

Supplementary Materials

Environmental Ratings and Subsequent Reported Emissions Intensity: A Layered Validity Test in China and Korea

Contents and evidence boundary

This file reports supplementary methods, original model coverage, external-source provenance and reviewer-requested analyses in Tables S1–S23. It contains aggregate results and measurement definitions. Licensed firm-level observations and authenticated source rows are retained in the controlled research record.

- Supplementary Methods S1: Field-specific calendar alignment and common support.
- Supplementary Methods S2: Model families, inference, multiplicity, and external validation.
- Table S1: Korean Greenhouse Gas Inventory and Research Center (GIR) boundary sensitivity results.
- Table S2: Primary-model sample-flow detail.
- Table S3: External-source provenance and redistribution boundary.
- Table S4: Public variable and construct dictionary.
- Table S5: Complete registered-model map.
- Table S6: All 18 non-core model–window fits.
- Table S7: Firm-cluster bootstrap agreement uncertainty.
- Table S8: Common-window descriptive statistics and within-firm and between-firm variation.
- Supplementary Methods S3 and Tables S9–S19: reviewer-requested selection, precision, score variation, horizon, prior-outcome, agreement, small-cluster and strict-reported analyses. Supplementary Methods S4 and Tables S20–S23 provide documentary anchors, measurement diagnostics, covariance checks and prior-study effect-scale context.

Supplementary Methods S1. Field-specific calendar alignment

The reconstruction does not assign a single calendar year to FY0, the workbook's current relative fiscal-period label. For each firm, LSEG field, and relative fiscal period, the field-specific period-end date determines the calendar year. Values without directly retrievable field dates are excluded from calendar-year inference. This rule prevents rating, environmental, and financial fields with different reporting lags from being joined under one nominal fiscal label.

The reconstructed skeleton covers 324 coverage-screened firms and calendar years 2014 through 2025. The common China–Korea exposure window is 2019 through 2023, with next-year outcomes observed through 2024. The extended 2015 through 2023 exposure window is a coverage sensitivity analysis. Missing values are neither forward-filled nor coded as zero.

Timing alignment does not resolve disagreement in organizational scope. LSEG company-group values and Korean GIR legal-entity or facility values remain separate unless their entity and emissions boundaries are demonstrably comparable. Agreement and criterion-validity analyses therefore use explicit boundary scenarios instead of mechanical pooling or imputation.

Supplementary Methods S2. Models and inferential families

The four primary models combine environmental-pillar and emissions scores with two next-year log intensity series: the provider total field, defined as direct Scope 1 plus indirect Scope 2, and the separately summed combined Scope 1 and Scope 2 series, which can include provider estimates. Both use positive emissions divided by positive USD consolidated revenue. Scores retain original country–industry–year standardization with a country–year fallback for cells smaller than five or with zero variance. The strictly reported sensitivity is additional and appears in Table S19.

Models include firm fixed effects, country-by-year fixed effects, TRBC two-digit-industry-by-year fixed effects, four current-period financial controls, and interactions between each financial control and the Korea indicator. We use the type-1 cluster-robust covariance estimator (CR1), clustered by firm. The China slope, Korea slope, and Korea-minus-China difference are estimated as two-sided contrasts. The 12 primary contrasts are adjusted with the Benjamini–Hochberg (BH) procedure separately in the common and extended windows.

Country-reference coding and the quantity estimated

The primary estimand is a conditional within-firm slope per one-unit-higher standardized score, with the standardization cells and fallback stated above. It is not an absolute raw-rating point or a within-firm SD. Let $K_i = \text{Korea}(i)$, $C_i = 1 - K_i$ and S_{it} denote the standardized score. The original score component $[\beta_{\text{CN}} + \beta_{\text{Diff}} K_i] S_{it}$ equals $[(\beta_{\text{CN}} + \beta_{\text{Diff}}) - \beta_{\text{Diff}} C_i] S_{it}$. Thus, a Korea-reference formulation uses $\beta_{\text{KR}} = \beta_{\text{CN}} + \beta_{\text{Diff}}$ and $\beta_{\text{CN-KR}} = -\beta_{\text{Diff}}$. For every control, $\gamma_{\text{KR}} = \gamma + \delta$ and $\delta_{\text{CN-KR}} = -\delta$. The sample, score standardization and all absorbed effects are retained.

For $b = (\beta_{\text{CN}}, \beta_{\text{Diff}})'$ and $T = [[1, 1], [0, -1]]$, the transformed coefficients and covariance are $b^* = Tb$ and $V^* = TVT'$. In particular, $\text{Var}(\beta_{\text{KR}}) = V11 + V22 + 2V12$ and $\text{Var}(\beta_{\text{CN-KR}}) = V22$. Country-specific slopes and standard errors therefore do not depend on the chosen reference. An original Korea-minus-China interval $[L, U]$ becomes $[-U, -L]$ for China minus Korea, with the same two-sided p value. The BH families contain the same hypotheses, so their adjusted q values are unchanged. This is an exact re-expression of one model, not a new fit or a different cross-country standardization.

The Corporate Climate Action Transparency Index (CATI) correlations test action/disclosure construct convergence. The IPE result is a retrieval-time accountability boundary dated 9 August 2026, not a historical panel. Korean GIR models use the restricted 22-firm overlap with both CR1 inference and 9,999 restricted wild-cluster bootstrap replications. A result is classified as robust only when both the CR1-adjusted and wild-bootstrap-adjusted q values are below 0.05, the firm-clustered 95% confidence interval excludes zero, and the common-window estimate has the same direction as the corresponding extended-window estimate.

LSEG-GIR agreement is evaluated using Pearson and Spearman correlations, Lin's concordance coefficient, and the two-way absolute-agreement single-measure intraclass correlation, $\text{ICC}(A,1)$, on paired log total emissions. We also report geometric and median LSEG/GIR ratios, descriptive Bland-Altman ratio limits, and the shares within $\pm 10\%$, $\pm 20\%$ and a factor of two. The following procedure constructs whole-firm percentile intervals separately for each of the five agreement samples in Table S16. It differs from the null-imposed wild-cluster bootstrap for the GIR regression coefficients.

Whole-firm percentile bootstrap for Table 5

1. Define the scenario's observed paired sample and sort firms by identifier. Store each firm's complete paired history as one cluster and compute point estimates from the original pooled observations. The full sample has 182 pairs from 22 firms; excluding the complete histories of the four documentary-supported mismatch firms leaves 142 pairs from 18 firms. The other three scenarios are defined in Table S16.
2. Initialize `numpy.random.default_rng(20260829)` separately for each scenario. For each replicate, draw G cluster indices independently with replacement and equal probability from the G observed firms.
3. Concatenate all paired years of the selected firms. Both emissions-source values for a firm-year remain together; selecting a firm twice duplicates its complete paired history. Do not resample years or the two sources independently. Exactly G firm histories are selected per draw, counting duplicates, but the number of pairs can vary because firms have unequal observed history lengths.
4. Recalculate each agreement statistic from the concatenated pairs and repeat for 9,999 draws. The pooled statistics are pair-weighted: equal-probability cluster selection does not convert the point estimate into an equally firm-weighted average.
5. Use the 2.5th and 97.5th percentiles of finite replicate values, calculated with `numpy.quantile` and its default linear interpolation, as pointwise 95% confidence bounds. Every one of the 19 archived statistics in each of the five scenarios has 9,999 finite replicates. These are not simultaneous confidence bands.

For $x = \log(\text{LSEG total emissions})$, $y = \log(\text{GIR emissions})$ and $d = x - y$, Lin concordance is $2s_{xy}/[s_x^2 + s_y^2 + (\bar{x} - \bar{y})^2]$, using sample variances and covariance (denominator $n-1$). The geometric mean ratio is $\exp(\text{mean } d)$, the median ratio is $\text{median}(\exp d)$, and the descriptive Bland-Altman ratio limits are $\exp(\text{mean } d \pm 1.96 \text{ SD}(d))$, also with sample SD. Tolerance shares count the pooled observed ratios in $[0.9, 1.1]$, $[0.8, 1.2]$ and $[0.5, 2.0]$. The ratio limits describe the observed discrepancy distribution; they are not bootstrap confidence bounds or a universal interchangeability threshold.

The Table 5 columns map to `A0_ALL_182_PAIRS` and `A3_EXCLUDE_4_PERSISTENT_FIRMS` in `aggregates/boundary/agreement_metrics_with_cluster_bootstrap.csv` within the code archive. The stored Lin concordances are 0.7344310 [0.4152404, 0.9721040] and 0.9893271 [0.9709175, 0.9964793], respectively; rounding

gives the displayed 0.734 [0.415, 0.972] and 0.989 [0.971, 0.996]. These point estimates are computed from the two original observed samples, not from bootstrap means. The implementation is `original_scripts/paper1_revision_boundary_20261007.py`, functions `agree_metrics` and `run_agreement`. The increase in agreement is a documentary-informed exclusion sensitivity, not positive verification of every remaining historical boundary.

Table S1. Korean rating to GIR boundary sensitivity models

Boundary scenario	Window	Environmental-pillar beta [95% CI]; CR1-adjusted/wild-bootstrap-adjusted q	Emissions-score beta [95% CI]; CR1-adjusted/wild-bootstrap-adjusted q
All 22 firms	Common 2019-2023	0.086 [-0.025, 0.197]; 0.201/0.245	-0.026 [-0.067, 0.015]; 0.201/0.245
All 22 firms	Extended 2015-2023	0.037 [-0.095, 0.169]; 0.565/0.687	-0.029 [-0.091, 0.033]; 0.565/0.687
Exclude 29 discrepant firmoutcome-year pairs	Common 2019-2023	0.070 [-0.048, 0.187]; 0.227/0.381	-0.035 [-0.076, 0.006]; 0.184/0.257
Exclude 29 discrepant firmoutcome-year pairs	Extended 2015-2023	0.028 [-0.123, 0.180]; 0.700/0.833	-0.044 [-0.111, 0.023]; 0.367/0.382
Exclude four persistently boundary-incompatible firms	Common 2019-2023	0.070 [-0.048, 0.187]; 0.227/0.381	-0.035 [-0.076, 0.006]; 0.184/0.257
Exclude four persistently boundary-incompatible firms	Extended 2015-2023	0.037 [-0.108, 0.182]; 0.595/0.757	-0.032 [-0.108, 0.044]; 0.595/0.757
Exclude all five discrepant firms (strict scenario)	Common 2019-2023	0.121 [0.023, 0.220]; 0.038/0.280	-0.027 [-0.083, 0.029]; 0.319/0.341
Exclude all five discrepant firms (strict scenario)	Extended 2015-2023	0.042 [-0.134, 0.218]; 0.621/0.832	-0.072 [-0.151, 0.007]; 0.144/0.165

Note. Each result reports beta [95% confidence interval (CI)], followed by the CR1-adjusted q value and the wild-cluster-bootstrap-adjusted q value, in that order. The strict 17-firm common-window environmental-pillar result satisfies the CR1 $q < 0.05$ rule but not the wild-bootstrap rule and therefore fails the prespecified joint criterion. None of the scenarios is classified as robust. In the common window, excluding 29 discrepant firmoutcome-year pairs and excluding four persistently boundary-incompatible firms produce the same final set of 90 observations from 18 firms after the prespecified two-observation-per-firm rule; identical coefficients are therefore expected.

