



What Drives CO₂ Emission Decoupling in Middle-Income Economies? Evidence from Renewable Energy, Green Innovation, Trade Openness, and Institutional Quality

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ABSTRACT

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Middle-income economies face a critical policy challenge: sustaining economic growth while reducing CO₂ emissions. CO₂ emission decoupling provides a useful framework for assessing whether economic growth can be separated from emission growth. However, prior studies have largely relied on descriptive and decomposition approaches, while econometric evidence on the country-level determinants of decoupling remains limited. This study analyzes the factors associated with CO₂ emission decoupling in 29 middle-income economies over the period 2002–2021, focusing on renewable energy consumption, green innovation, trade openness, and institutional quality. The Tapio decoupling model is applied to classify growth–emissions relationships, with strong and weak decoupling treated as decoupling outcomes. A pooled binary logit model with year effects and country-clustered robust standard errors is employed, complemented by alternative specifications and sensitivity checks. The estimation results indicate that renewable energy consumption has a positive effect on CO₂ emission decoupling, although its statistical significance is more sensitive across robustness specifications. Green innovation also has a positive and consistent effect, highlighting the importance of environmentally oriented technological capability. Trade openness has a positive and robust effect, indicating that international integration may support cleaner technology diffusion and production upgrading. A notable finding is the negative effect of institutional quality on decoupling, which should be interpreted cautiously within the sampled middle-income economies. The findings suggest that middle-income economies need integrated strategies that strengthen renewable energy substitution, promote green innovation, align trade with cleaner production, and orient institutional capacity toward credible environmental governance and low-carbon policy implementation.

1. INTRODUCTION

Climate change has increased pressure on countries to reduce CO₂ emissions while sustaining economic growth [1]. This challenge remains difficult because economic expansion is still closely linked to energy consumption, fossil-fuel dependence, and carbon-intensive production [2]. The central policy issue is therefore not only how to reduce emissions, but how to weaken the structural link between output expansion and emission growth. In this context, CO₂ emission decoupling provides a useful framework for assessing whether economies can continue to grow while reducing, or at least slowing, the growth of emissions. By comparing changes in economic output with changes in CO₂ emissions, decoupling analysis captures whether economic growth is becoming less carbon-dependent [3, 4].

This issue is especially relevant for middle-income economies. These economies continue to require sustained growth to support structural transformation, industrial upgrading, employment creation, and income convergence,

while facing increasing pressure to reduce carbon emissions. Unlike many high-income economies, middle-income economies often remain more exposed to fossil-fuel-based energy systems and carbon-intensive production structures [2, 5]. This creates a difficult policy challenge: expanding output without deepening carbon lock-in. Middle-income economies therefore provide an important empirical setting for examining the conditions under which economic growth can be separated from CO₂ emission growth.

CO₂ emission decoupling is shaped by energy, technological, trade, and institutional conditions. Renewable energy contributes to decoupling when it replaces carbon-intensive energy inputs and reduces the emissions generated by output expansion [6]. Green innovation can support decoupling by improving energy efficiency, enabling cleaner production, and reducing the carbon intensity of output [7]. Trade openness may contribute to decoupling through technology diffusion, access to cleaner capital goods, and production upgrading, although its effect depends on whether technique effects outweigh scale effects [8, 9]. Institutional

quality can also influence decoupling through environmental regulation, policy enforcement, and the credibility of low-carbon strategies [10]. These factors suggest that decoupling is not merely a mechanical relationship between GDP and emissions, but a process shaped by the conditions under which growth occurs.

Despite the growing literature on CO₂ emissions and low-carbon development, several gaps remain. First, many empirical studies examine CO₂ emission levels as the main outcome, which helps identify the drivers of emissions but does not directly show whether economic growth is becoming less carbon-dependent [6, 11]. Second, existing decoupling studies have largely relied on classification and decomposition approaches to identify decoupling states and trace historical drivers of emission changes [12, 13]. Although these approaches are valuable, they provide limited econometric evidence on how country-level energy, technological, trade, and institutional conditions are associated with CO₂ emission decoupling outcomes. Third, middle-income economies have received less systematic attention as a distinct empirical setting, despite facing a particularly strong tension between economic growth and low-carbon transition [12, 14].

