

Article

Energy Transition Strategy and the Scale–Composition Association: How Fiscal Instruments Relate to Renewable-Energy Share, Energy Demand, and Decarbonization for Sustainable Development Across Developing and Developed Economies

Wenlong Lou ^{1,2}  and Rabab Benemman ^{2,*}¹ Policy Research Center for County Development, Yanshan University, Qinhuangdao 066004, China² School of Public Administration, Yanshan University, Qinhuangdao 066004, China

* Correspondence: r.benemman@gmail.com or rababbenemman@stumail.ysu.edu.cn

Abstract

National energy strategies increasingly treat renewable-capacity expansion as a proxy for decarbonization progress. This paper tests that proxy by separating energy-system change into two margins—composition (renewable share) and scale (energy demand)—and estimating how three fiscal instruments (tax revenue, government expenditure, public debt) relate to each before assessing their combined association with net CO₂ emissions. Using a panel of 62 developing and developed economies (2002–2022), estimated with two-way fixed effects and Driscoll–Kraay standard errors, we find the scale channel is associated with emissions at a standardized magnitude 10–28 times larger than any fiscal-instrument coefficient. In developing economies, fiscal instruments are associated with renewable-energy composition but not energy-use scale, though a bootstrap mediation test does not confirm this pathway (all indirect effects null); institutional quality strengthens this composition channel rather than redirecting allocation toward scale. In developed economies, only tax revenue reaches both margins; government expenditure and public debt are associated with composition only, and with a lower, not higher, renewable share. A complementary carbon-intensity specification—addressing the concern that CO₂ per capita is partly definitional in energy use—shows tax revenue and government expenditure are independently associated with higher carbon intensity in both groups: an open complication in the composition-channel story. These results are associational, not causal; the demand-restraint implication for developing-economy strategy is offered as a hypothesis, not an established result. These findings bear directly on SDG 7 (affordable clean energy), SDG 13 (climate action), and, through the distributional check, SDG 10 (reduced inequalities).

Keywords: energy transition strategy; fiscal policy; renewable energy; energy demand; decarbonization; sustainable development; institutional quality; panel data



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1. Introduction

Global energy-related CO₂ emissions reached a record level in 2023, with fossil fuels still supplying more than 80% of primary energy despite two decades of climate policy attention and a substantial expansion of public fiscal commitment to the energy transition [1]. Public investments in clean-energy infrastructure, environmental taxation, carbon pricing, and climate-aligned sovereign debt now feature prominently in national energy strategies and in the Global Stocktake process under the Paris Agreement [2]. Much of

this activity rests on an implicit assumption: that fiscal resources, once mobilized and reasonably well-targeted, translate into emissions reduction. Given the scale of the gap between current emissions trajectories and what a 1.5-consistent pathway requires—roughly a 43% reduction by 2030 relative to 2019, with net zero at mid-century [3]—this assumption merits closer empirical scrutiny than it has generally received.

The empirical literature on whether fiscal policy reduces emissions is divided. Some studies report emission-reducing associations, typically where fiscal resources are directed at clean infrastructure or where environmental taxation operates within strong institutional settings [4–6]. Others, concentrated in developing-economy samples, report the opposite: fiscal expansion associated with energy-intensive growth and rising emissions [7–9]. We argue that this disagreement is better understood as a specification issue than as a substantive contradiction across country samples. CO₂ is emitted by the combustion of fossil fuels, not by government budgets, so any credible transmission from fiscal policy to emissions outcomes must run through the energy system. Most existing studies regress emissions directly on fiscal aggregates without modeling that system explicitly, which limits what can be inferred about mechanism from a single net coefficient.

The energy system offers two distinct margins through which fiscal policy could plausibly operate, and these margins need not move together. The first is compositional: the share of total energy supply coming from renewable sources. The second is a scale margin, largely independent of composition: the volume of energy an economy consumes per capita. A fiscal instrument can move one margin without moving the other, both, or neither. This decomposition is established in energy economics, tracing to Grossman and Krueger's [10] composition–scale framework and developed further by Stern [11], but it has rarely been incorporated into the fiscal-policy literature specifically. An economy can expand renewable capacity in a manner consistent with climate policy objectives and still see emissions rise, if per capita energy demand grows faster than the renewable share reduces carbon intensity. This is not a theoretical possibility only; it is close to the situation facing several large developing economies undergoing rapid industrialization, and it is the mechanism this paper tests directly.

Three additional considerations motivate the empirical strategy. First, fiscal policy is not a single instrument: tax revenue, government expenditure, and public debt operate through different sectoral and intertemporal channels, and there is limited theoretical basis for assuming they move the composition and scale margins in the same direction or magnitude; most studies nonetheless aggregate them into a single fiscal variable. Second, institutional quality could in principle redirect fiscal resources toward better-targeted allocation, or it could simply increase the efficiency with which an existing allocation pattern is executed; the literature is split between these readings [12,13] without a clear basis for adjudicating between them using existing specifications. Third, decarbonization strategy carries distributional implications that the just-transition literature has documented—rising household energy costs and displaced fossil-sector labor absent deliberate mitigation [14,15]—which we treat as a secondary consideration relevant to the practical durability of any recommended strategy shift.

This paper estimates each of the three fiscal instruments' association with renewable-energy composition and aggregate energy-use scale as two separate outcomes, prior to estimating their combined association with net CO₂ emissions. This sequencing allows us to observe, for a given instrument and income group, whether it functions as an effective composition lever, an effective scale lever, both, or neither—and whether a positive net-emissions association reflects a composition channel that is working alongside an unaddressed scale channel, rather than a uniformly ineffective instrument. Institutional quality is entered as an interaction term against each channel separately, rather than against the

net emissions outcome alone, which allows us to distinguish governance capacity that redirects fiscal instruments toward a different strategic channel from governance capacity that amplifies whichever channel an instrument already reaches. Income inequality is retained as a secondary distributional check on the resulting recommendations.

Using a balanced panel of 62 economies (30 developing, 32 developed) over 2002–2022, the paper offers four contributions. It separates renewable composition and energy-scale associations as distinct, explicitly estimated outcomes rather than a single reduced-form emissions regression—an approach we are not aware of being applied previously in this literature, though we note this as a contribution to specification rather than a claim of definitive priority. It documents a coefficient-level pattern—which we term, provisionally, the scale–composition offset—in which developing-economy fiscal instruments show a robust composition–channel association without a corresponding scale–channel association; we test this pattern formally with mediation analysis in Section 4 and report that the formal test does not, on its own, confirm it, a limitation we carry through the Discussion and Conclusion rather than setting aside. It shows that institutional quality is associated with amplifying existing fiscal-allocation patterns rather than independently correcting them, which complicates a common policy prescription pairing governance reform with expanded fiscal space. And it extends the analysis to a secondary distributional check, providing a preliminary basis for assessing whether the demand-side strategy shift this paper considers is likely to carry a meaningful equity cost.

Section 2 reviews the relevant literature—energy-systems economics, fiscal-policy effectiveness, and institutional governance—and the specification gap that runs across them. Section 3 describes the data and empirical strategy. Section 4 presents results, from net fiscal-instrument associations through the channel-level decomposition and the formal mediation test. Section 5 discusses implications for energy strategy design. Section 6 concludes.

2. Literature Review

2.1. Energy Systems and the Composition–Scale Distinction

CO₂ is emitted through fossil-fuel combustion, so any transmission from fiscal policy to emissions outcomes runs through the energy system rather than around it. The energy system offers two distinct margins along which this transmission can occur. The compositional margin—renewable share of energy supply—is associated with lower emissions through reduced carbon intensity in a substantial cross-country literature [16–20]. The scale margin—energy consumed per capita, independent of source mix—follows Grossman and Krueger’s [10] original decomposition and Stern’s [11] subsequent formalization, and is typically held constant rather than modeled directly in the compositional literature.

Nathaniel and Iheonu [21] note that renewable deployment reduces emissions only to the extent that it substitutes for fossil generation rather than adding capacity alongside a growing fossil baseline. In a stagnant-demand economy this distinction has limited practical consequence, since renewable additions largely displace fossil generation by construction. In a high-growth developing economy, where aggregate energy demand rises for reasons largely unrelated to the composition of new generation capacity—industrialization, urbanization, income growth—the distinction becomes consequential: renewable capacity and composition share can both increase while net emissions still rise, because the scale margin grows faster than the composition margin reduces carbon intensity. The IPCC’s synthesis [3] is explicit that 1.5-consistent pathways require both margins to move together—expanding renewable supply while reducing aggregate energy intensity—a requirement rarely made explicit in the fiscal-policy literature specifically.

2.2. Fiscal Policy as a Strategic Lever

Fiscal instruments are among the primary tools available for shaping capital accumulation, sectoral investment, and technology adoption [22,23], and environmental taxation, green public investment, and climate-aligned sovereign debt feature prominently in national energy and climate strategy across both OECD and emerging-market contexts [1,24]. The empirical literature testing whether this activity supports decarbonization is divided. One body of work reports emission-reducing associations where fiscal resources are directed at clean infrastructure or clean-technology deployment, or where environmental taxation operates within higher-capacity institutional settings [4–6,25,26]. A second body, concentrated disproportionately in developing-economy samples, reports positive associations between fiscal expansion and emissions, generally attributed to growth-oriented allocation supporting energy-intensive industrialization [7–9,27,28].

