulatory incentive to reduce their emissions, minimize compliance costs, and benefit from potential revenues generated from the sale of unused emissions allowances (Mathews 2008). ETS membership signals a firm's commitment to climate initiatives, and this impacts how market participants perceive CCRs (Sautner et al. 2020). Although participation in an ETS can encourage innovation in clean technologies and promote sustainable business operations, the implications for a firm's climate risk are complex and multifaceted. On the one hand, ETS participation may incentivize firms to adopt emission-reducing technologies, potentially decreasing their overall climate risk. On the other hand, the costs of compliance, the volatility of carbon markets, and the risk of superficial compliance or greenwashing can paradoxically increase a firm's exposure to climate risks. For instance, firms might focus on meeting regulatory requirements superficially without making substantive operational changes, leading to increased vulnerability to regulatory penalties, reputational damage, or operational disruptions in the future. PH highlights that although environmental regulations can drive innovation, they may also lead to inefficiencies or unintended adverse outcomes if not well-designed (Porter and Linde 1995). Furthermore, the Stakeholder Theory and Legitimacy Theory highlight the pressures firms face to appear compliant with environmental standards, which might encourage superficial rather than substantive adherence to ETS requirements, ultimately increasing climate risk (Freeman 1984; Suchman 1995). The perception and awareness of firm climate risk exposure have implications for climate resilience expenses, innovation, and value creation. Furthermore, such perceptions of firm commitment to sustainability enhance legitimacy (Luo 2019) since the perceived overlook of environmental and social performance increases the risk of regulatory costs, reputational damage, and loss of legitimacy (Choi et al. 2013). Therefore, we hypothesize that

Hypothesis 1. *Membership of ETS is associated with an increase in firms' climate risk.*

Furthermore, companies participating in an ETS must adhere to emission caps and are subject to penalties if they surpass these limits. As a result, regulatory pressures will likely guide firms toward adopting measures to decrease their carbon footprint. Abrupt fluctuations in the prices of emission credits can significantly increase compliance costs, subsequently reducing overall profits (Da Silva et al. 2016), thereby offering an additional incentive to invest in decarbonization efforts. Previous studies have also identified a learning effect among firms engaged in an ETS, as they gain valuable information about their emissions profile and effective strategies for emission reduction from industry counterparts (Engels et al. 2008).

From a governance perspective, ETS involvement necessitates additional disclosure and adherence to regulatory requirements, allowing firms to signal their commitment to environmental sustainability and the robustness of their governance structure to external stakeholders. However, we consider that the impact of ETS on climate risk may vary depending on a firm's specific characteristics, particularly its carbon dependency. Carbon-intensive firms, which rely heavily on processes that emit significant levels of GHGs, are likely to be more affected by ETS regulations. Thus, the potential for reducing climate risk through ETS participation might be more significant for these firms (Ben-Amar et al. 2017). This suggests that carbon-intensive firms, due to their higher exposure to regulatory and physical climate risks, will benefit more significantly from the emissions reductions required by ETS, leading to a more significant decrease in overall climate risk. Accordingly, we put forth the following hypothesis:

Hypothesis 2. *The negative association between ETS membership and a firm's climate risk is stronger for firms with high carbon dependency.*

In addition to firm-specific factors, the influence of ETS membership on CCRs may also be affected by variations in the geographical location of firms and country-specific governance mechanisms, such as the divergent impacts of common and civil law approaches to corporate governance on firms' environmental proactivity (Andreou and Kellard 2021). Historically, global emissions were primarily driven by firms in America and Europe; however, recent trends have seen a significant increase in emissions from Asian firms, particularly those in China. Moreover, contemporary differences in governance systems are often linked to disparities in legal origins, which, in turn, are associated with heterogeneity in corporate environmental responsibility (La Porta et al. 1998; Lu and Wang 2021).

Common law countries typically adopt a shareholder-oriented approach that emphasizes short-term returns on investment and aligns closely with shareholder primacy (Smith and Rönnegard 2016). In contrast, corporate governance systems in civil law jurisdictions like Germany tend to encompass multiple stakeholders and are more receptive to long-term stakeholder considerations. These distinctions suggest that firms in different regions and under different legal systems may experience varying impacts of ETS membership on their climate risk, with firms in civil law countries potentially experiencing a stronger reduction in climate risk through ETS participation compared with those in common law countries, which often focus more on short-term shareholder returns. This debate gives rise to our subsequent hypotheses:

Hypothesis 3. *The association between ETS membership and CCR varies by geographical location.*

Hypothesis 4. *The negative association between ETS membership and CCR is more pronounced among firms in civil law countries compared with those in common law countries.*

TABLE 1 | Data distribution.

Panel A: Data distribution by country		
Country	**Freq.**	**Percent**
Argentina	15	0.05
Australia	1315	4.02
Austria	138	0.42
Belgium	143	0.44
Bermuda	129	0.39
Brazil	312	0.95
Canada	1803	5.51
Cayman Islands	30	0.09
Chile	90	0.27
China	366	1.12
Colombia	37	0.11
Costa Rica	2	0.01
Cyprus	31	0.09
Czech Republic	15	0.05
Denmark	199	0.61
Egypt	10	0.03
Faroe Islands	4	0.01
Finland	226	0.69
France	982	3
Germany	858	2.62
Gibraltar	14	0.04
Greece	68	0.21
Hong Kong	281	0.86
Hungary	19	0.06
India	598	1.83
Indonesia	25	0.08
Ireland	342	1.04
Isle Of Man	14	0.04
Israel	136	0.42
Italy	306	0.93
Japan	913	2.79
Kazakhstan	2	0.01
Kenya	6	0.02
Korea (South)	97	0.3
Kuwait	6	0.02
Luxembourg	104	0.32
Malaysia	73	0.22

(Continues)

TABLE 1 | (Continued)

Panel A: Data distribution by country		
Country	**Freq.**	**Percent**
Malta	13	0.04
Mexico	142	0.43
Monaco	16	0.05
Morocco	8	0.02
Netherlands	476	1.45
New Zealand	182	0.56
Norway	269	0.82
Panama	4	0.01
Papua New Guinea	9	0.03
Peru	10	0.03
Philippines	33	0.1
Poland	67	0.2
Portugal	66	0.2
Puerto Rico	5	0.02
Qatar	7	0.02
Russian Federation	224	0.68
Saudi Arabia	9	0.03
Singapore	122	0.37
South Africa	373	1.14
Spain	401	1.22
Sweden	382	1.17
Switzerland	538	1.64
Thailand	33	0.1
Turkey	83	0.25
Ukraine	5	0.02
United Arab Emirates	29	0.09
United Kingdom	2648	8.09
United States	16,889	51.57
Total	32,752	100

Panel B: Data distribution by year		
Year	**Freq.**	**Percent**
2002	300	0.92
2003	394	1.2
2004	530	1.62

(Continues)

TABLE 1 | (Continued)

Panel B: Data distribution by year		
Year	**Freq.**	**Percent**
2005	691	2.11
2006	709	2.16
2007	782	2.39
2008	965	2.95
2009	1055	3.22
2010	1266	3.87
2011	1340	4.09
2012	1507	4.6
2013	1524	4.65
2014	1514	4.62
2015	1896	5.79
2016	2242	6.85
2017	2740	8.37
2018	3226	9.85
2019	3443	10.51
2020	3592	10.97
2021	3036	9.27
Total	32,752	100
Panel C: Data distribution by continent		
Continent	**Freq.**	**Percent**
Africa	397	1.21
Asia	2844	8.68
Europe	8537	26.07
North America	19,004	58.02
Oceania	1506	4.6
South America	464	1.42
Total	32,752	100
Panel D: Data distribution by industry		
Industry	**Freq.**	**Percent**
Basic materials	3006	9.18
Consumer discretionary	6410	19.57
Consumer staples	2333	7.12
Energy	2630	8.03
Health care	4127	12.6
Industrials	6852	20.92
Real estate	518	1.58

(Continues)

TABLE 1 | (Continued)

Panel D: Data distribution by industry		
Industry	**Freq.**	**Percent**
Technology	3741	11.42
Telecommunications	1257	3.84
Utilities	1878	5.73
Total	32,752	100

Note: This table presents the sample distribution of the data.

