Journal of Environmental Management 351 (2024) 119970

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Firm-level pollution and membership of emission trading schemes

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ARTICLE INFO

Handling editor: Lixiao Zhang

JEL classification:
Q50
Q52
Q53
Q54
Q58
Q59
G0

Keywords:
Emission trading scheme (ETS)
CO_2
Corporate carbon emission
Carbon abatement
Harmful gases
Decarbonisation

ABSTRACT

Several firms have joined emission trading schemes in response to the call for corporate climate action. Using a comprehensive international data set on corporate membership of emission trading schemes (ETSs), we find that members of the scheme emit more CO_2 than non-participants. This result also holds when exploring the corporate discharge of sulphur and volatile organic compounds (VOCs). The magnitude of this relationship persists even in the long run showing little evidence of a reduction from the firms in polluting the environment. We also find that firms that select to exit the scheme continue to pollute at a higher rate in the following years. Firms that enter the scheme for the first time increase their pollution in the following years. Although we identify significant differences at a country and continental level on the effectiveness of ETSs, our results raise some concerns about ETSs' role.

1. Introduction

The call for corporate climate action has seen interest in emission trading schemes surge in the past two decades. As of 2022, there were 25 emission trading schemes in operation and 22 other trading systems under consideration or being developed (ICAP, 2023). In theory, the schemes are meant to levy a premium on corporations that use more fossil fuels for production whilst incentivising their counterparts that rely more on green production processes. Ultimately, proponents in support of the scheme argue that uptake of the scheme would catalyse decarbonisation efforts of member firms. However, burgeoning evidence on the effectiveness of the scheme remains unclear. Our study contributes to the ongoing debate by exploring the effectiveness of emission trading schemes (ETSs) in promoting corporate decarbonisation efforts and encouraging environmentally responsible behaviour, particularly regarding pollution at the firm level.

The widely regarded Porter hypothesis is one theoretical explanation for firm participation or abstinence from ETSs. The theory posits that there are realisable strategic and competitive benefits of participating in emission-reducing initiatives (Porter, 1979). In the context of emission trading schemes, membership may force firms to garner a competitive advantage in sustainable production which could enhance profitability. Consequently, in pursuit of future profitability, firms may opt to join emission trading schemes. Alternatively, they may choose to abstain from such schemes if theoretically, it could reduce future profitability. Another theoretical explanation for corporate participation in ETS is the signalling theory. The theory supposes that as a result of the asymmetry of information between firms and stakeholders, corporations may use corporate decisions to signal to stakeholders. In the context of emission trading schemes, firms' decision to join the scheme may signal their commitment to combatting their environmental exposure (Lam et al., 2016). One further explanation of corporate membership in emission trading schemes is the institutional theory. Institutional theory posits that corporate decisions are not necessarily motivated solely by economic arguments (Tate et al., 2011). Therefore, so-called acceptable institutional standards, values, and practices could influence corporate decisions (Dimaggio and Powell, 1983). With regard to emission trading schemes, pressure from environmental stakeholders could explain

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https://doi.org/10.1016/j.jenvman.2023.119970
Received 7 November 2023; Received in revised form 13 December 2023; Accepted 24 December 2023
Available online 1 January 2024

corporate membership.

Several studies have empirically explored the impact of emission trading schemes, producing mixed findings. On the one hand, studies such as by Akter et al. (2012) contend that emission trading schemes may not effectively address corporate environmental misconduct. Wei et al. (2022) also demonstrate that price bubbles exist in the EU, New Zealand, South Korea, and Chinese ETSs. The distortions in carbon pricing markets would inevitably weaken the effectiveness of ETS in incentivising green innovation among corporations. Similarly, membership in the European Union's (EU) ETS inflates the material costs in the power sector (Chan et al., 2013). This could inadvertently affect the survival of firms in the scheme. ETS member firms can simply pass the additional compliance cost to consumers and as such evade environmental monitoring. Complementing this view, Kirat and Ahamada (2011) find that electricity producers from Germany and France that partake in the EU ETS were constrained to integrate the carbon price into their cost functions.

On the other hand, several studies have documented some benefits of ETSs in combating corporate climate exposure. Chapple et al. (2013) posit that due to the launch of the Australian ETS, a value penalty was placed by the market on carbon-intensive firms. In effect, market forces can compel companies to act on their over-reliance on hydrocarbons. Likewise, ETS in China could stimulate total factor productivity by approximately 23% (Wu et al., 2022). Similarly, Huang et al. (2022) reveal that carbon emission intensity weakened in ETS pilot regions in China by 7.3% whereas the value stood at 4.3% in non-pilot regions. Finally, Hu et al. (2020) posit that CO_2 emission trading schemes in China decreased energy consumption in industries regulated in the pilot areas.

Using an international dataset, we find that ETSs are attractive to firms that emit high levels of carbon, with high ESG scores, big firms (i.e., in terms of total assets), and with sizeable property plants and equipment (PPE). Firms in carbon-intensive industries are also more likely to be part of the schemes. As regards the impact of the scheme on firm carbon emissions, our evidence indicates that firms that are members of the schemes tend to pollute more than counterparts that are non-members. One explanation for this finding is that membership in the schemes may encourage creative compliance whilst exacerbating carbon leakage (Naegele and Zaklan, 2019). Therefore, members of ETSs may move their carbon-heavy production to regions or countries with lax emission regimes.

Based on our analysis of continental disparities, we find that ETSs are a viable solution for reducing CO2 emissions in firms located in Asia and South America. However, we find that membership in ETSs has led to an increase in emissions levels for companies based in Europe. The results documented in Europe are at odds with the argument of Orazalin et al. (2023) who posit that the presence of the EU ETS is an effective carbon abatement tool. The performance of ETSs in Asia and South America corroborates the argument of the Porter's hypothesis. Indeed, climate initiatives like ETS can yield environmental dividends and force firms to take responsible environmental actions (Dong et al., 2019). Notably, participating in these schemes can significantly boost a company's efforts to reduce its carbon footprint. In dichotomising our results across years, we find that the efficacy of the scheme in stimulating corporate carbon abatement is pronounced in the period after 2015. Significant climate agreements like the Kyoto Protocol and the Paris Agreement could have galvanised concerted corporate and national efforts on environmental actions.

When examining the impact of ETS membership on corporate emissions of harmful gases, our research reveals that companies participating in such schemes release higher levels of sulphur and volatile organic compounds (VOCs) as compared to non-members. This suggests that members of the scheme are equally notorious for the emission of various pollutants. This result indicates that emission-trading schemes may be garnering interest from firms with questionable environmental credentials. In examining this line of inquiry, we explore the environmental practices of firms that join ETSs. The findings from this exploration demonstrate that firms involved in ETSs typically experience more environmental controversy than their counterparts who are not part of the scheme. Since the benefits of joining ETSs may not be evident immediately, we investigate if the dividends of enrolling manifest in the future. The result shows that membership of the scheme has a positive long-run effect on firm carbon emissions levels. In effect, joining the scheme does not reduce but rather increases corporate carbon emissions in the long run however, the rate of increase declines over time.

Lastly, we examine how joining or exiting the scheme affects the carbon footprint of new and ex-members. For new joiners, the evidence suggests that their carbon emissions level increases years after joining the scheme. One possible explanation for this finding is that firms join the scheme if they expect high emissions in the future and joining the scheme enables them to buy emission rights. Another possible explanation is that the changes in emissions level years after joining the scheme are attributable to the peer effect as well as increased regulatory scrutiny. New joiners may be less skilled in navigating the scheme when they first join but are able to take advantage of the scheme and increase their emissions level in the medium to long term. Upon investigation of firms that leave the program, it has been observed that these firms emit a higher amount of carbon emissions compared to their counterparts who remain in the program or do not join in the first instance.

We contribute to the burgeoning conversation on climate mitigation schemes in several ways. Firstly, the question of whether ETSs are effective for corporate carbon abatement remains open and unanswered, with several mixed findings (e.g., Dong et al.,2019; Hu et al., 2020). Our study fills this void in the literature by examining how membership in ETSs affects firm-level pollution. Prior studies in the literature have focussed on how the industrial heterogeneity of participants of the scheme affects environmental outcomes (see for instance, Kirat and Ahamada, 2011; Chan et al., 2013; Hu et al., 2020). Distinct from earlier studies, we investigate the role of ETS in shaping environmental outcomes at the firm level. In particular, we explore how the scheme affects firm-level pollution.

Secondly, previous studies that have examined the outcome of emission trading schemes have explored this phenomenon from the lenses of regional or country outcomes and little is known as regards its effectiveness in reshaping corporate environmental behaviour (e.g., Hu et al., 2020). We instead examine if country and continental differences affect the dividend of ETSs. We extend the literature on mitigation scepticism (see for example, Akter et al., 2012), by examining if corporate climate action mitigation schemes and in particular emission trading schemes are indeed effective in alleviating corporate carbon emissions. We complement recent studies that have advocated for stricter pricing regimes of carbon by demonstrating the implications of the existing price discovery process (see for example, Diaz-Rainey and Tulloch, 2018; Lin and Jia, 2019; Ju et al., 2019; Adamolekun, 2024).

Our findings also have important implications for policymakers and firms. Our evidence suggests that some ETSs are not delivering the promised dividends of the initiative. To ensure the effective extraction of the promised deliverables from the schemes, policymakers must tighten regulation and work concertedly across continents and nations to curb carbon leakages or other incidences of regulatory arbitrage (Naegele and Zaklan, 2019). Similarly, draconian measures like advocating for higher prices of carbon rights could enhance the efficiency of ETSs and as such disincentivise over-reliance on fossil fuels and incentivise aggressive corporate investment in green technologies (Lin and Jia, 2019; Ju; Fujikawa, 2019; Adamolekun, 2024).

The remainder of this paper proceeds as follows. Section 2 briefly reviews relevant literature. Section 3 discusses the data and methodology used. Section 4 reports the empirical findings, and finally, Section 5 concludes this study.