Chen et al. [29] identify a specification concern relevant to reconciling these findings: most of this literature specifies emissions as a direct function of fiscal aggregates, which does not distinguish a fiscal instrument that fails to move renewable composition from one that succeeds on composition but does not restrain scale—both would appear as a positive net emissions coefficient under that specification. Resolving the disagreement between these two bodies of work may accordingly depend less on reconciling country samples than on separating the channels through which each instrument could plausibly operate. Recent work has moved toward disaggregation in response to a closely related concern, though along a different axis: Skhiri et al. [30] disaggregate fiscal policy by instrument type—separating compliance-based carbon-pricing tools, individual tax categories, and expenditure categories to identify which specific levers are effective—and additionally test whether revenue recycling toward emission-reducing expenditure conditions that effectiveness. The present study disaggregates along the transmission channel instead, separating a given instrument’s association with renewable-energy composition from its association with aggregate energy-use scale; the two approaches are complementary rather than competing, since an instrument found effective at the aggregate level in one framework may still be reaching only one of the two channels the other framework distinguishes.

2.3. Institutional Quality: Redirecting or Amplifying Existing Allocation

Governance dimensions—government effectiveness, regulatory quality, rule of law, control of corruption—shape the credibility of policy commitment and the efficiency of resource allocation [31]. A substantial body of work associates stronger institutions with better environmental outcomes generally [32–34] and with more effective renewable-energy policy specifically [35]. A separate line of work, following Tamazian et al. [36] and extended by Ali et al. [37], proposes that stronger institutions may instead raise the efficiency with which an existing development model is executed, without altering its underlying direction, meaning governance improvement in an economy with fossil-oriented fiscal priorities could reinforce rather than correct that orientation.

Recent work treats these positions as complementary by modeling institutional quality as a moderator of fiscal-energy transmission [12,13,38]. Nguyen [13], for example, explicitly models the interaction between public spending and governance in explaining CO₂ emissions, providing evidence that institutional quality can condition the environmental effect of fiscal policy. We view this framing as appropriate but incomplete as typically specified: a moderator can be shown to redirect vs. amplify existing allocation only if the underlying allocation—which channel a fiscal instrument reaches—is itself observed. Estimated against a net emissions outcome alone, an institutional-quality interaction cannot distinguish “institutions are redirecting fiscal policy toward decarbonization” from

“institutions are making an already carbon-intensive allocation more efficient,” since both would produce a same-signed coefficient on the same outcome variable.

2.4. Distributional Implications

A smaller literature documents the distributional implications of both rising emissions and the energy transition itself—health and productivity costs from environmental degradation [15,39], and higher household energy costs, fossil-sector labor displacement, and uneven distribution of renewable-investment benefits during the transition [40,41], consistent with the just-transition principle [14]. We treat this as a secondary consideration in the analysis that follows, given that a cross-country panel of this kind does not support a full household-level distributional incidence analysis.

2.5. Gap Addressed by This Study

Combining the literature suggests a common specification limitation rather than three unrelated gaps. The energy-systems literature establishes that composition and scale are distinct, potentially offsetting margins, but this distinction has generally not been incorporated into fiscal-policy specifications, which continue to regress net emissions on fiscal aggregates directly. The resulting split in the fiscal-policy literature—emission-reducing in some samples, emission-increasing in others—is consistent with a specification that cannot identify which channel, if any, a given fiscal instrument reaches. The parallel disagreement in the institutional-quality literature is not resolvable on the same specification, since the moderator is tested against an outcome variable that already collapses the distinction the underlying theory depends on.

This study estimates fiscal instruments’ associations with renewable composition and energy-use scale as separate outcomes rather than a single reduced-form emissions regression, disaggregates fiscal policy into three instruments (tax revenue, government expenditure, public debt) rather than a single aggregate, enters institutional quality as an interaction against each channel separately rather than against net emissions alone, and subjects the resulting composition–scale pattern to a formal mediation test with country-clustered bootstrap inference rather than treating the coefficient pattern alone as evidence of a mechanism.

3. Data and Methodology

3.1. Sample and Variable Construction

The analysis uses a balanced panel of 62 countries—30 developing and 32 developed economies, classified according to IMF World Economic Outlook groupings—observed annually from 2002 to 2022 (21 years). Data are drawn from the World Bank World Development Indicators (energy, environmental, and macroeconomic series), the IMF World Economic Outlook database (fiscal series), the World Bank Worldwide Governance Indicators (institutional series), and the IMF Financial Development Index. Table 1 lists the variables, their measurement, and their sources. The full country composition of each income group is listed in Appendix A.

Table 1. Variable descriptions, sources, and role in the energy-strategy framework.

Symbol	Variable	Measurement	Source
TR	Tax revenue	% of GDP	IMF-WEO
GE	Government expenditure	% of GDP	IMF-WEO
PD	Public debt	% of GDP	IMF-WEO
RE	Renewable-energy share	% of total energy consumption	WDI

Table 1. Cont.

Symbol	Variable	Measurement	Source
EU	Energy use	kg oil equivalent per capita	WDI (EG.USE.PCAP.KG.OE)
CO ₂	CO ₂ emissions	Metric tons per capita	WDI
IQI	Institutional Quality Index	1st principal component of 6 WGI dimensions (Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption); mean zero, not unit variance	WGI
GI	Income inequality	Gini index (0–1 scale)	World Bank
GDPC	GDP per capita growth	Annual %	WDI
TRD	Trade openness	% of GDP	WDI
FDIX	Financial development index	Index (0–1)	IMF FDI
PG	Population growth	Annual %	WDI

The Institutional Quality Index (IQI) is constructed as the first principal component of six standardized World Governance Indicators—Voice and Accountability, Political Stability, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption—extracted once from the full stacked panel within each income-group subsample, rather than pooled across income groups or re-estimated by year, and oriented so that higher values indicate stronger governance. Principal component analysis was preferred to simple averaging because it extracts the dominant common governance signal without imposing equal weights across dimensions that need not, in principle, carry equal information. Appendix B reports the loadings and variance-explained diagnostics: the first component explains 60.1% of the variance in the developing-economy subsample and 83.0% in the developed-economy subsample, and all six loadings are positive and of broadly comparable magnitude in both subsamples, indicating that the index captures a general governance signal rather than being dominated by any single WGI dimension. The index is standardized to mean zero but not to unit variance (SD = 1.70 in the developing-economy subsample, 2.03 in the developed-economy subsample; Table 2); interaction coefficients involving IQI throughout Tables 3–5 should accordingly be interpreted as the effect of a one-unit change in the index score rather than a one-standard-deviation change. Table 4’s low, mean, and high governance values are similarly constructed as the subsample mean $\pm$ 1 SD of this unstandardized index, computed separately within each income group; the associated marginal effects are therefore not directly comparable in scale across income groups, given the differing dispersion of the index between subsamples.

Table 2. Descriptive statistics by income group.

Variable	Dev. Mean	Dev. SD	Dev. Min	Dev. Max	Adv. Mean	Adv. SD	Adv. Min	Adv. Max
CO ₂ (t/cap)	2.613	2.272	0.070	9.546	8.506	4.601	0.903	26.043
RE (%)	30.125	22.919	0.700	88.100	22.255	17.693	0.100	82.900
EU (kg/cap)	1043	710	148	3336	4086	2772	639	18,213
ln (EU)	6.729	0.672	4.997	8.113	8.174	0.567	6.460	9.809
TR (%GDP)	21.77	7.50	5.12	49.85	40.37	9.25	13.13	63.05
GE (%GDP)	25.13	8.02	9.63	49.92	43.45	8.01	15.99	64.89
PD (%GDP)	49.21	21.01	7.30	147.20	63.56	36.93	4.23	253.23
IQI	0.000	1.700	−3.948	4.330	0.000	2.032	−9.235	3.219

Table 3. (a,b) Net emissions models (lever $\times$ IQI interaction)—developing economies. (c) Standardized (1-SD) comparison of scale-channel and fiscal-lever associations with net emissions.