Table S2. Primary-model sample-flow detail

Model	Window	Country	Eligible	Score observed	Outcome at t+1	Controls	Final complete-case rows	Firms
R1-P01	Extended 2015-2023	China	1881	1419	1357	1844	1273	209
R1-P01	Extended 2015-2023	Korea	1035	981	923	1011	901	115
R1-P01	Common 2019-2023	China	1045	1027	1027	1044	1008	209
R1-P01	Common 2019-2023	Korea	575	575	563	575	563	115
R1-P02	Extended 2015-2023	China	1881	1419	1357	1844	1273	209

Model	Window	Country	Eligible	Score observed	Outcome at t+1	Controls	Final complete-case rows	Firms
R1-P02	Extended 2015-2023	Korea	1035	981	923	1011	901	115
R1-P02	Common 2019-2023	China	1045	1027	1027	1044	1008	209
R1-P02	Common 2019-2023	Korea	575	575	563	575	563	115
R1-P03	Extended 2015-2023	China	1881	1419	1550	1844	1405	209
R1-P03	Extended 2015-2023	Korea	1035	981	996	1011	967	115
R1-P03	Common 2019-2023	China	1045	1027	1045	1044	1026	209
R1-P03	Common 2019-2023	Korea	575	575	573	575	573	115
R1-P04	Extended 2015-2023	China	1881	1419	1550	1844	1405	209
R1-P04	Extended 2015-2023	Korea	1035	981	996	1011	967	115
R1-P04	Common 2019-2023	China	1045	1027	1045	1044	1026	209
R1-P04	Common 2019-2023	Korea	575	575	573	575	573	115

Note. Model identifiers and interpretations are as follows: R1-P01, environmental-pillar score to next-year total emissions intensity; R1-P02, emissions score to next-year total emissions intensity; R1-P03, environmental-pillar score to next-year combined Scope 1 and Scope 2 emissions intensity; and R1-P04, emissions score to next-year combined Scope 1 and Scope 2 emissions intensity. Eligible is the number of firm–exposure–year rows in the window before variable-specific missingness. Score observed, Outcome at t+1, and Controls are separate availability counts rather than sequential attrition stages. The Final complete-case rows column reports the estimation sample. Counts are aggregate and non-identifying.

Table S3. External-source provenance and reuse boundary

Source	Release/file	Access date	Role	Time/entity boundary	Redistribution boundary
LSEG Workspace (Legacy ESG and related environmental and financial fields)	Authenticated Workspace exports, 10-12 August 2026; Legacy ESG fields interpreted using LSEG D&A ESG Scores Methodology, document version 2.0, model version 1.1, effective 1 July 2026	2026-08-10 to 2026-08-12	ratings, reported outcomes, field dates, controls	retrospective 2026 snapshot; not point-in-time; provider company/group	third-party licensed data accessed through an authorized institutional subscription; no firm-level values or identifiers redistributed; aggregate results only
IPE (IPE_CATI_LISTE D_2022)	Listed-company CATI report 2022; SHA-256 80844BAF2B759C AC2B8272FDE27E 2CB27856FE24DF 94FCD2C65662319 42E7CFD	2026-08-09	China information/action validation	2022 release; listed company as reported	row-level terms not confirmed; aggregates only

Source	Release/file	Access date	Role	Time/entity boundary	Redistribution boundary
IPE (IPE_CATI_LISTED_2023)	Listed-company CATI report 2023; SHA-256 B16D7D82497177F05698C0094025DFA9C8A7BC045C279DA8333B26BC10EBCF71	2026-08-09	China information/action validation	2023 release; listed company as reported	row-level terms not confirmed; aggregates only
IPE (IPE_RETRIEVAL_20260809)	Authenticated environmental-performance retrieval snapshot	2026-08-09	China accountability boundary	retrieval time only; displayed entity	authenticated rows excluded
Greenhouse Gas Inventory and Research Center (GIR_STATEMENT_EMISSIONS_2011_2024)	Annual statement emissions Excel files 2011-2024	2026-08-09	Korea regulatory validation and agreement	verified emissions year; regulated legal entity/facility	official downloads; linked company rows excluded from supplementary materials
Financial Supervisory Service OpenDART (OPENDART_CORPCODE_20260809)	Corporation-code archive; SHA-256 D69F08A018AC6657FC3757B1229F08036689139B77894410BABC5C4EB77FA102	2026-08-09	identity linkage	retrieval snapshot; filing corporation	no API key or identity bridge included
World Bank (WORLD_BANK_KR_GDP_DEFLATOR)	GDP deflator indicator NY.GDP.DEFL.ZS	2026-08-09	real Korean revenue denominator	calendar year; national price index	CC BY 4.0 default; attribution required

Note. Stable source URLs and local cryptographic manifests are retained in the controlled research record. ESG denotes environmental, social, and governance; D&A, Data & Analytics; SHA-256, the 256-bit Secure Hash Algorithm checksum; API, application programming interface; GDP, gross domestic product; and CC BY 4.0, the Creative Commons Attribution 4.0 license. This supplement reports source provenance but does not redistribute licensed or authenticated row-level content.

Table S4. Public variable and construct dictionary

Variable	Role	Layer	Time meaning	Boundary/use restriction
environmental_pillar_score_z	predictor	information	field-specific reported period end	LSEG environmental-pillar score standardized under the prespecified country–industry–year rule; access: licensed
emissions_score_z	predictor	information	field-specific reported period end	Legacy LSEG emissions-category score standardized under the same rule; access: licensed
ln_emissions_intensity_revenue_lead1	outcome	reported physical	consecutive calendar year t+1	Log next-year reported total greenhouse gas emissions per revenue unit; access: licensed/derived
ln_scope12_combined_intensity_revenue_lead1	outcome	reported physical	consecutive calendar year t+1	Log next-year combined reported/estimated Scope 1 and Scope 2 emissions per revenue unit; access: licensed/derived

Variable	Role	Layer	Time meaning	Boundary/use restriction
financial_controls	controls	financial	calendar year t	Log assets, return on assets, debt-to-assets, and capital-expenditure-to-revenue; access: licensed/derived
cati_rank_percentile	external criterion	information/action	2022 or 2023 evaluation year	Within-release CATI rank transformed so higher is stronger; access: external source/derived
ipe_retrieval_rank_percentile	external criterion	accountability	retrieval 2026-08-09; not historical	IPE relative rank at retrieval; access: authenticated source/derived
gir_ln_intensity_real_revenue_lead1	external outcome	regulator-verified physical	verified emissions in t+1	Log GIR-verified emissions divided by real revenue from OpenDART separate financial statements (OFS code); access: public source/derived

Note. Variables represent different validity layers. GHG denotes greenhouse gas; ROA denotes return on assets; capex denotes capital expenditure; and OFS is the OpenDART code for separate financial statements. Information/action, reported physical outcomes, retrieval-time accountability, and regulator-verified outcomes are not combined into one cross-country score.

Supplementary results: complete registered-model coverage

The main text prioritizes four rating-to-reported-emissions models. Tables S5 and S6 report the complete prespecified registry and every non-core model–window fit. Model identifiers are retained as reproducibility keys and paired with descriptive predictor and outcome names so that every model remains interpretable without the identifier.

Table S5. Complete registered-model map

Model	Registered tier	Predictor	Outcome	Benjamini–Hochberg family	Interpretive boundary
R1-P01	primary	environmental_pillar_score_z	ln_emissions_intensity_revenue_lead1	R1_PRIMARY_12	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R1-P02	primary	emissions_score_z	ln_emissions_intensity_revenue_lead1	R1_PRIMARY_12	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R1-P03	primary	environmental_pillar_score_z	ln_scope12_combined_intensity_revenue_lead1	R1_PRIMARY_12	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R1-P04	primary	emissions_score_z	ln_scope12_combined_intensity_revenue_lead1	R1_PRIMARY_12	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect

Model	Registered tier	Predictor	Outcome	Benjamini–Hochberg family	Interpretive boundary
R1-S01	resource secondary	resource_use_score_z	ln_energy_intensity_revenue_lead1	R1_RESOURCE_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R1-S02	resource secondary	resource_use_score_z	ln_water_intensity_revenue_lead1	R1_RESOURCE_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R1-S03	resource secondary	resource_use_score_z	ln_waste_intensity_revenue_lead1	R1_RESOURCE_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-P01	commitment primary	long_term_net_zero_target	ln_emissions_intensity_revenue_lead1	R2_COMMITMENT_6	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-P02	commitment primary	tcf reporting	ln_emissions_intensity_revenue_lead1	R2_COMMITMENT_6	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-S01	target conditional	emission_reduction_target_pct_10pp	ln_emissions_intensity_revenue_lead1	R2_TARGET_3	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-S02	verification secondary	environmental_data_independent_verification	ln_emissions_intensity_revenue_lead1	R2_VERIFICATION_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-S03	verification secondary	environmental_data_assurance_standard	ln_emissions_intensity_revenue_lead1	R2_VERIFICATION_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect
R2-S04	management secondary	iso14000_or_ems_certified	ln_emissions_intensity_revenue_lead1	R2_VERIFICATION_9	retrospective within-firm temporal alignment; not point-in-time prediction or causal effect

Note. The registered tier reproduces the original registry classification. For this manuscript, R1-P01 through R1-P04 are the primary models; all nine remaining models are supplementary non-core analyses, including R2 rows whose registry tier contains the word primary. Model identifiers are reproducibility keys rather than conceptual abbreviations. In variable names, z denotes a standardized score, ln denotes the natural logarithm, lead1 denotes the following calendar year, and 10pp denotes a 10-percentage-point increment. BH denotes Benjamini–

Hochberg adjustment; TCFD, Task Force on Climate-related Financial Disclosures; ISO, International Organization for Standardization; and EMS, environmental management system.

