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The effect of science-based targets on corporate emissions trajectories

Fernando Loaiza

fernando.loaiza@ip.mpg.de

Max Planck Institute for Innovation and Competition https://orcid.org/0000-0002-1428-6682

Benedict Probst

Max Planck Institute for Innovation and Competition https://orcid.org/0000-0002-1149-8938

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The effect of science-based targets on corporate emissions trajectories

Abstract

Voluntary corporate climate targets are intended to reduce emissions, but their effects may depend on how those emissions are accounted for. Using CDP disclosures for 4,186 firms between 2016 and 2025 and a staggered difference-in-differences design, we find that science-based target approval lowers market-based Scope 2 emissions by about 27%, while Scope 1 and location-based Scope 2 remain unchanged. The renewable share of purchased electricity rises by 7.8 percentage points, with no change in electricity consumption or grid carbon intensity. The shift runs through contractual sourcing, with the largest response in unbundled energy attribute certificates, which are bought separately from electricity supply, without necessarily adding new generation. Market-based accounting can therefore register reductions without a corresponding change in physical emissions. Contractual sourcing can support decarbonization, but assessing progress toward corporate climate goals requires distinguishing it from changes in energy use and the electricity system.

Voluntary corporate climate targets now cover more than 11,000 companies representing over 40% of global market capitalization [1]. A leading framework for setting and assessing these targets is the Science Based Targets initiative (SBTi) [2]. SBTi approval is often seen as a signal that a firm's targets are credible and aligned with science-based emissions pathways [3, 4]. Whether this credibility translates into reductions in firms' physical emissions remains less clear.

Research has raised questions about how far corporate climate targets lead to physical decarbonization. Studies have pointed to differences in target-setting methods, governance and the metrics used to measure progress [4–7]. Existing evaluations focus largely on whether SBTi participation is associated with improved aggregate Scope 1 and Scope 2 emissions performance [8, 9]. Companies with ambitious targets make greater progress when those targets are approved by the SBTi [10]. However, the effects on individual emission scopes are still not clear. Most studies combine the two Scope 2 accounting methods or study SBTi participation rather than formal target approval. Schüder and Zülch [11] come closest to this distinction. They find lower Scope 1 and market-based

Scope 2 carbon intensity, but no change in location-based Scope 2 or Scope 3. However, their treatment starts at commitment rather than formal approval. They also suggest potential explanations for these results, but do not test the underlying mechanisms directly. Ruiz Manuel and Blok [12] show descriptively that most large SBTi and RE100 members reduce emissions by purchasing renewable electricity rather than by changing their operations. Whether formal approval changes emissions across individual scopes, and what drives the different responses, therefore remains untested.

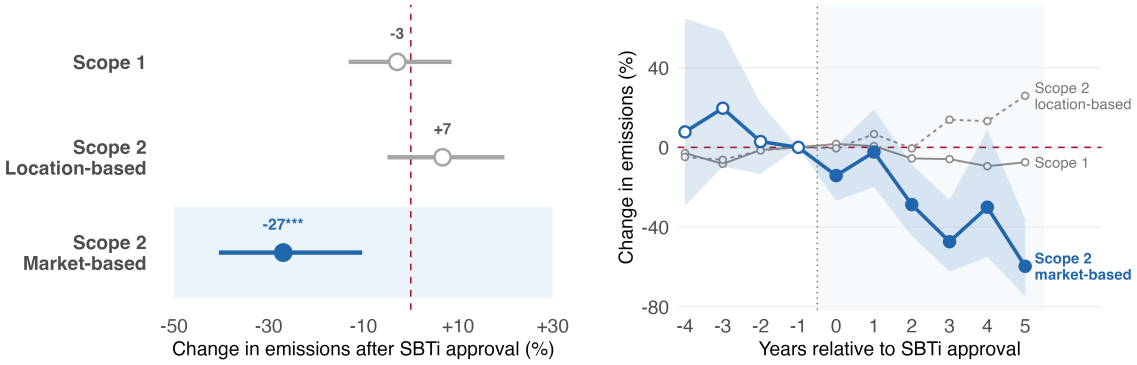
Voluntary environmental programmes can influence firm behaviour by linking participation to reputational benefits [13]. Evidence from environmental certification also shows that firms respond to the metrics used to assess their performance [14]. This is important for corporate emissions because different measures require different responses. Reducing Scope 1 usually requires changes in fuel use, production processes or energy efficiency. Location-based Scope 2 depends on electricity use and the carbon intensity of the local grid, which firms influence mainly through efficiency measures or electrification rather than through procurement. Market-based Scope 2 instead depends on how firms purchase electricity [15]. Firms can use energy attribute certificates (EACs, also known as renewable energy certificates or guarantees of origin), green tariffs or power purchase agreements (PPAs), which differ in how closely the contractual claim is linked to the underlying electricity generation [16, 17]. These instruments can lower market-based Scope 2 even if electricity use and grid emissions do not change [18, 19]. Firms can also generate electricity on site, which reduces the electricity they purchase rather than changing how that electricity is accounted for. The three measures can therefore respond to different changes in firm behaviour and in the electricity system. This allows us to ask whether SBTi approval leads to reductions across emission scopes or whether the response depends on the metric included in the approved target.