(a)			
Variable	TR Model	GE Model	PD Model
Fiscal lever	0.032 *** (0.010)	0.014 ** (0.007)	0.004 *** (0.001)
Institutional quality	−0.217 *** (0.050)	−0.201 *** (0.053)	−0.041 (0.040)
Lever $\times$ IQI	0.008 *** (0.002)	0.006 *** (0.001)	0.000 (0.001)
Renewable-energy (composition)	0.006 (0.008)	0.008 (0.007)	0.012 (0.008)
Log energy use (scale)	3.627 *** (0.429)	3.672 *** (0.431)	3.725 *** (0.424)
Log financial development	−0.181 ** (0.091)	−0.124 (0.116)	−0.066 (0.117)
Observations	609	609	609
R-squared	0.620	0.601	0.597
(b)			
Variable	TR Model	GE Model	PD Model
Fiscal lever	0.028 ** (0.014)	−0.035 *** (0.012)	−0.008 ** (0.003)
Institutional quality	−0.291 (0.187)	−0.023 (0.165)	0.277 (0.175)
Lever $\times$ IQI	0.007 (0.006)	−0.001 (0.005)	−0.005 *** (0.001)
Renewable-energy (composition)	−0.089 *** (0.009)	−0.092 *** (0.011)	−0.083 *** (0.012)
Log energy use (scale)	7.012 *** (0.423)	6.861 *** (0.393)	6.973 *** (0.338)
Log financial development	−2.040 *** (0.335)	−2.102 *** (0.355)	−2.460 *** (0.348)
Observations	672	672	672
R-squared	0.526	0.530	0.556
(c)			
Group	Lever	1-SD Effect, Lever (t/cap)	1-SD Effect, Scale (t/cap)
Developing	Tax revenue	0.237	2.437
Developing	Gov. expenditure	0.113	2.467
Developing	Public debt	0.090	2.503
Developed	Tax revenue	0.260	3.978
Developed	Gov. expenditure	−0.280	3.892
Developed	Public debt	−0.278	3.956

Driscoll–Kraay standard errors in parentheses (Bartlett kernel, bandwidth 4). *** $p < 0.01$; ** $p < 0.05$. GDPC and trade-openness rows omitted for space. (a) Reports positive associations between all three fiscal levers and CO₂ emissions in developing economies (tax revenue: 0.032, $p < 0.01$; government expenditure: 0.014, $p < 0.05$; public debt: 0.004, $p < 0.01$). Taken at face value, this pattern is consistent with the growth-oriented, energy-intensive allocation reported elsewhere for developing-economy samples [7,8]. Section 4.4 examines whether this net association reflects a uniformly ineffective set of levers or a more specific pattern in which one channel is functioning while the other is not.

Table 4. Net emissions association by lever, at low/mean/high governance capacity.

Fiscal Lever	Dev. Low IQI	Dev. Mean IQI	Dev. High IQI	Adv. Low IQI	Adv. Mean IQI	Adv. High IQI
Tax revenue	0.019 ** (0.009)	0.032 *** (0.010)	0.044 *** (0.011)	0.014 (0.012)	0.028 ** (0.014)	0.042 * (0.022)
Government expenditure	0.003 (0.007)	0.014 ** (0.007)	0.025 *** (0.008)	−0.033 * (0.018)	−0.035 *** (0.012)	−0.036 *** (0.011)
Public debt	0.004 ** (0.002)	0.004 *** (0.001)	0.005 *** (0.002)	0.002 (0.002)	−0.008 ** (0.003)	−0.017 *** (0.005)

Low = mean − 1 SD; High = mean + 1 SD governance capacity, computed separately within each income group (see Section 3.1 on differing IQI dispersion across groups). Driscoll–Kraay standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 5. Fiscal lever associations with composition (RE) and scale (EU) channels—developing economies.

(a)						
Term	RE-TR	RE-GE	RE-PD	EU-TR	EU-GE	EU-PD
Fiscal lever	0.183 ** (0.062)	0.152 *** (0.056)	0.030 * (0.015)	0.001 (0.002)	−0.001 (0.001)	−0.001 (0.001)
Institutional quality	−4.497 *** (0.332)	−5.798 *** (0.458)	−2.532 *** (0.465)	0.016 (0.021)	0.019 (0.017)	0.044 *** (0.006)
Lever × IQI	0.124 *** (0.012)	0.164 *** (0.017)	0.018 ** (0.009)	0.000 (0.001)	0.000 (0.001)	−0.001 *** (0.000)
Renewable-energy (RE)	—	—	—	−0.012 *** (0.002)	−0.011 *** (0.002)	−0.011 *** (0.002)
Log financial development	−2.508 *** (0.633)	−2.405 *** (0.861)	−1.931 *** (0.500)	0.198 *** (0.025)	0.207 *** (0.023)	0.203 *** (0.016)
Observations	630	630	630	609	609	609
R-squared	0.233	0.271	0.199	0.363	0.365	0.387
(b)						
Term	RE-TR	RE-GE	RE-PD	EU-TR	EU-GE	EU-PD
Fiscal lever	−0.066 (0.074)	−0.168 *** (0.054)	−0.026 * (0.013)	−0.006 *** (0.002)	0.000 (0.001)	0.000 (0.000)
Institutional quality	−4.191 *** (1.189)	−4.269 *** (0.905)	−2.301 *** (0.626)	0.138 *** (0.033)	0.090 *** (0.024)	0.048 *** (0.013)
Lever × IQI	0.070 *** (0.022)	0.069 *** (0.016)	0.006 *** (0.002)	−0.002 *** (0.001)	−0.001 (0.001)	0.000 (0.000)
Renewable-energy (RE)	—	—	—	0.000 (0.002)	0.000 (0.002)	−0.001 (0.003)
Log financial development	−8.422 *** (1.712)	−7.202 *** (1.380)	−10.816 *** (1.661)	0.265 *** (0.038)	0.287 *** (0.035)	0.320 *** (0.048)
Observations	672	672	672	672	672	672
R-squared	0.322	0.345	0.316	0.351	0.332	0.329

Driscoll–Kraay standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. GDPC and trade-openness rows omitted for space.

The Gini index used in the distributional check (Equation (4)) is measured on a 0–1 scale, drawn from the World Bank series, as reported in Table 1.

3.2. Two Strategic Channels: Composition and Scale

We treat energy strategy as operating through two margins that are conceptually distinct and need not move together: a composition channel—renewable-energy’s share of total energy consumption—and a scale channel—energy use per capita, independent of source mix. Throughout this paper, “the scale channel” and “scale-channel coefficient” refer to this per capita measure specifically, not to a country’s total (population-weighted) energy consumption; where the text uses shorthand such as “aggregate energy demand,” it denotes the per capita quantity defined here, not an economy-wide total. We use the per capita rather than total measure because the paper’s outcome variable, CO₂ emissions, is itself measured per capita (Table 1); a per capita scale measure keeps the composition, scale, and outcome variables on a consistent population-adjusted basis and avoids a mechanical link between country size and the scale coefficient that a total-consumption measure would introduce. This choice matters most in developing economies with faster population growth, where total and per capita energy-use trends can diverge. A fiscal instrument may move one, both, or neither margin, and its net association with emissions depends on the combination that actually occurs. Because energy use is right-skewed and spans roughly two orders of magnitude across our sample (148 to 18,213 kg oil-equivalent per capita), the scale channel is modeled in natural-log form throughout; this both stabilizes variance and lets the scale-channel coefficients in the net-emissions model (Equation (3)) be interpreted as approximate elasticities.

3.3. Empirical Model

Four equations are estimated in sequence. The first two isolate each strategic channel; the third evaluates the net emissions association once both channels are accounted for; the fourth extends the framework to a secondary distributional check.

Composition-channel model (renewable-energy share):

$$RE_{it} = a_0 + a_1 FP_{it} + a_2 IQI_{it} + a_3 (FP_{it} \times IQI_{it}) + a_4 GDPC_{it} + a_5 TRD_{it} + a_6 \ln(FDIX_{it}) + u_i + \lambda_t + e_{it} \quad (1)$$

where FP is entered alternately as tax revenue (TR), government expenditure (GE), or public debt (PD).

Scale-channel model (aggregate energy use, log form):

$$\ln(EU_{it}) = b_0 + b_1 FP_{it} + b_2 IQI_{it} + b_3 (FP_{it} \times IQI_{it}) + b_4 GDPC_{it} + b_5 TRD_{it} + b_6 \ln(FDIX_{it}) + b_7 RE_{it} + u_i + \lambda_t + v_{it} \quad (2)$$

Net emissions model:

$$CO_2_{it} = g_0 + g_1 RE_{it} + g_2 \ln(EU_{it}) + g_3 FP_{it} + g_4 IQI_{it} + g_5 (FP_{it} \times IQI_{it}) + g_6 GDPC_{it} + g_7 TRD_{it} + g_8 \ln(FDIX_{it}) + u_i + \lambda_t + w_{it} \quad (3)$$

Secondary distributional check:

$$GI_{it} = d_0 + d_1 \ln(CO_2_{it}) + d_2 FP_{it} + d_3 IQI_{it} + d_4 (FP_{it} \times IQI_{it}) + d_5 GDPC_{it} + d_6 \ln(FDIX_{it}) + d_7 PG_{it} + u_i + \lambda_t + h_{it} \quad (4)$$

All specifications include country fixed effects (u_i) and year fixed effects (λ_t). Standard errors are computed using the Driscoll and Kraay [42] estimator (Bartlett kernel, 4-lag bandwidth), which is robust to heteroskedasticity, serial correlation, and cross-sectional dependence—a relevant concern given the panel's global country coverage and the likelihood that energy and fiscal shocks are correlated across countries in a given year. The framework is estimated separately for developing and developed economies throughout, motivated by the structural differences in fiscal capacity and energy-demand levels documented in Table 2 and confirmed statistically by the diagnostic tests in Section 4.6. The scale-channel equation (Equation (2)) does not condition on industrial structure, urbanization, or domestic energy pricing; each of these plausibly affects aggregate energy use independently of the fiscal levers tested here, and their omission is addressed as a limitation in Section 5.6 rather than in the current specification, since none of these series is available in the compiled panel at the country-year frequency this study requires.