Table S6. All non-core registered model–window fits

Model	Window	Complete-case observations/firms	China beta [95% CI] (q)	Korea beta [95% CI] (q)	Korea-minus-China beta [95% CI] (q)
R1-S01	Common 2019-2023	1522/319	0.005 [-0.055, 0.064] (0.881)	-0.041 [-0.101, 0.019] (0.390)	-0.046 [-0.129, 0.038] (0.421)
R1-S01	Extended 2015-2023	2124/319	-0.089 [-0.167, -0.012] (0.160)	0.018 [-0.136, 0.172] (0.815)	0.108 [-0.065, 0.280] (0.331)
R1-S02	Common 2019-2023	1464/312	0.025 [-0.058, 0.108] (0.626)	0.138 [0.013, 0.264] (0.279)	0.114 [-0.036, 0.263] (0.390)
R1-S02	Extended 2015-2023	2034/313	-0.106 [-0.224, 0.012] (0.237)	0.249 [-0.066, 0.564] (0.272)	0.355 [0.024, 0.685] (0.160)
R1-S03	Common 2019-2023	1268/294	0.099 [-0.036, 0.235] (0.390)	0.050 [-0.029, 0.129] (0.390)	-0.050 [-0.204, 0.105] (0.626)
R1-S03	Extended 2015-2023	1722/298	0.090 [-0.041, 0.221] (0.317)	0.146 [-0.126, 0.417] (0.375)	0.056 [-0.235, 0.347] (0.795)
R2-P01	Common 2019-2023	1219/324	-0.029 [-0.192, 0.135] (0.730)	0.090 [-0.126, 0.305] (0.556)	0.119 [-0.154, 0.391] (0.556)
R2-P01	Extended 2015-2023	1334/324	-0.068 [-0.234, 0.097] (0.448)	0.128 [-0.178, 0.434] (0.448)	0.197 [-0.158, 0.551] (0.448)
R2-P02	Common 2019-2023	1219/324	0.089 [-0.149, 0.326] (0.556)	-0.224 [-0.531, 0.084] (0.461)	-0.312 [-0.703, 0.078] (0.461)
R2-P02	Extended 2015-2023	1334/324	0.105 [-0.167, 0.377] (0.448)	-0.358 [-0.798, 0.082] (0.330)	-0.463 [-0.978, 0.052] (0.330)
R2-S01	Common 2019-2023	667/215	0.004 [-0.016, 0.025] (0.679)	-0.007 [-0.020, 0.005] (0.536)	-0.011 [-0.036, 0.013] (0.536)
R2-S01	Extended 2015-2023	748/215	0.003 [-0.016, 0.023] (0.728)	-0.008 [-0.020, 0.004] (0.512)	-0.011 [-0.034, 0.012] (0.512)
R2-S02	Common 2019-2023	1140/324	0.053 [-0.102, 0.207] (0.993)	0.051 [-0.151, 0.254] (0.993)	-0.001 [-0.266, 0.264] (0.993)
R2-S02	Extended 2015-2023	1222/324	0.074 [-0.088, 0.236] (0.647)	0.107 [-0.153, 0.368] (0.647)	0.034 [-0.288, 0.355] (0.837)
R2-S03	Common 2019-2023	1140/324	0.071 [-0.072, 0.214] (0.993)	0.064 [-0.137, 0.265] (0.993)	-0.007 [-0.263, 0.249] (0.993)
R2-S03	Extended 2015-2023	1221/324	0.082 [-0.065, 0.229] (0.647)	0.133 [-0.131, 0.397] (0.647)	0.051 [-0.269, 0.371] (0.837)
R2-S04	Common 2019-2023	1571/324	0.020 [-0.090, 0.131] (0.993)	0.032 [-0.220, 0.285] (0.993)	0.012 [-0.261, 0.285] (0.993)
R2-S04	Extended 2015-2023	2174/324	0.056 [-0.084, 0.196] (0.647)	0.142 [-0.186, 0.469] (0.647)	0.085 [-0.261, 0.432] (0.807)

Note. N denotes complete-case observations; CI, confidence interval; and q, the Benjamini–Hochberg-adjusted p value within the registered family and window. Each contrast reports beta [firm-clustered 95% CI] (q). These supplementary analyses do not replace the 12-test primary family. No model has $q < 0.05$ in either window within its registered family.

Supplementary agreement uncertainty

Table S7 reports percentile intervals from 9,999 firm-cluster bootstrap resamples. Resampling the 22 firms while retaining all observed years for each selected firm preserves the repeated-measures structure. The intervals quantify uncertainty in this selected overlap and do not establish transportability to all Korean listed firms.

Table S7. Firm-cluster bootstrap intervals for LSEG–GIR agreement

Metric	Estimate	Firm-cluster bootstrap 95% CI	Valid replications	Seed
Pearson correlation, log emissions	0.772	[0.520, 0.976]	9999	20260829
Spearman correlation, log emissions	0.789	[0.502, 0.962]	9999	20260829
Lin's concordance correlation coefficient	0.734	[0.415, 0.972]	9999	20260829
Intraclass correlation coefficient, ICC(A,1), absolute agreement	0.735	[0.416, 0.972]	9999	20260829
Geometric mean LSEG/GIR ratio	1.566	[1.125, 2.348]	9999	20260829
Median LSEG/GIR ratio	1.036	[1.004, 1.221]	9999	20260829
Bland–Altman ratio limit, lower	0.193	[0.110, 0.610]	9999	20260829
Bland–Altman ratio limit, upper	12.701	[2.208, 43.368]	9999	20260829
Share within ±10%	53.3%	[37.6%, 69.1%]	9999	20260829
Share within a factor of 2	84.1%	[68.4%, 97.2%]	9999	20260829

Note. Agreement is calculated on log emissions; exponentiating the Bland–Altman limits therefore yields ratios. ICC denotes intraclass correlation coefficient, and CI denotes confidence interval. The point estimates describe observed spread. Firm-cluster bootstrap intervals account for repeated observations without treating the 182 matched firm–year pairs as independent.

Supplementary common-window descriptives

Table S8 separates overall dispersion from within-firm and between-firm variation. Within-firm standard deviation (SD) is calculated after subtracting each firm's mean; between-firm SD is the SD of the firm means. Each statistic uses all available observations for that variable and therefore may not equal the complete-case sample size of any regression. Of 3,006 observed rating records in the reconstructed panel, 2,855 (95.0%) use country–industry–year standardization and 151 (5.0%) use the prespecified country–year fallback. In the original Table S8, within SD uses $\sqrt{\text{within sum of squares}/N}$. The reviewer-added Table S11 uses $\sqrt{\text{within sum of squares}/(N-G)}$; these differing denominators explain its larger within SD. The sum-of-squares share in S11 is unaffected by that SD convention.

Table S8. Common-window descriptive statistics

Variable	Country	N	Mean	SD	P25	Median	P75	Within-firm SD	Between-firm SD
Environmental-pillar score (z)	China	1027	-0.000	1.000	-0.659	0.064	0.762	0.497	0.871
Environmental-pillar score (z)	Korea	575	0.000	1.001	-0.619	0.241	0.722	0.423	0.910

Variable	Country	N	Mean	SD	P25	Median	P75	Within-firm SD	Between-firm SD
Emissions score (z)	China	1027	-0.000	1.000	-0.733	0.103	0.786	0.530	0.850
Emissions score (z)	Korea	575	-0.000	1.001	-0.454	0.309	0.682	0.508	0.865
Next-year log total emissions intensity	China	1027	-9.604	2.314	-11.203	-9.728	-8.085	0.471	2.285
Next-year log total emissions intensity	Korea	563	-10.263	1.883	-11.614	-10.586	-8.921	0.374	1.854
Next-year log combined Scope 1 and Scope 2 intensity	China	1045	-9.642	2.148	-11.169	-9.850	-8.212	0.423	2.110
Next-year log combined Scope 1 and Scope 2 intensity	Korea	573	-10.209	1.821	-11.506	-10.529	-8.926	0.285	1.804
Log total assets	China	1044	23.509	1.901	22.160	23.179	24.533	0.242	1.889
Log total assets	Korea	575	23.373	1.525	22.331	23.155	24.366	0.150	1.523
Return on assets	China	1044	0.045	0.053	0.013	0.032	0.068	0.030	0.044
Return on assets	Korea	575	0.028	0.052	0.006	0.021	0.048	0.036	0.038
Debt-to-assets	China	1044	0.246	0.182	0.095	0.205	0.380	0.046	0.176
Debt-to-assets	Korea	575	0.244	0.160	0.107	0.246	0.360	0.048	0.153
Capital-expenditure-to-revenue	China	1044	0.166	1.628	0.030	0.061	0.129	1.349	0.911
Capital-expenditure-to-revenue	Korea	575	0.073	0.092	0.027	0.048	0.084	0.058	0.072

Note. The common exposure window is 2019–2023. N denotes available firm–year observations; P25 and P75 denote the 25th and 75th percentiles, respectively; and SD denotes standard deviation. Counts vary because variables are summarized according to availability. Table S2 reports the regression sample flow separately.

Supplementary reproducibility statement

The accompanying archive separates public aggregate reproduction from licensed empirical re-estimation. A tested clean-directory command checks non-identifying outputs and rebuilds all four figures from relative paths. The run log records commands, runtime versions, input/output hashes and successful checks. Estimation scripts and plans remain

available, but their source-panel inputs require provider authorization. Plans for added diagnostics were written after peer review and before those diagnostics were estimated; they are not prospective preregistrations of the original study.

Supplementary Methods S3 Reviewer-requested analyses

The following analyses were added after peer review. They preserve the original cohort, archived score standardization, controls and fixed-effect estimator. Exact calendar-year joins define t+h. Outcomes end in 2024. Available-support windows end in 2023, 2022 and 2021 for h = 1, 2 and 3. Identical-support analyses require all three outcomes on the same baseline rows. Missing observations are not filled. In some new restricted samples, the estimator retains one-row firms; their firm-demeaned observations supply no slope variation, and singleton counts are included in the aggregate sample audit.

M1 and M2 use environmental-pillar and emissions scores, respectively, with the provider total Scopes 1+2 field. M3 and M4 use the same scores with the separately summed combined Scopes 1+2 series, including estimates. Model numbering corresponds to original R1-P01–R1-P04. All regression tables report pointwise firm-clustered 95% intervals and actual BH q values. N is firm–years; firms are independent clusters. The twelve original one-year contrasts per window remain their original family. New available horizons use 24 contrasts per window; identical-support comparisons use 36. Each current-outcome, paired unadjusted and prior-outcome diagnostic has its own twelve-test family per window. Strict-reported comparisons and paired combined-series fits each have six contrasts per window.

Precision diagnostics approximate 80% minimum detectable magnitude as $SE \times [t(1-\alpha/2, G-1) + \Phi^{-1}(.80)]$. Nominal alpha is .05; the conservative Bonferroni-12 reference is .05/12. These references are conditional on achieved standard errors and are not equivalence or excluded-effect bounds. Within SD is $\sqrt{\text{within sum of squares}/(N-G)}$; between SD is the SD of firm means. Their squares need not add for an unbalanced panel. The within share uses within/total sums of squares.

Regarding agreement scenarios, A0 retains all 182 pairs, A1 excludes 28 documentary-linked discrepant rows, A2 excludes all 29 factor-two discrepant rows, A3 excludes all observations from four persistent-mismatch firms, and A4 excludes all five flagged firms. A2 is outcome-selected. Recent documentary anchors do not positively verify the boundaries of all remaining historical observations. Firm-bootstrap intervals use 9,999 resamples and seed 20260829. GIR inference scenarios S0–S3 are the original all-firm, 29-row exclusion, four-firm exclusion and five-firm exclusion definitions; they differ from agreements A0–A4.

GIR wild-bootstrap sensitivity uses base seeds 20260811, 20261007 and 20261008 at 9,999 draws, plus 4,999 and 19,999 draws at base seed 20260811. Actual seeds add the deterministic original model–window character-code offset recorded in the code and per-configuration CSV. Each two-score scenario–window family is adjusted separately. Cluster-size and score-information concentration measures describe information distribution, not alternative degrees of freedom. A random-intercept association model would mix within- and between-firm information under assumptions about the dependence of firm effects and scores. That is a different estimand from the retained within-firm model. A latent true emissions calibration additionally requires common-boundary anchors or identified error restrictions; the two differently scoped sources do not supply them. No such model is claimed.