2. Literature review

2.1. Background of ETSs

In abating the contribution of firms to global warming, climate mitigation schemes like the ETSs have been well received by companies and other stakeholders. The uptake of the scheme has seen carbon markets emerge in the USA, Europe, China, Korea, Canada, New Zealand, the UK, and Australia (ICAP, 2023). All over the world, the scheme is making inroads. It is currently estimated that 33% of the world population is subject to a form of emission trading scheme (ICAP, 2023).

In Europe, for example, the EU ETS has emerged as the pacesetter for other schemes in some regard. It is the world's first international carbon market (EU, 2023). In terms of development, it has gone through three phases, and it is currently in its fourth phase. It commenced with phase 1 which was a 3-year pilot phase. It was restricted to carbon emissions from power generators and other energy-intensive industries (ICAP, 2023). Most allowances in this phase were given freely and the penalty for non-compliance was set at €40 per tonne (EU, 2023). Phase 2 of the EU ETS covered the period 2008–2012, unlike Phase 1, the penalty for non-compliance increased to €100 per tonne. The portion of free allocation declined to 90% and the aviation industry was also included in the scheme (EU, 2023; ICAP, 2023). Phase 3 covered the period from 2013 to 2020. Remarkable developments in this phase include the abolishment of free allocation and the emergence of auction as the method adopted for the allocation of emission permits as well as the inclusion of more industries and gases (EU, 2023). Phase 4 of the EU ETS will cover the period from 2021 to 2030. Notably, the use of offset will not be permitted in Phase 4. As regards the success of the scheme, it covers about 38% of the region's emissions (ICAP, 2023).

In the case of Asia, there is no centrally regulated emission trading scheme. However, carbon markets exist in Asian countries like China, South Korea, and Kazakhstan. The Korean emissions trading scheme was established in 2015 and is the first national ETS in South Asia. In terms of success, it captures about 74% of South Korea's greenhouse gas emissions (ICAP, 2023). Industries covered by the scheme include power, waste, transport, industrial, buildings, and aviation spanning across 684 of the country's largest emitters (ICAP, 2023). The scheme runs on free allocation and at least 10% auctioning and allows carbon offsetting. Elsewhere in China, the national emission trading system took effect in 2021 with the coverage currently limited to the power sector (ICAP, 2023). It is regarded as the world's largest ETS regulating over 2000 firms and covering more than 4 billion tonnes of carbon. It accounts for about 40% of the country's emissions. The current program is an expansion of multiple pilot initiatives in different areas like Beijing, Chongqing, Guangdong, Shanghai, Shenzhen, and Tianjin. Alternatively, Kazakhstan's emission trading scheme launched in 2013 covers the power sector, heating, extractive, and manufacturing industries (ICAP, 2023). It operates using free allocation of emissions whilst allowing for offsetting (ICAP, 2023).

In New Zealand, the emission trading scheme was formed in 2008 and regulates entities in power, aviation, transport, waste, forestry, and building industries (IETA, 2023, 2023; ICAP, 2023). It functions through both allocation and auctioning but currently does not allow for carbon offsetting (IETA, 2023; ICAP, 2023). In North America and South America, there are no continental or national emission trading schemes. However, at the provincial and state level, emission trading schemes exist. For instance, in the USA, areas like California, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, Oregon, New Jersey, New York, Rhode Island, Vermont, Virginia, and Washington have carbon markets in operation (ICAP, 2023). Similarly, emission trading systems are currently in operation in regions such as Nova Scotia and Quebec in Canada (ICAP, 2023).

2.2. Theoretical framework

Three theoretical frameworks are linked with our empirical work. First, Porter's five forces theory posits that an understanding of a firm's profitability in an industry includes a mix of the bargaining power of suppliers, the bargaining power of buyers, the threat of new entrants, the threat of substitutes, as well as the intensity of competitive rivalry (Porter, 1979). The application of this theory has spanned across several industries including the competitiveness of renewable energy generation (Zhao et al., 2016), particularly with an emphasis on successful strategies for enhancing firm positioning and competitiveness. In the context of environmental practices, this theory provides a framework for modelling the competitive forces that influence a company's environmental performance such as the bargaining power of suppliers in terms of environmentally sustainable raw materials. A strong bargaining position for suppliers can lead to higher prices for sustainable raw materials, making it difficult for firms to incorporate them into their products, and vice versa in terms of the bargaining power of buyers. Other factors such as the threat of substitutes, and the intensity of competitive rivalry can also affect a firm's environmental performance.

As a priority to firms, the drive to remain competitive directly affects profitability. This includes corporate environmental practices in recent times that capture actions that companies take to reduce their impact on the environment. These practices can include being part of ETS, reducing greenhouse gas emissions, conserving natural resources, reducing waste, and improving the sustainability of their supply chains. Participation in ETS can have a significant impact on corporate environmental practices. By putting a price on carbon emissions, ETS creates a financial incentive for companies to reduce their emissions. This can lead to investments in renewable energy, energy-efficient technologies, and cleaner production processes, and can also encourage companies to collaborate on emissions reduction projects, leading to greater innovation and efficiency.

Companies that adopt environmentally sustainable practices can benefit from improved brand reputation, increased customer loyalty, and reduced costs through energy efficiency and waste reduction. By utilising Porter's Five Forces Theory, Dong et al. (2019) argue that incorporating ETS into corporate environmental practices can lead to both economic and environmental dividends as a comprehensive approach to environmental sustainability. By analysing the competitive forces that influence a firm's environmental performance, businesses can position themselves to be more competitive and adopt more sustainable practices. Additionally, ETS can create a financial incentive for companies to reduce their emissions, leading to investments in cleaner technologies and processes.

The signalling theory is also relevant to our work since it explores how organizations behave and communicate their quality or ability to external stakeholders when parties have access to varying degrees of information. Consequently, organizations observe the behaviour of others to comprehend their capabilities and interpret their actions accordingly (Connelly et al., 2011). In the context of environmental practices, signalling theory suggests that firms can signal their environmental commitment or quality to stakeholders, such as customers, investors, and regulators, by engaging in environmentally friendly practices or by adopting environmental management systems including being part of ETSs for example. In this way, signalling theory explains how firms can overcome the problem of asymmetric information, where stakeholders may not have complete information about the firm's environmental quality, by providing credible signals that demonstrate their environmental commitment.

The adoption of environmental initiatives, such as the ETS, which is an internationally recognised environmental management system is a key application of signalling theory in corporate environmental practice examined in this study. These environmental initiatives can signal to investors the viability of firms and their overall global image and reputation in contributing to mitigating the climate change crisis (Lam et al., 2016). By adopting these standards, firms can signal to stakeholders that they are committed to environmental stewardship and are willing to invest in environmentally sustainable practices. Similarly, firms can signal their environmental commitment by engaging in eco-labelling or eco-certification programs, which provide consumers with information about the environmental impact of the products they purchase. Firms that report their environmental performance and initiatives can signal their environmental commitment to stakeholders, including customers, investors, and regulators. This signalling can enhance financial performance (Siddique et al., 2021). Voluntary disclosure can also provide firms with a competitive advantage by enhancing their reputation and brand image, which can lead to increased customer loyalty and market share in addition to actual carbon performance (Luo and Tang, 2014).

Finally, institutional theory is a theoretical proposition close to our work. Institutional theory posits that corporate decisions are not necessarily motivated solely by economic arguments (Tate et al., 2011). In effect, firm decisions are guided by so-called acceptable institutional standards, values, and practices (Dimaggio and Powell, 1983). The reward for adherence to these principles includes increased organizational legitimacy which could potentially bolster resources and as such enhance corporate survival capacity (Guler et al., 2002).

In the context of green transition, firm adoption and transition to green and sustainable business practices can be viewed through the lenses of institutional theory. Factors such as changes in societal values, advancements in technology, and vicissitudes in legislation can explain corporate choices concerning environmental decisions (Tate et al., 2011). Ultimately, the institutional theory contends that pressure from environmental stakeholders, governmental institutions, media houses, and industry associations stimulates responsible corporate actions (Delmas and Toffel, 2004; Rivera, 2004). In the context of membership in emission trading schemes, pressure from environmental stakeholders could force firms to take corporate climate actions in this form.

2.3. Close empirical studies to our work

Sceptics opine that climate change mitigation schemes like ETS may be ineffective in combatting global warming (Akter et al., 2012). According to a segment of the literature, pricing inefficiencies can diminish the efficacy of the system. Wei et al. (2022) support this claim by showcasing the existence of price bubbles in ETSs across the EU, China, New Zealand, and South Korea. With such carbon market pricing inefficiencies, corporations could evade environmental scrutiny and exceed pollution quotas. Supporting this perspective, Lin and Jia (2019) state that ETSs become ineffective when carbon prices are low. Such pricing distortions could also result in ETSs becoming price takers rather than makers (Diaz-Rainey and Tulloch, 2018). Ultimately, the consensus is that, for ETSs to perform at the optimal level, there is a need for carbon prices to increase in the future (Diaz-Rainey and Tulloch, 2018; Lin and Jia, 2019; Ju and Fujikawa, 2019). However, hikes in carbon prices could undermine global economic growth acutely (Lin and Jia, 2019).

Membership in emission trading schemes could also threaten the going concern of members. To this end, the associated trading cost of membership could directly inflate material costs (Chan et al., 2013). This phenomenon could squeeze bottom lines, exacerbate liquidity risk and ultimately heighten bankruptcy risk. In support of this opinion, Oestreich and Tsiakas (2015) argue that members of ETSs are more sensitive to cash flow risk. In addition, Da Silva et al. (2016) opine that price volatility in carbon markets increases compliance costs and reduces corporate earnings. To circumvent this situation, firms may simply pass on the additional membership compliance cost to customers, thus inflating the cost of goods and services (Kirat and Ahamada, 2011). The uptake of emission trading schemes may also result in the erosion of competitive advantages. In China, Wang and Zhang (2022) contend that the market power of high-carbon enterprises has declined by 27% as a result of their membership in ETSs. However, competitive losses as a result of membership are argued to be minute (Demailly and Quirion, 2008).