Regarding the observation count: Tables 2–5 report 630 developing-economy observations for the composition-channel and net-emissions equations but 609 wherever the scale channel (EU or $\ln(EU)$) enters the specification. This is not a data-quality inconsistency across equations; it traces to a single country. The WDI energy-use series (EG.USE.PCAP.KG.OE, IEA-sourced via the World Bank) is missing for all 21 years for Mali, the one developing-economy country in this panel without coverage on this indicator, so any equation that includes $\ln(EU)$ —whether as the dependent variable in Equation (2) or as a regressor in Equation (3)—drops Mali's 21 country-years, while the composition-channel Equation (1), which does not use EU, retains the full 630. Every other country in the panel has non-missing values on this series for every year from 2002 through 2022.

3.4. Scope of Inference

This is an observational, sequential-equation framework, not a causal-identification strategy. Country and year fixed effects absorb time-invariant heterogeneity and common annual shocks, but they do not resolve time-varying confounding or the possibility of reverse causality—emissions outcomes may themselves shape fiscal choices. Institutional quality was treated as a candidate source of endogeneity and tested directly: using the third lag of the institutional-quality index as an instrument (first-stage t-statistics of 11.5 and 13.0 in the developing and developed subsamples, respectively, well above conventional weak-instrument thresholds), a Durbin–Wu–Hausman comparison of the fixed-effects and instrumental-variable estimates does not reject exogeneity in either subsample ($\chi^2(1) = 0.002$, $p = 0.961$ for developing economies; $\chi^2(1) = 0.062$, $p = 0.803$ for developed economies). We therefore retain institutional quality as specified rather than instrumenting it throughout, while continuing to describe the results as conditional associations consistent with the proposed composition–scale pattern rather than as causal effects. The fiscal instruments themselves—tax revenue, government expenditure, and public debt—were not instrumented and are likely jointly determined with energy and emissions outcomes; this limitation applies throughout and is not resolved by the institutional-quality exogeneity test, which speaks only to IQI.

4. Results

4.1. Structural Differences Between Income Groups

Table 2 shows that developed economies average 8.51 tons of CO₂ per capita against 2.61 for developing economies, but this gap does not primarily originate in the composition channel: mean renewable shares are broadly comparable across groups (22.3% vs. 30.1%), while energy use per capita differs by roughly a factor of four (4086 vs. 1043 kg oil-equivalent). Read together with the fiscal–capacity gap—tax revenue averaging 40.4% of GDP in developed economies against 21.8% in developing economies—this suggests the emissions gap between income groups is better characterized as a scale-channel gap than a composition-channel gap, a distinction that motivates separating the two channels in what follows rather than a starting assumption of the analysis (Figure 1).

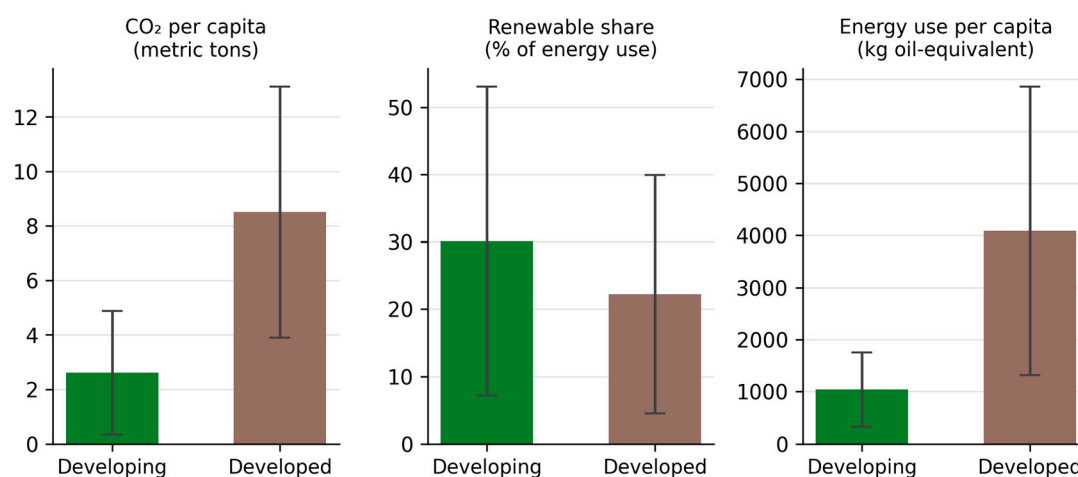


Figure 1. Structural differences between developing and developed economies, 2002–2022 means $\pm$ 1 SD: CO₂ emissions per capita, renewable-energy share, and energy use per capita (Table 2).

4.2. Net Association Between Fiscal Levers and Emissions

Across both income groups, the scale-channel coefficient (3.63–3.73 in developing economies; 6.86–7.01 in developed economies) is numerically larger than any fiscal-lever coefficient in Table 3a,b, but the raw coefficients are not directly comparable: the scale

coefficient is expressed in tons per capita per log-unit of energy use, while the fiscal-lever coefficients are expressed in tons per capita per percentage point of GDP. To make the comparison meaningful we report standardized effects—the change in predicted CO₂ per capita associated with a one-standard-deviation change in each regressor, using each variable's own standard deviation in the estimation sample (Table 3c).

Because the fiscal-lever and scale-channel coefficients in Table 3 are expressed in different units, standardized (1-SD) effects are reported here for a directly comparable magnitude. On this basis the scale channel is 10 to 28 times larger than any individual fiscal lever, though the ratio varies considerably by lever (roughly 10–15× for tax revenue in both groups, up to 22–28× for government expenditure and public debt in developing economies).

Renewable-energy share is significantly associated with lower emissions in developed economies (−0.083 to −0.092, $p < 0.01$) but not distinguishable from zero in developing economies at the net level, a pattern we return to once the channels are opened separately in Section 4.4.

Governance capacity is associated with the direction fiscal levers already point, not only their magnitude, and the pattern differs across income groups. In developing economies, the tax-revenue × IQI and government-expenditure × IQI interactions are both positive (0.008 and 0.006 respectively, $p < 0.01$), consistent with governance capacity reinforcing the existing net-positive fiscal-emissions association rather than offsetting it. In developed economies, the public-debt × IQI interaction is negative and significant, and the tax-revenue × IQI interaction is not statistically distinguishable from zero once financial development is controlled for; this second point bears directly on Section 4.3 below.

4.3. Governance Capacity and Lever Effectiveness

Evaluated at low, mean, and high governance capacity (Table 4), the tax-revenue association with emissions in developing economies rises from 0.019 ($p < 0.05$) to 0.044 ($p < 0.01$), moving from low to high governance capacity, and government expenditure moves from statistically indistinguishable from zero to significantly emission-increasing over the same range. Figure 2 plots these marginal effects with their 95% confidence intervals.

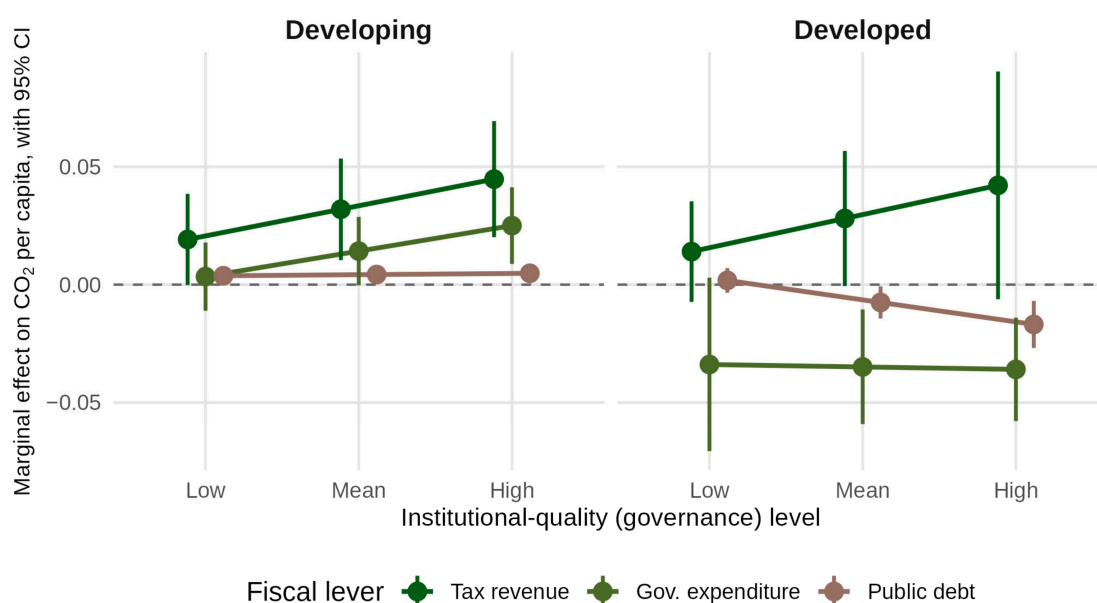


Figure 2. Net-emissions association by fiscal lever, at low, mean, and high governance capacity (companion to Table 4, Section 4.3). Points show the marginal effect of each lever on CO₂ per capita, with 95% confidence intervals from the delta method using Driscoll–Kraay standard errors. The dashed horizontal line marks zero.

