

Beyond participation: where carbon accounts cannot distinguish sustainable practice from development constraint

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Abstract

Sustainable-lifestyle commitments now sit inside G20, UNEA and national climate pledges, yet the accounts that will judge them count participation and pressure, not realised practice. Here we show where consumption-based carbon accounts can and cannot distinguish sustainable practice from constrained consumption, using open data for 118 countries covering 90% of world population. Realised emissions per capita track income, electricity access and urbanisation closely ($R^2 = 0.86$). For 3.1 billion people in 35 countries, expected impacts already fall below the level compatible with 1.5°C pathways, so a low reading is uninformative: restraint and constraint are indistinguishable. Among the remaining 83 informative countries, none sits significantly below expectation, in-sample or under leave-one-country-out out-of-sample prediction. Under a pre-specified design with exclusion tests and no rankings, with per-capita rates and population-scale totals reported side by side without bonus or credit, we provide the measurement diagnosis that post-2030 sustainability frameworks currently lack.

Introduction

Sustainable lifestyles have moved from the margins of climate diplomacy to its operational core. The Paris Agreement's mitigation arithmetic, successive G20 communiques, and United Nations Environment Assembly resolutions all now lean on the proposition that how billions of people move, eat, buy and discard will determine whether national pledges are met^{1,2,3,4,5}. India has placed this proposition at the centre of its international positioning through Mission LiFE⁶. Yet the measurement systems that will judge these commitments were built for a different question. The measurement attached to these commitments still tracks participation: enrolment, access, reported behaviour, stated willingness^{1,7,8,9,10}. The Sustainable Development Goals framework, whose final comprehensive indicator review concluded in 2025, does contain hard pressure accounts, material footprint and domestic material consumption under Goal 12¹¹; but pressure accounts cannot say whether a low reading reflects chosen restraint or constrained consumption. With the SDG era closing in 2030, the successor framework to be opened at the 2027 SDG Summit will inherit whatever instruments exist at that moment^{12,13,2}. What is not instrumented now will not be measured later.

Participation metrics carry a structural blindness that adjacent fields learned to correct decades ago. Health systems research distinguishes service coverage from effective coverage, because contact with a service is not the same as benefit from it¹⁴. Energy access measurement abandoned binary connection counts in favour of multi-tier frameworks once it became clear that a connection says little about the supply actually usable¹⁵. Lifestyle monitoring has no equivalent correction^{16,17}. A country whose citizens consume little because they cannot afford more is observationally identical, in participation and footprint data, to a country whose citizens choose restraint with the means to do otherwise^{9,18,19}; goal frameworks have punished the poor for their poverty before²⁰. The first is constrained consumption; the second is sustainable practice. Aggregate accounts do not distinguish them, and the consequences are not symmetric: countries with large low-income populations can appear

virtuous on consumption-side metrics without any practice occurring, while affluent countries can register concern without behavioural consequence^{21,22,23,24,25,26,27}. Both distortions follow from the same missing distinction.

The distinction matters now for three reasons. First, the behavioural literature has established that attitudes, intentions and realised behaviour diverge systematically, and that the size of the divergence is itself conditioned by income, infrastructure and price^{28,29,30,31,32,33,34,35,36}. Treating reported participation as practice therefore imports a known, measurable bias as if it were noise. Second, consumption-side emissions inequality is large and patterned: the footprints of the top deciles within and across countries exceed those of the bottom half by an order of magnitude, which means the policy content of “sustainable lifestyles” depends entirely on whose behaviour is being counted and against what counterfactual^{37,38,24,25,27}. Third, the post-2030 design conversation has already begun. Proposals for the successor indicator architecture emphasise flexibility, with core, optional and custom components³⁹. Flexibility, however, cannot rescue an architecture that cannot tell practice from constraint; it merely distributes the confusion across more indicators.

Here we demonstrate the blindness empirically and specify its correction. Using fully open consumption-based national carbon accounts for 2023^{40,41} and enabling-condition covariates from the World Development Indicators⁴², we estimate, for 118 countries covering 90% of world population, the consumption emissions per capita expected from each country’s means, and compare them with realised emissions. This expectation model operationalises the four-layer architecture of Fig. 1 at country level: enabling conditions define what is expected; practice, if it occurs, resides in the deviation from expectation, which aggregate accounts cannot attribute; persistence is the stability of that deviation across two decades; and environmental consequence is reported twice, per capita and at population scale, never averaged. Three design commitments govern the analysis. All thresholds and model specifications were fixed in a written design document before headline classifications were computed, classifications were computed algorithmically with no country-level discretion, and no country rankings are produced: results are reported as estimates with uncertainty, alphabetically in tables, with no population bonus and no deprivation credit applied to any country. A pre-specified exclusion test asks whether any headline finding survives the removal of any single country, including India, whose national programmes make it the politically most salient case and therefore the one the design must be most indifferent to^{43,44,6}.