Nonetheless, the emergence of the scheme has garnered some success. In Australia for instance, since the announcement of ETSs, market forces have discounted the value of firms that rely heavily on hydrocarbons (Chapple et al., 2013). This penalty could incentivise carbon-intensive firms to wean themselves of overdependence on fossil fuels. Furthermore, curbing dependence on carbon could accelerate the transition to green production processes. In support of this view, Zhao et al. (2016) posit that the uptake of ETSs could stimulate green innovation. Areas with emission trading regulations may also reap some benefits. Accordingly, Huang et al. (2022) assert that in pilot areas where ETSs were enforced in China, carbon emission intensity declined by 7.3%. However, in non-pilot areas, the value of the decline stood at 4.3%. In effect, installing the schemes could accelerate the carbon transition in areas with enforcement.

However, concerns about round-tripping and carbon leakage remain unaddressed. Further evidence suggests that ETSs could also enhance energy use efficiency. In regions where ETSs were piloted, energy consumption declined (Hu et al., 2020). Membership in an emission trading scheme necessitates corporate carbon reporting whilst enhancing knowledge sharing of emissions reduction among participants (Engels et al., 2008). Consequently, carbon markets can engender positive environmental practices among peers. Members of the scheme may also choose to participate simply to signal their commitment to the challenges of climate change rather than actual dedication to reducing their carbon footprint. Therefore, the motivation for joining the scheme may stem from their interest in swaying public and stakeholder sentiment in their favour. Nevertheless, joining ETSs may also signpost guaranteed commitment to positive environmental practice thus engendering confidence in the corporate governance structure of member firms (Kolk and Pinkse, 2008).

Despite the successful uptake of the scheme among firms, empirical evidence on the role of the scheme in combating firm-level pollution is scarce. The literature is mute on whether or not the scheme has been effective in curbing firm-level pollution as well as the dynamics of this relationship. This is a gap that we explore in this study.

3. Data

We include in our sample all international corporations that report on their membership in an ETS scheme. We use Rifinitiv Eikon to collect data on whether or not a firm has membership in an emission trading scheme. Similarly, we collect data on corporate carbon emissions and other environmental-related data from Refinitiv Eikon. Our measure of corporate carbon emissions captures both direct (Scope 1) and indirect emissions (Scope 2). Other firm-level data were sourced from Worldscope. We provide further details of our data in Appendix A.

In Fig. 1, we report corporate carbon emissions level by country. According to our sample, on average firms in Saudi Arabia emit more greenhouse gas than other countries. A potential explanation for this is that Saudi Arabian Oil company (Saudi Aramco) which is included in the sub-sample of Saudi Arabian companies has one of the largest carbon footprints in the world which skews the mean. The evidence from data collected from Refinitiv aligns with recent articles in the Guardian (2019). Based on our data, it appears that Liechtenstein is the country with the lowest average carbon emissions among firms. Additionally, Malta, Gibraltar, and Georgia are also notable for their significantly low levels of corporate carbon emissions. Notable contributors to corporate carbon emissions worldwide include China, Russia, and India.

3.1. Summary statistics

Table 1 reports the summary statistics at the country level. On average, companies in Saudi Arabia emit 41.45 million tonnes of carbon, this is the maximum reported in the sample. We also find that on average

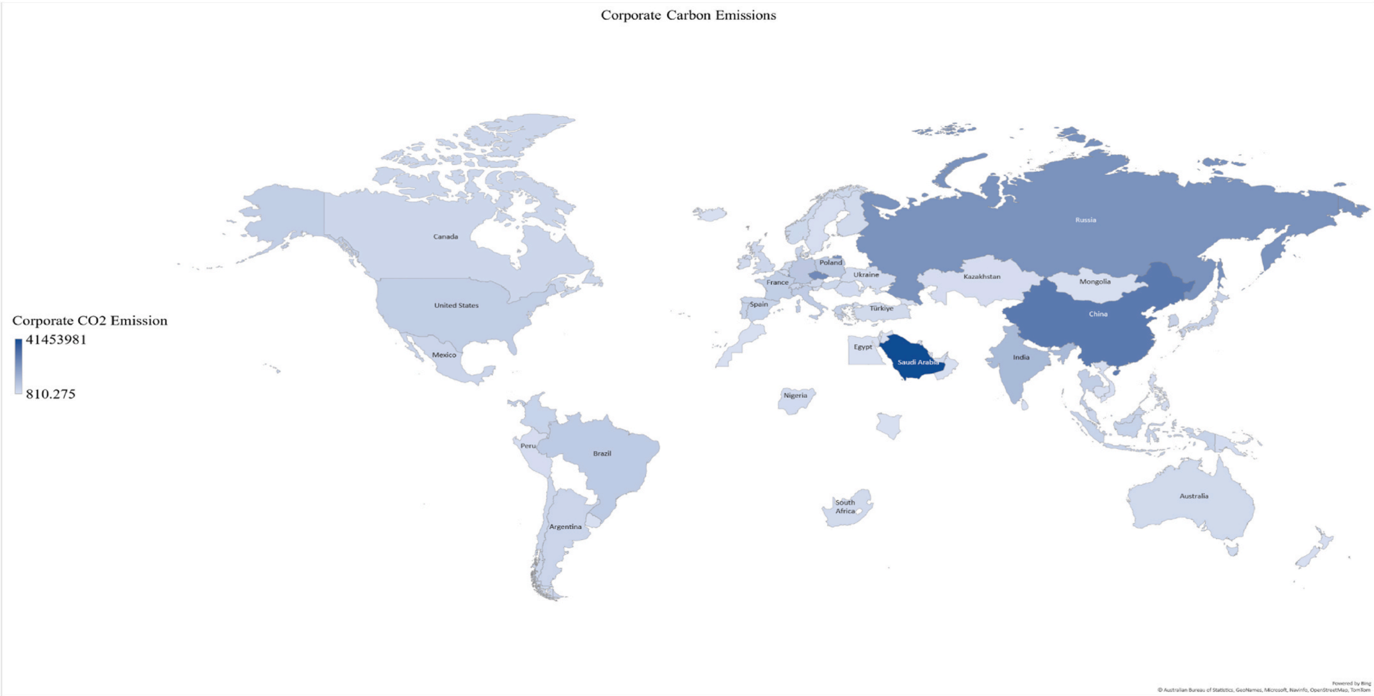


Fig. 1. Firm Carbon Emissions by Countries
The figure presents the geographical representation of corporate carbon emissions by country.

companies in Russia, Czech, China, and India emit 17.2 million, 25.8 million, 24.3 million, 21 million, and 11.3 million tonnes of carbon respectively. Instead, companies in Sri Lanka, Cambodia, Kazakhstan, South Korea, Finland, Hungary, and France are more environmentally responsible than their counterparts.

3.2. Membership and non-membership of ETS

In Table 2, we test the differences between firms that partake in an ETS and their counterparts that do not by estimating a *t*-test to compare their means. We report here the first evidence that firms that are members of an ETS emit more carbon than their counterparts. A plausible explanation for this finding could be that firms that partake in the scheme may be members of carbon-intensive industries and as such by nature rely more on hydrocarbons than their peers. For this reason, we explore further multivariate results to control for alternative explanations. Similarly, we find that ETS firms are more aggressive in their carbon reduction efforts. As regards firm characteristics, we document that ETS member firms are bigger, more highly leveraged, more profitable, and have a higher ESG score than non-member firms. Firms that are members of the scheme hold a lesser slack (i.e., the proportion of current assets deflated by total assets) and a lower market-to-book ratio. Firms that participate in the scheme also emit more volatile organic compounds (VOCs) than their counterparts who are non-members.

4. Empirical findings

4.1. What kind of firms join ETSs?

We commence our empirical analysis by evaluating the likelihood of joining an ETS. To test this hypothesis, we estimate the following Probit regression:

$$Probit(ETS_{itc} = 1) = \delta_0 + \delta_1 (X)_{itc} + \lambda_j + \varphi_c + \vartheta_t + \varepsilon_{itc}$$

ETS is a binary variable that identifies if a firm is a member of an emissions trading scheme. The vector X captures firm-level characteristics such as carbon emissions level, ESG score, property plant and equipment (PPE), RoA, leverage, slack, size, and carbon-intensive industries. λ_j φ_c and ϑ_t represent industry, country, and year respectively. ***itc*** indexes firm, year, and country.

Table 3 reports the empirical results. We find that firms with high carbon emissions are more likely to join emissions trading schemes. Our findings complement the work of Hu et al. (2020) who document that launching ETS reduces CO_2 emissions in the pilot area. Whilst their study focuses on the impact of ETS on the CO_2 emission of the location of launch, in this instance, we examine if membership in the scheme is more attractive for high-emitting firms. Similarly, the scheme is more attractive to firms with high ESG scores, property plant and equipment (PPE), and size. Firms in carbon-intensive industries are more likely to join the scheme than their peers in non-carbon-intensive industries. This confirms the view that membership in the scheme could be a signalling tool (Kolk and Pinkse, 2008).

4.2. Do members of the ETS emit less or more CO_2?

We then examine the level of pollution by members of ETS which is one of the main interests in this paper. To answer this question, we examine the relationship between corporate CO_2 and membership of an ETS using a generalized linear model (GLM) of this form:

$$g(y_i) = \alpha_0 + \sum_{j=1}^{p} \beta_i X_i + \varepsilon_i$$

Where *g* ( ) is a monotonic link function that serves as an intermediary between the response variable y (i.e. corporate carbon emission) and the covariates (ETS, RoA, Slack, Size, Leverage, Market to Book, PPE, HHI, CVI, and GDP). There are a few advantages of specifying a GLM model. Firstly, the model can leverage exponential family properties, and as such the assumption of a normally distributed y (i.e. corporate carbon emissions) can be relaxed (Sellers and Shmueli, 2010). Likewise, the model generates accurate estimates by fitting the models through a maximum likelihood estimation (Sellers and Shmueli, 2010). We report the results of the log-likelihood of the baseline GLM regression as well as other pre- and post-estimation tests in Appendix B. Our choice of control variables is motivated by recent studies in this strand of the literature

Table 1
Sample distribution.