3 | Data and Methodology

3.1 | Description of Data and Sources

To explore the relationship between ETS membership and CCR, we employ global firm-level data from Refinitiv Eikon and Sautner's (2020) data depository. We merge firms based on their ISIN code from both data sources. Matching on this criterion resulted in a sample of 32,752 firm-year observations for 5364 unique firms from 65 countries across Africa, Asia, Europe, Oceania, North America, and South America. Notably, firms from the United States, United Kingdom, Canada, and Australia represent a significant portion of our sample. Details of the sample distribution are presented in Table 1.

Our sample for this study covers the period from 2002 to 2021. We are constrained to this timeframe for two reasons. First, as of the time of writing this paper, all the firm-level data used in the empirical strategy are only available until 2021. Second, our choice of this timeframe is hinged on the importance of the era. The period falls within an era where several companies, international agencies, and national governments accelerated efforts to reduce GHG emissions, planning the transition into clean energy sources through sustainable investments. Carbon pricing was part of such efforts to achieve these targets, whose fallout is the significant growth in the establishment of emission trading systems by several countries since 2005.

3.2 | Measurement of Variables

3.2.1 | Dependent Variable

The dependent variable in our model is the *climate change risk of firms*. To capture this proxy, we employ the novel firm-level climate change risk exposure developed by Sautner et al. (2020). Prior studies utilized a similar measure (see, e.g., Huang et al. 2018; Huang et al. 2022; Ahmad et al. 2023). Our use of this proxy in the context of carbon pricing differs from those of earlier studies. In explaining firms' climate risk, Sautner et al. (2023) counted the number of climate change bigrams mentioned in a sentence with words like "risk," "uncertainty," or similar words. Our measure of firm-level climate risk reflects the perception and awareness of firm climate risk exposure from the perspective of key stakeholders (Sautner et al. 2020). Although this offers insights into the perceived climate risks and the level of discourse around such issues within firms, it does not necessarily reflect direct measures of actual climate risk exposure. Therefore, interpreting the data demands a nuanced understanding that increased mentions might indicate heightened awareness or transparency regarding climate risks rather than concrete risk metrics. This can be defined by the equation:

$$Corporate\ Climate\ Risk_{it} = 1 / B_{i,t}\left(1\left[b \in \mathbb{C}\right] \times 1\left[b, r \in S\right]\right) \quad (1)$$

a

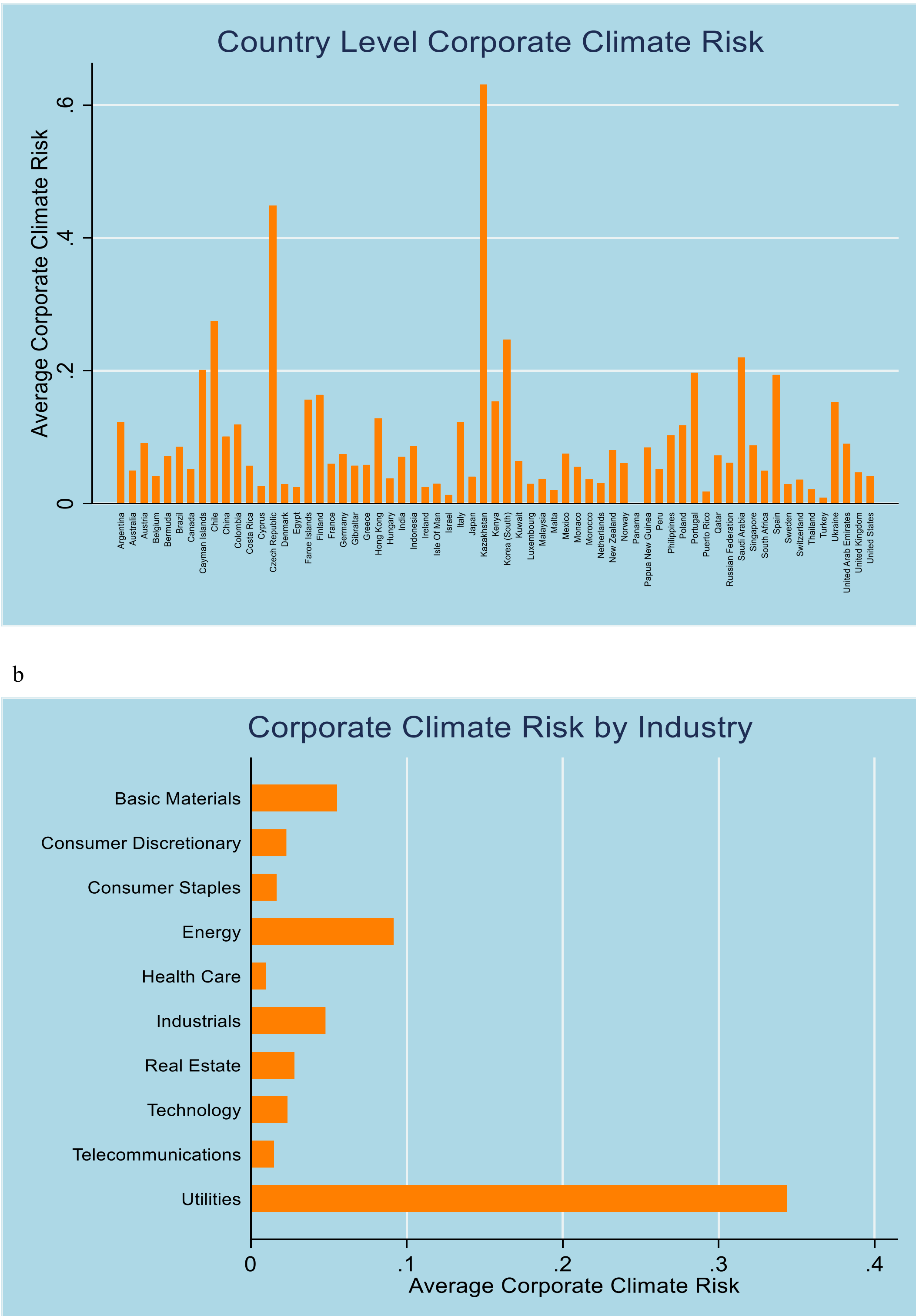
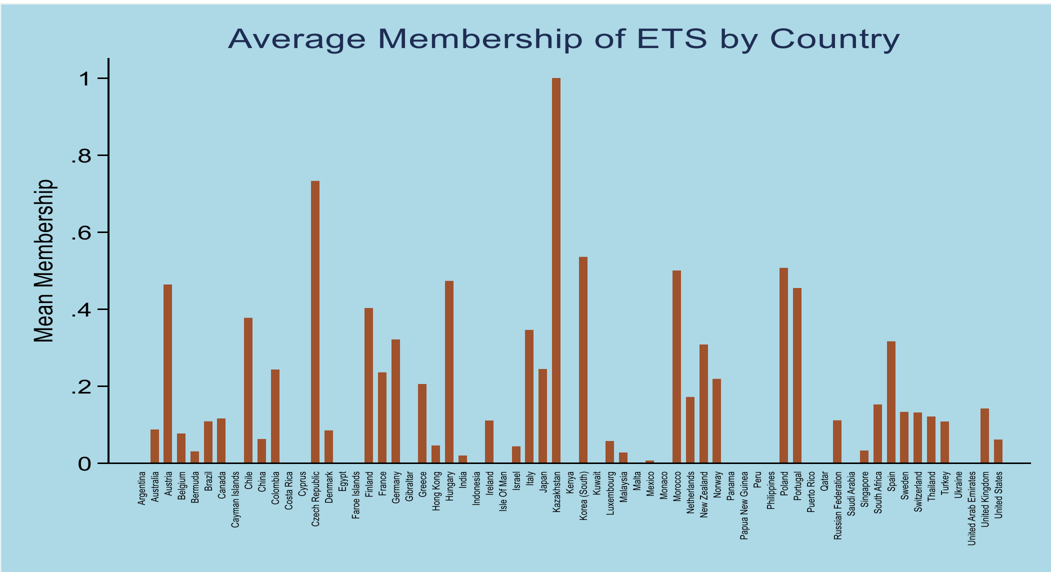


FIGURE 1 | Corporate climate risk. This figure details the average firm-level climate risk exposure by country (a) and by industry (b).