Table S9 Coverage selection comparison

Country / group	Firms	Usable years median [IQR]	Assets USD bn	Environmental score	Intensity tCO2e/USDm
China / ≥5 retained	209	6.00 [5.00, 8.00]	11.69 [4.80, 41.24]	57.78 [46.92, 68.39]	60.23 [13.31, 303.45]
China / 1–4 not retained	587	3.00 [1.00, 3.00]	3.57 [1.87, 8.06]	49.64 [36.90, 61.27]	72.34 [14.60, 276.98]
Korea / ≥5 retained	115	9.00 [6.00, 10.00]	10.78 [5.01, 36.17]	64.49 [53.40, 74.87]	23.95 [10.12, 97.22]
Korea / 1–4 not retained	53	3.00 [2.00, 4.00]	2.73 [1.10, 5.67]	47.33 [29.18, 57.94]	23.15 [5.73, 68.95]

Firm summaries use original usable FY–1 to FY–10 screening rows. Asset/intensity summaries are within-firm geometric means; scores are arithmetic means, summarized by median [IQR] across firms. Comparators have at least one usable year; zero-usable-year firms are not represented. Reconstructed Korean membership sets are identical with and without an observed CSR-field condition; CSR=False is retained, so there is no affirmative reporting restriction. No significance tests are used.

Table S10 Achieved precision of the twelve common-window contrasts

Model / contrast	β [95% CI]	SE	Nominal MDE log	MDE -% / +%	Bonf12 MDE log	MDE -% / +%
M1/china	-0.029 [-0.098, 0.039]	0.035	0.098	-9.3 / 10.3	0.130	-12.2 / 13.9
M1/korea	-0.032 [-0.103, 0.038]	0.036	0.101	-9.6 / 10.6	0.134	-12.5 / 14.3
M1/korea_minus_china	-0.003 [-0.102, 0.096]	0.050	0.141	-13.2 / 15.1	0.187	-17.1 / 20.6
M2/china	-0.008 [-0.064, 0.049]	0.028	0.080	-7.7 / 8.3	0.106	-10.1 / 11.2
M2/korea	0.011 [-0.045, 0.067]	0.028	0.080	-7.7 / 8.3	0.106	-10.0 / 11.2
M2/korea_minus_china	0.019 [-0.061, 0.099]	0.041	0.114	-10.8 / 12.1	0.151	-14.0 / 16.3
M3/china	-0.020 [-0.100, 0.060]	0.041	0.115	-10.8 / 12.1	0.152	-14.1 / 16.4
M3/korea	-0.055 [-0.151, 0.041]	0.049	0.137	-12.8 / 14.7	0.182	-16.7 / 20.0
M3/korea_minus_china	-0.035 [-0.156, 0.087]	0.062	0.174	-16.0 / 19.0	0.231	-20.6 / 26.0
M4/china	-0.022 [-0.079, 0.035]	0.029	0.081	-7.8 / 8.5	0.108	-10.2 / 11.4
M4/korea	-0.023 [-0.092, 0.047]	0.036	0.100	-9.5 / 10.5	0.132	-12.4 / 14.2
M4/korea_minus_china	-0.001 [-0.091, 0.090]	0.046	0.129	-12.1 / 13.8	0.171	-15.7 / 18.7

Country-difference exponentiation is a ratio of multiplicative slopes, not a country-specific change. MDE values do not rule out smaller effects.

Table S11 Raw and standardized score variation

Model / window	Country / scale	N / firms	Total SD	Within SD	Between SD	Within-share %	Firms varying
M1/Extended	China/raw	1273/209	21.094	16.756	14.848	52.8	209
M1/Extended	China/standardized	1273/209	0.992	0.632	0.828	33.9	209
M1/Extended	Korea/raw	901/115	23.004	14.829	18.822	36.3	115
M1/Extended	Korea/standardized	901/115	0.980	0.492	0.899	22.1	115
M1/Common	China/raw	1008/209	20.560	14.236	16.228	38.0	209
M1/Common	China/standardized	1008/209	1.000	0.556	0.871	24.5	209
M1/Common	Korea/raw	563/115	20.249	11.776	17.468	27.0	115
M1/Common	Korea/standardized	563/115	0.989	0.467	0.901	17.8	115
M2/Extended	China/raw	1273/209	24.897	20.232	17.083	55.2	209
M2/Extended	China/standardized	1273/209	0.990	0.643	0.812	35.3	209
M2/Extended	Korea/raw	901/115	25.749	19.693	18.872	51.1	115
M2/Extended	Korea/standardized	901/115	0.964	0.600	0.837	33.9	115
M2/Common	China/raw	1008/209	24.130	17.571	18.361	42.1	209
M2/Common	China/standardized	1008/209	1.004	0.592	0.856	27.6	209

Model / window	Country / scale	N / firms	Total SD	Within SD	Between SD	Within-share %	Firms varying
M2/Common	Korea/raw	563/115	21.106	14.118	17.593	35.7	115
M2/Common	Korea/standardized	563/115	0.981	0.563	0.867	26.3	115
M3/Extended	China/raw	1405/209	22.320	18.253	15.002	57.0	209
M3/Extended	China/standardized	1405/209	1.001	0.661	0.817	37.2	209
M3/Extended	Korea/raw	967/115	24.865	15.711	19.990	35.2	115
M3/Extended	Korea/standardized	967/115	1.000	0.509	0.886	22.8	115
M3/Common	China/raw	1026/209	20.512	14.173	16.136	38.1	209
M3/Common	China/standardized	1026/209	1.001	0.556	0.872	24.6	209
M3/Common	Korea/raw	573/115	20.272	11.738	17.435	26.8	115
M3/Common	Korea/standardized	573/115	0.998	0.473	0.908	18.0	115
M4/Extended	China/raw	1405/209	26.648	22.079	17.622	58.5	209
M4/Extended	China/standardized	1405/209	1.001	0.678	0.804	39.0	209
M4/Extended	Korea/raw	967/115	28.950	21.528	20.761	48.8	115
M4/Extended	Korea/standardized	967/115	0.998	0.617	0.831	33.7	115
M4/Common	China/raw	1026/209	24.105	17.475	18.341	41.9	209
M4/Common	China/standardized	1026/209	1.001	0.593	0.850	28.0	209
M4/Common	Korea/raw	573/115	21.542	14.187	17.455	34.7	115
M4/Common	Korea/standardized	573/115	1.002	0.566	0.867	25.6	115

Both time windows and all four complete-case primary samples are shown. Scale matters: raw and standardized within-firm shares differ.

Table S12 Added available support horizons

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M1	Extended	2015–2022; h=2	1944/324	1131/813	-0.104 [-0.180, -0.029] (0.025)	0.212 [0.017, 0.408] (0.081)	0.316 [0.105, 0.528] (0.021)
M1	Extended	2015–2021; h=3	1668/324	953/715	-0.104 [-0.183, -0.025] (0.031)	0.173 [0.017, 0.328] (0.079)	0.276 [0.102, 0.451] (0.021)
M1	Common	2019–2022; h=2	1256/324	805/451	-0.028 [-0.088, 0.031] (0.781)	0.052 [-0.011, 0.114] (0.503)	0.080 [-0.007, 0.167] (0.432)
M1	Common	2019–2021; h=3	939/323	600/339	-0.078 [-0.138, -0.019] (0.239)	0.037 [-0.064, 0.139] (0.867)	0.116 [-0.003, 0.234] (0.432)
M2	Extended	2015–2022; h=2	1944/324	1131/813	-0.037 [-0.114, 0.041] (0.402)	0.114 [-0.026, 0.253] (0.165)	0.151 [-0.010, 0.311] (0.132)
M2	Extended	2015–2021; h=3	1668/324	953/715	-0.004 [-0.073, 0.065] (0.910)	0.080 [-0.015, 0.175] (0.162)	0.084 [-0.033, 0.201] (0.192)

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M2	Common	2019–2022; h=2	1256/324	805/451	-0.017 [-0.083, 0.050] (1.000)	0.052 [-0.018, 0.123] (0.515)	0.069 [-0.028, 0.166] (0.515)
M2	Common	2019–2021; h=3	939/323	600/339	-0.019 [-0.064, 0.027] (0.840)	0.043 [-0.033, 0.118] (0.707)	0.061 [-0.027, 0.149] (0.515)
M3	Extended	2015–2022; h=2	2048/324	1196/852	-0.120 [-0.205, -0.035] (0.025)	0.089 [-0.035, 0.214] (0.192)	0.209 [0.057, 0.362] (0.025)
M3	Extended	2015–2021; h=3	1724/324	987/737	-0.122 [-0.203, -0.042] (0.021)	0.106 [-0.021, 0.233] (0.162)	0.228 [0.077, 0.379] (0.021)
M3	Common	2019–2022; h=2	1275/324	817/458	-0.016 [-0.081, 0.049] (1.000)	-0.011 [-0.122, 0.100] (1.000)	0.005 [-0.124, 0.134] (1.000)
M3	Common	2019–2021; h=3	951/324	608/343	-0.061 [-0.118, -0.005] (0.401)	-0.050 [-0.156, 0.056] (0.781)	0.012 [-0.109, 0.132] (1.000)
M4	Extended	2015–2022; h=2	2048/324	1196/852	-0.084 [-0.167, -0.000] (0.106)	0.011 [-0.080, 0.101] (0.851)	0.094 [-0.030, 0.219] (0.192)
M4	Extended	2015–2021; h=3	1724/324	987/737	-0.060 [-0.127, 0.007] (0.144)	0.023 [-0.071, 0.117] (0.687)	0.083 [-0.032, 0.199] (0.192)
M4	Common	2019–2022; h=2	1275/324	817/458	0.003 [-0.056, 0.062] (1.000)	0.004 [-0.087, 0.095] (1.000)	0.001 [-0.107, 0.110] (1.000)
M4	Common	2019–2021; h=3	951/324	608/343	-0.007 [-0.057, 0.043] (1.000)	-0.000 [-0.078, 0.078] (1.000)	0.007 [-0.086, 0.100] (1.000)

Only new h=2 and h=3 shown; BH family has 24 contrasts per window. Original h=1 estimates remain in Table 2. Exposure end changes with horizon; outcome endpoint is 2024.