Results

The expectation model: means explain most of impact

Across the 118 countries with complete data, consumption-based CO₂ per capita in 2023 rises with GDP per capita (PPP) with an elasticity of 0.83 (95% CI 0.68 to 0.98, $P < 0.001$), with electricity access adding independent information ($P = 0.006$) and the urbanisation coefficient more uncertain ($P = 0.056$; overall

$R^2 = 0.861$, $n = 118$). The model is the constraint-consistent expectation: the impact a country would show if its consumption simply followed its means. Figure 2 displays the expectation and its 95% prediction band against realised values for every country.

The blindness zone: 3.1 billion people whose restraint cannot be read

We defined the measurement blindness zone ex ante as the set of countries whose expected consumption emissions per capita, given their means, already fall below 2.3 t CO₂, an operational benchmark drawn from the 1.5°C lifestyle-footprint scenario literature^{45,46}. Thirty-five countries meet this criterion: home to 3.06 billion people, 38.0% of world population (36.7 to 39.2% across threshold sensitivity of 2.1 to 2.5 t). For these countries, a low measured impact is uninformative by construction: it is exactly what constraint predicts, so no existing aggregate account can credit any of their citizens' restraint as practice. India is in this zone (expected 1.57 t, realised 1.77 t, + 12% against expectation). This is not a finding about India's performance; it is a finding about the instrument. Whatever Mission LiFE achieves behaviourally, current aggregate accounts are structurally incapable of seeing it.

The symmetric result: practice cannot be certified anywhere either

Above the zone, where means make deviation readable, 80 countries sit within the prediction band and three sit significantly above it (Kuwait, Mongolia, Trinidad and Tobago). No country sits significantly below it: under the pre-specified two-tailed test at alpha 0.05, realised consumption restraint beyond what enabling conditions predict is observed in zero of the 83 informative countries. Because in-sample prediction bands can be attacked as lenient, we ran a post hoc out-of-sample check, added after pre-submission review and therefore outside the frozen design: the model was re-estimated 118 times, each time withholding one country, and the withheld country's realised value was compared with the 95% prediction interval computed from the remaining 117. Zero of 118 countries fall significantly below their held-out interval, four fall above it (Kuwait, Mongolia, Namibia and Trinidad and Tobago), and the blindness-zone classification is identical under held-out expectations (Supplementary Table S3). The test is strict in one direction: across the analytic sample, the lower 95% prediction bound ranged from 36.8% to 39.6% of expected consumption, so a realised value generally had to fall roughly 60 to 63% below expectation to register as restraint; even Sweden, 47% below expectation in 2023, remains statistically unreadable as practice. The measurement problem is therefore symmetric: aggregate accounts cannot certify practice where it would be most visible, and cannot even pose the question for 38% of humanity.

Persistence: positions relative to means are sticky

Re-estimating the expectation model independently for 2000 and 2010 and correlating country deviations across waves yields Spearman coefficients of 0.65 (2000 to 2010), 0.64 (2010 to 2023) and 0.43 across the full 23 years ($n = 117$; Fig. 3). Deviations from means are persistent structural positions,

not year-to-year noise: whatever drives practice-like or excess deviations is slow-moving, which is what a policy-relevant indicator must be able to track.

Dual reporting: per-capita and population-scale columns diverge sharply

Reported at population scale, the ten largest consumers of 2023 include seven countries that sit outside the per-capita top twenty (Fig. 4). India ranks 92nd of 118 per capita (1.77 t) and 3rd at population scale (2.54 Gt); China ranks 35th per capita (7.63 t) and 1st at population scale (10.77 Gt). Any indicator that silently averages these columns rewards size or punishes it, depending on construction. We therefore report both columns side by side (Table 1; Fig. 4), alphabetically and without ranks, and apply no population bonus and no deprivation credit.