The SBTi process lets us test this because we observe both when a target is approved and which emissions metric it covers. Firms first commit to setting a target and later submit it for technical review. Once approved, the target is added to the public registry and the firm is expected to report progress each year. We therefore treat approval, rather than the initial commitment, as the key event. During our study period, firms could set Scope 2 targets using different accounting methods. Market-based Scope 2 and Scope 3 became more common among approved targets, while location-based Scope 2 coverage declined (Supplementary Fig. 1). This variation allows us to test whether firms respond to the specific metric included in their approved target.

Results

Emissions respond only on the market-based measure

We use CDP disclosures for 4,186 firms observed between 2016 and 2025. The data report firms' SBTi status together with their emissions and energy use. Using a staggered difference-in-differences design, we find that approval reduces market-based Scope 2 emissions by about 27%, with no significant effect on Scope 1 or location-based Scope 2 emissions (Fig. 1a). The event studies show no evidence of different pre-approval trends. After approval, market-based Scope 2 emissions fall, while Scope 1 and location-based Scope 2 remain broadly stable (Fig. 1b). Although Scope 1 emissions are covered by most approved SBTi targets throughout the sample (Supplementary Fig. 1), we do not find evidence that approval leads to short-run reductions in firms' directly controlled emissions. This differs from Schüder and Zülch [11], who find lower Scope 1 carbon intensity following SBTi participation, defined from the commitment stage. The location-based Scope 2 result is also important because it shows that the market-based decline is not matched by a similar fall in the emissions linked to firms' electricity use.



(a) Effects by emission scope

(b) Event studies

Figure 1: **SBTi approval reduces market-based Scope 2 emissions only.** Panel (a) shows average treatment effects on the treated for each emission scope, estimated with the Sun and Abraham (2021) staggered difference-in-differences estimator. Blue estimates are statistically significant at the 5% level, grey estimates are not. Panel (b) shows event-study estimates for the same three outcomes, in years relative to approval. Market-based Scope 2 is shown in blue with its 95% confidence interval. Scope 1 and location-based Scope 2 are shown as grey reference lines, and their intervals are reported in panel (a). The period $t = -1$ is the reference year and is normalised to zero by construction. Pre-approval coefficients are individually insignificant for all three outcomes. The window is truncated to $t - 4$ to $t + 5$ for legibility. The estimates in panel (a) aggregate the full window.

Electricity use and grid carbon intensity do not change

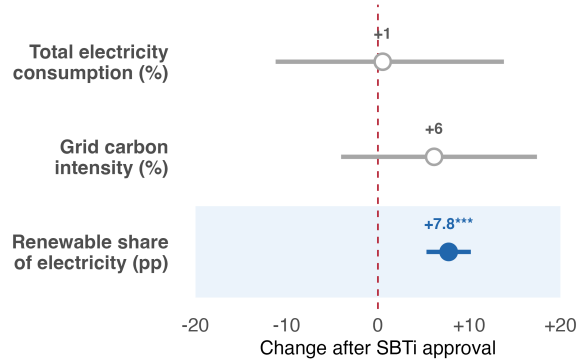
We then examine the electricity outcomes behind the market-based Scope 2 decline. After approval, the renewable share of purchased electricity rises by 7.8 percentage points, while total electricity consumption and implied grid carbon intensity do not change (Fig. 2a). The lack of change in either electricity use or grid carbon intensity suggests that neither lower demand nor a cleaner electricity grid is the main explanation. These measures capture changes at the firm's own point of consumption. A contract that supports new generation elsewhere on the system need not move a firm's own location-based factor within our observation window. The rise in the renewable share is exactly the type of change captured by market-based accounting, where renewable attributes are assigned through contractual sourcing. We find a similar pattern among both combustion-intensive and electricity-intensive firms (Supplementary Fig. 2).