Table S13 Identical baseline support across horizons

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M1	Extended	2015–2021; h=1	1494/322	837/657	-0.105 [-0.178, -0.032] (0.029)	0.185 [-0.003, 0.374] (0.140)	0.291 [0.087, 0.495] (0.029)
M1	Extended	2015–2021; h=2	1494/322	837/657	-0.097 [-0.169, -0.025] (0.039)	0.193 [-0.013, 0.399] (0.150)	0.289 [0.068, 0.511] (0.042)
M1	Extended	2015–2021; h=3	1494/322	837/657	-0.077 [-0.131, -0.023] (0.029)	0.118 [-0.022, 0.257] (0.174)	0.194 [0.043, 0.346] (0.044)
M1	Common	2019–2021; h=1	917/317	585/332	-0.019 [-0.093, 0.055] (0.873)	0.041 [-0.085, 0.167] (0.873)	0.060 [-0.087, 0.207] (0.815)
M1	Common	2019–2021; h=2	917/317	585/332	-0.006 [-0.093, 0.081] (0.946)	0.075 [-0.026, 0.176] (0.669)	0.081 [-0.053, 0.215] (0.707)
M1	Common	2019–2021; h=3	917/317	585/332	-0.082 [-0.144, -0.021] (0.325)	0.029 [-0.075, 0.133] (0.873)	0.111 [-0.011, 0.233] (0.661)
M2	Extended	2015–2021; h=1	1494/322	837/657	-0.037 [-0.106, 0.033] (0.378)	0.014 [-0.105, 0.134] (0.844)	0.051 [-0.089, 0.192] (0.548)

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M2	Extended	2015–2021; h=2	1494/322	837/657	-0.045 [-0.134, 0.044] (0.388)	0.064 [-0.059, 0.188] (0.378)	0.109 [-0.044, 0.263] (0.242)
M2	Extended	2015–2021; h=3	1494/322	837/657	-0.008 [-0.077, 0.061] (0.844)	0.062 [-0.018, 0.142] (0.208)	0.070 [-0.035, 0.175] (0.263)
M2	Common	2019–2021; h=1	917/317	585/332	0.024 [-0.053, 0.101] (0.873)	0.007 [-0.061, 0.075] (0.946)	-0.017 [-0.121, 0.087] (0.946)
M2	Common	2019–2021; h=2	917/317	585/332	0.001 [-0.093, 0.095] (1.000)	0.053 [-0.037, 0.144] (0.707)	0.052 [-0.078, 0.183] (0.815)
M2	Common	2019–2021; h=3	917/317	585/332	-0.023 [-0.069, 0.024] (0.758)	0.044 [-0.032, 0.120] (0.707)	0.066 [-0.023, 0.156] (0.669)
M3	Extended	2015–2021; h=1	1724/324	987/737	-0.096 [-0.197, 0.004] (0.145)	0.113 [-0.048, 0.274] (0.242)	0.209 [0.017, 0.401] (0.107)
M3	Extended	2015–2021; h=2	1724/324	987/737	-0.137 [-0.229, -0.046] (0.029)	0.146 [-0.013, 0.305] (0.150)	0.283 [0.099, 0.468] (0.029)
M3	Extended	2015–2021; h=3	1724/324	987/737	-0.122 [-0.203, -0.042] (0.029)	0.106 [-0.021, 0.233] (0.174)	0.228 [0.077, 0.379] (0.029)
M3	Common	2019–2021; h=1	951/324	608/343	-0.008 [-0.094, 0.078] (0.946)	0.095 [-0.018, 0.208] (0.669)	0.103 [-0.037, 0.242] (0.669)
M3	Common	2019–2021; h=2	951/324	608/343	-0.016 [-0.093, 0.060] (0.932)	0.052 [-0.050, 0.153] (0.757)	0.068 [-0.060, 0.196] (0.757)
M3	Common	2019–2021; h=3	951/324	608/343	-0.061 [-0.118, -0.005] (0.601)	-0.050 [-0.156, 0.056] (0.758)	0.012 [-0.109, 0.132] (0.946)
M4	Extended	2015–2021; h=1	1724/324	987/737	-0.089 [-0.179, 0.001] (0.140)	-0.006 [-0.118, 0.105] (0.913)	0.083 [-0.062, 0.228] (0.348)
M4	Extended	2015–2021; h=2	1724/324	987/737	-0.093 [-0.188, 0.002] (0.140)	0.032 [-0.074, 0.138] (0.619)	0.125 [-0.019, 0.270] (0.168)
M4	Extended	2015–2021; h=3	1724/324	987/737	-0.060 [-0.127, 0.007] (0.156)	0.023 [-0.071, 0.117] (0.687)	0.083 [-0.032, 0.199] (0.242)
M4	Common	2019–2021; h=1	951/324	608/343	0.006 [-0.058, 0.070] (0.946)	0.063 [-0.001, 0.127] (0.638)	0.057 [-0.035, 0.148] (0.707)
M4	Common	2019–2021; h=2	951/324	608/343	0.020 [-0.048, 0.087] (0.873)	0.048 [-0.035, 0.132] (0.707)	0.029 [-0.078, 0.136] (0.873)
M4	Common	2019–2021; h=3	951/324	608/343	-0.007 [-0.057, 0.043] (0.946)	-0.000 [-0.078, 0.078] (1.000)	0.007 [-0.086, 0.100] (0.946)

All three outcomes are required on the same baseline rows for each model–window comparison. Separate BH family of 36 contrasts per window.

Table S14A Current-outcome-controlled sensitivity

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M1	Extended	2015–2023; h=1	2004/324	1146/858	-0.031 [-0.074, 0.012] (0.292)	0.035 [-0.021, 0.092] (0.296)	0.066 [-0.004, 0.136] (0.191)
M1	Common	2019–2023; h=1	1513/323	957/556	-0.013 [-0.068, 0.043] (0.949)	-0.024 [-0.082, 0.035] (0.949)	-0.011 [-0.092, 0.070] (0.949)
M2	Extended	2015–2023; h=1	2004/324	1146/858	0.005 [-0.052, 0.062] (0.860)	0.014 [-0.032, 0.061] (0.654)	0.009 [-0.063, 0.082] (0.860)
M2	Common	2019–2023; h=1	1513/323	957/556	0.008 [-0.050, 0.065] (0.949)	0.010 [-0.041, 0.062] (0.949)	0.003 [-0.076, 0.081] (0.949)
M3	Extended	2015–2023; h=1	2371/324	1404/967	-0.059 [-0.117, -0.002] (0.171)	0.044 [-0.021, 0.109] (0.292)	0.103 [0.016, 0.190] (0.171)
M3	Common	2019–2023; h=1	1598/324	1025/573	-0.018 [-0.080, 0.044] (0.949)	-0.034 [-0.122, 0.054] (0.949)	-0.017 [-0.122, 0.089] (0.949)
M4	Extended	2015–2023; h=1	2371/324	1404/967	-0.034 [-0.085, 0.017] (0.292)	0.041 [-0.009, 0.091] (0.261)	0.074 [0.002, 0.147] (0.171)
M4	Common	2019–2023; h=1	1598/324	1025/573	-0.019 [-0.065, 0.027] (0.949)	-0.003 [-0.066, 0.060] (0.949)	0.016 [-0.062, 0.094] (0.949)

Current log intensity and its Korea interaction are added. Short-panel dynamic fixed-effect bias remains possible; twelve-test BH family per window.

Table S14B Paired unadjusted fits

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M1	Extended	2015–2023; h=1	2004/324	1146/858	-0.072 [-0.134, -0.010] (0.094)	0.060 [-0.064, 0.184] (0.527)	0.132 [-0.006, 0.270] (0.168)
M1	Common	2019–2023; h=1	1513/323	957/556	-0.035 [-0.099, 0.029] (0.937)	-0.036 [-0.109, 0.037] (0.937)	-0.001 [-0.098, 0.096] (0.987)
M2	Extended	2015–2023; h=1	2004/324	1146/858	-0.028 [-0.099, 0.042] (0.527)	-0.044 [-0.147, 0.058] (0.527)	-0.016 [-0.140, 0.108] (0.800)
M2	Common	2019–2023; h=1	1513/323	957/556	-0.006 [-0.068, 0.057] (0.940)	0.011 [-0.045, 0.067] (0.937)	0.016 [-0.068, 0.101] (0.937)
M3	Extended	2015–2023; h=1	2371/324	1404/967	-0.109 [-0.202, -0.016] (0.094)	0.023 [-0.084, 0.130] (0.732)	0.132 [-0.011, 0.275] (0.168)
M3	Common	2019–2023; h=1	1598/324	1025/573	-0.028 [-0.108, 0.052] (0.937)	-0.054 [-0.150, 0.042] (0.937)	-0.026 [-0.147, 0.095] (0.937)
M4	Extended	2015–2023; h=1	2371/324	1404/967	-0.097 [-0.171, -0.022] (0.094)	-0.051 [-0.139, 0.037] (0.504)	0.045 [-0.070, 0.161] (0.527)
M4	Common	2019–2023; h=1	1598/324	1025/573	-0.031 [-0.085, 0.023] (0.937)	-0.022 [-0.092, 0.048] (0.937)	0.009 [-0.080, 0.097] (0.940)

Same rows as S14A, without the current-outcome terms. Separate twelve-test BH family per window.

Table S15A Prior intensity and current rating

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M1	Extended	2015–2023; h=-1	1715/324	956/759	-0.094 [-0.172, -0.016] (0.044)	0.043 [-0.038, 0.123] (0.394)	0.137 [0.023, 0.251] (0.044)
M1	Common	2019–2023; h=-1	1394/324	851/543	-0.059 [-0.132, 0.013] (0.218)	0.019 [-0.053, 0.091] (0.808)	0.078 [-0.025, 0.181] (0.232)
M2	Extended	2015–2023; h=-1	1715/324	956/759	-0.097 [-0.175, -0.018] (0.044)	-0.101 [-0.269, 0.067] (0.357)	-0.004 [-0.190, 0.182] (0.964)
M2	Common	2019–2023; h=-1	1394/324	851/543	-0.067 [-0.143, 0.010] (0.213)	-0.079 [-0.217, 0.059] (0.394)	-0.012 [-0.172, 0.147] (0.881)
M3	Extended	2015–2023; h=-1	2054/324	1196/858	-0.106 [-0.182, -0.030] (0.038)	-0.047 [-0.156, 0.062] (0.435)	0.060 [-0.073, 0.192] (0.435)
M3	Common	2019–2023; h=-1	1516/324	950/566	-0.107 [-0.185, -0.029] (0.043)	-0.092 [-0.191, 0.006] (0.200)	0.015 [-0.114, 0.144] (0.881)
M4	Extended	2015–2023; h=-1	2054/324	1196/858	-0.064 [-0.140, 0.011] (0.160)	-0.216 [-0.361, -0.071] (0.038)	-0.151 [-0.311, 0.009] (0.127)
M4	Common	2019–2023; h=-1	1516/324	950/566	-0.010 [-0.095, 0.074] (0.881)	-0.240 [-0.397, -0.082] (0.036)	-0.230 [-0.408, -0.051] (0.047)

Outcome is the current standardized rating; predictor is prior-year log intensity. Coefficients therefore have different units from S12–S14. Twelve-test BH family per window.

Table S15B Descriptive prior intensity and current rating correlations

Model / window	Country	N / firms	Pooled Pearson	Pooled Spearman	Within-firm Pearson
M1/Extended	China	956/209	0.005	0.002	-0.139
M1/Extended	Korea	759/115	0.174	0.103	0.015
M1/Common	China	851/209	0.010	0.005	-0.090
M1/Common	Korea	543/115	0.181	0.102	-0.034
M2/Extended	China	956/209	-0.096	-0.089	-0.146
M2/Extended	Korea	759/115	0.176	0.147	-0.133
M2/Common	China	851/209	-0.097	-0.090	-0.099
M2/Common	Korea	543/115	0.184	0.145	-0.094
M3/Extended	China	1196/209	-0.048	-0.045	-0.133
M3/Extended	Korea	858/115	0.097	0.019	-0.065
M3/Common	China	950/209	-0.055	-0.051	-0.105
M3/Common	Korea	566/115	0.136	0.056	-0.126

Model / window	Country	N / firms	Pooled Pearson	Pooled Spearman	Within-firm Pearson
M4/Extended	China	1196/209	-0.093	-0.091	-0.075
M4/Extended	Korea	858/115	0.067	0.032	-0.200
M4/Common	China	950/209	-0.108	-0.106	-0.009
M4/Common	Korea	566/115	0.095	0.060	-0.200

Same complete cases as the corresponding reverse-temporal model. No p values treating repeated firm–years as independent are reported.