In developed economies, government expenditure's association with lower emissions is stable across the governance range (-0.033 to -0.036), while public debt shows a governance threshold: statistically null at low governance capacity and increasingly associated with lower emissions as governance strengthens (-0.008 at mean, -0.017 at high governance capacity). The developed-economy tax-revenue marginal effect in Table 4 rises from a non-significant 0.014 at low governance to a marginally significant 0.042 ($p < 0.10$) at high governance, even though the underlying tax-revenue $\times$ IQI interaction term in Table 3b is not statistically distinguishable from zero ($p = 0.27$). We flag this as an unresolved feature of the current results rather than as evidence of a governance gradient for this instrument: where the interaction coefficient itself is not significant, the apparent slope in the marginal-effects table should be treated as exploratory, and we do not draw a substantive conclusion from it in Section 5, Discussion (Section 5.3 relies instead on the public-debt interaction, which is significant).

4.4. Composition and Scale Channels Opened Separately

Table 5 is the paper's central diagnostic. In developing economies, tax revenue (0.183 , $p < 0.05$) and government expenditure (0.152 , $p < 0.01$) are both associated with renewable-energy share, an effect further amplified at higher governance capacity. The same two instruments show no measurable independent association with the scale channel (log energy use): coefficients of 0.001 and -0.001 respectively, both statistically indistinguishable from zero. The RE coefficient in the scale equation (-0.011 to -0.012 , $p < 0.01$) indicates that renewable share and aggregate energy use move in opposite directions in this subsample—consistent with renewable deployment displacing rather than simply adding to fossil-based consumption, the distinction raised by Nathaniel and Iheonu [21]—though we note this is a within-equation association conditional on the fiscal levers, not a directly identified substitution elasticity. Figure 3 plots these coefficients for both channels and both income groups.

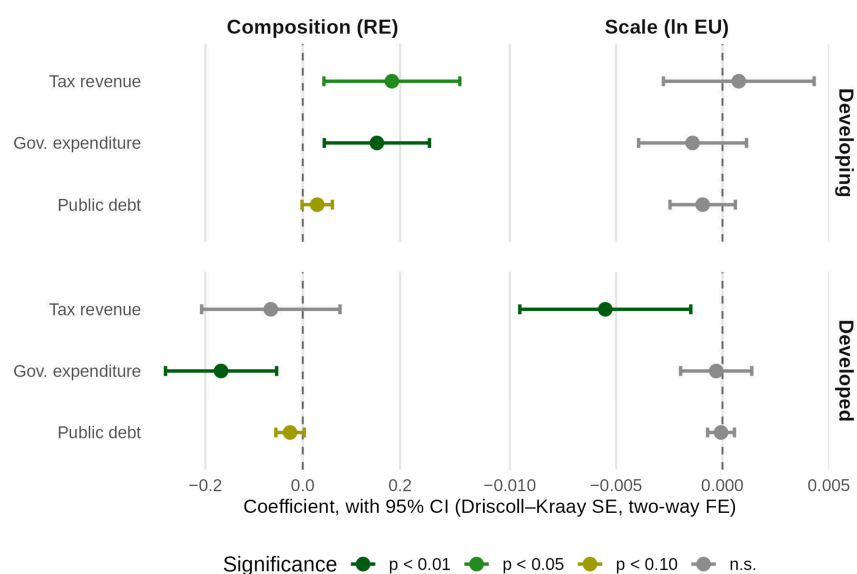


Figure 3. Fiscal-lever associations with the composition and scale channels (companion to Table 5a,b, Section 4.4). Points show the coefficient on each fiscal lever from the composition-channel model (left) and the scale-channel model (right), with 95% confidence intervals from Driscoll–Kraay standard errors; the two channels are plotted on independent axes given the difference in coefficient scale. The dashed vertical line marks zero; marker and bar colors indicate the significance level (n.s., not significant).

This pairing of results—a functioning composition lever alongside a scale channel these instruments do not appear to reach—is consistent with a composition lever operating inside an economy whose aggregate energy demand is growing for reasons the fiscal instruments tested here do not independently explain. We describe this pattern, provisionally, as a scale–composition offset. This label describes a pattern in the coefficient estimates in Tables 3 and 5; the formal mediation test of this pattern is reported immediately below (Table 6), and it does not corroborate the pattern as a mediation effect, which materially limits how far the offset framing can be pushed—see the qualification carried through Section 5.1.

Table 6. Indirect lever effects mediated through composition and scale channels: point estimates and country-clustered bootstrap 95% confidence intervals.

Group	Lever	Channel	Indirect Effect	95% CI (Percentile Bootstrap, 300 Country-Block Replicates)
Developing	Tax revenue	Composition	0.0016	[−0.0061, 0.0086]
Developing	Tax revenue	Scale	0.0028	[−0.0296, 0.0405]
Developing	Gov. expenditure	Composition	0.0013	[−0.0034, 0.0068]
Developing	Gov. expenditure	Scale	−0.0052	[−0.0263, 0.0264]
Developing	Public debt	Composition	0.0004	[−0.0006, 0.0021]
Developing	Public debt	Scale	−0.0035	[−0.0093, 0.0048]
Developed	Tax revenue	Composition	0.0058	[−0.0294, 0.0337]
Developed	Tax revenue	Scale	−0.0386	[−0.0936, 0.0352]
Developed	Gov. expenditure	Composition	0.0154	[−0.0134, 0.0349]
Developed	Gov. expenditure	Scale	−0.0020	[−0.0367, 0.0376]
Developed	Public debt	Composition	0.0022	[−0.0020, 0.0061]
Developed	Public debt	Scale	−0.0005	[−0.0193, 0.0130]

In developed economies, the picture in Table 5b is more mixed than a single “both margins” characterization allows. Tax revenue shows a negative association with the scale channel (-0.006 , $p < 0.01$) alongside its composition-channel association, consistent with reaching both margins. Public debt’s composition-channel coefficient is negative and significant (-0.026 , $p < 0.10$), but its scale-channel coefficient is 0.000 and not significant; among the three levers, only tax revenue shows a scale-channel association in this subsample. In addition, government expenditure (-0.168 , $p < 0.01$) and public debt (-0.026 , $p < 0.10$) are both negatively associated with renewable share in developed economies—that is, higher fiscal effort on these two levers is associated with a lower, not higher, renewable share in this subsample. This runs counter to a straightforward reading of developed-economy fiscal instruments as uniformly composition-supporting, and we do not have a basis in this panel for adjudicating between competing explanations (for example, aggregate expenditure capturing fossil-sector support that is not separable at this level of disaggregation vs. a denominator effect from rising total energy consumption). We flag this as an open finding requiring either disaggregated expenditure data or a dedicated robustness check before it can be interpreted further.

4.5. Formal Mediation Test

Each pathway’s indirect effect is the product of the lever $\rightarrow$ mediator and mediator $\rightarrow$ CO₂ coefficients. Confidence intervals come from a country-block bootstrap (300 replicates, percentile method), which avoids the normality assumption a para-

metric Sobel test requires. All twelve indirect effects are indistinguishable from zero at 95%—including two pathways (developed-economy tax revenue → scale and government expenditure → composition) that a Sobel test would have flagged as significant.

Table 6 is the only formal test in this paper of the composition–scale mediation pattern described in Section 4.4, and as reported it does not support that pattern in either income group. This null result should be read alongside two considerations. First, mediation tests in an observational panel where the lever, the mediator, and the outcome are all potentially endogenous cannot be interpreted as establishing a causal pathway even when significant; a null result here is accordingly a limit on how far the coefficient-level pattern in Section 4.4 can be pushed, not a claim that no such pathway exists. Second, bootstrap replicates in this panel are necessarily drawn from 30 or 32 countries, which limits the precision with which small indirect effects can be distinguished from zero; the confidence intervals in Table 6 are correspondingly wide. We treat the scale–composition offset described in Section 4.4 as a pattern consistent with the coefficient estimates in Tables 3 and 5, not as a mediation effect established by Table 6, throughout the remainder of this paper.

4.6. Secondary Distributional Check

Table 7 shows tax revenue and government expenditure both negatively and significantly associated with the Gini index in developing economies, and renewable-energy share carries a small but statistically significant negative association with inequality in both income groups. We report this as a secondary strategic consideration rather than a primary finding: it is drawn from an aggregate cross-country panel rather than a household-level incidence analysis, and it should not be read as evidence that any specific demand-restraint instrument would be distributionally neutral in practice.

Table 7. Secondary distributional check—income inequality models.

Variable	Dev. GI-TR	Dev. GI-GE	Dev. GI-PD	Adv. GI-TR	Adv. GI-GE	Adv. GI-PD
Fiscal lever	−0.001086 *** (0.000265)	−0.001307 *** (0.000289)	0.000161 (0.000192)	−0.000414 *** (0.000160)	0.000495 *** (0.000170)	−0.000004 (0.000027)
Renewable-energy	−0.001401 *** (0.000209)	−0.001420 *** (0.000216)	−0.001614 *** (0.000219)	−0.000403 *** (0.000132)	−0.000278 ** (0.000134)	−0.000472 *** (0.000097)
Log CO ₂ emissions	−0.017846 *** (0.005544)	−0.016841 *** (0.005784)	−0.020647 *** (0.004890)	−0.035405 *** (0.003802)	−0.035124 *** (0.004254)	−0.032621 *** (0.002916)
Observations	630	630	630	672	672	672
R-squared	0.242	0.257	0.225	0.091	0.097	0.073

Driscoll–Kraay standard errors in parentheses. *** $p < 0.01$; ** $p < 0.05$. Coefficients are reported to six decimal places because, on a 0–1 Gini scale, several genuinely significant small coefficients—e.g., the developed-economy renewable-energy coefficient, −0.0003 to −0.0005—would otherwise round to 0.000 at three decimals.