The change runs through contractual instruments

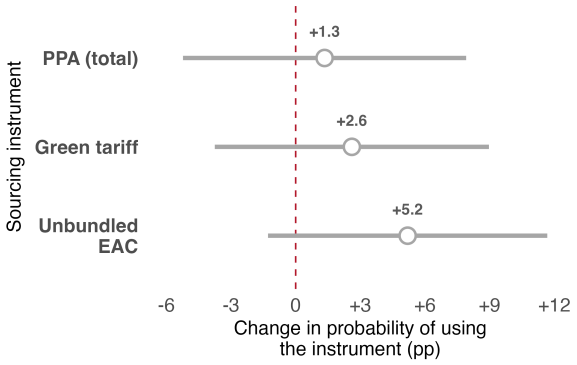
The pattern becomes clearer when we look at individual procurement instruments. Approval does not clearly affect whether firms use PPAs, green tariffs or unbundled EACs, as these estimates are not statistically significant (Fig. 2b). The clearer change is in the share of electricity covered by these instruments. Coverage by unbundled EACs rises by 5.1 percentage points and coverage by PPAs by 1.8 percentage points, while green tariffs show no significant change (Fig. 2c). The largest effect is for unbundled EACs. EACs have historically been the most widely used corporate procurement instrument, while the use of PPAs has grown substantially over the past decade [16]. Because these certificates are bought separately from electricity supply, they can increase reported renewable coverage without changing electricity consumption or the carbon intensity of the local grid. This distinction matters because the link between unbundled certificates and additional renewable generation is generally less direct than for project-linked PPAs [17, 20, 21]. The largest response therefore runs through the instrument whose link to additional generation is least direct. This pattern suggests that the decline in market-based Scope 2 emissions reflects greater contractual coverage of electricity purchases, through EACs or PPAs, rather than changes in physical electricity demand.

The response tracks the metric named in the target

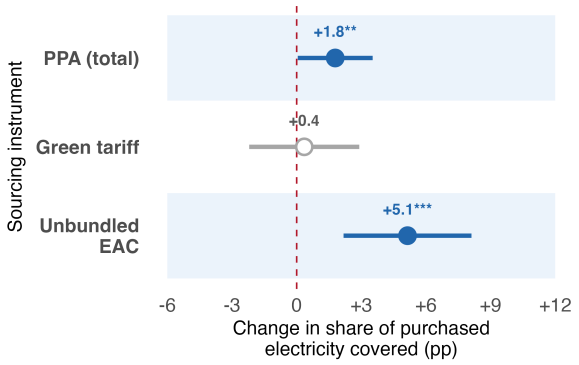
We also test whether these changes depend on the design of the approved target. Among firms whose targets cover market-based Scope 2, approval reduces market-based emissions by about 37%. This effect is larger than the pooled 27% estimate, which also includes approved firms whose targets do not cover market-based Scope 2. Firms without such coverage show no corresponding decline, and the difference between the two groups is



(a) Electricity consumption, renewable share and grid intensity



(b) Whether the instrument is used



(c) Share of electricity it covers

Figure 2: **The reduction comes from how electricity is purchased, not how much.** Panel (a) shows effects on purchased electricity, the renewable share of purchased electricity, and implied grid carbon intensity. The renewable share rises by 7.8 percentage points while consumption and grid intensity are unchanged. Panels (b) and (c) show effects on the contractual instruments behind that shift, estimated on the same sample and specification as Fig. 1. Panel (b) is the extensive margin, the change in the probability that a firm uses the instrument at all. Panel (c) is coverage, the change in the share of purchased electricity the instrument accounts for. Blue estimates are significant at the 5% level, grey are not. Panels (b) and (c) share an x-axis scale, but the coverage intervals are narrower, which is why smaller point estimates reach significance there.

statistically significant (Supplementary Fig. 3). The corresponding differences are not significant for Scope 1 or location-based Scope 2. This suggests that the response is specific to the accounting metric included in the approved target. A separate concern is that the result could simply reflect firms targeting an intensity measure. This is unlikely, since 91.6% of market-based Scope 2 targets in our sample are absolute.

Discussion

Combined with the electricity and procurement results, the evidence points to a response concentrated in contractual renewable sourcing, consistent with the descriptive evidence

of Ruiz Manuel and Blok [12]. Scope 1 and location-based Scope 2, which require more direct changes in operations or the electricity system, do not respond in a similar way. Contractual procurement can still support physical decarbonization, especially when it helps bring new renewable generation online. But a fall in market-based emissions does not necessarily mean that electricity demand or the local grid mix changes at the same time. Market-based Scope 2 allocates existing emissions according to contracts. It does not show whether procurement adds generation to the system.