This study examines CO₂ emission decoupling by treating decoupling status as an empirical outcome rather than merely a descriptive classification. The Tapio framework [4] is used to identify growth–emissions patterns, with strong and weak decoupling considered as decoupling outcomes. This classification is then linked to energy, technological, trade-related, and institutional factors to assess whether they help explain the likelihood of achieving CO₂ emission decoupling. The study advances the existing literature in three main respects. First, it uses decoupling status as the main outcome instead of analyzing CO₂ emissions alone, offering a policy-relevant measure of low-carbon growth. Second, it integrates the Tapio framework with binary response models, allowing decoupling outcomes to be analyzed econometrically. Third, it provides cross-country evidence for middle-income economies, where the challenge of sustaining growth while avoiding deeper carbon lock-in is particularly important. Together, these contributions clarify how energy transition, technological capability, trade integration, and institutional conditions shape CO₂ emission decoupling.

2. LITERATURE REVIEW

2.1 Conceptualizing CO₂ emission decoupling

Decoupling describes a process whereby economic activity generates lower resource use and environmental pressure relative to economic output [3, 15]. In carbon-emission studies, decoupling captures whether growth can occur while CO₂ emissions decline or increase at a slower pace. This concept is analytically useful because emission volume and carbon intensity alone may not fully indicate whether an economy is becoming less carbon-dependent. By comparing the direction and pace of changes in output and emissions, decoupling analysis provides a clearer basis for evaluating progress toward low-carbon growth.

The Tapio framework is widely used to measure CO₂ emission decoupling by comparing percentage changes in emissions and economic output and classifying their relationship into different decoupling states [4]. Within this framework, strong decoupling occurs when output increases

while CO₂ emissions decline, whereas weak decoupling occurs when both output and emissions increase but output grows faster than emissions. Although strong decoupling represents a deeper separation between growth and environmental pressure, weak decoupling remains meaningful because emissions rise more slowly than output. Empirical evidence also indicates that decoupling patterns vary across development levels. Wu et al. [16] show that developed countries tend to exhibit stronger decoupling patterns, while developing countries generally experience weaker decoupling between economic growth and CO₂ emissions.

2.2 Drivers of CO₂ emission decoupling

CO₂ emission decoupling should be viewed not only as a descriptive classification of changes in output and emissions, but also as an empirical outcome that can be explained by underlying economic and institutional conditions. In this context, decoupling depends on whether economic growth is supported by renewable energy substitution, green innovation, trade-related technology diffusion, and governance capacity oriented toward low-carbon transformation. This section discusses the theoretical and empirical basis for explaining how these factors may shape CO₂ emission decoupling.

2.2.1 Renewable energy consumption

Renewable energy consumption is an important channel through which economic growth can become less dependent on fossil-fuel-based energy systems. Since energy use remains a major link between production, output growth, and CO₂ emissions, greater reliance on renewable sources can reduce the carbon intensity of economic activity and support lower-emission growth [17, 18]. Empirical studies generally show that renewable energy consumption can reduce CO₂ emissions, although its effectiveness varies across countries, income levels, and energy systems [6].

Renewable energy supports decoupling when its expansion leads to a real shift in the energy mix, reduces reliance on fossil fuels, and lowers the carbon intensity of growth. Dehghan Shabani [19] shows that the environmental effect of renewable energy depends on human capital, implying that cleaner energy use becomes more effective when supported by complementary capabilities. Lundquist [14] provides supporting evidence from OECD countries, showing that renewable electricity production is associated with a greater likelihood of strong CO₂ decoupling. Wang et al. [20] also show that renewable energy expansion contributes to decoupling when it is accompanied by a decline in renewable-energy-related carbon intensity. The literature therefore suggests that renewable energy is most relevant for decoupling when it substitutes carbon-intensive energy rather than merely expanding total energy supply. This issue is particularly important for middle-income economies, where fossil-fuel dependence remains high and renewable energy has not yet fully transformed the overall energy structure. Accordingly, this study formulates the following hypothesis:

H1: *Renewable energy consumption increases the likelihood of CO₂ emission decoupling.*

2.2.2 Green innovation

Green innovation is a key channel through which economic growth can become less carbon-intensive. It covers environmentally oriented technological efforts that help reduce energy demand, raise resource productivity, and lower

environmental burdens through cleaner production methods, energy-saving practices, and pollution-control technologies [7, 21]. By improving energy efficiency and supporting cleaner production, green innovation can reduce the amount of CO₂ emissions generated per unit of output [22]. This mechanism is particularly relevant for middle-income economies, where technology-intensive production can help lower the emission intensity of industrial activity [23].