Table 1

Expectation and reality for the 15 largest population-scale consumers, 2023 (alphabetical; no ranks published). Expected values from the pre-specified model (log consumption CO₂ per capita on log GDP per capita PPP, electricity access,

urbanisation; $R^2 = 0.861$, $n = 118$). Exp: expected t CO₂ per capita; Real: realised t CO₂ per capita; Gap: realised relative to expected; Gt CO₂: population-scale emissions. Class codes: Zone = blindness zone, expected impact below 2.3 t CO₂ per capita, an operational benchmark from the 1.5°C lifestyle-footprint scenario literature^{45,46}; On = on expectation. The full 118-country table is Supplementary Table S2.

Country	GDP/cap (\$)	Exp (t)	Real (t)	Gap %	Gt CO ₂	Class
Brazil	21,193	4.16	2.23	-47	0.47	On
Canada	64,962	10.21	13.23	+ 30	0.53	On
China	25,200	4.18	7.63	+ 83	10.77	On
Germany	72,262	11.11	9.09	-18	0.76	On
India	9,853	1.57	1.77	+ 12	2.54	Zone
Indonesia	15,428	2.64	2.59	-2	0.73	On
Iran	18,933	3.54	7.38	+ 108	0.67	On
Japan	52,726	9.13	9.18	+ 1	1.14	On
Mexico	25,188	4.55	4.35	-4	0.56	On
Russia	44,299	7.09	9.67	+ 36	1.39	On
Saudi Arabia	71,624	11.20	19.66	+ 76	0.66	On
South Korea	57,430	9.14	13.70	+ 50	0.71	On
Turkey	43,196	7.59	5.53	-27	0.47	On
United Kingdom	60,787	9.70	7.09	-27	0.49	On
United States	82,587	12.27	15.81	+ 29	5.33	On

[Table 1 about here]

Exclusion tests

The pre-specified exclusion loop removed each country in turn and re-estimated the model and all classifications. Across the full 118-country loop, 104 exclusions changed no country's classification and 14 changed exactly one borderline case each (Supplementary Table S1). The six politically salient exclusions each changed zero classifications: excluding India moved the model R^2 by 0.001 (0.860 versus 0.861), and the blindness-zone total under India exclusion is mechanically smaller (1.62 billion)

only because India itself leaves the sample; excluding China, the United States, Indonesia, Brazil or Nigeria left zone totals between 2.84 and 3.06 billion. Model fit across all 118 exclusions stayed within $R^2 = 0.852$ to 0.868 . No headline finding depends on the presence of any single country.

Discussion

The instruments that will judge sustainable-lifestyle commitments currently reward the appearance of sustainable behaviour. This study quantifies the cost of that design. For 3.1 billion people in 35 countries, expected consumption given national means already sits below the 1.5°C -compatible per-capita level, so a low reading cannot distinguish practice from constraint; and among the 83 countries where means make deviations readable, none demonstrates statistically detectable restraint below expectation. The first number indicts the instruments applied to the world's poor; the second denies the world's rich any certified claim to practice. Neither side of the climate-justice argument can recruit these results, because the same pre-specified instrument produced both.

The findings cut in both political directions, by construction. Low-income countries in the blindness zone are not shown to be practising; they are shown to be unmeasured, which is a different and more actionable claim: their national lifestyle programmes, of which India's Mission LiFE is a prominent national example, are producing effort that no accepted aggregate account can register^{43,44,6}. High-income countries within or above the band are not shown to be insincere; they are shown to lack any demonstrated margin between their consumption and what their means predict. Any reading that recruits only one side of this result is a misreading of the method, which was fixed and automated precisely to foreclose selective use^{47,48,49}.

For the post-2030 process, the contribution is an offer, not a demand. The 2027 HLPF review of SDG 12 and the SDG Summit that follows need a practice-versus-constraint distinction in their indicator pool^{12,13,2}. The four-layer architecture demonstrated here, with fully open data and code, gives national statistical offices a computable starting point, and the blindness-zone map tells them exactly where country-level accounts suffice and where individual-level measurement is obligatory. Multi-decade individual-level survey series, above all the International Social Survey Programme Environment modules^{50,51,52,53,54,55}, make that within-country distinction observable in principle, because attitudes, reported behaviours and material constraints can be compared within the same populations. We identify that individual-level extension as the necessary next step; the present study claims nothing at that level. National programme dashboards measure reach rather than realised practice; this study claims nothing about their internal validity, and adds the cross-national comparability under constraint that no national instrument can supply alone.