Table S16A Boundary-specific agreement and uncertainty

Scenario	Pairs / firms	Metric	Estimate	95% cluster bootstrap interval
A0	182/22	Pearson log	0.772	[0.520, 0.976]
A0	182/22	Spearman log	0.789	[0.502, 0.962]
A0	182/22	lin ccc log	0.734	[0.415, 0.972]
A0	182/22	icc a1 log	0.735	[0.416, 0.972]
A0	182/22	mean log ratio	0.448	[0.118, 0.853]
A0	182/22	sd log ratio	1.068	[0.332, 1.505]
A0	182/22	geometric mean ratio	1.566	[1.125, 2.348]
A0	182/22	median ratio	1.036	[1.004, 1.221]
A0	182/22	ba ratio lower	0.193	[0.110, 0.610]
A0	182/22	ba ratio upper	12.701	[2.208, 43.368]
A0	182/22	within 10 percent	0.533	[0.376, 0.691]
A0	182/22	within 20 percent	0.637	[0.474, 0.798]
A0	182/22	within 25 percent	0.659	[0.492, 0.821]
A0	182/22	within factor two	0.841	[0.684, 0.972]
A0	182/22	between-firm log ratio variance share	0.614	[0.332, 0.978]
A0	182/22	within-firm log ratio variance share	0.386	[0.022, 0.668]
A0	182/22	within-firm log ratio rms	0.662	[0.124, 1.092]
A0	182/22	equal firm mean log ratio	0.377	[0.100, 0.735]
A0	182/22	equal firm geometric mean ratio	1.457	[1.106, 2.085]
A1	154/20	Pearson log	0.991	[0.979, 0.997]
A1	154/20	Spearman log	0.990	[0.956, 0.992]
A1	154/20	lin ccc log	0.990	[0.973, 0.996]
A1	154/20	icc a1 log	0.990	[0.973, 0.996]
A1	154/20	mean log ratio	0.068	[-0.001, 0.153]

Scenario	Pairs / firms	Metric	Estimate	95% cluster bootstrap interval
A1	154/20	sd log ratio	0.212	[0.134, 0.262]
A1	154/20	geometric mean ratio	1.071	[0.999, 1.166]
A1	154/20	median ratio	1.014	[0.991, 1.056]
A1	154/20	ba ratio lower	0.707	[0.660, 0.787]
A1	154/20	ba ratio upper	1.622	[1.316, 1.917]
A1	154/20	within 10 percent	0.630	[0.469, 0.789]
A1	154/20	within 20 percent	0.753	[0.590, 0.899]
A1	154/20	within 25 percent	0.779	[0.613, 0.924]
A1	154/20	within factor two	0.994	[0.979, 1.000]
A1	154/20	between-firm log ratio variance share	0.599	[0.124, 0.818]
A1	154/20	within-firm log ratio variance share	0.401	[0.182, 0.876]
A1	154/20	within-firm log ratio rms	0.134	[0.090, 0.171]
A1	154/20	equal firm mean log ratio	0.059	[0.001, 0.130]
A1	154/20	equal firm geometric mean ratio	1.061	[1.001, 1.139]
A2	153/20	Pearson log	0.992	[0.981, 0.997]
A2	153/20	Spearman log	0.992	[0.960, 0.993]
A2	153/20	lin ccc log	0.990	[0.975, 0.997]
A2	153/20	icc a1 log	0.991	[0.975, 0.997]
A2	153/20	mean log ratio	0.074	[0.007, 0.158]
A2	153/20	sd log ratio	0.200	[0.121, 0.249]
A2	153/20	geometric mean ratio	1.077	[1.007, 1.171]
A2	153/20	median ratio	1.016	[0.993, 1.056]
A2	153/20	ba ratio lower	0.728	[0.691, 0.804]
A2	153/20	ba ratio upper	1.594	[1.282, 1.890]
A2	153/20	within 10 percent	0.634	[0.471, 0.794]
A2	153/20	within 20 percent	0.758	[0.594, 0.906]
A2	153/20	within 25 percent	0.784	[0.619, 0.931]
A2	153/20	within factor two	1.000	[1.000, 1.000]
A2	153/20	between-firm log ratio variance share	0.637	[0.106, 0.853]
A2	153/20	within-firm log ratio variance share	0.363	[0.147, 0.894]
A2	153/20	within-firm log ratio rms	0.120	[0.079, 0.155]

Scenario	Pairs / firms	Metric	Estimate	95% cluster bootstrap interval
A2	153/20	equal firm mean log ratio	0.064	[0.010, 0.133]
A2	153/20	equal firm geometric mean ratio	1.067	[1.010, 1.143]
A3	142/18	Pearson log	0.991	[0.978, 0.997]
A3	142/18	Spearman log	0.990	[0.949, 0.992]
A3	142/18	lin ccc log	0.989	[0.971, 0.996]
A3	142/18	icc a1 log	0.989	[0.971, 0.997]
A3	142/18	mean log ratio	0.075	[-0.001, 0.166]
A3	142/18	sd log ratio	0.218	[0.139, 0.270]
A3	142/18	geometric mean ratio	1.077	[0.999, 1.180]
A3	142/18	median ratio	1.017	[0.994, 1.073]
A3	142/18	ba ratio lower	0.703	[0.652, 0.783]
A3	142/18	ba ratio upper	1.652	[1.330, 1.961]
A3	142/18	within 10 percent	0.606	[0.430, 0.775]
A3	142/18	within 20 percent	0.739	[0.564, 0.895]
A3	142/18	within 25 percent	0.761	[0.583, 0.915]
A3	142/18	within factor two	0.993	[0.977, 1.000]
A3	142/18	between-firm log ratio variance share	0.598	[0.119, 0.822]
A3	142/18	within-firm log ratio variance share	0.402	[0.178, 0.881]
A3	142/18	within-firm log ratio rms	0.138	[0.091, 0.177]
A3	142/18	equal firm mean log ratio	0.066	[0.003, 0.143]
A3	142/18	equal firm geometric mean ratio	1.068	[1.003, 1.154]
A4	135/17	Pearson log	0.992	[0.981, 0.997]
A4	135/17	Spearman log	0.992	[0.950, 0.992]
A4	135/17	lin ccc log	0.990	[0.973, 0.997]
A4	135/17	icc a1 log	0.990	[0.973, 0.997]
A4	135/17	mean log ratio	0.085	[0.009, 0.180]
A4	135/17	sd log ratio	0.208	[0.126, 0.257]
A4	135/17	geometric mean ratio	1.089	[1.009, 1.197]
A4	135/17	median ratio	1.018	[0.995, 1.101]
A4	135/17	ba ratio lower	0.724	[0.687, 0.803]
A4	135/17	ba ratio upper	1.637	[1.297, 1.956]

Scenario	Pairs / firms	Metric	Estimate	95% cluster bootstrap interval
A4	135/17	within 10 percent	0.607	[0.424, 0.784]
A4	135/17	within 20 percent	0.733	[0.546, 0.898]
A4	135/17	within 25 percent	0.756	[0.566, 0.919]
A4	135/17	within factor two	1.000	[1.000, 1.000]
A4	135/17	between-firm log ratio variance share	0.637	[0.098, 0.854]
A4	135/17	within-firm log ratio variance share	0.363	[0.146, 0.902]
A4	135/17	within-firm log ratio rms	0.125	[0.079, 0.163]
A4	135/17	equal firm mean log ratio	0.078	[0.015, 0.157]
A4	135/17	equal firm geometric mean ratio	1.081	[1.015, 1.170]

All metrics are reported in their stored units; tolerance shares are fractions from 0 to 1. 9,999 whole-firm resamples; seed 20260829. Ratio limits are descriptive spreads, not confidence limits.

Table S16B Log ratio variance decomposition

Scenario	Pairs / firms	Geometric ratio	Between-share %	Within-share %	Within log RMS
A0	182/22	1.566	61.4	38.6	0.662
A1	154/20	1.071	59.9	40.1	0.134
A2	153/20	1.077	63.7	36.3	0.120
A3	142/18	1.077	59.8	40.2	0.138
A4	135/17	1.089	63.7	36.3	0.125

Pair-weighted between-firm and within-firm sum-of-squares shares describe source discrepancy; they are not estimated true emissions measurement error components.

Table S17A GIR cluster size information concentration and influence

Scenario/model/window	N / firms	Cluster min / median / max	Size effective count	Max score share %	Score effective count	Leave-one-firm β range
S0/GIR-P01/Extended	191/22	5/9.0/9	21.70	20.4	10.86	-0.026 to 0.068
S0/GIR-P01/Common	110/22	5/5.0/5	22.00	21.4	8.29	0.051 to 0.141
S0/GIR-P02/Extended	191/22	5/9.0/9	21.70	16.5	10.55	-0.056 to -0.016
S0/GIR-P02/Common	110/22	5/5.0/5	22.00	15.5	10.73	-0.040 to -0.013
S1/GIR-P01/Extended	164/20	5/9.0/9	19.35	23.0	9.47	-0.054 to 0.063
S1/GIR-P01/Common	90/18	5/5.0/5	18.00	21.0	7.79	0.020 to 0.121
S1/GIR-P02/Extended	164/20	5/9.0/9	19.35	19.6	9.43	-0.073 to -0.028
S1/GIR-P02/Common	90/18	5/5.0/5	18.00	20.0	9.07	-0.050 to -0.024
S2/GIR-P01/Extended	155/18	5/9.0/9	17.70	22.7	9.40	-0.039 to 0.072

Scenario/model/window	N / firms	Cluster min / median / max	Size effective count	Max score share %	Score effective count	Leave-one-firm β range
S2/GIR-P01/Common	90/18	5/5.0/5	18.00	21.0	7.79	0.020 to 0.121
S2/GIR-P02/Extended	155/18	5/9.0/9	17.70	21.2	8.98	-0.072 to -0.015
S2/GIR-P02/Common	90/18	5/5.0/5	18.00	20.0	9.07	-0.050 to -0.024
S3/GIR-P01/Extended	146/17	5/9.0/9	16.71	28.9	7.61	-0.066 to 0.082
S3/GIR-P01/Common	85/17	5/5.0/5	17.00	34.2	5.80	0.073 to 0.151
S3/GIR-P02/Extended	146/17	5/9.0/9	16.71	16.3	10.18	-0.093 to -0.049
S3/GIR-P02/Common	85/17	5/5.0/5	17.00	17.6	10.58	-0.044 to -0.009

Size effective count= $N^2/\sum n_g^2$. Score effective count is the reciprocal sum of squared firm shares of residualized predictor sum of squares. Neither replaces degrees of freedom. Full quartiles are in the CSV.

Table S17B Wild bootstrap sensitivity over five configurations

Scenario / model / window	Raw p minimum	Raw p maximum	BH q minimum	BH q maximum	Max MC SE
S0/GIR-P01/Common	0.2447	0.2562	0.2447	0.2562	0.0061
S0/GIR-P01/Extended	0.6767	0.6865	0.6767	0.6865	0.0066
S0/GIR-P02/Common	0.2281	0.2386	0.2447	0.2562	0.0060
S0/GIR-P02/Extended	0.3744	0.3854	0.6767	0.6865	0.0069
S1/GIR-P01/Common	0.3792	0.3889	0.3792	0.3889	0.0069
S1/GIR-P01/Extended	0.8235	0.8376	0.8235	0.8376	0.0052
S1/GIR-P02/Common	0.1224	0.1287	0.2448	0.2574	0.0047
S1/GIR-P02/Extended	0.1800	0.1911	0.3600	0.3822	0.0055
S2/GIR-P01/Common	0.3792	0.3889	0.3792	0.3889	0.0069
S2/GIR-P01/Extended	0.7549	0.7661	0.7549	0.7661	0.0060
S2/GIR-P02/Common	0.1224	0.1287	0.2448	0.2574	0.0047
S2/GIR-P02/Extended	0.4168	0.4197	0.7549	0.7661	0.0070
S3/GIR-P01/Common	0.1402	0.1478	0.2804	0.2956	0.0050
S3/GIR-P01/Extended	0.8266	0.8376	0.8266	0.8376	0.0054
S3/GIR-P02/Common	0.3244	0.3409	0.3244	0.3409	0.0066
S3/GIR-P02/Extended	0.0792	0.0846	0.1584	0.1692	0.0039

All eighty settings and exact seeds are provided in the aggregate CSV. The five settings assess Monte Carlo variation, not the inferential adequacy of the small-cluster design.