Empirical evidence generally supports the emission-reducing role of green innovation, although its effect is not uniform across countries and development contexts. Obobisa et al. [11] show that green technological innovation reduces CO₂ emissions, while Lundquist [14] provides more direct evidence that green technologies can increase the likelihood of strong emissions decoupling. These findings suggest that green innovation can contribute to decoupling when technological advances are translated into cleaner production, energy efficiency, and lower carbon intensity. However, this effect is not automatic, as the contribution of green innovation may depend on income level, absorptive capacity, commercialization, and institutional support [7, 24]. Existing studies have largely examined green innovation as a determinant of CO₂ emission levels, while its role in explaining CO₂ emission decoupling outcomes remains less systematically examined, particularly in middle-income economies [7, 11, 14]. Based on this theoretical and empirical reasoning, the following hypothesis is proposed:

H2: *Green innovation increases the likelihood of CO₂ emission decoupling.*

2.2.3 Trade openness

Trade openness can affect CO₂ emission decoupling through scale, composition, and technique effects [8]. When trade expansion increases production and energy demand, especially in carbon-intensive activities, it may raise CO₂ emissions and make it more difficult to separate economic growth from environmental pressure [25, 26]. This explains why empirical studies often find heterogeneous effects of trade openness on emissions across countries, income groups, production structures, and policy environments [26, 27].

At the same time, trade openness can support decoupling when technique and composition effects become stronger than scale effects. Through technology diffusion, knowledge spillovers, and production upgrading, trade integration can help reduce the carbon intensity of economic activity by lowering energy intensity and facilitating cleaner production practices [28, 29]. In this sense, its environmental effect depends on whether trade expansion reinforces carbon-intensive growth or facilitates cleaner and more efficient production structures. Wang and Zhang [9] provide evidence that trade openness influences carbon-emission decoupling, with effects that vary across income groups. Wang et al. [30] further show that trade openness can support CO₂ emission decoupling after certain structural thresholds are reached. For middle-income economies, the key issue is whether trade integration facilitates technology upgrading and cleaner production, or instead reinforces carbon-intensive expansion. Accordingly, this study formulates the following hypothesis:

H3: *Trade openness increases the likelihood of CO₂ emission decoupling.*

2.2.4 Institutional quality

Institutional quality can shape CO₂ emission decoupling because the separation of economic growth from emissions

depends not only on energy and technological factors, but also on the ability of institutions to design, implement, and enforce environmental policies. Strong institutions can improve regulatory enforcement, strengthen policy credibility, reduce corruption-related distortions, and increase compliance with environmental standards [6, 10]. Through these channels, institutional quality can influence how renewable energy use and green innovation translate into lower emissions [6, 11].

Empirical studies suggest that institutional quality matters for environmental outcomes, but its effect is not uniform across countries and institutional settings. Better institutions may reduce CO₂ emissions by improving policy implementation and strengthening the governance conditions needed for long-term environmental strategies [6, 10]. However, institutional improvement does not automatically lead to lower emissions. When institutional capacity primarily supports investment, industrial expansion, or fossil-fuel-based growth, its environmental effect may be weaker or even adverse unless it is aligned with effective environmental enforcement and low-carbon priorities [11, 31].