where b is 0, 1 … … and $B_{i,t}$ refers to the bigrams in the earnings call transcript of a firm represented by the subscript i in quarter t. r in the equation denotes the words “risk,” “uncertainty,” or their equivalence. 1 represents the indicator function. $\mathbb{C}$ refers to the exposure measure. Our sample suggests that firms from Kazakhstan have the highest level of CCR, as inferred from their earnings call transcript. Following closely are firms from Chile, Saudi Arabia, and South Korea. In contrast, firms in Egypt, Puerto Rico, and Israel appear to be less exposed to this phenomenon. In Figure 1a, we report a pictorial representation of the average firm-level climate risk exposure by country. The CCR is also reported by industries in Figure 1b. The figure indicates that firms in the utility industry are most exposed to CCR. Companies in the energy, basic material, and industrial/manufacturing industries are equally exposed to a high degree of climate risk. Firms in the healthcare industry are the least exposed to the trend.

a: Membership of ETS by country

This figure details the average firm-level climate risk exposure by country.



b: Membership of ETS by industry

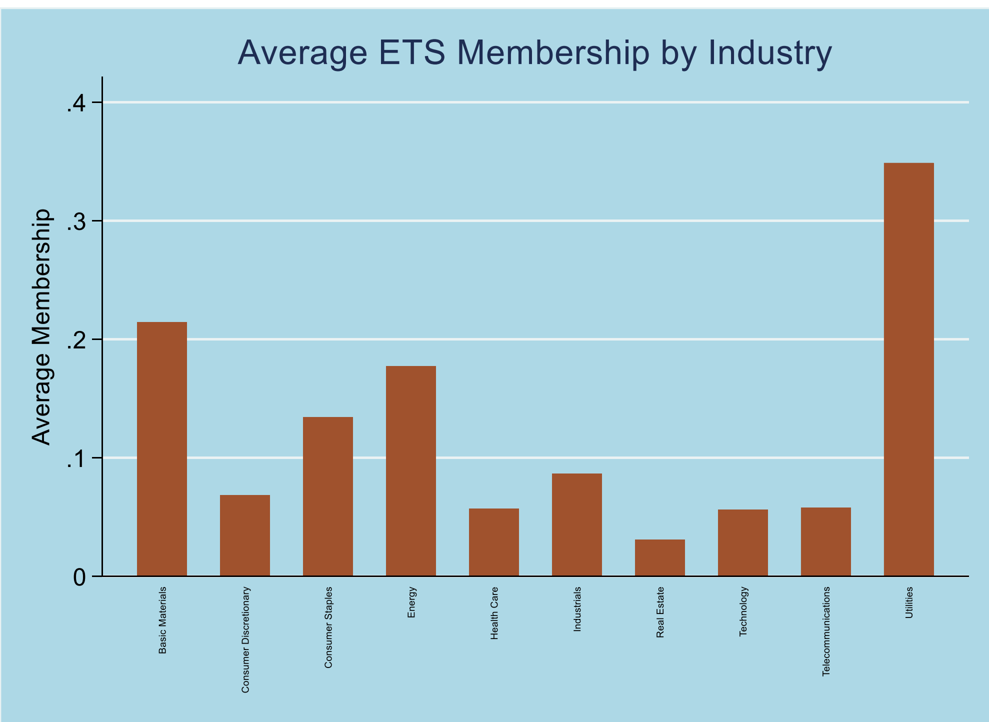


FIGURE 2 | Membership of ETS by country (a) and by industry (b). This figure details the average firm-level climate risk exposure by country.

3.2.2 | Explanatory Variables

Our main explanatory variable is the firm's climate action, which is measured using ETS participation. This proxy captures whether a firm participates in an ETS or not. This follows a binary structure that takes the value of 1 for firms participating in ETS and 0 for nonparticipating firms. Although ETS participation imposes significant costs on firms, a firm's decision to participate (or otherwise) demonstrates a commitment to reducing carbon emissions and investing in low-carbon technologies. We believe that this action could significantly impact a firm's climate risk exposure as it would capture the attention of the stakeholders keen to evaluate the sustainability of its climate actions. Interestingly, prior studies that have also employed a firm's ETS participation as a proxy for climate action report a significant impact of the proxy on firms' performance (see Huang et al. 2018; Makridou et al. 2019; Huang et al. 2022; Hossain et al. 2023).

In Figure 2, we report ETS membership by country and industry. According to our sample, a significant portion of firms from Kazakhstan, Czech, South Korea, and Poland are members of the ETS. Figure 2a reports further details of ETS membership by country. In Figure 2b, we present details of ETS membership by industry. The figure demonstrates that many firms in the utility industry are members of ETS. Similarly, many firms from the basic material and energy industries are members of ETS. The evidence suggests that a significant portion of firms from the real estate industry are not interested in the scheme.

3.2.3 | Control Variables

We follow extant studies in the carbon emission literature to control for firm-specific characteristics such as ESG score, return on assets, slack, size, leverage, market-to-book value, and

TABLE 2 | Summary statistics.

	ETS members					Non-ETS members					
Variable	**Count**	**Mean**	**p25**	**SD**	**p75**	**Count**	**Mean**	**p25**	**SD**	**p75**	**Difference**
Climate change risk [10^3]	3646	0.13	0.31	0.00	0.13	29,106	0.04	0.17	0.00	0.00	0.09**
ESG score	3646	65.46	16.37	55.82	77.93	29,106	44.10	19.41	28.39	58.78	21.36**
ROA	3646	0.04	0.08	0.00	0.07	29,106	0.02	0.18	0.00	0.08	0.02**
Slack	3646	0.33	0.16	0.20	0.43	29,106	0.42	0.23	0.23	0.57	−0.09**
Size	3646	24.24	2.20	22.83	24.96	29,106	22.25	2.13	20.94	23.27	1.99**
Leverage	3646	0.29	0.15	0.19	0.38	29,106	0.27	0.21	0.12	0.38	0.02**
MTB	3646	0.91	1.20	0.25	1.15	29,106	1.56	2.15	0.45	1.91	−0.65**
PPE	3646	0.40	0.23	0.21	0.58	29,106	0.28	0.25	0.09	0.43	0.12**

Note: This table presents descriptive statistics of variables used in the analysis. Our base sample consists of ETS-participating firms and nonparticipating firms. Definitions of variables are provided in Appendix 1. *, **, *** for level of significance at 10%, 5% and 1% respectively.

TABLE 3 | Correlation matrix.

		1	2	3	4	5	6	7	8
1	ETS								
2	Climate change risk	0.148***							
3	ESG score	0.332***	0.0964***						
4	ROA	0.0413***	0.000530	0.134***					
5	Slack	−0.127***	−0.106***	−0.142***	−0.137***				
6	Size	0.281***	0.109***	0.491***	0.152***	−0.283***			
7	Leverage	0.0349***	0.0423***	0.0542***	−0.0711***	−0.348***	0.130***		
8	MTB	−0.0984***	−0.0693***	−0.136***	−0.00542	0.302***	−0.366***	−0.171***	
9	PPE	0.153***	0.169***	0.0590***	0.0294***	−0.583***	0.195***	0.206***	−0.229***

Note: This table presents the correlation matrix for all key variables adopted in this study. Definitions of variables are provided in Appendix 1.
*$p < 0.05$,
**$p < 0.01$,
***$p < 0.001$.

property, plant, and equipment (PPE) (see Makridou et al. 2019; Koch and Mama 2019; Azar et al. 2021; Konadu et al. 2022; Pan et al. 2022; Ahmad et al. 2023). The firms' ESG (environmental, social, and governance) score is obtained from Refinitiv Eikon. A firm's score is constructed from 10 different indicators that ultimately reflect the firm's commitment and performance in the areas of environmental, social, and corporate governance. Since we conjectured earlier that the sampled firms are likely to demonstrate significant interest in pursuing net-zero emissions, expecting their ESG score to reflect climate actions and relate to their climate risk exposure is tenable. Studies that have also adopted ESG as a proxy for climate actions include Zhang et al. (2022) and Arvidsson and Dumay (2022), among others.

The return on assets variable is calculated as EBITDA divided by total assets. The slack variable is computed as current assets scaled by current liabilities. Size is proxied with the natural logarithm of total assets, and leverage is computed as total debt scaled by total assets. Market to book is defined as the market value of equity scaled by the book value of common equity, and PPE is calculated as property, plant, and equipment scaled by total assets.

3.3 | Empirical Strategy

In a panel data such as this study, the choice of whether fixed or random effect becomes a concern. Conventional wisdom in

TABLE 4 | Emission trading scheme and corporate climate change risk (Hypothesis 1).