Four limitations bound the claims. Consumption-based CO_2 accounts cover fossil emissions embodied in trade, not the full greenhouse-gas or land-use footprint, so the practice concept is operationalised here on its best-measured dimension. The expectation model is associational: its residuals contain energy mix, industrial structure, geography, climate, taxation and trade composition alongside any practice

signal, which is exactly why we claim that aggregate accounts cannot distinguish practice from constraint, not that we have separated them. Within-country heterogeneity is likewise invisible to it by design, which motivates the individual-level extension. The 2.3 t threshold is an operational benchmark drawn from the 1.5°C lifestyle-footprint scenario literature and is reported with sensitivity across 2.1 to 2.5 t rather than treated as exact. The below-expectation test is also permissive, registering only shortfalls of roughly 60% or more, so the empty restraint class marks the instrument's floor rather than proving that restraint exists nowhere. And governance context, including statistical capacity and survey-freedom conditions, varies across the sample; country-level covariates absorb part of this variation, and the zone classification is robust to its plausible range.

The measurement era that ends in 2030 counted who showed up. The era that follows will be judged on what changed. We have shown that the current instruments cannot make that judgement for two-fifths of humanity, and cannot certify it for the rest. An instrument that can distinguish practice from constraint is the minimum correction the next framework requires.

Methods

Data

Consumption-based (territorial emissions adjusted for trade) CO₂ per capita for 2023 come from the Global Carbon Budget 2025 (Global Carbon Project dataset version 15) as distributed by Our World in Data^{40,41}. Enabling-condition covariates come from the World Development Indicators: GDP per capita, PPP (current international \$), access to electricity (% of population), urban population (% of total), and total population, taking the most recent non-missing observation within 2020 to 2023 per country⁴². The analytic sample comprises the 118 countries with complete data and population above 300,000, a threshold fixed before analysis; the sample covers 90.0% of world population. All sources are openly downloadable without registration; the merged dataset and the complete replication code accompany this article as Supplementary Data S1 and Supplementary Code.

Expectation model and classification

The constraint-consistent expectation was estimated by ordinary least squares of log consumption CO₂ per capita on log GDP per capita (PPP), electricity access and urbanisation, yielding $R^2 = 0.861$ ($n = 118$). Classifications were computed algorithmically with no country-level discretion. A country is in the blindness zone if its expected emissions per capita fall below 2.3 t CO₂, an operational benchmark drawn from the 1.5°C lifestyle-footprint scenario literature^{45,46}; zone totals are reported with threshold sensitivity at 2.1 and 2.5 t. Among informative countries, a country is above expectation if its realised value exceeds the 95% prediction interval and below expectation (realised restraint) if it falls under it. Model residuals were consistent with approximate normality (Shapiro-Wilk $P = 0.052$; skewness 0.36), and the prediction intervals were additionally validated out of sample (below). Statistical tests are two-tailed with alpha 0.05; exact P values are reported; the small number of planned comparisons (three

model coefficients, three persistence correlations) renders multiplicity inflation negligible, and Benjamini-Hochberg control is applied where families of tests are reported in Supplementary Information⁵⁶.

Persistence analysis

The expectation model was re-estimated independently on 2000 and 2010 data with identical specification, and country deviations (residuals) were correlated across waves using Spearman rank correlation on the 117 countries observed in all three waves.

Dual reporting

Population-scale consumption emissions were computed as per-capita values multiplied by population for each country. Per-capita and population-scale estimates are reported side by side in every display; they are never averaged, weighted or combined into a composite, and no ranking is published. Rank positions are used only descriptively in text to characterise divergence between the two columns.

Exclusion tests

A pre-specified leave-one-country-out loop re-estimated the model and all classifications 118 times. Reported sensitivity focuses on the politically salient cases (India, China, United States, Indonesia, Brazil, Nigeria); the full loop is in Supplementary Table S1.

Post hoc out-of-sample check

Following pre-submission review, and outside the frozen design, the model was re-estimated 118 times, each time withholding one country, and the withheld country's 95% prediction interval was computed from the remaining 117 countries. Realised values were counted below or above their held-out intervals, and blindness-zone classifications were re-derived from held-out expectations. Results appear in Supplementary Table S3.

Design freeze

The full analysis plan, including the expectation-model specification, the 2.3 t threshold with its sensitivity range, the classification rules, the dual-reporting rule, the no-ranking commitment and the leave-one-country-out loop, was fixed in a written design document dated 18 August 2026 before the headline classifications were computed, and no rule was altered afterwards. The frozen design document is included as Supplementary Note 1. Classifications were computed algorithmically from the frozen rules with no country-level discretion, and no country label influenced any modelling decision. The document is a design freeze, not a preregistration; no registry deposit was made, and none is required for this article type.