S/No	Country	Corporate CO2 Emission	Carbon Reduction	CO2 Reduction Intensity	Environmental Score	Leverage	RoA	MTB	Slack
1	Argentina	3.15million	34%	−153%	42	21%	0%	4%	32%
2	Australia	1.46million	3%	−54%	48	25%	2%	87%	29%
3	Austria	2.52million	4%	−106%	55	30%	4%	66%	40%
4	Bahrain	5.99million			60	30%	2%	77%	17%
5	Belgium	1.16million	10%	−66%	58	35%	3%	101%	40%
6	Bermuda	0.57million	4%	−93%	43	38%	2%	58%	25%
7	Brazil	1.79million	15%	−20%	59	37%	2%	42%	36%
8	Cambodia	0.02million	−26%	−22%	75	22%	0%	0%	17%
9	Canada	2.47million	8%	−33%	52	25%	1%	72%	22%
10	Cayman Islands	0.02million	95%	90%	51	10%	−34%	437%	85%
11	Chile	3.31million	12%	−37%	56	32%	0%	1%	26%
12	China	17.2million	21%	−47%	50	24%	1%	28%	55%
13	Colombia	3.23million	23%	−34%	62	30%	0%	0%	17%
14	Cyprus	0.60million	40%	−39%	49	35%	2%	14%	29%
15	Czech Republic	24.3million	−6%	−19%	46	27%	0%	4%	25%
16	Denmark	0.66million	8%	−57%	50	24%	1%	31%	42%
17	Egypt	0.23million	−11%	−31%	41	12%	0%	4%	45%
18	Faroe Islands	0.06million	8%	−64%	61	15%	1%	23%	34%
19	Finland	2.30million	3%	−63%	67	27%	7%	127%	48%
20	France	4.61million	6%	−42%	69	29%	4%	94%	41%
21	Georgia	0.00million	11%	1%	31	25%	4%	24%	
22	Germany	5.58million	2%	−57%	61	25%	4%	114%	44%
23	Gibraltar	0.00million	−21%	−10%	44	10%	8%	328%	45%
24	Greece	4.58million	3%	−48%	59	33%	2%	50%	37%
25	Hong Kong	3.79million	10%	−68%	55	27%	0%	14%	39%
26	Hungary	0.42million	6%	−43%	68	20%	0%	0%	25%
27	Iceland	0.06million	0%	−548%	39	34%	0%	1%	34%
28	India	11.3million	8%	−55%	57	27%	0%	4%	41%
29	Indonesia	3.48million	12%	−27%	51	25%	0%	0%	29%
30	Ireland	1.77million	3%	−55%	51	27%	5%	130%	36%
31	Isle Of Man	0.02million	−6%	−22%	36	32%	7%	175%	29%
32	Israel	0.46million	−3%	−29%	52	21%	1%	31%	41%
33	Italy	6.20million	6%	−51%	57	33%	4%	93%	37%
34	Japan	3.40million	2%	−52%	62	23%	0%	1%	48%
35	Jordan	0.01million	2%	−11%	46	10%	1%	13%	
36	Kazakhstan	0.73million	0%	−2%	73	8%	0%	0%	34%
37	Kenya	0.05million	0%	−136%	56	8%	0%	6%	21%
38	Korea (South)	4.27million	6%	−18%	65	23%	0%	0%	42%
39	Kuwait	0.32million	−1%	−96%	41	24%	10%	168%	26%
40	Liechtenstein	0.00million	−24%	−37%	31	14%	0%	8%	
41	Luxembourg	3.17million	−2%	−55%	49	30%	4%	149%	38%
42	Malaysia	3.35million	4%	−61%	48	27%	2%	48%	35%
43	Malta	0.00million	−5%	−43%	35	23%	20%	398%	34%
44	Mexico	1.31million	7%	−25%	51	31%	0%	6%	30%
45	Monaco	2.02million	−12%	−317%	26	52%	−1%	19%	9%
46	Mongolia	0.26million				28%	0%	0%	15%
47	Morocco	0.30million	5%	−141%	34	25%	1%	20%	25%
48	Netherlands	1.38million	1%	−60%	63	28%	4%	131%	41%
49	New Zealand	0.38million	1%	−86%	38	27%	4%	90%	22%
50	Nigeria	1.40million			26	17%	0%	0%	22%
51	Norway	2.43million	4%	−51%	56	27%	0%	14%	39%
52	Oman	0.01million	19%	5%	37	14%	4%	31%	
53	Panama	5.34million	0%	−2%	67	55%	0%	0%	19%
54	Papua New Guinea	0.89million	−8%	−36%	40	38%	2%	81%	15%
55	Peru	0.20million	−7%	−22%	40	20%	1%	14%	32%
56	Philippines	0.99million	12%	−46%	46	34%	0%	2%	26%
57	Poland	6.24million	8%	−30%	51	20%	1%	15%	33%
58	Portugal	4.76million	3%	−29%	69	37%	4%	78%	28%
59	Qatar	0.11million	6%	−115%	26	19%	1%	12%	35%
60	Romania	0.94million	−14%	−22%	47	4%	1%	6%	31%
61	Russian Federation	25.8million	8%	−31%	49	33%	0%	2%	28%
62	Saudi Arabia	41.4million	4%	−38%	47	26%	2%	34%	28%
63	Singapore	1.26million	5%	−104%	50	27%	3%	58%	43%
64	Slovenia	0.06million	−19%	−23%	51	1%	14%	149%	56%
65	South Africa	1.80million	3%	−44%	50	21%	0%	9%	42%
66	Spain	3.61million	8%	−49%	69	34%	4%	97%	37%
67	Sri Lanka	0.35million	2%	−163%	74	34%	0%	0%	31%
68	Sweden	0.40million	6%	−94%	54	32%	1%	19%	39%
69	Switzerland	1.16million	4%	−53%	58	25%	5%	157%	45%
70	Thailand	4.74million	12%	−43%	55	34%	0%	10%	32%
71	Turkey	1.64million	4%	−61%	65	31%	1%	13%	48%
72	Ukraine	1.18million	17%	−19%	24	33%	0%	3%	50%
73	United Arab Emirates	1.49million	7%	−113%	38	23%	−2%	30%	39%
74	United Kingdom	2.09million	2%	−54%	49	27%	7%	169%	38%
75	United States	5.28million	1%	−50%	54	31%	5%	142%	35%

Table 2
Summary statistics.

	ETS Members					Non-ETS Members					Difference
	Obs	**Mean**	**SD**	**P25**	**P75**	**Obs**	**Mean**	**SD**	**P25**	**P75**	
CO2 Equivalence	4829	10.5m	21.4 m	0.34m	9.20m	25,309	2.76m	49.3m	0.02m	0.71m	7.74 million ***
Carbon Emissions Assets	4829	0.00	0.00	0.00	0.00	25,309	0.00	0.00	0.00	0.00	0.0%
Log Emissions	4829	14.28	2.45	12.74	16.04	25,309	11.76	2.63	10.22	13.47	2.5***
Carbon Reduction	4514	0.02	0.31	−0.08	0.06	20,484	0.04	0.40	−0.09	0.07	−3.00%***
Carbon Reduction Intensity	4514	−0.39	1.38	−0.29	−0.02	20,484	−0.55	1.94	−0.31	−0.01	16%***
Size	4829	24.65	2.45	22.98	25.69	25,309	23.66	2.64	21.80	25.15	1***
Leverage	4829	0.29	0.15	0.18	0.38	25,309	0.27	0.19	0.14	0.38	2%***
Return on Assets	4829	0.04	0.08	0.00	0.06	25,309	0.03	0.10	0.00	0.06	1%***
Market to book	4814	0.78	1.11	0.11	1.03	25,274	0.95	4.17	0.07	1.17	−0.16***
Slack	4399	0.33	0.16	0.20	0.43	20,809	0.39	0.21	0.23	0.53	−6%***
Property plant and equipment	4829	0.38	0.24	0.18	0.56	25,309	0.31	0.28	0.08	0.49	7.00%***
ESG Score	4828	66.14	15.35	56.77	77.89	25,281	55.20	16.56	43.68	67.59	10.94***
Sulphur	2582	24,638	100,910	103	14,459	5488	24,760	358,206	3	3000	−122
Volatile Organic Compounds	1443	15,392	46,537	214	6355	3097	4055	22,556	44	1215	11,337***
Log Sulphur	2552	7.15	3.41	4.78	9.61	5094	4.99	4.13	1.91	8.16	2.16***
Log (VOC)	1431	7.00	2.71	5.40	8.79	3029	5.44	2.66	3.94	7.14	1.56***

The table presents the summary statistics of the core variable used in the study. We split the sample into firms that are members of ETS and their counterparts that are non-members. We also report the results of a *t*-test that compares the mean of both samples. Details of variable description are provided in Appendix A. *** denotes significance level at below 5%.

Table 3
What drives the Membership of ETS.

	Emission Trading
Ln CO2	0.2014***
	(26.35)
ESG Score	0.0159***
	(19.17)
Property plant and equipment	0.1610**
	(2.32)
Return on Assets	0.1185
	(0.97)
Market to Book	0.0054***
	(2.60)
Slack	0.1384*
	(1.69)
Size	0.1132***
	(9.37)
Carbon Intensive Industry	0.1125***
	(4.45)
Constant	−8.1653***
	(-25.44)
Country Effect	Yes
Year Effect	Yes
Observations	24,779
Pseudo R squared	26%

The table presents the result of a probit regression that estimates the likelihood of joining emission trading schemes. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Table 4
Membership of ETS and corporate carbon emissions.