	(1)	(2)	(3)
ETS	0.0148***	0.0220***	0.0127***
	(3.67)	(5.46)	(3.12)
ESG score		0.0005***	0.0002**
		(6.97)	(2.57)
ROA		−0.0070	−0.0078
		(−1.07)	(−1.18)
Slack		0.0192**	0.0137
		(2.22)	(1.48)
Size		0.0053***	0.0010
		(5.47)	(0.73)
Leverage		−0.0026	−0.0092
		(−0.39)	(−1.36)
Market to book		0.0003	0.0006
		(0.48)	(0.99)
PPE		0.0936***	0.0322***
		(10.85)	(3.09)
Constant	0.0424	−0.1235***	0.0002
	(0.60)	(−5.59)	(0.00)
Industry dummies	Yes	No	Yes
Year dummies	Yes	No	Yes
Country dummies	Yes	No	Yes
Observations	32,752	32,752	32,752
R-squared	16%	4%	20%

Note: This table presents the main regression results for the nexus between firms' ETS participation and climate change risk. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. Model 1 shows the impact of only the main explanatory variable (ETS) on CCR. Model 2 includes the impact of all variables on CCR but with no industry, year, and country effects. Model 3 includes the impact of all variables on CCR, with industry, year, and country effects. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

TABLE 5 | Carbon-intensive industries, emission trading scheme, and corporate climate change risk (Hypothesis 2).

	Non–carbon intensive	Carbon intensive
ETS	0.0017	0.0185**
	(0.51)	(2.44)
ESG score	0.0001**	0.0004**
	(1.98)	(1.99)
ROA	−0.0042	−0.0124
	(−0.98)	(−0.70)
Slack	−0.0002	0.0428*
	(−0.04)	(1.79)
Size	−0.0002	0.0042
	(−0.16)	(1.30)
Leverage	−0.0020	−0.0111
	(−0.46)	(−0.63)
Market to book	0.0002	−0.0001
	(1.30)	(−0.04)
PPE	0.0112	0.0726***
	(1.41)	(3.28)
Constant	0.0102	−0.0862
	(0.09)	(−0.52)
Industry dummies	Yes	Yes
Year dummies	Yes	Yes
Country dummies	Yes	Yes
Observations	18,386	14,366
R-squared	7%	21%

Note: This table presents the regression results for the nexus between firms' ETS participation and climate change risk for both carbon-intensive and non–carbon-intensive industries. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The estimations include industry, year, and country effects. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

econometric modeling suggests that when the time span (T) is relatively smaller than the number of firms in a panel, the use of a random effect model is most suitable, as a fixed-effect model may cause misspecification, resulting in unreliable results (Thomas et al. 2014). Given the nature of our data (small T and large N), the random-effect model is most appropriate. To examine the relationship between corporate climate action and climate risk exposure, we start by specifying a simple panel random-effect regression model of this form:

$$CCR_{icjt} = \alpha + \beta' X_{icjt} + \nu_{icjt} + \varepsilon_{icjt} \tag{2}$$

where CCR refers to corporate climate risk; X_{cjt} is a $K \times 1$ vector of strictly exogenous predictors (i.e., ETS, ESG score, ROA, slack, size, leverage, MTB, and PPE); ν_{icjt} and ε_{icjt} are the disturbances and errors; and $_i$, $_c$, $_j$, and $_t$ indexes refer to firm, country, industry, and year effects, respectively.

To mitigate the asymptotic biases in our sample, we further specify our model using a PSM model. Adopting a PSM model lessens self-selection biases (Roberts and Whited 2013; Shipman et al. 2017). PSM can be specified from a binary choice model that can be defined as follows.

$$D_i = \alpha + \beta X_i + \varepsilon_i \tag{3}$$

The treated observations (i.e., $D_i = 1$) are matched to the control/untreated (i.e., $D_i = 0$) with the highest propensity score. According to our research design, firms that are part of an ETS are termed "treated," whereas those that are not members of a scheme are the "control/untreated" group. In general, the PSM generates a sample in common support/overlap (i.e., a sample of treated and untreated that are similar across X_i).

In addition to self-selection bias, another significant worry in the use of panel data is the issue of endogeneity, which often

TABLE 6 | Continent, emission trading scheme, and corporate climate risk (Hypothesis 3).

	Africa	Asia	Europe	North America	Oceania	South America
ETS	0.0733***	−0.0017	0.0144**	0.0063	0.0405**	0.0379
	(2.60)	(−0.11)	(2.27)	(1.07)	(2.54)	(0.64)
ESG score	−0.0006	−0.0003	0.0002	0.0003***	0.0004	0.0004
	(−0.82)	(−0.63)	(0.97)	(2.96)	(1.18)	(0.28)
ROA	0.5046	−0.0894	−0.0045	−0.0020	0.0303	−0.0305
	(1.13)	(−1.09)	(−0.32)	(−0.27)	(0.76)	(−0.09)
Slack	0.2326**	0.0239	0.0365**	−0.0071	0.0195	0.2071
	(2.52)	(0.49)	(2.12)	(−0.65)	(0.56)	(1.10)
Size	0.0059	0.0094	0.0078***	−0.0042**	−0.0018	0.0088
	(0.49)	(1.44)	(3.06)	(−2.50)	(−0.33)	(0.30)
Leverage	−0.0062	−0.0206	−0.0015	−0.0111	0.0071	−0.1391
	(−0.08)	(−0.48)	(−0.10)	(−1.46)	(0.22)	(−0.96)
Market to book	0.0953	0.0057	−0.0001	0.0011	−0.0011	0.0274
	(1.49)	(0.87)	(−0.07)	(1.52)	(−0.49)	(0.44)
PPE	0.0471	0.1624***	0.0226	0.0273**	0.0123	0.2885
	(0.55)	(2.95)	(1.23)	(2.12)	(0.39)	(1.56)
Constant	−0.1923	0.1721	−0.0593	0.1403	0.0000	−0.3488
	(−0.55)	(0.50)	(−0.47)	(0.98)	(.)	(−0.39)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	397	2844	8537	19,004	1506	464
Adj R^2	38%	39%	27%	17%	29%	39%

Note: This table presents the regression results for the nexus between firms' ETS participation and climate change risk. Estimation is based on the continental location of firms such as Africa, Asia, Europe, North America, Oceania, and South America. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. T-statistics are shown in parentheses. The estimations include industry, year, and country effects. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

causes the estimates to be inefficient. We are conscious of this problem, particularly for some of the control variables, and to correct for its possible presence, we use an instrumental variable method—the system generalized method of moments (GMM). We specify the model below:

$$Y_{it} = \alpha + Y_{it-1} + \beta' X_{it} + \delta_i + \mu_t + u_{it} \quad (4)$$

where Y_{it} refers to the CCR exposure. Y_{it-1} is the lagged value of CCR, X_{it} represents the explanatory variables, δ_i and μ_t denote firm and time effects, and u_{it} is the error term.

4 | Findings and Discussion

In Table 2, we report the summary statistics of splitting our sample into firms that are members of an ETS scheme and their counterparts that are not. The *t*-test of the means of the exogenous predictors is also reported in Table 2. The results suggest that members of ETS have a higher climate change risk than their nonmembers counterparts. This suggests that member firms may have acute exposure to climate risk. A plausible explanation for this could also be that ETSs are more attractive for firms exposed to climate risk looking to take action to stem their exposure. This affirms the argument of Zhang et al. (2022), who posit that such climate initiatives could propel corporate climate action. Similarly, member firms have a higher ESG score, higher ROA, higher leverage, and higher PPE and are bigger in size (total assets) than nonmembers. In effect, ETSs may be more attractive to profitable firms, highly leveraged firms, and firms with high ESG scores and high PPE. Contrastingly, member firms have lesser slack (i.e., current assets deflated by total assets) and lower market-to-book ratios (MTBs). We provide further details of the variable definition in Appendix 1.

Table 3 documents the result of the correlation between our variables. The correlation results indicate that membership in emission trading is positively associated with corporate climate change risk, ESG score, size, and PPE. Similarly, the result also reveals that ETS has a negative relationship with slack and MTB. Corporate climate change risk is also positively correlated with ESG score, size, leverage, and PPE. This implies that firms with these credentials may have acute exposure to climate risk. Alternatively, CCR is negatively related to MTB and slack. This may suggest that firms with substantial growth opportunities and slack could hedge against CCR.