4.7. Specification Diagnostics

Table 8 reports the specification diagnostics for the net-emissions model. Hausman tests compare fixed-effects against random-effects estimates and reject the random-effects specification in every case. The serial-correlation row uses a Wooldridge-style AR(1) test on the fixed-effects residuals (regressing each country’s residual on its own one-year lag, with standard errors clustered by country), which is more appropriate for panel data than a time-series test such as Breusch–Godfrey. Strong serial correlation is confirmed throughout (AR(1) coefficients of 0.78–0.83, $p < 0.0001$). The Pesaran cross-sectional dependence test is significant at the 5% level in the three developing-economy specifications, marginal in the developed-economy tax-revenue specification ($p = 0.059$), and not significant in the developed-economy government-expenditure and public-debt specifications.

Table 8. Specification diagnostics, net-emissions model, by income group and fiscal lever.

Group	Lever	Hausman $\chi^2(8)$	Hausman p	AR(1) Resid. Coefficient	AR(1) p	Pesaran CD Stat	Pesaran CD p
Developing	TR	394.99	<0.0001	0.783	<0.0001	−2.071	0.038
Developing	GE	364.13	<0.0001	0.793	<0.0001	−2.103	0.035
Developing	PD	188.16	<0.0001	0.789	<0.0001	−2.105	0.035
Developed	TR	235.94	<0.0001	0.830	<0.0001	1.888	0.059
Developed	GE	192.38	<0.0001	0.829	<0.0001	0.235	0.814
Developed	PD	269.00	<0.0001	0.815	<0.0001	0.515	0.607

Together, these diagnostics support fixed effects over random effects and confirm serial correlation throughout, both consistent with the use of Driscoll–Kraay standard errors. Cross-sectional dependence is confirmed in the developing-economy subsample but is weaker and, in two of three developed-economy specifications, not statistically significant at conventional levels; Driscoll–Kraay standard errors remain appropriate regardless, since they are robust to heteroskedasticity and serial correlation independent of whether cross-sectional dependence is present. We also note, as a limitation rather than a resolved issue, that Driscoll–Kraay’s finite-sample properties under a relatively short time dimension (21 years) combined with subsample splitting into 30 and 32 cross-sectional units warrant some caution and are not separately stress-tested here.

4.8. Carbon-Intensity Robustness Check

Regressing CO₂ per capita on log energy use (Equation (3)) partly recovers an accounting identity, since CO₂ per capita is definitionally the product of energy use per capita and the carbon intensity of that energy; the apparent dominance of the scale-channel coefficient in Table 3 could therefore be mechanical rather than behavioral. As a complementary specification—not a replacement for Equation (3)—we re-estimate the net-emissions model with the outcome switched to carbon intensity itself: $CI_{it} = CO_{2_it}$ (metric tons per capita) divided by EU_{it} expressed in metric tons of oil-equivalent, i.e., tons of CO₂ emitted per ton of oil-equivalent energy consumed (Table 9; a level-form version is reported in Appendix C). This outcome is not mechanically tied to the volume of energy used, so it gives the fiscal instruments and renewable share a genuinely independent dependent variable to act on.

Table 9. Carbon-Intensity model: $\ln(\text{carbon intensity})$ as outcome, by income group and fiscal lever.

Variable	Dev. TR	Dev. GE	Dev. PD	Adv. TR	Adv. GE	Adv. PD
Fiscal lever	0.0064 *** (0.0014)	0.0045 *** (0.0014)	0.0004 (0.0002)	0.0060 *** (0.0012)	0.0016 ** (0.0008)	−0.0002 (0.0002)
Institutional quality	0.0107 (0.0131)	0.0050 (0.0103)	−0.0182 *** (0.0040)	0.0268 ** (0.0128)	0.0517 *** (0.0117)	0.0542 *** (0.0131)
Lever $\times$ IQI	−0.0010 (0.0007)	−0.0006 (0.0005)	0.0002 (0.0002)	0.0004 (0.0003)	−0.0003 (0.0002)	−0.0002 *** (0.0001)
Renewable-energy (RE)	−0.0150 *** (0.0005)	−0.0149 *** (0.0005)	−0.0151 *** (0.0005)	−0.0149 *** (0.0005)	−0.0146 *** (0.0005)	−0.0148 *** (0.0005)
Observations	609	609	609	672	672	672
Within R-squared	0.571	0.546	0.512	0.569	0.553	0.562

Driscoll–Kraay standard errors in parentheses (Bartlett kernel, bandwidth 4), two-way fixed effects. *** $p < 0.01$; ** $p < 0.05$. GDPC, TRD, and $\ln FDI_{it}$ rows omitted for space.

Renewable share is negative and highly significant in every specification (−0.0146 to −0.0151, $p < 0.01$ throughout), consistent with the mechanical expectation that a larger renewable share lowers the carbon intensity of the overall energy mix; this is an internal validity check on the constructed variable rather than a new substantive finding.

This does not resolve as cleanly as a simple pass or fail. Tax revenue is positively and significantly associated with carbon intensity in both income groups (developing: 0.0064, $p < 0.01$; developed: 0.0060, $p < 0.01$), and government expenditure is positively and significantly associated with it as well (developing: 0.0045, $p < 0.01$; developed: 0.0016, $p < 0.05$). Public debt shows no association with carbon intensity in either group (Figure 4). This means the scale-channel dominance documented in Section 4.2 is not simply an artifact of the CO₂-on-energy-use accounting identity noted above: tax revenue and government expenditure are independently associated with how carbon-intensive the energy mix is, not only with how much energy is used.

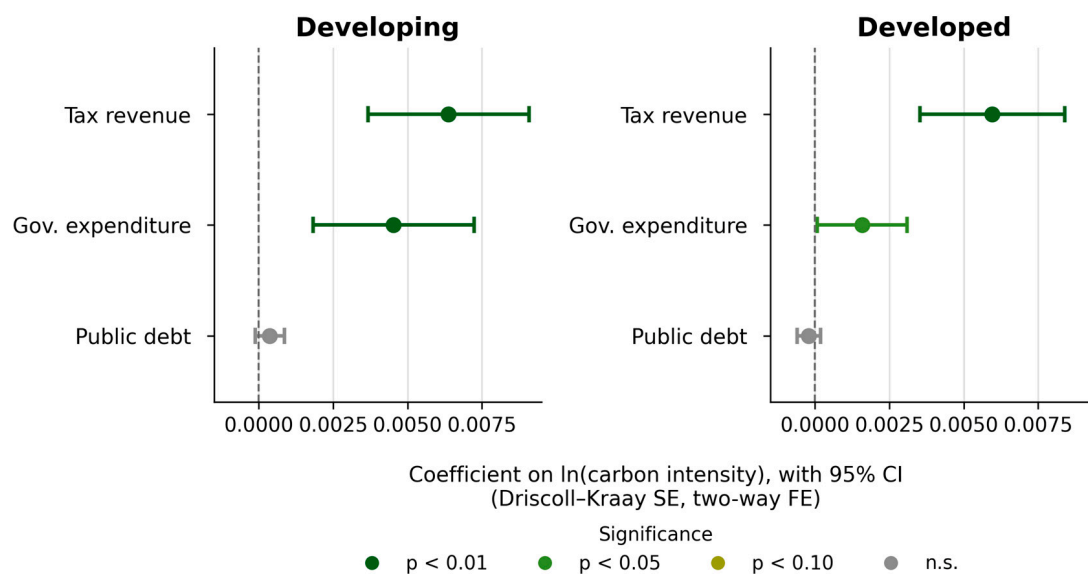


Figure 4. Fiscal-lever associations with carbon intensity (companion to Table 9, Section 4.8). Points show the coefficient on $\ln(\text{carbon intensity})$ for each fiscal lever, with 95% confidence intervals from Driscoll–Kraay standard errors. The dashed vertical line marks zero; marker colors indicate the significance level (n.s., not significant).

This creates a tension with Section 4.4 that we do not think should be resolved by omission. The same two instruments—tax revenue and government expenditure—that are positively associated with renewable-energy share in developing economies (Table 5a: 0.183, $p < 0.05$, and 0.152, $p < 0.01$) are, in this table, also positively associated with the carbon intensity of the overall energy mix. Both associations can hold simultaneously if the non-renewable portion of the energy mix is becoming more carbon-intensive even as the renewable share of the total grows—for example, a compositional shift within fossil generation toward coal, or a pattern in which the industrial or public-sector activity these fiscal instruments reach is itself more energy- and carbon-intensive per unit of output. We cannot adjudicate between these or other explanations with the variables available in this panel, and we treat this as a genuine, unresolved complication in the paper’s composition-channel narrative rather than a finding to reconcile away. We return to this in Section 5.1.