Reproducibility and reporting

All inputs are public and the full pipeline from download to figures is scripted. In accordance with the journal's policy on large language models: generative AI tools were used for literature organisation, text drafting and analysis-code generation under the author's direction. The author reviewed all text, verified

every reported value against the analysis outputs, and takes full responsibility for the content, analysis decisions and interpretations.

Data availability

Consumption-based CO₂ per capita: Global Carbon Budget 2025 (Global Carbon Project dataset v15, <https://doi.org/10.18160/GCP-2025>) via Our World in Data^{40,41}, accessed 18 August 2026. Covariates and population: World Bank, World Development Indicators, accessed 18 August 2026⁴². All inputs are publicly downloadable without registration. Supplementary Data S1 contains the merged 2023 analytic sample. The 2000 and 2010 waves used in the persistence analysis are rebuilt from the same public sources by the Supplementary Code, which writes each wave to disk as it runs.

Code availability

The complete analysis code, from data download to figures, is included as the Supplementary Code file and reproduces every estimate, table and figure in this article.

Declarations

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Author contributions

The sole author conceived the study, designed the measurement architecture, performed the analysis, and wrote the manuscript.

Competing interests

The author declares no competing interests. No government body was contacted, consulted or funded in relation to this work.

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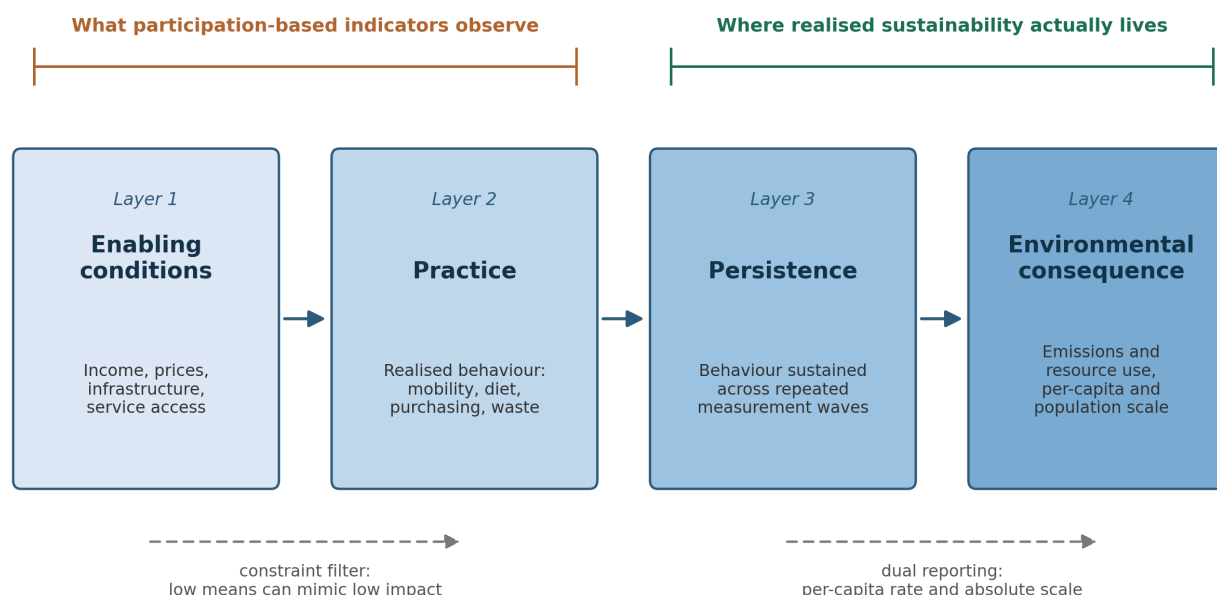
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Figures



Schematic of the study design. Country weights and thresholds are fixed before analysis (design frozen); no population bonus and no deprivation credit are applied at any layer.

Figure 1

Four-layer measurement architecture separating enabling conditions, practice, persistence and environmental consequence. Orange bracket: the domain observed by participation-based indicators. Blue-green bracket: the domain in which realised sustainability would be located. Dashed arrows mark the constraint filter and the dual-reporting rule. Thresholds and model specifications are fixed before classification; no population bonus and no deprivation credit are applied at any layer. At country level, aggregate accounts can locate where practice would have to reside, but cannot attribute deviations to practice alone.