To test Hypothesis 1, we specify a regression in the form of Equation (2). In Model 1 of Table 4, we specify the regression analysis without other exogenous predictors. The result suggests that membership in ETS increases CCR. In Models 2 and 3 of Table 4, we introduce the control variables as well as industry, year, and country dummies. The findings confirm the view that membership in emission trading increases firm-level climate risk. The results contradict the view that membership in ETSs would incentivize green innovation and, in effect, reduce CCR (Zhang et al. 2022). We argue that this initiative could disincentivize green innovation since firms do not necessarily need to stop relying on fossil fuels in their operation. Our results are at odds with Porter's theory, which postulates that environmental regulation would encourage green innovation (Porter 1991; Porter and Linde 1995). According to the theory, environmental regulation will stimulate corporate transition to sustainable production processes, reducing CCR. We document that corporate environmental regulation, as evidenced by the ETS, does not yield the desired results automatically. One explanation for the conundrum is that without the transnational coordination of ETSs, firms can easily circumvent the framework (Naegele and Zaklan 2019). At large, this is consistent with proponents of the legitimacy theory that argue that, in pursuit of legitimacy, companies may acquire artificial legitimacy. To this end, carbon-reliant firms may take up initiatives to prop up their environmental profile. The findings also indicate that high PPE and ESG scores are positively related to firm climate

TABLE 7 | Law of origin, emission trading scheme, and corporate climate risk (Hypothesis 4).

	Civil law	Common law
ETS	0.0257***	0.0074
	(2.67)	(1.40)
ESG score	−0.0001	0.0003***
	(−0.31)	(2.90)
ROA	−0.0168	−0.0060
	(−0.65)	(−0.87)
Slack	0.0460	0.0010
	(1.62)	(0.10)
Size	0.0116***	−0.0008
	(2.90)	(−0.53)
Leverage	0.0008	−0.0081
	(0.04)	(−1.13)
Market to book	−0.0002	0.0003
	(−0.06)	(0.94)
PPE	0.0448	0.0271**
	(1.47)	(2.25)
Constant	0.0000	0.0899
	(0.00)	(0.78)
Industry dummies	Yes	Yes
Year dummies	Yes	Yes
Country dummies	Yes	Yes
Observations	6042	21,913
R-squared	24%	18%

Note: This table presents the regression results for the nexus between firms' ETS participation and climate change risk. Estimation is based on the legal origin of the country where a firm is situated, such as civil or common law. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The estimations include industry, year, and country effects. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

risk exposure. One potential explanation for our findings is that membership in the scheme induced climate scrutiny, which exacerbated CCR. The findings are consistent with similar studies in the literature that have sought to address how internal and external features affect their carbon emission levels (see, for instance, Azar et al. 2021; Konadu et al. 2022).

In Table 5, we report the results of splitting our sample by the degree of their reliance on carbon. Since firms in carbon-intensive industries have greater exposure to climate risk (Ben-Amar et al. 2017), the impact of ETSs on firm climate risk may vary by the degree of dependency on carbon. Based on this dichotomy, the positive impact of ETSs is only prevalent in carbon-intensive industries. Firms that are heavily reliant on carbon would struggle to wean themselves of dependency on hydrocarbons. Consequently, their membership in ETSs may stifle their interest in green production processes. Furthermore, firms that belong to carbon-intensive industries may struggle not to exceed their emission quotas. Therefore, their membership in ETS will increase the degree of scrutiny they face as a result of this violation, which worsens their climate risk. Accordingly, the impact of ETS on CCR is insignificant among firms in non–carbon-intensive industries. The results suggest that policy action should be targeted at carbon-intensive industries since the positive impact of ETS on CCR is only pronounced among this category of firms.

Continental factors may enhance the effectiveness of ETSs. To address this line of argument, we divide our sample into continents and report the results of this analysis in Table 6. The result suggests that the positive impact of ETSs is more pronounced among firms from Africa, Europe, and Oceania. One explanation for this result is that countries in these regions are quite vulnerable to adverse climate events. Membership of ETS illuminates and highlights the consequences of this event on corporate operating infrastructure. Furthermore, extreme weather events could cause significant direct economic losses, such as the destruction of infrastructures, or indirect economic losses in the form of diminished operating capacity. Similarly, adverse climate events could disrupt the supply chains of firms situated in these regions, which have wide-ranging ramifications for their survival. For firms from South America, North America, and Asia, membership in the scheme has no impact on CCR. We interpret these results to mean that due to North America's geographical and climate diversity, climate risk is not felt at an aggregate level, and as such, the adverse impact of corporate membership of ETS is insignificant. Furthermore, unlike Europe, with concerted policies at a regional level aimed at decarbonization, stakeholder expectations in North America and South America are somewhat subdued. This implies that institutional factors and country-specific features could affect corporate outcomes from participating in the scheme (La Porta et al. 1998; Lu and Wang 2021). The results confirm the view that continental and regional carbon profiles should be considered when developing carbon reduction initiatives (Ren et al. 2022).

To address Hypothesis 4, we divide our sample into civil law and common law countries. We report the findings of this split in Table 7. The results reveal that the positive impact of emission trading is only positive for firms in civil law countries. For firms in common law countries, the impact is insignificant. In general, this may imply that ETS schemes have fewer negative impacts in market-based economies (Halkos and Tzeremes 2013). Nonetheless, the results may be indicative of the quality of corporate environmental reporting in civil law countries (Döring et al. 2023).

4.1 | Propensity Score Matching

Our preanalysis diagnosis indicates that the procedure was effective in reducing biases. In Figure 3, we report the results of the covariate bias reduction. The graphical representation

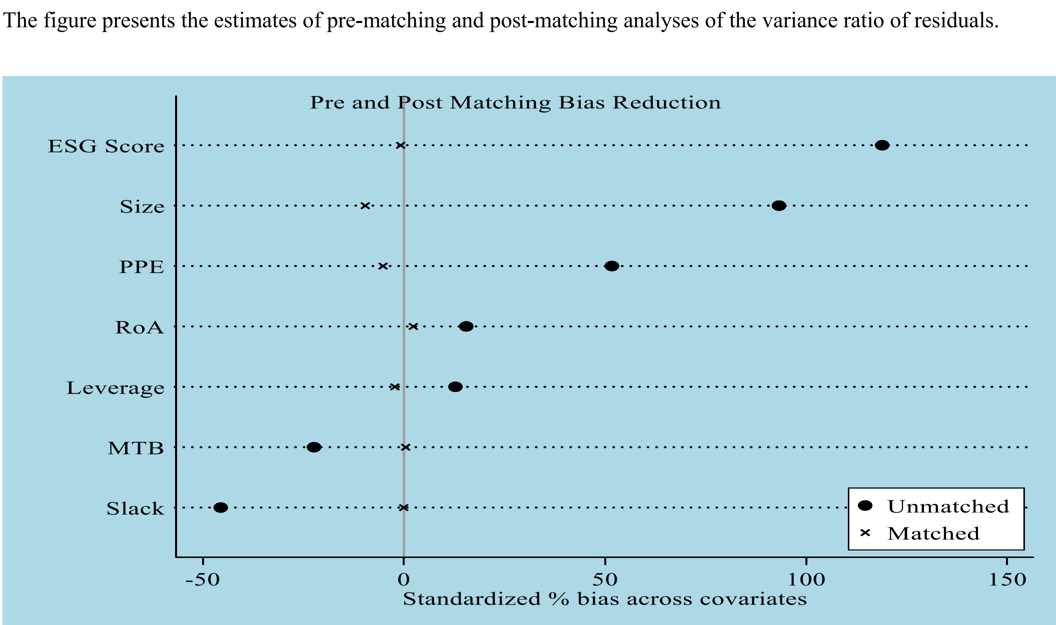


FIGURE 3 | Variance ratio of residuals. The figure presents the estimates of prematching and postmatching analyses of the variance ratio of residuals.

reveals that the matching was effective in reducing the bias of the covariates.

In Figure 4, we report the results of prematching and postmatching. The result implies that the covariates are within the acceptable variance ratio threshold of > 0.5 to < 2.

Panel A of Table 8 also reports the variance ratio of the covariates and confirms that after matching, the variance ratio of the variables is not below 0.5 and not greater than 2. The range of the variance ratio postmatching is 0.5–1.09. In Panel B of Table 8, we report the coefficient of the average treatment effect on the treated (ATT). The results confirm our view that firms that partake in ETSs have higher climate change risk than their counterparts that choose not to participate. This contradicts the proposition that carbon reduction initiatives like the ETS could accelerate corporate transition to green and sustainable production processes (Zhang et al. 2022).