This is relevant for the Corporate Net-Zero Standard Version 2.0, published in June 2026 [22] and effective from February 2027. The revised standard sets target ambition on the physical inventory, including location-based Scope 2, which speaks directly to the pattern we document. Unbundled certificates remain eligible instruments and hourly matching is reported rather than required, so the channel is narrowed rather than closed. Our results suggest that the metric used to define progress can shape how firms respond to the target. Firms may respond strongly, but that response can be concentrated in the emissions measure the target rewards. It is therefore important to distinguish changes in contractual procurement from changes in energy demand, production processes and the physical electricity system when assessing how far corporate climate targets lead to system-level decarbonization.

Methods

Data and sample

We combine CDP corporate disclosures from 2016-2025 with firm-level information on SBTi target approval. The main outcomes are Scope 1, location-based Scope 2 and market-based Scope 2 emissions, measured in metric tonnes of CO_2e and transformed as $\log(1 + \text{emissions})$. The market-based sample is smaller because many firms report only location-based Scope 2 emissions. We exclude Scope 3 because the categories and estimation methods used by firms vary substantially across disclosures and years.

We define treatment as the first year in which a firm reports an SBTi-approved target. Firms that have committed to the SBTi but have not yet received approval are not treated. Once approved, firms remain treated for the rest of the panel. Treated firms must have at least three observations before and three observations after approval. Never-approved firms must be observed for at least six years. The resulting sample contains 33,741 firm-year observations from 4,186 firms, including 601 firms that receive approval during the study period and 3,585 that remain unapproved.

Energy and sourcing measures

We also use CDP energy disclosures from 2018-2025 to measure purchased electricity, the reported renewable share of purchased electricity and implied grid carbon intensity, calculated as location-based Scope 2 emissions divided by purchased electricity. Approved Scope 2 targets are classified as absolute, intensity-based or both. Absolute targets predominate, at 91.6% of firms with market-based Scope 2 coverage, so the target-coverage analysis uses them and we do not estimate separate effects for the smaller intensity-based group.

Since 2018, CDP has asked firms to itemise the low-carbon electricity behind their reported market-based Scope 2 figure. Each row reports a sourcing method and a volume in megawatt-hours. Because the wording of these options changed across questionnaire versions, we harmonise them to a common set of methods. We focus on three instruments, unbundled energy attribute certificates (EAC), green tariffs and power purchase agreements (PPA), and express each as a share of the firm's purchased electricity. Firm-years that do not answer this question are treated as missing rather than as zero, because answering is itself more common after approval (78.8% of approved firm-years against 64.3% of the rest).

Estimation

We estimate the effect of SBTi approval using the interaction-weighted difference-in-differences estimator of Sun and Abraham. The estimator accommodates variation in approval timing and allows treatment effects to differ across cohorts and years since approval. Firms that never receive approval during the panel form the comparison group. All models include firm and year fixed effects, as well as country-by-year, industry-by-year and baseline-emitter-by-year fixed effects to absorb differential shocks across firms' geographic, sectoral, and initial emissions profiles. We additionally control for whether executive compensation is linked to climate performance. Standard errors are clustered by firm.

Identification and robustness

Identification requires that approved and never-approved firms would have followed similar outcome trends in the absence of approval, conditional on the included controls and fixed effects. We assess this assumption using event-study estimates and find no evidence of differential pre-approval trends for the three emissions outcomes. Firms might start acting at commitment rather than at approval. We see no decline before approval, and the decline we do find is specific to the metric named in the approved target rather than shared across firms in the SBTi process. As a robustness test, we repeat the analysis after matching

each approved firm to up to three never-approved firms based on pre-approval emissions levels and trends, prior market-based Scope 2 reporting, climate-linked incentives, country and industry. The matched estimates are similar to the main results.

We also test sensitivity to outliers by winsorizing and trimming outcomes at the 1st and 99th percentiles. The market-based Scope 2 effect remains negative and statistically significant across these specifications (Supplementary Table 1). The results for Scope 1 and location-based Scope 2 remain largely unchanged.