Table S18. Full field definitions, units, status and transformations

Analysis variable / original field	Unit and status	Time/missing rule; transformation
esg_score / TR.TRESGScore	0–100 provider percentile-score points; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
environmental_pillar_score / TR.EnvironmentPillarScore	0–100 provider percentile-score points; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
emissions_score / TR.TRESGEmissionsScore	0–100 provider percentile-score points; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
resource_use_score / TR.TRESGResourceUseScore	0–100 provider percentile-score points; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
csr_reporting / TR.CSRReporting	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
csr_external_audit / TR.CSRReportingExternalAudit	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
gri_guidelines / TR.CSRReportingGRI	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
emissions_total_reported / TR.CO2EmissionTotal	metric tons CO2 equivalent; Vendor value; no separate estimate-status flag exported. Total Scope 1+2, not Scope 3. Separate component sum is not substituted for this original field.	Direct dated value; derived transformations below.
scope1_reported / TR.CO2DirectScope1	metric tons CO2 equivalent; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
scope2_reported / TR.CO2IndirectScope2	metric tons CO2 equivalent; Vendor value; no separate estimate-status flag exported. Purchased electricity/heat/steam Scope 2; exported field does not carry a harmonized market-/location-based identifier.	Direct dated value; derived transformations below.
scope1_combined / TR.Scope1EstTotal	metric tons CO2 equivalent; Use companion scope1_combined_method field. Combined record may remain modeled even when a separate reported component exists.	Direct dated value; derived transformations below.
scope1_combined_method / TR.Scope1EstMethod	categorical text; Observed labels include Reported_value, Winsorized_low/high, Extrapolated, Aggregated_model; original labels retained.	Direct dated value; derived transformations below.

Analysis variable / original field	Unit and status	Time/missing rule; transformation
scope2_combined / TR.Scope2EstTotal	metric tons CO2 equivalent; Use companion scope2_combined_method field. Combined record may remain modeled even when a separate reported component exists.	Direct dated value; derived transformations below.
scope2_combined_method / TR.Scope2EstMethod	categorical text; Observed labels include Reported_value, Winsorized_low/high, Extrapolated, Aggregated_model; original labels retained.	Direct dated value; derived transformations below.
energy_use_total / TR.EnergyUseTotal	gigajoules; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
water_withdrawal_total / TR.WaterWithdrawalTotal	cubic metres; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
waste_total / TR.WasteTotal	metric tons; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
total_assets_usd / TR.F.TotAssets	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
revenue_total_usd / TR.F.TotRevenue	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
net_income_after_minority_usd / TR.F.NetIncAfterMinIntr	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
debt_total_usd / TR.F.DebtTot	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
capex_total_usd / TR.F.CAPEXTot	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
emission_reduction_target_pct / TR.EmissionReductionTargetPctage	percentage points in original provider field; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
emission_reduction_target_year / TR.EmissionReductionTargetYear	year; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
long_term_net_zero_target / TR.LTGHGEmissionNetZeroTargetSet1	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
long_term_ghg_base_year / TR.LTGHGEmissionBaseYearSet1	year; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
long_term_ghg_target_year / TR.LTGHGEmissionTargetYearSet1	year; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
long_term_ghg_target_set_year / TR.LTGHGEmissionTargetSetYearSet1	year; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.

Analysis variable / original field	Unit and status	Time/missing rule; transformation
long_term_ghg_target_type / TR.LTGHGEmissionTargetTypeSet1	categorical text; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
tcf reporting / TR.ReportingAgainsttheTCFDRRecommendations	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
revenue_environmental_products_pct / TR.RevenueEnvProducts	percentage points in original provider field; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
biodiversity_targets / TR.BiodiversityTargets	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
self_reported_environmental_fines_usd / TR.SelfReportedEnvFines	USD; source export currency setting, not USD millions; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
environmental_data_independent_verification / TR.EnvironmentalDataIndependentVerification	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
environmental_data_assurance_standard / TR.EnvironmentalDataAssuranceStandard	binary; missing kept distinct from false; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
iso14000_or_ems_status / TR.ISO14000	categorical text; Vendor value; no separate estimate-status flag exported.	Direct dated value; derived transformations below.
scope12_combined / TR.Scope1EstTotal + TR.Scope2EstTotal	metric tons CO2e; Both components required in same calendar year; method pair retained; no reported-value override.	s1_combined + s2_combined
scope12_reported_strict / TR.CO2DirectScope1 + TR.CO2IndirectScope2	metric tons CO2e; Both separately reported components required; positive summed emissions and revenue for logarithm.	s1_reported + s2_reported
ln_emissions_intensity_revenue / TR.CO2EmissionTotal / TR.F.TotRevenue	log metric tons CO2e/USD; Both positive and aligned to same calendar year; display tCO2e/USD million multiplies ratio by 10^6 only.	ln(total/revenue)
ln_scope12_combined_intensity_revenue / (TR.Scope1EstTotal + TR.Scope2EstTotal) / TR.F.TotRevenue	log metric tons CO2e/USD; Same-calendar-year numerator/denominator; both positive.	ln(combined sum/revenue)
ln_scope12_reported_strict_intensity_revenue / (TR.CO2DirectScope1 + TR.CO2IndirectScope2) / TR.F.TotRevenue	log metric tons CO2e/USD; Both components and revenue observed; same strict sample used for paired combined comparator.	ln(reported sum/revenue)
ln_total_assets_usd / TR.F.TotAssets	natural log USD; Assets >0; same predictor year.	ln(assets)

Analysis variable / original field	Unit and status	Time/missing rule; transformation
roa / TR.F.NetIncAfterMinIntr / TR.F.TotAssets	unitless fraction, not percentage points; Nonzero denominator; income may be negative; original model no extra winsorization.	income/assets
debt_to_assets / TR.F.DebtTot / TR.F.TotAssets	unitless fraction; Nonzero denominator; original model no extra winsorization.	debt/assets
capex_to_revenue / TR.F.CAPEXTot / TR.F.TotRevenue	unitless fraction; Nonzero denominator; provider sign retained; original model no extra winsorization.	capex/revenue
environmental_pillar_score_z / derived from TR.EnvironmentPillarScore	Standardized score; dimensionless. Raw dated score retained separately.	$z=(x-\text{mean})/\text{SD}$, ddof=0; first country×TRBC two-digit industry×year cells with $n \geq 5$ and $\text{SD} > 0$. Remaining fallback observations are standardized within their country×year subset, not against all country–year observations. No filling of missing scores.
emissions_score_z / derived from TR.TRESGEmissionsScore	Standardized score; dimensionless. Raw dated score retained separately.	$z=(x-\text{mean})/\text{SD}$, ddof=0; first country×TRBC two-digit industry×year cells with $n \geq 5$ and $\text{SD} > 0$. Remaining fallback observations are standardized within their country×year subset, not against all country–year observations. No filling of missing scores.
resource_use_score_z / derived from TR.TRESGResourceUseScore	Standardized score; dimensionless. Raw dated score retained separately.	$z=(x-\text{mean})/\text{SD}$, ddof=0; first country×TRBC two-digit industry×year cells with $n \geq 5$ and $\text{SD} > 0$. Remaining fallback observations are standardized within their country×year subset, not against all country–year observations. No filling of missing scores.

Metadata were checked against archived exports and the legacy ESG Scores methodology, document version 2.0 (July 2026), archived 11 August 2026. Fiscal-period dates are not public-release dates. Histories can include provider revisions. Scope 2 accounting basis is not identifiable from the exported field labels and was not silently assigned as location-based or market-based.

Table S19A Strict reported Scope 1 and Scope 2 sensitivity

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M3	Extended	2015–2023; h=1	1954/320	1090/864	-0.128 [-0.203, -0.054] (0.005)	0.027 [-0.074, 0.128] (0.721)	0.155 [0.028, 0.283] (0.052)
M3	Common	2019–2023; h=1	1480/320	922/558	-0.051 [-0.115, 0.013] (0.684)	-0.023 [-0.096, 0.050] (0.684)	0.028 [-0.069, 0.125] (0.684)
M4	Extended	2015–2023; h=1	1954/320	1090/864	-0.040 [-0.114, 0.034] (0.572)	-0.029 [-0.126, 0.068] (0.721)	0.011 [-0.113, 0.136] (0.858)
M4	Common	2019–2023; h=1	1480/320	922/558	-0.011 [-0.067, 0.046] (0.706)	0.018 [-0.039, 0.074] (0.684)	0.028 [-0.053, 0.109] (0.684)

Both scope components must be reported. Two scores × three contrasts form a six-test BH family per window. Total scope definition is unchanged; construction and coverage differ.

Table S19B Combined series on the strict reported sample

Model	Window	Exposure; horizon	N / firms	CN / KR rows	China β [CI] (q)	Korea β [CI] (q)	Korea–China β [CI] (q)
M3	Extended	2015–2023; h=1	1954/320	1090/864	-0.131 [-0.216, -0.046] (0.016)	0.015 [-0.084, 0.115] (0.761)	0.146 [0.013, 0.280] (0.064)
M3	Common	2019–2023; h=1	1480/320	922/558	-0.053 [-0.121, 0.015] (0.721)	-0.033 [-0.103, 0.037] (0.721)	0.021 [-0.078, 0.120] (0.778)
M4	Extended	2015–2023; h=1	1954/320	1090/864	-0.082 [-0.149, -0.014] (0.053)	-0.041 [-0.126, 0.044] (0.514)	0.041 [-0.069, 0.150] (0.558)
M4	Common	2019–2023; h=1	1480/320	922/558	-0.030 [-0.081, 0.021] (0.721)	-0.008 [-0.062, 0.047] (0.778)	0.022 [-0.053, 0.097] (0.778)

Uses identical baseline rows to S19A with the combined reported/estimated outcome, separating construction from sample selection. Separate six-test BH family per window.

Supplementary Methods S4. Documentary, measurement and covariance audits

All directly dateable fields below share one rule: the exported field-specific period-end date determines year, without FY-label or publication-date substitution. Missing value or date excludes the cell. Duplicate variable/year cells are audited rather than averaged. Logs require positive finite values; missing and false binary values remain distinct. Table S18 supplies field-specific units, method labels and derived formulas. Scope 2 basis and record-level source priority are not inferable when absent from the exports.