4.2 | Additional Analysis

In Table 9, we examine if the dynamics of the relationship between ETS and CCR changed as a result of the 2015 Paris Agreement. The result demonstrates that the positive impact of emission trading on firm climate risk was not significant before the Paris Agreement. However, after the 2015 Paris Agreement, the impact of ETS on firm climate risk became pronounced. This implies that membership in ETSs may be driven by an attempt to sway positive environmental sentiment rather than a genuine interest in curbing dependency on fossil fuels.

Since membership may have a delayed effect on CCR, we proceed by evaluating how membership of the scheme affects future CCR. We report the results of this analysis in Table 10. The findings suggest that the impact of the ETS on firm climate risk is evident 1 year after joining the scheme. However, the relationship

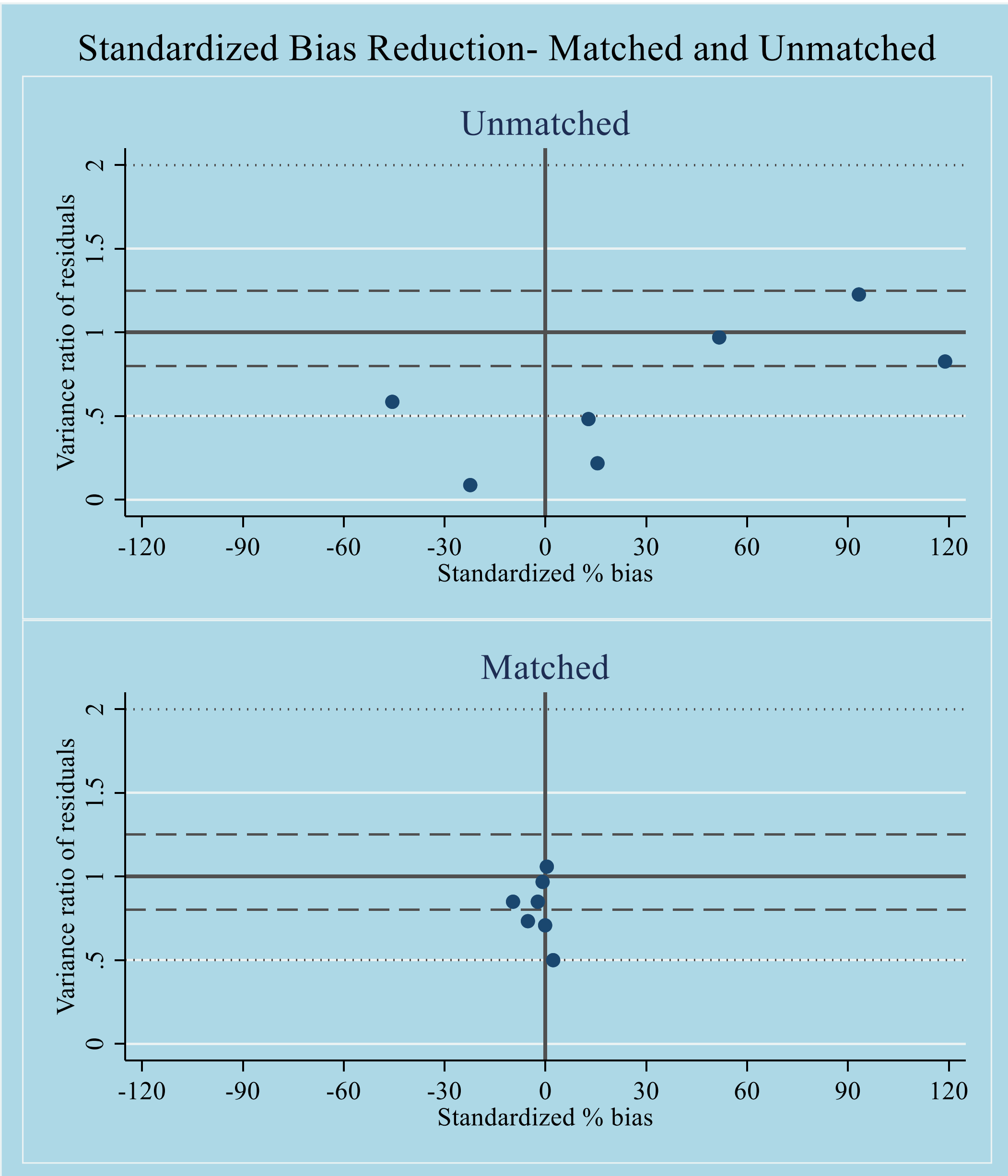


FIGURE 4 | Variance ratio across covariates.

TABLE 8 | Propensity score matching estimation.

Panel A: Test of imbalance of variables							
Variable	**Category**	**Treated**	**Control**	**% Bias**	**% Reduction in bias**	***t*-test**	**Variance ratio**
ESG score	Unmatched	65.423	44.069	118.9	99.3	63.83	0.71
	Matched	65.423	65.574	−0.8		−0.39	0.96
ROA	Unmatched	0.04	0.018	15.5	85.1	7.18	0.2
	Matched	0.04	0.037	2.3		1.38	0.5
Slack	Unmatched	0.326	0.418	−45.5	99.8	−23.28	0.52
	Matched	0.326	0.327	−0.1		−0.04	0.71
PPE	Unmatched	0.402	0.279	51.7	89.9	28.74	0.87
	Matched	0.402	0.414	−5.2		−2.16	0.77
Size	Unmatched	24.235	22.234	93.3	89.7	54.14	1.09
	Matched	24.235	24.442	−9.6		−3.69	0.72
Leverage	Unmatched	0.29	0.267	12.8	82.3	6.47	0.48
	Matched	0.29	0.294	−2.3		−1.16	0.86
MTB	Unmatched	0.914	1.597	−22.4	98.1	−9.91	0.08
	Matched	0.914	0.901	0.4		0.46	1.04

Panel B: Propensity score matching estimates						
Variable	**Category**	**Treated**	**Controls**	**Difference**	**SE**	***T*-stat**
Climate change risk	Unmatched	0.134	0.042	0.092	0.003	27.04
	Matched–ATT	0.134	0.116	0.019	0.009	2.04

Note: The table presents the results of the propensity score matching procedure. Panel A reports the variance ratio and bias reduction level because of the matching. * identifies covariates that are bad postmatching (i.e., variance ratio < 0.5 or > 2). Panel B of the table reports the results of the propensity matching estimates. ATT refers to the average treatment effect on the treated. Our model accounts for year, industry, and country differences. Standard errors do not consider that the propensity score is estimated.

remains dormant from $t+2$ to $t+4$ but reappears 5 years after joining the scheme. Put together, the impact of membership is evident even up to 5 years after joining the scheme. Across the models, the most consistent determinant of CCR is PPE. In effect, asset-heavy companies may be exposed to higher levels of climate risk.

4.3 | Robustness Test

To further alleviate endogeneity concerns, we specify a system GMM and report the results of the estimation in Column 1 of Table 11. One argument for specifying a model of this form is that the scheme's membership may be driven by high exposure to climate risk. In effect, joiners may participate in the scheme to reduce their climate risk. Consistent with our previous analysis, the findings show that, indeed, membership in the ETS increases firm climate change risk. Thus, the positive relationship between ETS and CCR is not spurious or driven by high exposure to climate risk.

Although the primary measure of CCR exposure employed the novel firm-level metric developed by Sautner et al. (2023), we also consider other measures as alternative dependent variables for robustness purposes. First, we consider the firm climate change exposure (CCE) measure developed by Sautner et al. (2023). We present the findings of this analysis in Column 2 of Table 11. In addition to CCE, motivated by prior literature that has extensively used firm-level carbon emissions data as a proxy for climate risk exposure (see, e.g., Altunbas et al. 2022; Bose et al. 2021; Jung et al. 2018; Nguyen and Phan 2020), we consider firm carbon emissions. However, from the prior literature, we adjust firm carbon emissions by the industry mean carbon emissions. We report the result of this analysis in Column 3 of Table 11. By examining the impact of ETS participation on CCE and adjusted carbon emissions, we can assess the consistency of our findings across different measures of firms' environmental performance and climate-related risks. Across all the adopted measures, we find support for the argument that membership in ETSs increases firm climate risk.

Firm corporate governance structure could potentially exacerbate or mitigate outcomes with respect to their environmental risk exposure (Palea and Drogo 2020; Altunbas et al. 2022; Hoang et al. 2024; Khatri 2024). Drawing on recent studies in the literature (Adamolekun et al. 2024), we examine if the introduction of key corporate governance variables affects the coefficient of the relationship between ETS and firm climate risk. We

TABLE 9 | Paris Agreement, emission trading scheme, and corporate climate risk.