Heterogeneity by target coverage

For the target-coverage heterogeneity analysis, we estimate the model separately for firms with and without market-based Scope 2 coverage. We then test whether the treatment effects differ between the two groups using 2,000 firm-clustered bootstrap replications, re-estimating both subgroup models in each resample and calculating the difference between their average treatment effects. This accounts for sampling uncertainty in the two subgroup estimates and for the fact that both groups are compared with the same pool of never-approved firms. The difference is highly significant for market-based Scope 2, but not for Scope 1 or location-based Scope 2.

Instrument outcomes

The instrument analysis uses the same sample and specification as the emissions results, with the outcome replaced, so the two sets of coefficients are directly comparable. Of the 9,468 firm-years used to estimate the market-based Scope 2 effect, 6,426 answer the sourcing question, and 392 approved firms are observed both before and after approval. Firms seen on only one side contribute nothing once their own fixed effect is absorbed, so we report that count.

For each instrument we estimate two outcomes. The first is whether the firm uses it at all. Because that outcome is binary, its coefficients are changes in the probability of use and are reported in percentage points. The second is the share of the firm's purchased electricity the instrument covers, which captures how much of its consumption carries a renewable attribute. Coverage is defined over all firm-years that answer the sourcing question, with zero for firms reporting no volume, and is therefore not conditional on being a user. Reported volumes occasionally exceed a firm's total purchased electricity, which reflects unit errors in the disclosures rather than firm behaviour, so coverage is capped at 100%. Certificate coverage estimates range from 4.2 to 5.2 percentage points across five alternative treatments of these rows, all significant at the 1% level.

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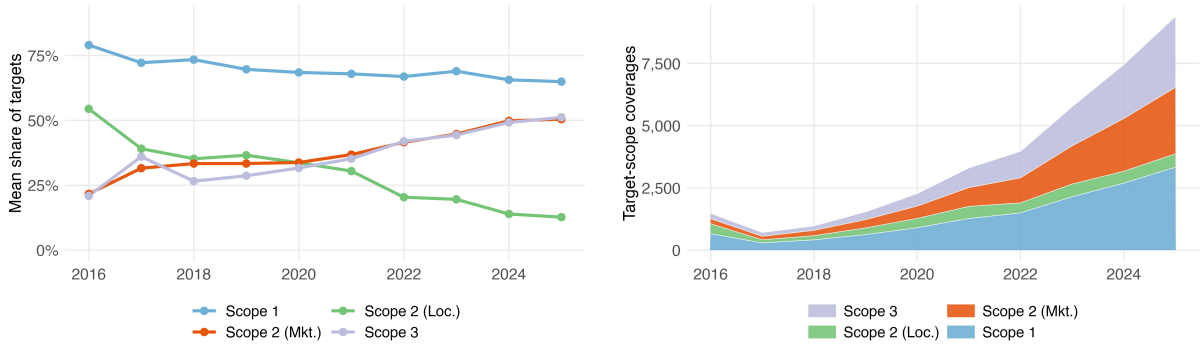
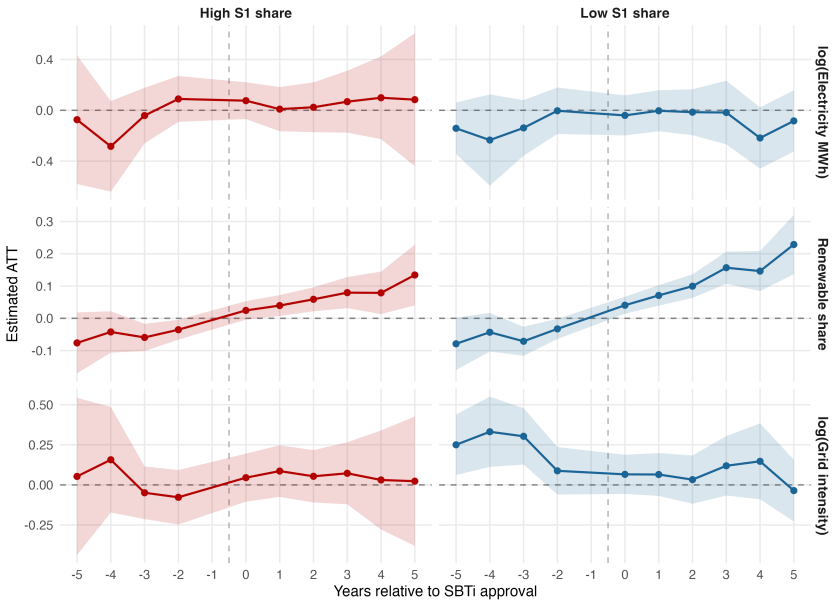