	(1)	(2)
Emission Trading	1.2211***	0.7277***
	(39.38)	(25.45)
HHI	−2.0554***	−2.2851***
	(-17.10)	(-20.22)
CVI	3.7966***	−0.9949**
	(8.94)	(-2.44)
GDP	−0.0036	0.0339***
	(-0.64)	(6.53)
RoA		1.1981***
		(11.12)
Slack		−0.3799***
		(-5.07)
Size		0.5411***
		(86.08)
Leverage		0.1969***
		(3.16)
Market to Book		−0.0631***
		(-8.74)
PPE		1.8150***
		(26.53)
Constant	13.5330***	1.8532***
	(50.00)	(6.41)
Industry Effect	Yes	Yes
Year Effect	Yes	Yes
Continent Effect	Yes	Yes
Observations	28,776	24,101

The table presents the results of a generalized linear model (GLM) that explores the relationship between carbon emissions and emission trading. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

(see for instance, Azar et al., 2021; Safiullah et al.,2022; Konadu et al., 2022; Adamolekun et al.,2022). Notably, we include firm size and PPE to account for the volume of a firm's business activity as well as their potential credit constraint (Azar et al.,2021).

In Table 4, we report the results of this estimation. Column (1) reports univariate results and column (2) multivariate results. We find that the parameter coefficient on emission trading is significantly positive at the 1% level firms showing that firms that are members of the emission trading scheme emit more corporate CO_2. We thus show that the current design of ETSs may be ineffective in curtailing corporate carbon emissions. As shown from the parameter coefficients in our control variables, we find that corporate carbon emissions are positively associated with RoA, Slack, size, HHI, and GDP. Corporate CO_2 is also negatively related to market-to-market-to-book ratio and country-level climate vulnerability (CVI). The findings of the control variables corroborate the works of Lee and Min (2015), Atif et al. (2021), and Azar et al. (2021).

For added rigour in our examination, we run separate baseline regression where we exclude firms from the USA since it represents a significant portion of our sample. Despite this exclusion criteria, our results remain consistent. For brevity, we report the results of the regression in Appendix C.

4.2.1. *Does the effectiveness of ETS vary by continent?*

Motivated by the marked geographical differences in the development of ETS worldwide (ICAP, 2023), we examine whether these differences affect the effectiveness of carbon markets in curbing firm-level pollution. For instance, in terms of continental regulation, only the EU

ETS has a concerted continental approach to regulating emissions. Nonetheless, country-level and state-level carbon markets are present in China, the USA, Kazakhstan, Canada, New Zealand, and South Korea all of which could affect emission trading schemes. However, with most firms characterised by multi-nationality, the appeal to join ETS is popular despite the potential absence of the scheme in a firm's country of residence. More so, prior literature documents conflicting results on the impact of ETS in various continents (for instance, Chan et al., 2013; Wang and Zhang, 2022). However, it is unknown if these continental differences have visible implications on firm-level pollution.

To test this, we split firms into continents and report the results of the interaction term between membership and continent of origin. We report the results of this analysis in Table 5. The results suggest that firms in Asia and South America that are members of an emission trading scheme emit less CO_2 than their counterparts from other continents. In contrast, we find that firms from Europe who belong to an ETS emit more carbon than their peers who are not members of the scheme. Our results imply that the effectiveness of emission trading schemes varies with continents.

To ensure optimal rewards from ETSs, there must be a concerted effort among countries, regions, and continents. This will dissuade participants from taking advantage of regulatory arbitrage and carbon leakages (Naegele and Zaklan, 2019).

4.3. Propensity score matching (PSM)

The decision to join an emission trading scheme may be driven by inherent firm qualities that are observable. For example, larger firms may find it easier to join emission trading schemes than smaller ones. We thus employ propensity score matching to account for this. Using matching algorithms can reduce to some extent asymptotic biases that arise from sample self-selection challenges or endogeneity concerns (Roberts and Whited, 2013; Shipman et al., 2017).

The propensity score matching estimation involves first predicting

Table 5
ETS across continents and corporate carbon emissions.

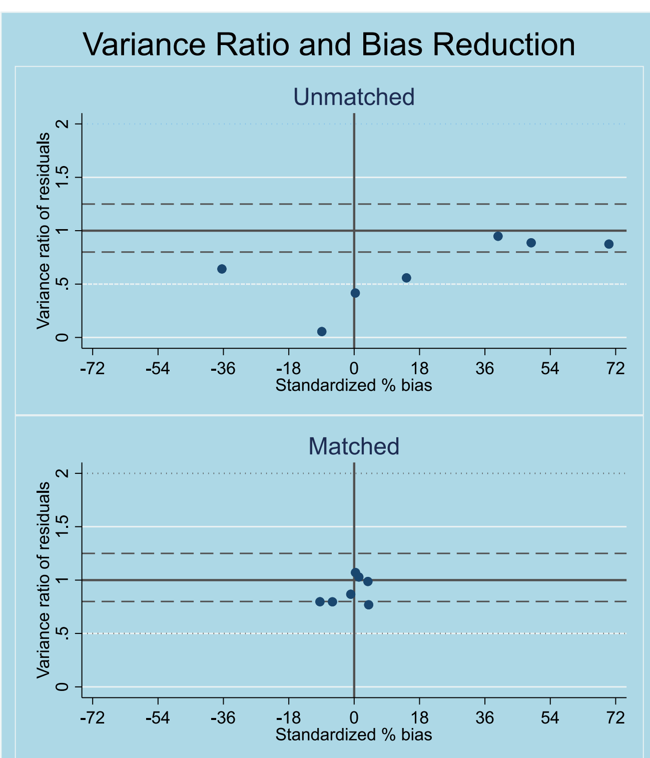
	Asia	Europe	North America	South America	Oceania	Africa
Emission Trading	0.8297***	0.5511***	0.8172***	0.7500***	0.7372***	0.7438***
	(26.58)	(14.24)	(24.13)	(25.16)	(24.36)	(24.89)
ETS # Asia	−0.9340***					
	(-11.79)					
ETS # Europe		0.5291***				
		(9.76)				
ETS # North America			−0.0601			
			(-1.05)			
ETS # South America				−0.8780***		
				(-4.60)		
ETS # Oceania					0.1798	
					(1.39)	
ETS # Africa						−0.2822
						(-1.39)
RoA	1.2049***	1.3301***	1.2650***	1.3023***	1.2925***	1.2937***
	(10.88)	(11.94)	(11.59)	(11.64)	(11.50)	(11.51)
Slack	−0.5902***	−0.8831***	−0.5950***	−0.9442***	−0.9611***	−0.9393***
	(-7.72)	(-11.64)	(-7.97)	(-12.42)	(-12.56)	(-12.31)
PPE	1.9242***	1.6839***	1.7554***	1.6567***	1.7466***	1.7311***
	(27.45)	(23.96)	(25.53)	(23.44)	(24.66)	(24.45)
Size	0.5446***	0.4693***	0.4812***	0.4902***	0.4759***	0.4909***
	(86.85)	(79.39)	(83.62)	(82.88)	(79.31)	(81.92)
Leverage	0.3229***	0.4474***	0.2361***	0.4908***	0.4201***	0.4642***
	(5.06)	(7.00)	(3.76)	(7.64)	(6.50)	(7.20)
Market to Book	−0.0490***	−0.0490***	−0.0640***	−0.0456***	−0.0473***	−0.0431***
	(-6.62)	(-6.57)	(-8.76)	(-6.10)	(-6.29)	(-5.74)
HHI	−1.5855***	−2.3461***	−2.6716***	−1.5435***	−1.5267***	−1.5840***
	(-14.47)	(-20.11)	(-23.99)	(-13.93)	(-13.62)	(-14.24)
CVI	−2.1344***	−9.4978***	−5.6124***	−6.5010***	−6.7276***	−7.6007***
	(-6.14)	(-29.31)	(-19.20)	(-21.80)	(-22.50)	(-24.39)
GDP	0.0535***	0.0347***	0.0238***	0.0327***	0.0368***	0.0468***
	(10.18)	(6.60)	(4.61)	(6.19)	(6.95)	(8.70)
Asia	−1.0218***					
	(-22.61)					
Europe		−0.6368***				
		(-21.75)				
North America			0.9631***			
			(36.29)			
South America				−1.0672***		
				(-12.76)		
Oceania					−0.3758***	
					(-7.14)	
Africa						0.6165***
						(8.84)
Constant	2.2181***	6.7797***	4.6898***	5.0165***	5.4090***	5.2761***
	(8.80)	(28.47)	(21.14)	(22.09)	(23.59)	(23.16)
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,101	24,101	24,101	24,101	24,101	24,101

The table presents the results of the GLM regression estimate that examines the dynamics of the relationship between ETS, corporate carbon emissions, and the continent of a firm. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

the likelihood of joining an ETS scheme. In effect, this step estimates the probability of joining an ETS. The second aspect of the PSM matches firms that join an ETS with firms that choose not to join an ETS but are similar except for their choice. This strategy enables us to isolate what is driven by the membership of an emission-trading scheme. In Fig. 2, we present a pictorial representation of the PSM. The figure demonstrates that the PSM was effective in reducing biases.

In Table 6, we present the result of the PSM analysis. Panel A of Table 6 reports the balancing property between the treated (i.e., firms that are members of an ETS) and the control group (i.e., firms that are not members of an ETS). To evaluate the degree of covariate imbalance, we report the *t*-test for the equality of mean in the treated (ETS members) and the matched (non-ETS members). In addition, the standardised percentage bias and the variance ratio are also reported. This result indicates the empirical strategy was effective in reducing bias. Similarly, the *t*-test demonstrates that in most cases the means of the samples did not significantly differ after matching. Lastly, the variance ratio of the matched sample ranges from 0.67 to 1.22 which is within the 0.5 to 2 band suggested by Rubin (2001). Overall, our results indicate that the PSM procedure was effective in mitigating imbalance in the sample.

More importantly, Panel B of Table 6 reports the average treatment effect on the treated (ATT). We find that our conclusions are unchanged with this matching approach. The coefficient reported (0.66) indicates that members of ETS emit more carbon than their counterparts who are non-members. For robustness, we also perform additional matching techniques. In Appendix D, we match firms according to the Mahalanobis matching algorithm employing the control variables. In Appendix E, using the entropy-matching technique, we match firms according to their control variables. We also specify our model accounting for firm fixed effect. Across all the methods, we document a positive relationship between ETS and firm carbon emissions. These results confirm the view



The figure details the variance ratio of the residuals of the covariates for the PSM as well as the rate of bias reduction.