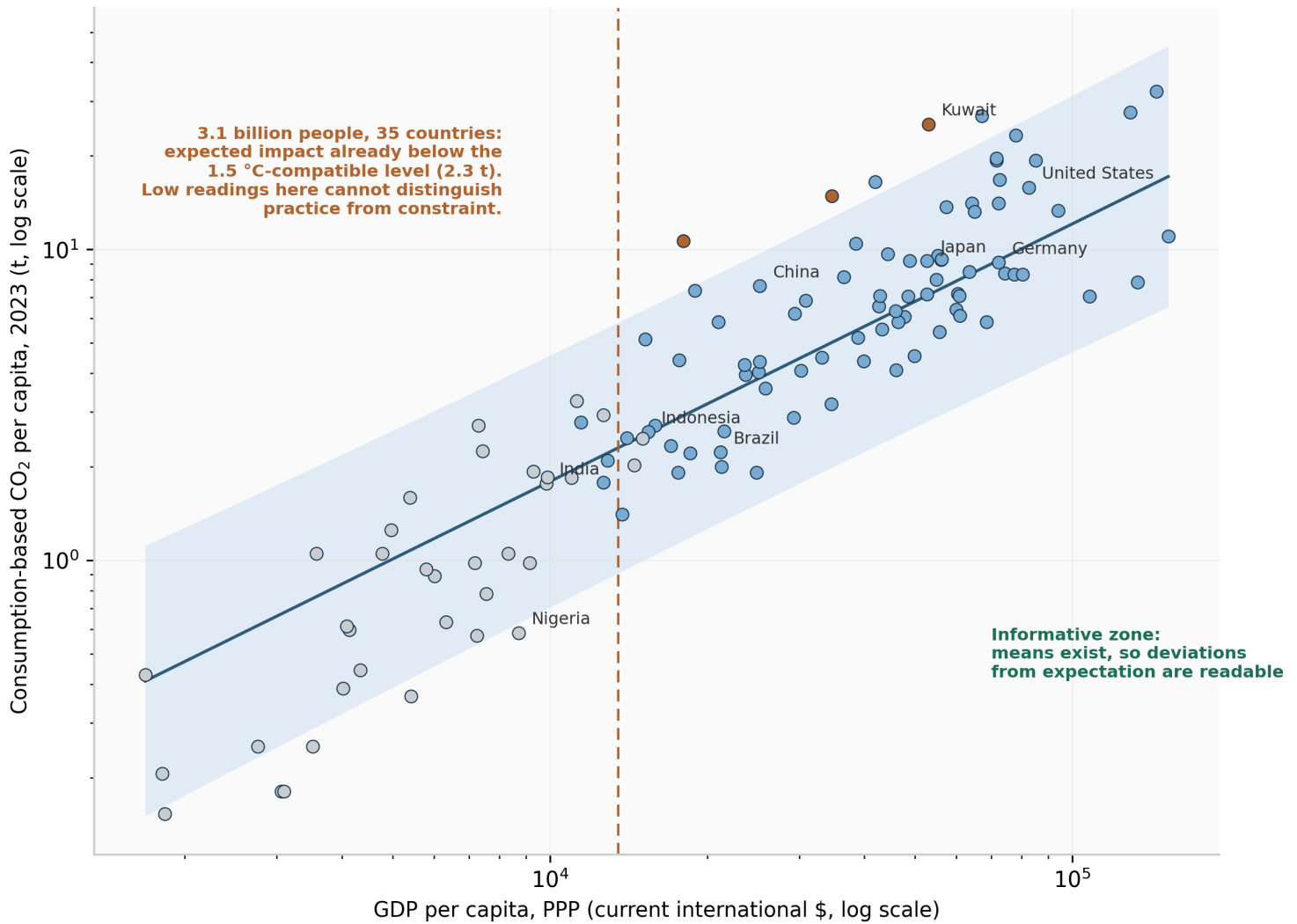


Figure 2

The measurement space. Each dot is one of 118 countries (90% of world population). Solid line: constraint-consistent expectation from the pre-specified model; shaded band: 95% prediction interval. Dashed orange line: the enabling level below which expected impact falls under 2.3 t CO₂ per capita, the 1.5 °C-compatible level. Left of that line, 35 countries holding 3.06 billion people, a low reading cannot distinguish practice from constraint. Grey dots: blindness zone. Blue dots: informative countries on expectation. Orange dots: significantly above expectation (Kuwait, Mongolia, Trinidad and Tobago). No country with means sits significantly below expectation; under leave-one-country-out out-of-sample prediction, zero of 118 countries fall below their held-out band (Supplementary Table S3).