	Pre–Paris Agreement	Post–Paris Agreement
ETS	0.0070	0.0360***
	(1.46)	(5.04)
ESG score	0.0002**	0.0002*
	(2.11)	(1.90)
ROA	−0.0028	−0.0092
	(−0.25)	(−1.16)
Slack	−0.0010	0.0169
	(−0.07)	(1.43)
Size	0.0012	0.0008
	(0.46)	(0.46)
Leverage	0.0069	−0.0176**
	(0.66)	(−1.97)
Market to book	0.0012	0.0008
	(0.87)	(1.13)
PPE	0.0508***	0.0103
	(3.09)	(0.78)
	−0.0288	0.0000
Constant	(−0.12)	(0.00)
	Yes	Yes
Industry dummies	Yes	Yes
Year dummies	Yes	Yes
Country dummies	0.0070	0.0360***
Observations	16,715	16,037
R-squared	20%	22%

Note: This table presents the regression results for the nexus between firms' ETS participation and climate change risk. Estimation is conditioned on pre– and post–Paris Agreement. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The estimations include industry, year, and country effects. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

report the results in Columns 1 and 2 of Table 12. Accordingly, the findings from this analysis confirm the view that membership in ETSs exacerbates firm climate risk. Next, we consider if our results are robust to the introduction of country-unique factors such as climate vulnerability, carbon emissions, GDP growth, regulatory quality, rule of law, and law of origin. In addition to the aforementioned, we also include a variable that captures the degree of carbon dependency in the industry. Despite the introduction of the following control variables, we find consistent results. We present the result of this analysis in Columns 3 and 4 of Table 12.

5 | Conclusion

The devastating impact of climate change has stimulated a wave of climate initiatives, one of which is the ETS. However, little is known as regards the effectiveness of ETSs in curbing firm climate risk. We fill this gap by examining the impact of ETSs on CCR. Using 32,752 firm-year observations from 65 countries over the period of 2002–2021, we demonstrate that membership in the scheme increases CCR. A possible explanation for this finding is that membership in ETSs enhances climate regulatory scrutiny, thereby exacerbating CCR.

Furthermore, we find that this relationship holds only for firms in carbon-intensive industries. We also document that the degree of the relationship varies across continents. In answering the question of whether the legal framework could moderate or exacerbate the impact of ETSs on firm climate risk, we split our sample into firms of civil law and common law origin. The results of the split indicate that this relationship is only predominant among firms of civil law origin. Similarly, the association between ETSs and CCR only became pronounced in the period after the Paris Agreement. Lastly, membership in ETSs has both short- and medium-term implications, with the relationship remaining positively significant even after 5 years. To ensure our results are robust, we estimate our baseline model using both PSM and GMM and find consistent results.

The central message of our paper is that carbon mitigation initiatives like ETSs are ineffective in abating CCR. Emission trading schemes may disincentivize green innovation since firms with large carbon footprints could choose to maintain the status quo rather than pursue aggressive green transition policies. Firms and policymakers may need to consider other drastic measures to alleviate the damaging impacts of climate change.

The implications of our findings are vital on at least three grounds—policy making, industry, and academia. From the angle of policy making, we reckon that establishing ETS by some countries is a significant step toward mitigating climate crises. The tendency for industrial firms to emit indiscriminately will likely be reduced by imposing pricing mechanisms. However, the incidence of carbon leakage due to regulatory arbitrage undermines the plausibility of the ETS initiative. This situation does not help to abate the climate crises as it only leads to the migration of emissions and pollutants from ETS countries (firms), where there are strict environmental regulations, to non-ETS countries (firms), where there are seemingly lax regulations. We, therefore, recommend a holistic climate framework that will prevent such migration to pollution havens. An integrated global ETS policy may be required to restrict companies from subverting the efforts toward net-zero emissions.

From an industry perspective, our findings are crucial to managers, investors, and financial analysts on the risk exposure of firms. Although ETS participation seeks to substantiate firms' climate action, the findings that it increases CCR can be a dangerous signal to investors and lenders (financial institutions) of ETS-participating firms. This could increase firms' borrowing costs and potentially

TABLE 10 | Additional analysis: Lead lag effect.

	(t+1)	**(t+2)**	**(t+3)**	**(t+4)**	**(t+5)**	**(t+10)**
ETS	0.0078*	−0.0008	−0.0027	0.0035	0.0121**	−0.0002
	(1.79)	(−0.19)	(−0.57)	(0.71)	(2.36)	(−0.03)
ESG score	0.0004***	0.0003***	0.0001	0.0002	0.0001	0.0002
	(4.11)	(3.62)	(1.32)	(1.50)	(0.57)	(0.88)
ROA	−0.0075	0.0023	−0.0074	0.0079	−0.0020	−0.0162
	(−1.03)	(0.28)	(−0.84)	(0.74)	(−0.15)	(−0.86)
Slack	0.0054	0.0031	0.0022	0.0155	0.0065	0.0010
	(0.55)	(0.29)	(0.19)	(1.25)	(0.46)	(0.05)
Size	−0.0003	−0.0002	0.0012	0.0022	0.0024	0.0094**
	(−0.22)	(−0.14)	(0.64)	(1.17)	(1.08)	(2.57)
Leverage	−0.0046	−0.0055	−0.0195**	−0.0141	−0.0139	−0.0156
	(−0.62)	(−0.69)	(−2.16)	(−1.43)	(−1.26)	(−0.83)
Market to book	0.0002	−0.0002	0.0004	0.0001	0.0012	0.0033
	(0.30)	(−0.19)	(0.39)	(0.06)	(0.84)	(1.40)
PPE	0.0392***	0.0290**	0.0348***	0.0590***	0.0550***	0.0336
	(3.57)	(2.53)	(2.64)	(4.38)	(3.73)	(1.35)
Constant	0.0356	0.0174	0.2212*	−0.0987	−0.1116	−0.1801*
	(0.41)	(0.19)	(1.91)	(−0.71)	(−0.66)	(−1.93)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	26,084	21,867	18,220	15,135	12,692	5513
R-squared	23%	25%	28%	30%	31%	32%

Note: This table presents the regression results for the nexus between firms' ETS participation and climate change risk. Estimation is based on lead–lag effects of the explanatory variables on corporate climate change risk. $t+1$ implies a 1-year effect, $t+2$ indicates the effect after 2 years, $t+3$ is the effect after 3 years, $t+4$ is the effect after 4 years, and $t+5$ indicates a 5-year effect. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The estimations include industry, year, and country effects. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

threaten investments in technology-driven clean energy solutions. To prevent this, we urge governments to incentivize firms that are committed to providing climate solutions. More so, engaging in ETS typically necessitates comprehensive documentation of emissions, which can enhance openness and establish confidence among stakeholders, such as investors, regulators, and the general public. In order to adhere to their emissions limit, firms may be required to allocate resources toward the adoption of environmentally friendly technologies and the implementation of more efficient procedures. This has the potential to drive innovation by enhancing energy efficiency, promoting the adoption of renewable energy, and advancing the development of low-carbon products. The knowledge from this study can also help investors and portfolio managers to understand the susceptibility of ETS member firms, especially carbon-intensive ones, and effectively construct a hedging strategy to insulate their portfolios.

To the academic community, our study contributes to the myriad of studies examining the impact of climate change and actions on firm decisions and performance. In contrast to the extant studies in this area, we provide new insights into how firms' climate-mitigating initiatives (such as ETS participation) can affect their risk exposure using a novel data set. More importantly, although prior studies have used country-level data, we complement the current literature by employing firm-level datasets from across different countries and regions. This provides a comprehensive and microlevel perspective on the ongoing discourse on climate change.

In sum, our study provides a robust understanding of the intricacies around ETS and the consequences for firms participating in the scheme. Despite the robust and exciting outcomes we have unraveled, we acknowledge that this study is not without

TABLE 11 | Additional analysis—System GMM and alternative measures of climate risk.