Fig. 2. Variance ratio and Bias Reduction
The figure details the variance ratio of the residuals of the covariates for the PSM as well as the rate of bias reduction.

that climate mitigation schemes may be an ineffective tool for regulating corporate environmental behaviour (Akter et al., 2012).

4.4. Membership in ETS and carbon reduction

In Table 7, using once again a GLM estimation, we examine if membership in an ETS affects corporate carbon reduction efforts. The results suggest that firms that are members of ETS reduce their carbon emissions significantly when compared with their peers that are not members of an ETS. The parameter coefficient on emission trading is significantly negative at the 1% level. This implies that the ETS may be effective in stimulating corporate carbon reduction efforts. Even though firms that are members of the ETS are heavy polluters as shown earlier, they reduce their emissions relative to previous years.

Since the effectiveness of ETS may differ by location, we examine if this effect varies with continents. The result suggests that this effect is only significant for ETS in Europe. The results complement the proposition that ETSs could accelerate carbon transition under the right framework (Hu et al.,2020; Huang et al., 2022). To this end, membership in emission trading schemes could encourage responsible energy usage among participants (Hu et al.,2020).

4.5. Carbon intensive industries and membership of ETS

In the spirit of Baboukardos (2017) and Konadu et al. (2022), we examine if belonging to a carbon-intensive industry mitigates or exacerbates the impact of ETS on corporate CO_2 and firm carbon reduction efforts. In Table 8 we report the results of this testing by interacting with emission trading and firms in the carbon-intensive industry. The findings indicate that the role of ETS on corporate carbon emission is amplified among firms that are members of carbon-intensive industries. A potential explanation for this finding is that since carbon intensive industries rely heavily on fossil fuels for their production, membership of ETS will increase their regulatory scrutiny and ultimately improve carbon reporting quality.

4.6. Additional analysis

We previously tested the relationship between ETS membership and Ln CO2 considering that it is the most commonly used in the literature (e.g., Azar et al., 2021; Safiullah et al.,2022; Konadu et al., 2022). In addition to our previous test, we test if the effect of being a member of an ETS affects the corporate emission of other harmful gases; sulphur, and volatile organic compounds (VOCs). Table 9 reports these additional results.

We find that our results remain strong with the use of these additional harmful gases. The parameter coefficient on emission trading is significantly positive at the 1% level in both estimations. Firms that are members of these schemes emit more sulphur and more volatile organic compounds (VOCs) than their peers that are not members of the scheme.

Since the conversation concerning the impact of CO_2 became more pressing in the last decade or so, we examine if our baseline results differ across periods. Using the period surrounding the Kyoto and Paris Agreement as a reference point, we split our sample into periods before and after 2015. As shown in Table 10, we find that in the period before and after 2015, the impact of ETS on corporate CO_2 remains positive and significant at similar magnitude and statistical levels in both sub-periods. Interestingly, we find that the impact of ETS on corporate carbon reduction efforts is more pronounced in the period after 2015.

4.7. Do members of ETS have poor environmental records?

To help make sense of our findings, we examine if firms that choose to partake in the scheme have a history of poor environmental practices. To test this, we collect data from Refinitiv Eikon on the number of environmental controversies ETS member firms have faced compared to

Table 6
Carbon emission and membership of ETS - PSM estimation.

Panel A: Test for Covariance Imbalance

Variable	Category	Treated	Control	Bias	Reduction in Bias	*t*-test	Variance Ratio
Return on Assets	Unmatched	0.04	0.04	3.3	24.4	1.79	0.53
	Matched	0.04	0.04	2.5		1.23	0.67
Slack	Unmatched	0.33	0.39	−34.3	89.7	−19.21	0.65
	Matched	0.33	0.32	3.5		1.72	0.79
Property plant and equipment	Unmatched	0.41	0.32	38.4	80.4	22.5	0.94
	Matched	0.41	0.43	−7.5		−3.41	0.85
Size	Unmatched	24.45	23.32	47.1	86.2	27.85	0.89
	Matched	24.44	24.60	−6.5		−2.92	0.78
Leverage	Unmatched	0.30	0.28	10.7	70	5.92	0.56
	Matched	0.30	0.30	−3.2		−1.68	0.85
Market to Book	Unmatched	0.84	1.08	−7.2	88.2	−3.45	0.06
	Matched	0.84	0.81	0.8		1.23	1.22

Panel B: Propensity Score Matching ATT

	Variable	Treated	Controls	Difference	S.E.	T-stat
Carbon Emissions	Unmatched	14.62	12.15	2.464	0.041	59.42
	Matched - *ATT*	14.61	13.89	0.722	0.072	9.95

The table reports the results of the propensity score matching (PSM) estimation. In Panel A, we present the variance ratio as well as the bias reduction level as a result of the matching procedure. * * denotes covariates that are bad post-matching (i.e., variance ratio <0.5 or >2). In panel B of the table, we present the results of the PSM estimates. ATT therein is the average treatment effect on the treated. The model includes year, industry, and country effects. Details of variable description are provided in Appendix A.

Table 7
Continent and membership of emissions trading scheme and carbon reduction.

Panel A: ETS and Carbon Reduction

	(1)	(2)
Emission Trading	−0.0314***	−0.0268***
	(-4.49)	(-3.66)
RoA		0.0533*
		(1.84)
Slack		−0.0556***
		(-2.72)
Size		−0.0024
		(-1.41)
Leverage		−0.0144
		(-0.85)
Market to Book		−0.0020
		(-1.03)
PPE		−0.0557***
		(-3.02)
HHI	0.1168***	0.1035***
	(4.07)	(3.38)
CVI	0.3229***	0.2840**
	(3.18)	(2.57)
GDP	0.0081***	0.0080***
	(6.15)	(5.74)
Constant	−0.0431	0.0774
	(-0.69)	(1.01)
Industry Effect	Yes	Yes
Year Effect	Yes	Yes
Continent Effect	Yes	Yes
Observations	23,875	20,020

Panel B: ETS and Carbon Reduction by Continent

	Africa	Asia	Europe	North America	Oceania	South America
Emission Trading	0.0053	−0.0240	−0.0398***	−0.0150	−0.0013	−0.1384
	(0.10)	(-1.25)	(-3.12)	(-1.25)	(-0.03)	(-1.57)
Control	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.7764	0.2428	−0.0367	0.1584	0.1346	−0.5888
	(0.70)	(1.48)	(-0.32)	(0.98)	(0.24)	(-0.59)
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	614	3891	8111	5964	1046	394

The table presents the results of a generalized linear model (GLM) that explores the relationship between corporate carbon reduction efforts and membership in emission trading. Panel A reports the results of the relationship between corporate carbon reduction efforts and ETS membership. Panel B reports the result of panel A split by continent. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Table 8
ETS, carbon intensive industries and corporate carbon reduction efforts.

	(1)	(2)	(3)
	Ln CO2	Carbon Reduction	Carbon Reduction Intensity
Emission Trading	0.4990***	−0.0142	−0.0650
	(10.87)	(-1.22)	(-1.21)
Emission Trading # CI	0.3600***	−0.0200	0.0894
	(6.32)	(-1.37)	(1.34)
RoA	1.2029***	0.0525*	0.1678
	(11.18)	(1.81)	(1.26)
Slack	−0.4060***	−0.0546***	0.0851
	(-5.42)	(-2.67)	(0.91)
Size	0.5427***	−0.0026	0.0037
	(86.38)	(-1.48)	(0.47)
Leverage	0.2040***	−0.0153	0.1966**
	(3.27)	(-0.91)	(2.55)
Market to Book	−0.0617***	−0.0020	−0.0091
	(-8.56)	(-1.05)	(-1.02)
PPE	1.7953***	−0.0562***	−0.1396*
	(26.25)	(-3.04)	(-1.65)
Carbon Intensive Industry [*CI*]	3.2609***	0.1022	−0.0734
	(6.13)	(0.69)	(-0.11)
HHI	−2.3226***	0.1043***	0.3116**
	(-20.57)	(3.41)	(2.22)
CVI	−1.0415**	0.2865***	−0.1322
	(-2.56)	(2.59)	(-0.26)
GDP	0.0342***	0.0080***	0.0033
	(6.60)	(5.72)	(0.52)
Constant	−1.4395**	−0.0206	−1.1086
	(-2.39)	(-0.12)	(-1.45)
Industry Effect	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes
Observations	24,101	20,020	20,020

The table presents the results of a generalized linear model (GLM) that explores the relationship between carbon emissions (natural log), corporate carbon reduction efforts, corporate carbon reduction intensity, and emission trading whilst considering the degree of carbon intensity in the industry. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

their counterparts who are not members of an emission trading scheme. Using PSM, the result reveals that firms that are a member of an ETS have more environmental scandals. The results of this analysis are presented in Table 11. The implication of this finding is that membership in an ETS could be motivated by greenwashing. Juxtaposing our findings with the results on the positive impact of membership of ETSs and corporate carbon emissions level, it implies that despite the scheme being more attractive to firms with questionable environmental history, joining does not decrease their carbon footprint.

4.8. Is there a delayed impact of joining ETSs?

Arguably, there may be a time lag between when firms enter emission trading schemes and when the effect of membership reflects on their environmental practice and ultimately their carbon footprint. To dispel this possibility, we examine how membership of ETSs affects corporate carbon emissions between 1 and 10 years after joining and report the results of this analysis in Table 12. We find that even up to 10 years after joining ETS, membership has a positive effect on corporate carbon emissions. However, the coefficient of the relationship between membership and corporate carbon emission appears to decline over time. The parameter coefficient on emission trading is equal to 0.6875 at year t and becomes gradually 0.4378 at year t+10. This reduction may be linked to the reduction in carbon emission that we reported earlier in Table 7.

Table 9
ETS & other harmful gases.