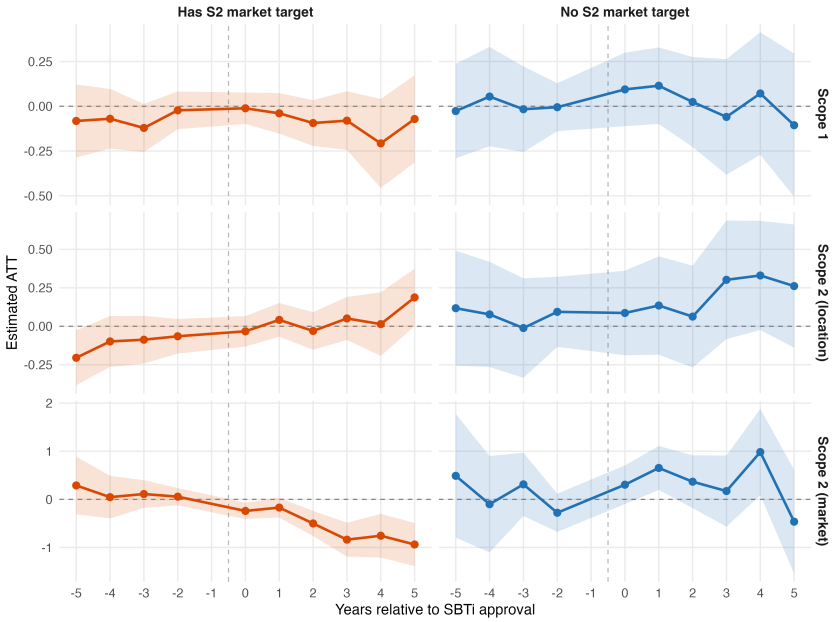
(a) Scope composition over time

(b) Growth in approved target scope coverages

Supplementary Fig. 1: **Evolution of scope coverage among approved SBTi targets.** Panel (a) shows average share of approved targets covering each scope. Panel (b) shows absolute counts. Market-based Scope 2 coverage has risen from 22% to 51% of approved targets between 2016 and 2025. Location-based Scope 2 has declined from 55% to 13%.



Supplementary Fig. 2: **Renewable procurement rises in both emission profiles, while consumption and grid intensity do not.** Event-study estimates for purchased electricity (top), renewable share (middle) and implied grid carbon intensity (bottom), for combustion-intensive (left) and electricity-intensive (right) firms. Shaded bands are 95% confidence intervals.



Supplementary Fig. 3: **Reductions track target accounting method.** Event-study coefficients by emission scope (rows) and Scope 2 target type (columns). Left: firms with market-based Scope 2 targets show large reductions in market-based emissions only. Right: firms without market-based Scope 2 coverage show no corresponding reduction in market-based emissions and no detectable change in Scope 1 or location-based Scope 2. The difference between the two groups is statistically significant for market-based Scope 2, but not for Scope 1 or location-based Scope 2. Shaded bands are 95% confidence intervals.

Supplementary Table 1: Effects of SBTi approval on firm emissions

	Scope 1	Scope 2 Location	Scope 2 Market
Panel A. Full sample			
Raw	−0.029	0.065	−0.314***
	(0.057)	(0.059)	(0.105)
Winsorized	−0.009	0.064	−0.298***
	(0.053)	(0.051)	(0.101)
Trimmed	0.048	0.084*	−0.263***
	(0.052)	(0.044)	(0.101)
Observations	33,562	33,419	9,468
Panel B. Propensity-score matched sample			
Raw	−0.038	0.059	−0.326***
	(0.059)	(0.061)	(0.108)
Winsorized	−0.031	0.055	−0.308***
	(0.057)	(0.059)	(0.106)
Trimmed	−0.027	0.050	−0.277***
	(0.055)	(0.057)	(0.104)

Notes: Entries report average treatment effects on the treated (ATT) estimated using the Sun & Abraham (2021) staggered difference-in-differences estimator. Outcomes are $\log(1 + \text{emissions})$. Panel A reports estimates for the full sample. Panel B reports estimates for the propensity-score matched sample, where each treated firm is matched to up to three never-treated firms based on pre-treatment emissions, emission trends, reporting history, and observable firm characteristics (caliper = 0.2 SD). All specifications include firm, year, country×year, industry×year, and baseline-emitter×year fixed effects, as well as controls for climate incentives. Winsorized and trimmed specifications use the 1st and 99th percentiles. Standard errors clustered at the firm level are reported in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.