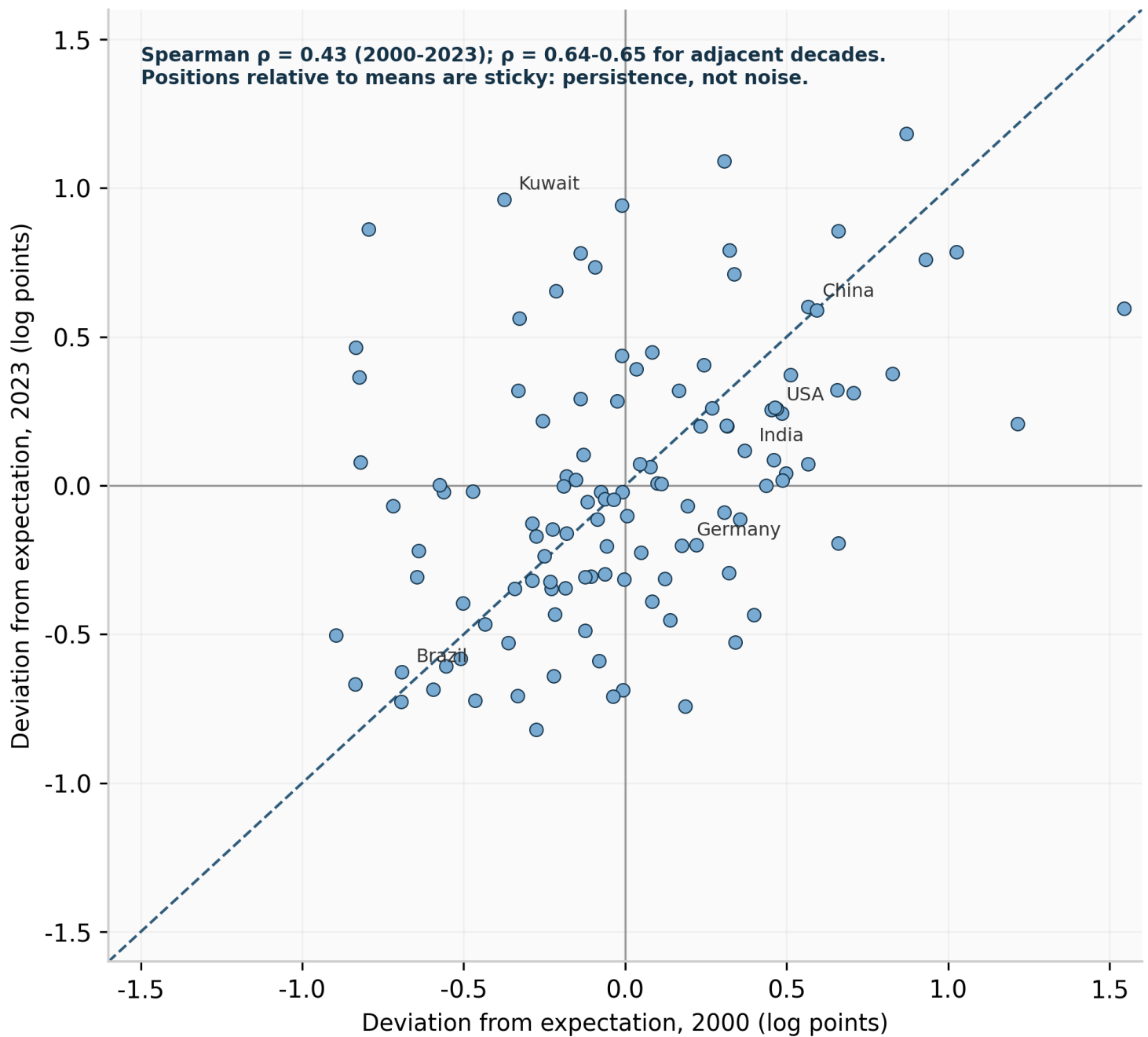


Figure 3

Persistence of position. Country deviations from expectation (model residuals, log points) in 2000 against 2023, $n = 117$ countries observed in both waves. Dashed line: perfect persistence. Spearman $\rho = 0.43$ across 23 years, and $\rho = 0.65$ (2000 to 2010) and 0.64 (2010 to 2023) for adjacent decades: deviations from means are stable structural positions, not noise.