	(1)	(2)
	Ln Sulphur	Volatile Compounds
Emission Trading	0.5009***	0.3560***
	(6.45)	(5.08)
RoA	−0.1110	0.6292**
	(-0.25)	(2.34)
Slack	0.9521***	0.2659
	(2.84)	(0.94)
Size	0.8400***	0.8055***
	(26.33)	(28.70)
Leverage	0.1183	−0.1231
	(0.51)	(-0.57)
Market to Book	−0.0728	−0.1136***
	(-1.34)	(-3.15)
PPE	2.9826***	2.5395***
	(10.98)	(10.38)
HHI	5.2671*	0.7411
	(1.88)	(0.27)
CVI	42.9591***	−17.7022*
	(3.85)	(-1.80)
GDP	−0.0064	0.0097
	(-0.32)	(0.52)
Constant	−31.6401***	−6.0699*
	(-6.85)	(-1.84)
Industry Effect	Yes	Yes
Year Effect	Yes	Yes
Continent Effect	Yes	Yes
Observations	7060	4328

The table presents the results of a generalized linear model (GLM) that explores the relationship between other harmful gases and emissions trading. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Table 10
Does the impact of ETS vary per period?

	Ln CO2		*Carbon Reduction*	
	Before 2015	After 2015	Before 2015	After 2015
Emission Trading	0.7126***	0.8182***	−0.0255***	−0.0250**
	(22.05)	(16.41)	(-2.58)	(-2.20)
RoA	0.6174***	1.4264***	0.0215	0.0551
	(4.30)	(9.00)	(0.47)	(1.44)
Slack	−0.2703***	−0.4963***	−0.1016***	−0.0170
	(-2.69)	(-4.54)	(-3.16)	(-0.63)
Size	0.5562***	0.5314***	−0.0014	−0.0021
	(60.33)	(60.66)	(-0.47)	(-0.97)
Leverage	0.0763	0.3102***	0.0016	−0.0208
	(0.92)	(3.40)	(0.06)	(-0.95)
Market to Book	−0.0298**	−0.0644***	0.0036	−0.0031
	(-2.12)	(-7.07)	(0.80)	(-1.41)
PPE	1.5815***	2.0329***	−0.0800***	−0.0319
	(17.66)	(20.11)	(-2.80)	(-1.30)
HHI	−1.9759***	−2.4740***	0.1510***	0.0725*
	(-14.37)	(-13.69)	(3.38)	(1.67)
CVI	−0.0394	−1.7402***	0.3469**	0.2935**
	(-0.07)	(-2.90)	(2.03)	(1.99)
GDP	0.0311***	0.0385***	0.0069***	0.0088***
	(4.10)	(5.36)	(2.90)	(5.02)
Constant	1.1497***	1.0371***	0.0097	−0.0126
	(3.24)	(2.99)	(0.09)	(-0.15)
Industry Effect	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes	Yes
Observations	11,784	12,317	9812	10,208

The table presents the results of a generalized linear model (GLM) that explores the relationship between carbon emissions, corporate carbon reduction efforts and emissions trading split in the period before and after 2015. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Table 11
ETS membership and environmental controversy.

Panel A: Sample Comparison						
Variable	Category	Treated	Control	Bias	Reduction in Bias	*t*-test
Return on Assets	Unmatched	0.031	0.026	7	74.3	0.68
	Matched	0.031	0.03	1.8		0.2
Slack	Unmatched	0.252	0.246	4.2	−802	0.42
	Matched	0.24	0.296	−38.1		−3.12
Property plant and equipment	Unmatched	0.528	0.531	−1.3	−1782.3	−0.13
	Matched	0.542	0.49	24.6		2.23
Size	Unmatched	25.655	24.631	51.1	83	5.02
	Matched	25.599	25.772	−8.7		−0.74
Leverage	Unmatched	0.309	0.323	−9.1	−367.9	−0.9
	Matched	0.322	0.385	−42.6		−3.89
Market to Book	Unmatched	0.735	0.881	−11.1	20.3	−1.11
	Matched	0.771	0.654	8.8		0.8
Panel B: Propensity Score Matching ATT						
Variable	Sample	Treated	Control	Difference	SE	T-stat
Environmental Controversy	Unmatched	2.062	1.466	0.596	0.162	3.68
	ATT	2.073	1.493	0.580	0.320	1.81

The table explores the relationship between ETSs membership and environmental controversy. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses.

Table 12
Lead effect and ETS schemes.

	T + 1 year	*T + 2 year*	*T + 3 year*	*T + 4 year*	*T + 5 year*	*T + 10 year*
Emission Trading	0.6875***	0.6648***	0.5987***	0.5552***	0.5193***	0.4378***
	(22.98)	(21.86)	(19.39)	(17.32)	(15.59)	(8.78)
RoA	0.9351***	1.0971***	1.1012***	1.0402***	0.7156***	0.1487
	(7.92)	(7.66)	(7.13)	(6.46)	(4.36)	(0.65)
Slack	−0.3971***	−0.4049***	−0.4261***	−0.4372***	−0.5011***	−0.1892
	(-4.80)	(-4.62)	(-4.60)	(-4.36)	(-4.65)	(-1.10)
Size	0.5426***	0.5350***	0.5421***	0.5606***	0.5698***	0.6804***
	(77.73)	(70.83)	(66.26)	(61.44)	(57.34)	(38.33)
Leverage	0.0592	0.0122	0.0232	−0.0085	−0.1022	−0.6146***
	(0.87)	(0.17)	(0.30)	(-0.10)	(-1.13)	(-4.45)
Market to Book	−0.0579***	−0.0511***	−0.0465***	−0.0073	0.0203	0.1318***
	(-6.71)	(-5.17)	(-3.97)	(-0.49)	(1.27)	(5.57)
PPE	1.7121***	1.5366***	1.4575***	1.4342***	1.3795***	1.3390***
	(22.97)	(19.46)	(17.39)	(15.84)	(14.13)	(8.31)
HHI	−2.2033***	−2.0286***	−1.8944***	−1.7269***	−1.4144***	−0.0636
	(-17.49)	(-15.38)	(-13.56)	(-11.55)	(-8.90)	(-0.27)
CVI	−0.1932	−0.2973	0.3492	1.2572**	2.0500***	2.4189**
	(-0.43)	(-0.63)	(0.71)	(2.40)	(3.69)	(2.56)
GDP	0.0393***	0.0669***	0.0661***	0.0552***	0.0423***	0.0466***
	(6.56)	(8.98)	(8.78)	(7.07)	(5.31)	(3.01)
Constant	1.5898***	1.5994***	1.3024***	0.4657	0.0026	−2.7433***
	(5.14)	(5.01)	(3.96)	(1.33)	(0.01)	(-4.39)
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,520	15,281	12,625	10,603	8978	3249

The table presents the results of a generalized linear model (GLM) that explores the relationship between carbon emissions and membership emissions trading in years t+1, t+2, t+3, t+4, t+5 & t+10. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

4.9. How does the exiting and entrance of the scheme affect the corporate carbon emissions level?

Finally, we examine how exiting and entering the scheme affects corporate carbon emissions and present the results of this analysis in Table 13. As shown in columns 1 to 3, we find that former members who select to exit the scheme emit more than their counterparts who remain in the scheme or those who chose not to be involved in the first instance. There is not much difference in the magnitude of the relation, moving from 0.7904 at year 0–0.6847 two years later (both parameter coefficients are significant at the 1% level). The exit from the scheme does not seem to change significantly firms' pollution patterns.

Interestingly, when we explore the carbon emissions of new entrants, we find that their pollution is significantly affected after joining. The parameter coefficient on emission trading moves from 0.2416 at year zero to 0.2865 two years after joining. This result may indicate evidence of peer-to-peer learning since new entrants change their emission intensity after joining. The peer learning effect we document aligns with the supposition in the corporate finance literature that firms imitate their peers when making important decisions (Machokoto et al.,2021). Another plausible explanation is that increased regulatory scrutiny forces more accurate carbon reporting. A simple yet possible interpretation of the result is that firms join the scheme when they expect an increase in their emissions in the near future.

Table 13
Entrance and exiting ETS schemes.

	Year 0	*T+1 year*	*T+ 2 year*	*Year 0*	*T+1 year*	*T + 2 year*
Exiters from ETS	0.7904***	0.7394***	0.6847***			
	(25.04)	(22.71)	(20.74)			
New ETS Entrants				0.2416***	0.2886***	0.2865***
				(3.42)	(4.02)	(3.93)
RoA	1.1984***	0.9449***	1.1143***	1.2137***	0.9555***	1.1259***
	(11.12)	(8.00)	(7.77)	(11.12)	(7.98)	(7.75)
Slack	−0.3797***	−0.3943***	−0.3967***	−0.3490***	−0.3612***	−0.3693***
	(-5.06)	(-4.77)	(-4.52)	(-4.59)	(-4.31)	(-4.15)
Size	0.5447***	0.5445***	0.5387***	0.5709***	0.5723***	0.5659***
	(86.93)	(78.12)	(71.39)	(91.27)	(82.33)	(75.18)
Leverage	0.2061***	0.0648	0.0226	0.2062***	0.0609	0.0193
	(3.30)	(0.95)	(0.31)	(3.26)	(0.88)	(0.26)
Market to Book	−0.0620***	−0.0581***	−0.0523***	−0.0616***	−0.0573***	−0.0511***
	(-8.58)	(-6.73)	(-5.28)	(-8.42)	(-6.54)	(-5.09)
PPE	1.8293***	1.7236***	1.5540***	1.8570***	1.7562***	1.5790***
	(26.73)	(23.12)	(19.66)	(26.79)	(23.25)	(19.71)
HHI	−2.2761***	−2.1867***	−2.0102***	−2.2984***	−2.2162***	−2.0658***
	(-20.13)	(-17.35)	(-15.21)	(-20.07)	(-17.35)	(-15.43)
CVI	−1.1128***	−0.2818	−0.4248	−1.7720***	−0.9529**	−1.0529**
	(-2.73)	(-0.63)	(-0.90)	(-4.30)	(-2.12)	(-2.20)
GDP	0.0356***	0.0413***	0.0688***	0.0339***	0.0391***	0.0658***
	(6.86)	(6.88)	(9.22)	(6.44)	(6.43)	(8.71)
Constant	1.9060***	1.6601***	1.6360***	1.4079***	1.1252***	1.1076***
	(6.58)	(5.36)	(5.11)	(4.81)	(3.60)	(3.42)
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	24,101	18,520	15,281	24,101	18,520	15,281