A secondary observation concerns institutional quality. In developed economies, the IQI main effect is positive and significant in every specification (0.027 to 0.054, $p < 0.05$ or better), associating stronger governance capacity with higher, not lower, carbon intensity. In developing economies, the corresponding coefficient is not significant except for public debt, where it is negative (-0.018 , $p < 0.01$). This is a further data point bearing on the institutional-amplifier interpretation developed in Section 5.3, and we incorporate it there.

5. Discussion

5.1. Why the Net Coefficient Understates What the Composition Channel Is Doing—With a Caveat

The developing-economy results in Section 4.4 are difficult to reconcile with a reading of Section 4.2's positive net-emissions coefficients as straightforward evidence of fiscal-policy failure, on the coefficient patterns alone. A one-percentage-point increase in tax revenue as a share of GDP is associated with a 0.183 percentage-point increase in renewable share, while the same instrument's coefficient on log energy use is statistically indistinguishable from zero. Taken together, this is consistent with a composition lever operating inside an economy whose aggregate energy demand it does not independently restrain.

This reading should be treated with caution, however. The formal mediation test in Table 6 does not corroborate it: all six developing-economy indirect effects are null, and the country-clustered bootstrap confidence intervals are wide enough to comfortably include zero in every case. This means the scale–composition offset described above rests on comparing separately estimated coefficients across Tables 3 and 5, not on a mediation pathway that has been formally tested and confirmed. We do not think this null result rules out the pattern—with only 30 developing-economy countries, the bootstrap has limited power to detect a mediated effect even if one is present—but this section's claim should be read as a plausible, coefficient-consistent interpretation rather than an established mechanism. We also do not observe expenditure sub-components, so we cannot directly confirm that the residual positive net association in developing economies operates through carbon-intensive infrastructure spending specifically, as opposed to some other correlated channel this panel does not model.

A further complication comes from Section 4.8. Tax revenue and government expenditure—the same two instruments driving the composition-channel result just described—are also positively and significantly associated with the carbon intensity of the overall energy mix (Table 9), independent of the scale channel. We do not think this overturns the composition-channel finding, since renewable share and carbon intensity are estimated as separate outcomes and both associations are internally well-identified within their own equations; but it does mean the phrase “composition lever” should not be read as implying the rest of the energy system is fixed while renewable share moves. It is possible that the same fiscal activity that expands renewable share is also associated with a more carbon-intensive non-renewable residual—a genuinely more complicated story than either a pure composition success or a pure scale failure. We flag this as an open question for future work with access to disaggregated fiscal or generation-mix data, rather than resolving it here.

5.2. The Developed-Economy Comparison

The developed-economy pattern is less uniform than a single “both margins” characterization suggests. Tax revenue is the only one of the three levers with a clear, statistically supported association with the scale channel in this subsample; public debt's scale-channel coefficient is not distinguishable from zero, despite showing a significant composition-channel association. At the same time, government expenditure and public debt are both negatively associated with renewable share in developed economies—an association running in the opposite direction from what a simple “developed-economy instruments support the transition on both margins” reading would predict. We do not have a basis in this panel to adjudicate between the candidate explanations for this (fossil-sector support embedded in aggregate expenditure figures, a denominator effect from rising total consumption, or another mechanism not directly observable at this level of aggregation), and we present it here as an open finding rather than a resolved one.

GDP per capita growth does not absorb the fiscal-instrument coefficients in Table 5—where growth is significant in the composition equations, it is negatively signed, and the fiscal terms remain large and precisely estimated after its inclusion—which is consistent with, though does not conclusively establish, a design or administrative-capacity difference between income groups rather than a pure income effect: advanced-economy fiscal systems may have built the capacity to pair demand-management with renewable-capacity support in the case of tax revenue specifically, where the developing-economy systems in this sample appear, on this evidence, to have built out the composition side alone. We flag this as the more plausible reading rather than a confirmed mechanism, since we do not observe the underlying administrative or program-design variables directly.

5.3. Institutional Quality as an Amplifier

The results in Section 4.3 are consistent with the institutional lock-in view [36,37] rather than the view that stronger institutions straightforwardly redirect fiscal allocation toward better environmental outcomes [32,34], though the evidentiary basis for this claim is narrower than the net-emissions results in Section 4.2 alone would suggest. In the developing-economy subsample, governance capacity strengthens the existing net-positive association between tax revenue and emissions rather than weakening it (interaction coefficient significant at $p < 0.01$); in the developed-economy subsample, the amplification pattern rests on the public-debt $\times$ IQI interaction, which is significant and negative, strengthening debt's association with lower emissions as governance improves. We do not extend this claim to the developed-economy tax-revenue interaction, which is not statistically significant in Table 3b (see the qualification in Section 4.3) despite an apparent gradient in the unconditional marginal-effects table. Read together, institutional quality in this data behaves less like an independent corrective and more like a multiplier on whichever direction the underlying fiscal allocation already points, for the instrument-group combinations where the underlying interaction term is itself significant—which has a direct, if uncomfortable, implication for policy sequencing: governance-capacity investment introduced ahead of, rather than alongside, a change in what fiscal instruments finance may not deliver the environmental benefit often assumed to follow from it. Section 4.8 adds a further, direct data point to this picture: in developed economies, the institutional-quality main effect on carbon intensity itself is positive and significant in every specification (0.027 to 0.054), meaning stronger governance capacity is associated with a more, not less, carbon-intensive energy mix in that subsample. This is consistent with, and strengthens, the amplifier reading rather than the corrective one for developed economies specifically. In developing economies, the corresponding coefficient is significant only for public debt (negative), which does not extend the amplifier story to that group's other two levers on this particular outcome.

5.4. Distributional Considerations

The results in Section 4.6 do not fully resolve concerns about whether a demand-restraint policy layered onto existing fiscal instruments would carry distributional costs, but they narrow the concern somewhat: existing fiscal levers and renewable deployment both show a negative association with inequality in the developing-economy subsample, which is at least permissive of pairing a demand-side counterpart with existing composition-oriented instruments. We are cautious about overstating this: the evidence here is an aggregate cross-country association, not an incidence analysis of any specific instrument, and a poorly designed demand-restraint measure could still generate regressive outcomes this panel cannot rule out.

5.5. Practical and Policy Implications

Four design implications follow from the results above, offered with the qualifications developed in the preceding subsections and, in particular, with the mediation test null result from Section 4.5 in mind throughout.

First, renewable-investment instruments in developing economies would benefit from an explicit, separately tracked demand-restraint requirement rather than being evaluated solely against renewable-capacity targets, given the absence of a measurable scale-channel association for the instruments tested here (Table 5)—offered as a design hypothesis consistent with, rather than established by, the coefficient pattern, since the formal mediation test does not confirm the underlying pathway.

Second, carbon-pricing revenue recycling in developing-economy contexts may do more strategic work directed toward efficiency and demand-management investment than toward additional renewable-capacity subsidy, which the existing fiscal architecture in this sample already appears to support without further carbon-price incentive. We note that neither carbon prices nor green bonds are variables in any of the four equations estimated here; this recommendation and the two that follow are explicitly policy conjectures extending beyond the estimated model, not effects directly demonstrated by the analysis.

Third, green bond and climate-debt eligibility criteria in developing economies could reasonably require demonstrable demand-side impact alongside renewable-capacity impact, consistent with the tax-revenue result in the developed-economy subsample (Section 5.2) and with the governance-threshold result for public debt (Section 4.3), while recognizing that government expenditure and public debt showed a negative, not positive, association with renewable share in that same subsample (Section 4.4)—a pattern this paper does not fully explain and that qualifies how far the developed-economy comparison can be generalized as a model to follow.

Fourth, institutional-capacity investment attached to energy-sector reform programs should be sequenced alongside, rather than assumed to precede, a redefinition of what the targeted fiscal instruments finance, given the amplification pattern documented in Section 5.3 for the instrument-group pairs where that pattern is statistically supported.

These recommendations map most directly onto SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), with the distributional check in Section 4.6 bearing on SDG 10 (Reduced Inequalities).

5.6. Limitations and Directions for Further Work

The framework is observational. Fixed effects absorb time-invariant heterogeneity and common shocks but cannot rule out reverse causality in the fiscal levers themselves, which were not instrumented. Section 4.8 addresses the concern that the scale-channel result in Equation (3) partly reflects an accounting identity between energy use and emissions, by re-estimating the model with carbon intensity as the outcome; the fiscal-lever associations that survive this check are reported there and carried into Section 5.1 rather than treated as a resolved robustness check, since they introduce a new complication rather than removing one. A dynamic-panel extension using System GMM [43,44] was estimated as a robustness check on the net-emissions equation, following the same estimator family and instrument-restriction convention used elsewhere in this literature. It is not reported here: the Sargan test of overidentifying restrictions rejected instrument validity in every specification tested ($p < 0.02$ throughout), a known limitation of System GMM at a moderate cross-sectional dimension (30–32 countries) relative to the instrument count this specification requires [45]. We therefore retain two-way fixed effects with Driscoll–Kraay standard errors as the primary specification.