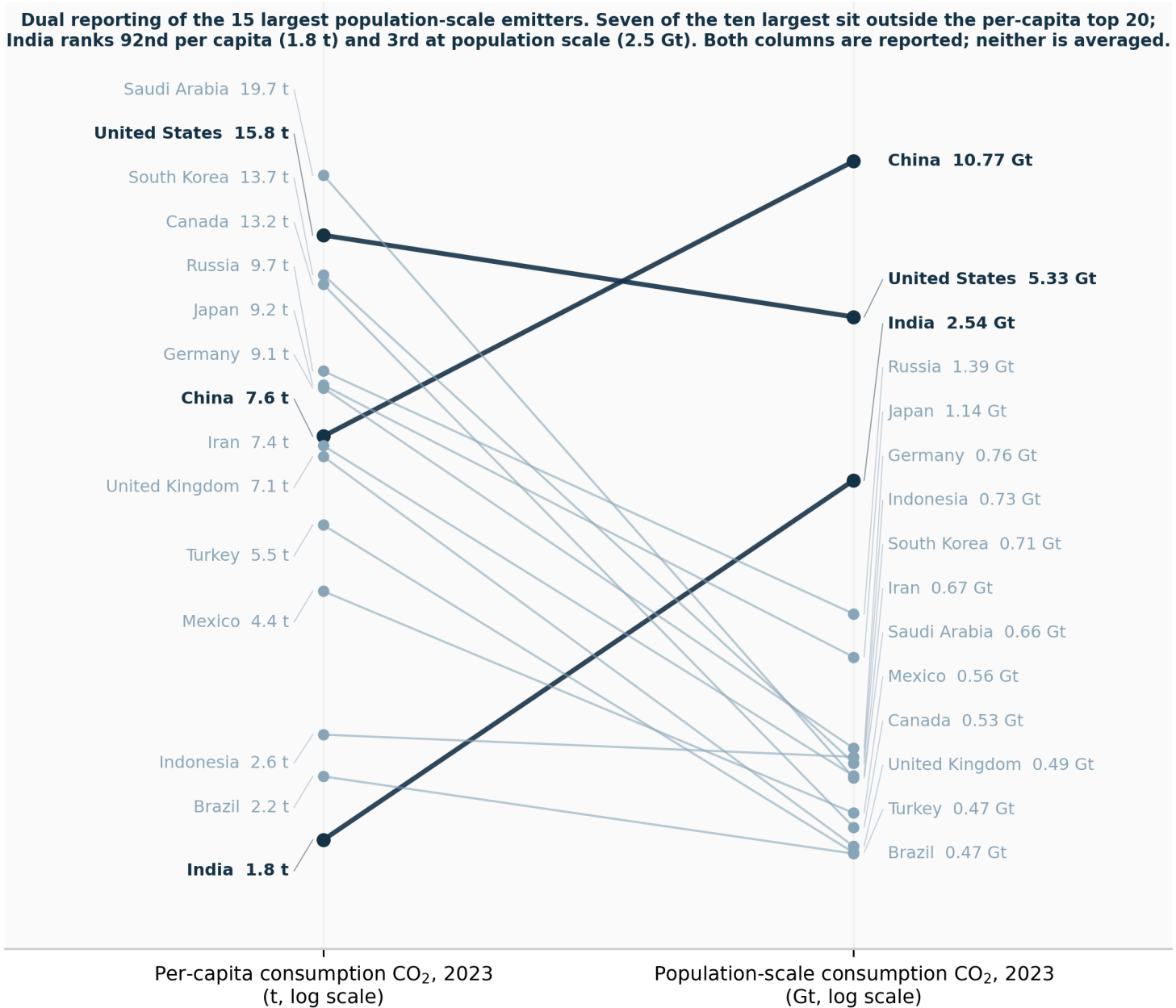


Figure 4

Dual reporting. The 15 largest population-scale consumers of 2023, with per-capita consumption CO₂ (left, log scale) and population-scale consumption CO₂ (right, log scale). Seven of the ten largest population-scale consumers sit outside the per-capita top 20. India ranks 92nd of 118 per capita (1.77 t) and 3rd at population scale (2.54 Gt). Both columns are reported in every display; neither is averaged, and no composite is constructed.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [BeyondParticipationCommsSustainSupplementaryInformationAnonymizedFINAL.docx](#)

- [SupplementaryCodeAnonymized.txt](#)
- [SupplementaryDataS1analysisdataset.csv](#)