The Korean export contained 3,029 listed-security records representing 2,823 provider organizations. Of these, 168 distinct organizations had at least one usable ESG/emissions observation and 115 met the five-year complete-bundle threshold. Reconstructing each membership set with an observed CSR-field requirement gives the same members at both stages; the original screening-script predicate order is not recoverable. False CSR responses were retained, so this was an observed-field check rather than an affirmative CSR-reporting restriction. Table S9 compares the retained organizations with the 53 organizations having one to four usable years.

The factor-two discrepancy queue was assembled before public-document adjudication in August 2026. The four-company exclusion reuses those decisions as an outcome-screened measurement sensitivity, not as a prospectively selected validation cohort. Each company contributes ten paired years (2015–2024). Only the recent years shown in this table have direct documentary anchors; classification of other years is extrapolative. The 40-pair company rule and 28-pair documented-anomaly rule differ by 12 pairs, all from CJ CheilJedang and KEPCO. Public-report identities and page anchors are disclosed here, without licensed annual observations.

Firm-clustered covariance estimates use CR1 with the multiplier $G/(G-1) \times (N-1)/(N-K)$, where G is the number of firms, N is the complete-case observation count and K is the rank of the slope design after absorption; absorbed fixed-effect coefficients are not included in K . Two-sided tests and confidence intervals use Student t reference distributions with $G-1$ degrees of freedom. An independent implementation audit reconstructed all eight primary model/window combinations and sixteen additional two- and three-year model/window combinations. Pivoted-QR projections with statsmodels 0.14.6 cluster sandwich covariance and PyFixest 0.60.0 under explicitly matched finite sample settings reproduced coefficients, standard errors and family-adjusted inference. Full absorbed-rank and nonnested-rank corrections, and iterative singleton exclusion, are separately reported as convention sensitivities. The same matched covariance checks were also applied to the sixteen primary GIR model–window–scenario settings, without rerunning their wild bootstrap.

An association-model random intercept and a latent emissions measurement model answer different questions. A random intercept mixes within- and between-firm variation and requires restrictions on the relationship between firm effects and scores. The retained fixed-effect estimand uses within-firm variation. Separately, identifying latent common-boundary emissions requires calibration anchors or defensible error restrictions not identified by two differently scoped observed series. The present supplement quantifies source discrepancies rather than assuming a latent correction.

Table S20. Public boundary evidence and scope of exclusion

Public company (KRX code)	Public report / PDF pages	Direct anchor years; other study years	Firm-rule / anomaly- rule pairs	Boundary evidence
Korean Air Co., Ltd. (003490)	2024 Korean Air ESG Report PDF pp. 2, 86	2023 direct; 2015–2022 and 2024 extrapolated	10 / 10	Domestic Korean business-site Scopes 1+2 versus international aviation operations; separately assured in the same report.
Samsung Electro- Mechanics Co., Ltd. (009150)	2023–2024 Samsung Electro- Mechanics Sustainability Report PDF pp. 2, 112, 132	2023 direct; 2015–2022 and 2024 extrapolated	10 / 10	Consolidated worldwide production subsidiaries versus Korean domestic sites; report distinguishes location-based and market-based Scope 2.
CJ CheilJedang Corporation (097950)	CJ CheilJedang Sustainability Report 2024 PDF pp. 2, 101; CJ CheilJedang Sustainability Report 2025 PDF pp. 2, 108	2022–2024 direct; 2015– 2021 extrapolated	10 / 4	Food, BIO and Feed&Care divisions and multiple domestic/overseas legal entities versus Korean parent legal entity. Later report changes consolidated perimeter after Feed&Care disposal and restates earlier data; 2025 is outside the paired study outcomes.
Korea Electric Power Corporation (015760)	KEPCO Sustainability Report 2023 PDF pp. 2, 32, 33, 88; KEPCO environmental ESG data center, archived 12 August 2026 HTML: Greenhouse Gas Emissions table; no PDF pagination	2022–2024 direct; 2015– 2021 extrapolated	10 / 4	KEPCO and six generating group companies, including domestic/overseas activity, versus the parent legal entity. Parent-level Scope 1 and Scope 2 table supplies recent-year regulatory-boundary anchor; not a group-generation total.

The factor-two discrepancy queue was assembled before public-document adjudication in August 2026. The four-company exclusion reuses those decisions as an outcome-screened measurement sensitivity, not as a prospectively selected validation cohort. Each company contributes ten paired years (2015–2024). Only the recent years shown in this table have direct documentary anchors; classification of other years is extrapolative. The 40-pair company rule and 28-pair documented-anomaly rule differ by 12 pairs, all from CJ CheilJedang and KEPCO. Public-report identities and page anchors are disclosed here, without licensed annual observations. Page numbers are PDF positions, including cover pages. Sources: Korean Air [37]; Samsung Electro-Mechanics [38]; CJ CheilJedang [39, 40]; KEPCO [41, 42]. The KEPCO 2023 report is found by report title/year at the official report index; the historical downloaded snapshot is hashed in the controlled record.

Table S21. Combined versus separately reported components on identical samples

Window / country	N / G	Equal sums n (%)	Different: modeled / both reported labels	Combined/reported ratio p5 / median / p95
main_2015_2023 / Pooled	1954 / 320	1281 (65.6%)	356 / 317	0.683 / 1.000 / 1.183
main_2015_2023 / China	1090 / 205	822 (75.4%)	219 / 49	0.537 / 1.000 / 1.121
main_2015_2023 / Korea	864 / 115	459 (53.1%)	137 / 268	0.805 / 1.000 / 1.202
common_2019_2023 / Pooled	1480 / 320	1012 (68.4%)	279 / 189	0.650 / 1.000 / 1.156
common_2019_2023 / China	922 / 205	697 (75.6%)	187 / 38	0.517 / 1.000 / 1.054

Window / country	N / G	Equal sums n (%)	Different: modeled / both reported labels	Combined/reported ratio p5 / median / p95
common_2019_2023 / Korea	558 / 115	315 (56.5%)	92 / 151	0.789 / 1.000 / 1.208

Identical strict reported/combined comparison samples are those of Table S19, pooled N=1954 and 1480; both primary predictors have the same sample support. Equal sums use atol=1e-6 metric tons and rtol=1e-10. Modeled denotes any combined component not labeled Reported_value. All four component dates are identical in every compared observation. Separate fields remain distinct even when their method labels are Reported_value; source-priority and market/location metadata are not available to assign the residual differences to a single mechanism. Component sensitivity to looser equality tolerances is included in the accompanying aggregate CSV.

Table S22A. Independent matched CR1 covariance checks and finite sample convention sensitivity.

Covariance convention	Window	Horizons	Family tests	Minimum BH q	q < 0.05	Decisions changed
Original matched CR1: QR + statsmodels	Common	h1	12	0.920	0	0
Original matched CR1: QR + statsmodels	Common	h2/h3	24	0.239	0	0
Original matched CR1: QR + statsmodels	Extended	h1	12	0.059	0	0
Original matched CR1: QR + statsmodels	Extended	h2/h3	24	0.021	8	0
Original matched CR1: PyFixest	Common	h1	12	0.920	0	0
Original matched CR1: PyFixest	Common	h2/h3	24	0.239	0	0
Original matched CR1: PyFixest	Extended	h1	12	0.059	0	0
Original matched CR1: PyFixest	Extended	h2/h3	24	0.021	8	0
Full absorbed FE rank convention	Common	h1	12	0.969	0	0
Full absorbed FE rank convention	Common	h2/h3	24	0.776	0	0
Full absorbed FE rank convention	Extended	h1	12	0.121	0	0
Full absorbed FE rank convention	Extended	h2/h3	24	0.055	0	8
Explicit nonnested FE rank convention	Common	h1	12	0.925	0	0
Explicit nonnested FE rank convention	Common	h2/h3	24	0.261	0	0
Explicit nonnested FE rank convention	Extended	h1	12	0.069	0	0
Explicit nonnested FE rank convention	Extended	h2/h3	24	0.025	8	0
Matched CR1 after iterative singleton exclusion	Common	h1	12	0.920	0	0
Matched CR1 after iterative singleton exclusion	Common	h2/h3	24	0.239	0	0
Matched CR1 after iterative singleton exclusion	Extended	h1	12	0.059	0	0
Matched CR1 after iterative singleton exclusion	Extended	h2/h3	24	0.021	8	0

h1 retains the original 12-test family in each window; h2/h3 retains the separate 24-test added family. All estimates use the same controls, country interactions and three absorbed fixed effects; firm clustering and Student $t(G-1)$ inference are retained. Matched implementations count only the rank K of the slope design in $G/(G-1) \times (N-1)/(N-K)$. The explicit nonnested convention sets K to slope rank plus absorbed FE rank minus the firm FE dimension; the full-rank convention counts the complete absorbed FE rank. Iterative singleton exclusion applies to all three fixed-effect dimensions. These alternative counts are explicitly defined sensitivity conventions, not unverified claims about Stata or another package default.

Table S22B. Independent matched GIR covariance implementation checks.

Implementation	Settings	Maximum $ \Delta\beta $	Maximum $ \Delta SE $	Maximum $ \Delta \text{covariance} $	Maximum $ \Delta BH \ q $	Decision changes
PyFixest, matched CRV1	16	3.47e-16	6.94e-16	1.13e-13	3.22e-15	0
Statsmodels, independent QR	16	5.90e-16	5.97e-16	2.04e-14	9.02e-15	0

Sixteen settings comprise two rating predictors, two windows and four existing sensitivity scenarios. Both implementations match the original complete-case sample and minimum-two-observations-per-firm rule, firm/year fixed effects, controls, firm clustering, slope-only CR1 with $K=5$, and $t(G-1)$ inference. BH adjustment retains the existing two-test family within each scenario/window. This table checks the raw covariance and CR1 inference only; it neither recomputes the wild bootstrap nor increases the number of independent clusters.

Table S23. Closest prior evidence and effect-scale comparability

Prior study / criterion	Design and reported scale	Relation to the present estimand
Cregan et al. [16]: airline carbon outcomes	57-airline coverage frame; 2012–2021 ratings/emissions, with prediction horizons up to five years. Includes emissions per revenue–passenger and revenue–ton kilometer.	Operational-output intensity differs from consolidated revenue intensity; the study reports no reliable capture/prediction rather than a common standardized-score effect size.
Qian and Liu [14]: carbon emission efficiency	Chinese A-share firms; publisher highlights report an efficiency increase of 0.0112 for a 1% ESG-rating increase.	Composite ESG, percentage rating changes and efficiency units differ from an environmental-score SD and log emissions per USD. The published headline is not converted into a comparable percentage abatement effect.
Zhang and Lai [15]: corporate environmental performance	Chinese A-share firms, 2008–2023; difference-in-differences using SynTao rating variation. Performance includes positive and negative environmental scores.	Rating introduction and performance-score outcomes differ from a within-firm LSEG environmental-rating slope against subsequently dated emissions intensity.
Park et al. [17]: Korean emissions trading	Listed firms, 2011–2017; first-phase Korean ETS comparison. Environmental ratings increase, but emissions reduction relative to controls is not statistically established.	Intervention contrast with Korean Corporate Governance Service ratings, rather than provider-score criterion validity. No common effect-size scale is assumed.

Descriptions use the cited original publisher material. Only Qian and Liu provide a readily verifiable headline effect magnitude in that material; it is retained in its original stated units. No unavailable coefficients, implicit causal equivalence or conversion across outcome scales is supplied. These comparisons contextualize achieved precision but do not define a smallest effect of interest.