The table presents the results of a generalized linear model (GLM) that explores the relationship between carbon emissions and corporate exit and entering emission trading schemes. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

5. Conclusion

We examine in this study if membership in emission trading schemes affects corporate environmental practices. Our evidence indicates that firms that are members of ETS emit on average more carbon than their counterparts that are not members of the scheme. Members of emission trading schemes are more effective in their carbon reduction efforts. Firms that are members of an ETS emit significantly more sulphur and volatile organic compounds (VOCs) than their peers that are not members of an ETS. We also find that members of ETS typically have more environmental scandals than their counterparts who are non-members. This result implies that firms may join the scheme simply for greenwashing purposes. Such firms may have no interest in improving their environmental credentials through the scheme. The implications of the findings are far-reaching, the results show that membership in the scheme could discourage a speedy transition to more sustainable operation processes. The effect of membership has thus long-term implications for corporate carbon emissions. We also report that firms that choose to exit the scheme continue emitting more than their counterparts. Similarly, there is an indication of peer-to-peer learning as we document that new entrants increase their emissions in the years following their entrance. Furthermore, new joiners of the scheme may be motivated to join simply to meet the demands of increased emissions in the future.

We believe that the results of this study have implications for policymakers and other stakeholders. We argue that a collaborative regulatory framework coordinated across continents and countries would reduce the incidence of regulatory arbitrage and carbon leakages. We also join the strand of the literature that has called for higher pricing of carbon emission permits and allowances. Such a regime shift will tighten corporate environmental scrutiny whilst encouraging a transition to more sustainable production processes.

CRediT authorship contribution statement

Gbenga Adamolekun: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Festus Fatai Adedoyin:** Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Antonios Siganos:** Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing.

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.

Data availability

Data will be made available on request.

Appendix A. Variable Definition

Variable	*Definition*
Emission Trading	ETS is a variable that is denoted 1 if a firm is a member of an ETS and 0 if it is not.
Exit from ETS	This captures firms that exit an emission trading scheme in a year.

(*continued on next page*)

(*continued*)

Variable	*Definition*
New ETS Entrants	This identifies firms that become members of an emission trading scheme in a year.
Corporate CO2 Emission/CO2 Equivalence	This is the total value of a firm's Scope 1 and Scope 2 emissions in a year.
Ln Co2/Log Emissions	This is the natural log of a firm's Scope 1 and Scope 2 emissions for a year.
Carbon Reduction	This is simply the year-on-year changes in firm carbon emissions
CO2 Reduction Intensity	This is the industry-adjusted carbon reduction of a firm in a year.
ESG Score	ESG Score refers to a firm's Refinitiv ESG score for a year. The estimated value is calculated based on the self-reported environmental, social, and corporate governance pillars.
Sulphur	This captures the total value of sulphur emitted by a firm in a year.
Log Sulphur	This is the natural log of a firm's sulphur for a year.
Volatile Organic Compounds (VOCs)	This is the total effusion of VOCs by a firm in a year.
Log Volatile Organic Compounds	This refers to the natural logarithm of a firm's volatile organic compounds (VOCs).
Return on Assets	Return on Assets (RoA) is defined as the return on assets of a firm. It is simply EBITDA divided by total assets.
Slack	Slack refers to current assets divided by total assets.
Size	Size is the natural logarithm of a firm's total assets.
Leverage	This refers to the total debt of a firm divided by total assets.
Market to Book	Market-to-book (MTB) ratio is defined as the market value of equity divided by the book value of equity.
Property plant and equipment	This refers to the property plant and equipment (PPE) of a firm divided by total assets.
HHI	This captures the degree of market concentration in a country
CVI	This identifies a country's susceptibility to climate-related challenges
GDP	This is the first difference in a country's GDP per capita.

Appendix B. GLM Tests

Log Likelihood	−46461.6
Scale parameter	2.771986
(1/df) Deviance	2.771986
(1/df) Pearson	2.771986
AIC	3.859307
BIC	−176042
Deviance	66,682.9
Pearson	66,682.9

The Table presents the GLM tests for the main model regression.

Appendix C. Regression Analysis without USA

	(1)	(2)
Emission Trading	1.2369***	0.7907***
	(33.69)	(22.54)
HHI	2.1980***	−4.3952***
	(4.02)	(-8.19)
CVI	4.0859***	−0.5619
	(9.32)	(-1.29)
GDP	−0.0024	0.0320***
	(-0.42)	(5.80)
RoA		1.1164***
		(8.70)
Slack		−0.4007***
		(-4.44)
Size		0.4938***
		(67.79)
Leverage		0.3120***
		(4.07)
Market to Book		−0.0550***
		(-6.45)
PPE		1.5399***
		(18.73)
Constant	12.9322***	2.9621***
	(41.64)	(8.76)
Industry Effect	Yes	Yes
Year Effect	Yes	Yes
Continent Effect	Yes	Yes
Observations	21,879	18,021

The Table presents the results of the regression analysis after excluding the USA from the sample. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Appendix D. Mahalanobis Matching

Panel A: Summary Statistics				
	Before Treatment		After Treatment	
	Treated	Control	Treated	Control
C02 Emission	14.63	12.15	14.18	14.28
RoA	0.04	0.04	0.04	0.04
Slack	0.33	0.39	0.32	0.33
Size	24.28	23.27	24.09	24.65
Leverage	0.3	0.28	0.30	0.29
MTB	0.87	1.11	0.87	0.78
PPE	0.41	0.32	0.41	0.38
HHI	0.09	0.09	0.09	0.09
CVI	0.32	0.33	0.32	0.32
GDP	0.77	0.92	0.88	0.77

Panel B: Mahalanobis Regression				
	Before Matching		After Matching	
Emission Trading	1.2211***	0.7277***	0.6235***	0.4543***
	(39.38)	(25.45)	(14.85)	(13.01)
HHI	−2.0554***	−2.2851***	−2.1246***	−2.3643***
	(-17.10)	(-20.22)	(-9.71)	(-12.32)
CVI	3.7966***	−0.9949**	3.4023***	1.9460**
	(8.94)	(-2.44)	(3.40)	(2.28)
GDP	−0.0036	0.0339***	0.0585***	0.0484***
	(-0.64)	(6.53)	(4.62)	(4.51)
RoA		1.1981***		1.3233***
		(11.12)		(5.02)
Slack		−0.3799***		−0.1731
		(-5.07)		(-1.13)
Size		0.5411***		0.6311***
		(86.08)		(52.69)
Leverage		0.1969***		−0.1362
		(3.16)		(-1.04)
Market to Book		−0.0631***		−0.2488***
		(-8.74)		(-12.81)
PPE		1.8150***		2.1265***
		(26.53)		(18.12)
Constant	13.5330***	1.8532***	15.9519***	−1.1068**
	(50.00)	(6.41)	(35.46)	(-2.15)
Industry Effect	Yes	Yes	Yes	Yes
Year Effect	Yes	Yes	Yes	Yes
Continent Effect	Yes	Yes	Yes	Yes
Observations	28,776	24,101	8900	8476

The Table presents the results of the regression analysis using the Mahalanobis matching algorithm. Panel A reports the summary statistics while panel B presents the results of the regression analysis. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Appendix E. Entropy Balancing Analysis

Panel A: Summary Statistics				
	Before Treatment		*After Treatment*	
	Treated	*Control*	*Treated*	*Control*
C02 Emission	14.63	12.15	14.63	14.63
RoA	0.04	0.04	0.04	0.04
Slack	0.33	0.39	0.33	0.33
Size	24.28	23.27	24.28	24.28
Leverage	0.30	0.28	0.30	0.30
MTB	0.87	1.11	0.87	0.87
PPE	0.41	0.32	0.41	0.41
HHI	0.09	0.09	0.09	0.09
CVI	0.32	0.33	0.32	0.32
GDP	0.77	0.92	0.77	0.77

Panel B: Entropy Regression Analysis		
	Before Matching	After Matching
Emission Trading	0.0511***	0.7277***
	(3.47)	(25.85)
RoA	0.0818*	1.1981***
	(1.91)	(8.44)
Slack	0.2186***	−0.3799***
	(3.80)	(-4.67)
Size	0.6457***	0.5411***
	(65.93)	(70.69)
Leverage	−0.1655***	0.1969***
	(-4.06)	(2.79)

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(*continued*)

Market to Book	−0.0058**	−0.0631***
	(-2.14)	(-8.89)
PPE	1.0296***	1.8150***
	(16.66)	(21.23)
HHI	−1.1630***	−2.2851***
	(-5.27)	(-20.19)
CVI	0.3282	−0.9949**
	(0.40)	(-2.20)
GDP	−0.0018	0.0339***
	(-0.85)	(5.79)
Constant	−1.4631***	1.8532***
	(-3.34)	(5.86)
Industry Effect	Yes	No
Year Effect	Yes	Yes
Continent Effect	Yes	Yes
Observations	24,101	24,101

The Table presents the results of the regression analysis using the Entropy balancing approach. Panel A reports the summary statistics while panel B presents the results of the regression analysis. Details of variable description are provided in Appendix A. T-statistics are reported in parentheses. ***, **, & * indicate significance level at below 0.1%, 5% and 10% respectively.

Appendix F. Robustness Firm Fixed Effect – Mahalanobis Matching

	CO2 Natural Log	CO2 Natural Log
Emission Trading	0.0246**	0.0246**
	(1.69)	(1.69)
Controls	Yes	Yes
Constant	10.1042***	10.1042***
	(13.66)	(13.66)
Year Effect	Yes	Yes
Firm Effect	Yes	Yes
Continent Effect	Yes	Yes
Industry Effect	Yes	Yes
Observations	8900	8900

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