	System GMM	Climate change exposure	C_{o2} Log[Adjusted]
Climate change risk $_{[t-1]}$	0.2269***		
	(52.09)		
Climate change risk $_{[t-2]}$	0.0239***		
	(6.44)		
Climate change risk $_{[t-3]}$	−0.0081***		
	(−2.88)		
Emission trading	0.0129***	0.0001***	0.0361*
	(2.98)	(3.39)	(1.84)
ESG score	0.0002**	0.0000	0.0034***
	(2.35)	(1.53)	(5.55)
ROA	0.0198***	−0.0001	−0.1461**
	(2.77)	(−0.95)	(−2.28)
Slack	0.0202	0.0002**	0.2641***
	(1.58)	(2.31)	(3.41)
Size	0.0074**	0.0000	0.6828***
	(2.19)	(0.03)	(48.41)
Leverage	0.0137	−0.0002***	−0.0452
	(1.26)	(−3.25)	(−0.80)
Market to book	0.0003	0.0000	−0.0058
	(0.20)	(1.60)	(−0.91)
PPE	0.0290	0.0006***	1.2294***
	(1.54)	(5.37)	(14.75)
Constant	−0.1747**	−0.0012	−19.2190***
	(−2.29)	(−1.06)	(−20.85)
Industry dummies	No	Yes	Yes
Year dummies	No	Yes	Yes
Country dummies	No	Yes	Yes
Observations		32,752	16,979
R-squared		0.511	0.467
Sargan–Hansen	0.21		

Note: This table presents the results of the robustness tests conducted. In Column 1, we present the results of the system generalized method of moments (GMM). The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. The models are specified with robust standard errors. The instrument for the level equation is the leveled difference of CCR. For the differenced equation, we use the difference of ETS, ESG score, ROA, slack, size, leverage, market to book, and PPE. We also account for country and year. For Columns 2 and 3, the outcome variable is climate change exposure and Firm C_{o2} adjusted for industry mean. T-statistics are shown in parentheses. The estimations include industry, year, and country effects. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

limitations, and to this end, we provide avenues for future research. We examine the effect of ETS participation on firms' climate change risk exposure, and our findings suggest that the relationship varies significantly between firms in civil and common law countries and firms in carbon-intensive and low-carbon industries. Our study, however, does not investigate the underlying mechanisms driving these differences. Future research could explore the specific legal and regulatory features of civil and common law systems, such as environmental regulations, enforcement rigor, and legal accountability, that impact the relationship between ETS membership and CCR. Similarly, country- and industry-specific studies could explore the unique

TABLE 12 | Corporate governance structure and country factors.

	(1)	(2)	(3)	(4)
Emission trading	0.0132***	0.0177***	0.0183***	0.0182***
	(3.23)	(3.60)	(3.74)	(3.70)
Board size	−0.0008**		−0.0009***	−0.0008**
	(−2.51)		(−2.65)	(−2.36)
Board tenure	−0.0007		−0.0007	−0.0006
	(−1.62)		(−1.27)	(−1.07)
Female directors	0.0123		−0.0079	0.0083
	(1.06)		(−0.57)	(0.56)
Board qualification	0.0002		0.0001	0.0014
	(0.07)		(0.02)	(0.38)
Board age	0.0006		0.0005	0.0003
	(1.60)		(0.97)	(0.68)
CEO duality	0.0043		0.0066**	0.0064**
	(1.59)		(2.15)	(2.08)
ESG score	0.0002***	0.0002	0.0002**	0.0002*
	(2.74)	(1.59)	(2.18)	(1.84)
ROA	−0.0078	−0.0055	−0.0047	−0.0053
	(−1.16)	(−0.68)	(−0.58)	(−0.65)
Slack	0.0143	−0.0014	0.0014	−0.0004
	(1.54)	(−0.12)	(0.12)	(−0.04)
Size	0.0020	0.0005	0.0016	0.0016
	(1.33)	(0.30)	(0.97)	(0.88)
Leverage	−0.0094	−0.0017	−0.0003	−0.0017
	(−1.39)	(−0.20)	(−0.03)	(−0.21)
Market to book	0.0007	0.0004	0.0007	0.0005
	(1.06)	(0.51)	(0.78)	(0.57)
PPE	0.0327***	0.0405***	0.0433***	0.0415***
	(3.13)	(3.15)	(3.37)	(3.22)
CO2 emissions (kg per PPP $ of GDP)		−0.1434*	0.0692**	−0.1498*
		(−1.85)	(2.04)	(−1.90)
Regulation quality		0.0172	0.0094	0.0169
		(1.32)	(0.88)	(1.29)
Rule of law		0.0377	−0.0009	0.0374
		(1.61)	(−0.08)	(1.60)
Climate vulnerability index		0.6575*	0.0996	0.6385*
		(1.70)	(1.06)	(1.65)
Common law		0.0254	−0.0211***	0.0219
		(0.74)	(−2.93)	(0.64)

(Continues)

TABLE 12 | (Continued)

	(1)	(2)	(3)	(4)
Industry carbon intensity		0.0016	0.0053	0.0044
		(0.02)	(0.07)	(0.06)
GDP growth (annual %)		−0.0018*	−0.0008	−0.0018*
		(−1.80)	(−0.90)	(−1.82)
Constant	−0.0438	−0.2469*	−0.1048	−0.2729*
	(−0.54)	(−1.74)	(−1.14)	(−1.89)
Industry dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	No	Yes
Observations	32,723	21,978	21,966	21,966
R-squared	0.203	0.185	0.179	0.185

Note: This table presents the main regression results for the nexus between firms' ETS participation and climate change risk. Estimation is performed using panel random-effect regression with coefficients computed using standard errors robust to heteroskedasticity. *T*-statistics are shown in parentheses. The outcome variable is corporate climate change risk (CCR). The key explanatory variable is ETS, and the control variables included in the model are ROA, slack, size, leverage, MTB, and PPE. Model 1 shows the impact of ETS on CCR controlling for both firm-level characteristics and key corporate governance variables with industry, year, and country effects. Model 2 controls for the firm-level characteristics and country-level factors with industry, year, and country effects. Model 3 includes the impact of all variables on CCR, with industry and year effects. Model 4 includes the impact of all variables on CCR, with industry, year, and country effects. *, **, and *** denote significance at 10%, 5%, and 1%, respectively. Definitions of variables and data sources are provided in Appendix 1.

characteristics and challenges associated with ETS membership as a tool for climate risk mitigation. We urge future studies to examine how ETS participation could affect firms' cash holdings, market share, and credit rating vulnerability, among others. Shedding light on these areas would provide vital information to firms' stakeholders and the academic community on some financial implications of ETS participation on firms. In this study, we have also subjected our data to different econometric techniques that account for endogeneity, selection bias, and heteroscedasticity; we leave it to future research to enrich our data and utilize other methodologies to test the consistency and veracity of our findings.

Author Contributions

Gbenga Adamolekun: conceptualization, review & editing, writing original draft, methodology, data curation, visualization, software, and formal analysis. **Ammar Ahmed:** conceptualization, review & editing, writing the original draft. **Nana Abena Kwansa:** conceptualization, review & editing, writing the original draft. **Rodiat Lawal:** conceptualization, review & editing, writing the original draft. **Rilwan Sakariyahu**: conceptualization, review & editing, writing original draft, methodology, and formal analysis.

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Appendix 1

Definition, Source, and Measurement of Variables.

Variable	Definition	Source
ETS	This is a dummy variable that is equal to 1 if a firm is a member of an emission trading scheme in a year and 0 if otherwise.	LSEG
Climate change risk (CCR)	This refers to climate change bigrams mentioned in a sentence with words like "risk," "uncertainty," or similar words extracted from the earnings call transcript (Sautner et al. 2020).	Sautner
ESG score	This is a company's Refinitiv ESG score deduced from its self-reported environmental, social, and corporate governance pillars.	LSEG
ROA	ROA is a firm's return on assets. It is simply EBITDA deflated by total assets. It captures a firm's profitability.	Worldscope
Slack	Slack is computed by deflating current assets by total assets.	Worldscope
Size	This is the natural logarithm of total assets. This measures the size of a firm.	Worldscope
Leverage	This refers to total debt deflated by total assets. It measures the degree of a firm's indebtedness.	Worldscope
MTB	Market-to-book (MTB) ratio is the market value of equity divided by the book value of equity.	Worldscope
PPE	This is property, plant, and equipment deflated by total assets. This measures the degree of asset dependency of a firm.	Worldscope
Board size	This captures the number of directors that sit on a company's board.	Boardex
Board tenure	This measures the average tenure of a company's board of directors.	Boardex
Female directors	This captures the proportion of female directors on a company's board.	Boardex
Board qualification	This captures the average number of academic qualifications held by the board members of a company.	Boardex
Board age	This proxy identifies the age of the board members. It is calculated by estimating their average age.	Boardex
CEO duality	This dummy variable takes the form of 1 if a CEO is also the chairman of the board and 0 if otherwise.	Boardex