The scale-channel equation (Equation (2)) does not condition on industrial structure, urbanization, or domestic energy pricing, each of which plausibly affects aggregate energy use independently of the fiscal levers tested here; their omission is relevant because the paper's central scale-channel finding is a null result, and a null result is more persuasive once the confounders most likely to dominate the outcome have been conditioned on. This is left as a direction for further work rather than addressed in the current specification, since none of these series is available in the compiled panel at the required frequency. The static two-way fixed-effects specification may also understate lever effects that build gradually over several years rather than within a single fiscal year. Finally, the composition-channel interpretation in Section 5.1 rests on indirect evidence and a mediation test that does not, on its own, confirm the proposed pathway, since expenditure sub-components are not available at the country-year frequency this panel requires; disaggregated fiscal data, where available, would allow a more direct test of the mechanism proposed here.

A further limitation concerns what the three fiscal levers can be taken to represent. Tax revenue, government expenditure, and public debt, each measured as a share of GDP, are broad macro-fiscal aggregates rather than dedicated energy-transition policy instruments such as environmental taxes, green public investment, renewable-energy subsidies, carbon-pricing revenue, or climate finance. Tax revenue and government expenditure each contain substantial activity unrelated to energy or the environment, and public debt measures financing scale rather than climate-policy intent; what this study identifies is accordingly an association between aggregate fiscal size and the two energy-transition margins, not the effect of a specific, targeted climate-fiscal tool. We use "fiscal lever" throughout to mean fiscal capacity and its channels, not a climate-policy instrument in the narrower sense, and the findings here should not be extended to claims about the effectiveness of any particular environmental tax, subsidy, or carbon-pricing design, which this panel cannot speak to directly.

A related limitation concerns the sequential structure of Equations (1)–(3). Renewable share and log energy use enter the net-emissions model (Equation (3)) as regressors, but both are themselves outcomes potentially shaped by the same fiscal levers being tested (Equations (1) and (2)); conditioning on a variable that is itself downstream of the regressor of interest can bias the coefficient on that regressor, so the fiscal-lever coefficients in Table 3 are best read as associations net of the composition and scale channels already estimated, not as the total, unconditional association between a lever and emissions. Estimating the three equations in sequence makes this dependency visible; it does not resolve it. The causal chain implied by the composition–scale offset framing—fiscal policy shaping composition or scale, which in turn shapes CO₂—is a pattern suggested across the three equations, not one established by the sequential estimation itself, and the null results of the formal mediation test in Table 6 are consistent with this caution rather than a contradiction of it.

Finally, the developing/developed split, while it produces the paper's central contrast, bundles income level together with fiscal capacity, energy mix, industrial structure, institutional quality, and infrastructure—dimensions that move together across this classification but are not individually held constant within it. Coefficient differences between the two subsamples are consistent with a development-stage account of how fiscal instruments reach the composition and scale channels, but they are equally consistent with any of these correlated structural differences operating on their own terms; this panel cannot adjudicate between them. The developing/developed framing used throughout should accordingly be read as a description of the sample split that produced these results, rather than as evidence that income level itself, as opposed to the structural features correlated with it, is the operative mechanism.

6. Conclusions

This study examined whether three fiscal instruments—tax revenue, government expenditure, and public debt—are associated with effective levers within energy transition strategy, using a framework that separates their association with renewable-energy composition from their association with aggregate energy-use scale across 62 developing and developed economies over 2002–2022.

Three patterns stand out, with the qualifications noted below. First, the scale channel is associated with net emissions outcomes at a magnitude 10 to 28 times larger, in standardized terms, than any fiscal-lever coefficient in either income group (Table 3c), suggesting that renewable-capacity investment alone is unlikely to be sufficient for decarbonization where aggregate energy demand continues to grow. Second, in developing economies, the fiscal instruments tested here show an association with renewable-energy composition but no measurable independent association with the scale channel—a pattern consistent with an incomplete strategic pairing, though the formal mediation test of this pathway (Table 6) returns null results throughout, with country-clustered bootstrap confidence intervals that comfortably include zero, so this should be read as a coefficient-level pattern rather than a confirmed mechanism. Third, in developed economies, the picture is more mixed than uniform movement on both channels: tax revenue is the clearest case of an instrument reaching both margins, public debt reaches composition but not scale, and government expenditure and public debt are both associated with lower rather than higher renewable share, an association this paper does not explain. Fourth, a complementary carbon-intensity specification (Section 4.8), constructed to give the fiscal instruments a dependent variable not mechanically tied to energy volume, shows that tax revenue and government expenditure are independently associated with the carbon intensity of the energy mix itself, in both income groups—including in developing economies, where the same two instruments are simultaneously associated with a larger renewable share. This complicates rather than resolves the composition-channel story in Section 4.4 and is reported here as an open question rather than a reconciled one.

These findings point toward a testable design principle—that fiscal levers aimed at renewable-energy composition may benefit from an explicit, separately monitored demand-restraint counterpart—offered as a hypothesis consistent with the coefficient patterns documented here, and explicitly not as a causally established result, nor, in the case of the composition–scale offset, as a formally mediation-tested one. Institutional quality’s exogeneity was tested directly and not rejected (Section 3.4); the fiscal levers themselves were not instrumented; and the country sample composition and institutional-quality index construction are now documented in Appendixes A and B respectively. These limitations should be weighed accordingly by readers evaluating how far these results can be generalized.

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Appendix A. Country Composition of the Panel

Table A1 lists the full 62-country sample by income-group classification, matching the classification used to construct the developing- and developed-economy data files underlying this analysis. The specific IMF World Economic Outlook edition used to assign each country is not recorded here; since WEO country groupings are revised periodically, citing a specific vintage would improve replicability.

Table A1. Country composition by income group ($n = 62$).

Developing Economies ($n = 30$)	Developed Economies ($N = 32$)
Argentina, Bangladesh, Bolivia, Brazil, China, Colombia, Ecuador, Egypt, India, Indonesia, Iran, Jordan, Kenya, Malaysia, Mali, Mexico, Morocco, Nigeria, Pakistan, Panama, Paraguay, Peru, Philippines, Senegal, South Africa, Sri Lanka, Thailand, Tunisia, Türkiye, Vietnam	Australia, Austria, Belgium, Canada, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States.

Appendix B. Institutional Quality Index—Principal Component Diagnostics

Table A2 reports principal component diagnostics for the institutional-quality index: the proportion of variance explained by the first principal component of the six Worldwide Governance Indicators, the loadings on each dimension, and the sign convention, extracted separately within each income-group subsample (not pooled), consistent with the group-specific standard deviations already reported in Table 2.

Table A2. First principal component of the six WGI dimensions, by income group.

Dimension	Loading (Developing)	Loading (Developed)
Voice and Accountability	0.189	0.420
Political Stability	0.344	0.320
Government Effectiveness	0.463	0.427
Regulatory Quality	0.442	0.411
Rule of Law	0.469	0.438
Control of Corruption	0.465	0.421
Variance explained by PC1	60.1%	83.0%

All six loadings are positive in both subsamples and of broadly comparable magnitude (no single dimension dominates), supporting the reading of IQI as a general governance signal rather than a proxy for one specific dimension such as political stability or corruption control. The first component's correlation with the IQI variable used elsewhere in this panel is 0.989 (developing) and 0.997 (developed); the near-unity but non-exact correlation is consistent with a minor difference in standardization convention between the two constructions.

Appendix C. Carbon-Intensity Robustness Check—Level-Form Results

Table A3 reports the level-form companion to Table 9 (Section 4.8), with carbon intensity (tons CO₂ per ton oil-equivalent) entered untransformed rather than in log form. It is included for completeness; $\ln(CI)$, reported as Table 9, is treated as the primary specification because the level-form within R^2 falls substantially in the developed-economy subsample (0.43 vs. 0.57 for $\ln(CI)$), indicating carbon intensity is better behaved in log form.

Table A3. Carbon-Intensity model: CI (Level) as outcome, by income group and fiscal lever.

Variable	Dev. TR	Dev. GE	Dev. PD	Adv. TR	Adv. GE	Adv. PD
Fiscal lever	0.0150 *** (0.0029)	0.0090 *** (0.0026)	0.0004 (0.0004)	0.0047 *** (0.0018)	0.0016 (0.0017)	−0.0005 * (0.0003)
Institutional quality	0.0048 (0.0283)	−0.0009 (0.0237)	−0.0480 *** (0.0094)	0.0849 *** (0.0280)	0.1073 *** (0.0339)	0.0823 *** (0.0258)
Lever × IQI	−0.0015 (0.0014)	−0.0010 (0.0012)	0.0006 * (0.0003)	−0.0001 (0.0004)	−0.0007 (0.0005)	−0.0001 (0.0001)
Renewable-energy (RE)	−0.0332 *** (0.0012)	−0.0329 *** (0.0011)	−0.0332 *** (0.0011)	−0.0252 *** (0.0023)	−0.0248 *** (0.0026)	−0.0258 *** (0.0022)
Observations	609	609	609	672	672	672
Within R-squared	0.580	0.549	0.525	0.432	0.431	0.431

Driscoll–Kraay standard errors in parentheses (Bartlett kernel, bandwidth 4), two-way fixed effects.

*** $p < 0.01$; * $p < 0.10$. GDPC, TRD, and lnFDIX rows omitted for space.

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