This conditional role is particularly relevant for middle-income economies, where institutional capacity may support economic expansion without always ensuring effective environmental enforcement. Institutions may promote decoupling when they align growth objectives with credible regulation, cleaner production incentives, and low-carbon policy implementation. However, their effects may be limited or even adverse when institutional capacity primarily facilitates carbon-intensive expansion without adequate environmental enforcement. On this theoretical and empirical basis, the following hypothesis is proposed:

H4: *Institutional quality is associated with the likelihood of CO₂ emission decoupling.*

3. METHODOLOGY

3.1 Data and variables

This study uses annual panel data for 29 middle-income economies over the period 2002–2021, yielding 580 country-year observations. To calculate the Tapio index for 2002, CO₂ emissions and real GDP data for 2001 are used only as previous-year reference values and are not included in the estimation sample. The sample is defined according to the World Bank's income-group classification and includes both lower-middle- and upper-middle-income economies. The selection of countries and the study period are determined by the availability of consistent data across all variables used in the empirical analysis. A complete list of sample countries is presented in Appendix Table A1.

Data on CO₂ emissions, real GDP, renewable energy consumption, urbanization, GDP per capita, trade openness, FDI inflows, and industry share are drawn from the World Development Indicators [32]. Green innovation is measured using OECD environment-related technology patent data [33]. The OECD patent dataset reports inventive activity by reference area based on inventors' countries of residence and is not restricted to OECD member economies, allowing non-OECD economies to be included where data are available. Institutional quality is constructed from the Worldwide Governance Indicators [34].

The dependent variable is a binary CO₂ decoupling outcome constructed from the Tapio decoupling index. The

independent variables include renewable energy consumption, green innovation, trade openness, institutional quality, GDP per capita, FDI inflows, and urbanization. Renewable energy consumption reflects cleaner energy use, green innovation captures environmentally oriented technological progress, and

trade openness represents external economic integration through technology diffusion, production restructuring, and international market exposure. Table 1 summarizes the definitions and data sources of the variables used in the empirical analysis.

Table 1. Description of variables and data sources

Variables	Symbol	Description	Sources
Dependent variable			
CO ₂ decoupling outcome	D	Binary variable derived from the Tapio decoupling index; 1 = strong or weak decoupling, 0 = otherwise Data used to construct the CO ₂ decoupling outcome	Authors' calculation based on World Development Indicators (WDI) data
CO ₂ emissions	CO ₂	CO ₂ emissions (total) excluding land use, land-use change and forestry (Mt CO ₂ e)	WDI
Real GDP	GDP	GDP (constant 2015 US\$)	WDI
Independent variables			
Renewable energy consumption	RE	Renewable energy consumption (% of total final energy consumption)	WDI
Green innovation	GI	Environment-related technology patents	OECD
Trade openness	TO	Trade (% of GDP)	WDI
Institutional quality	IQ	Principal component analysis (PCA)-based composite index constructed from the six Worldwide Governance Indicators	Authors' calculation based on Worldwide Governance Indicators (WGI) data
Control variables			
GDP per capita	GDPC	GDP per capita at constant 2015 US\$	WDI
Foreign direct investment inflows	FDI	Foreign direct investment, net inflows (% of GDP)	WDI
Urbanization	UB	Urban population (% of total population)	WDI
Industry share	IND	Industry (including construction), value added (% of GDP)	WDI

Institutional quality represents governance capacity and is measured using a principal component analysis (PCA)-based composite index constructed from the Worldwide Governance Indicators covering voice and accountability, political stability and absence of violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption. The first principal component from the PCA procedure is retained as the institutional quality index, with higher values indicating better institutional quality. GDP per capita controls for income-level differences and the stage of economic development. FDI inflows are included to control for the role of international capital flows, while urbanization controls for demographic concentration. Industry share is included as an additional control in the robustness analysis to account for differences in industrial structure. To reduce skewness and account for proportional changes, the natural logarithm is applied to renewable energy consumption, green innovation, trade openness, urbanization, GDP per capita, and industry share. Green innovation is transformed as $\ln(GI + 1)$ to account for zero patent observations. Institutional quality and FDI inflows are retained in their original form because institutional quality is an index-based variable, while FDI inflows may take negative values.

3.2 Measurement of CO₂ emission decoupling

This study applies the Tapio framework [4] to identify CO₂ emission decoupling by comparing changes in CO₂ emissions and real GDP. The resulting index captures the responsiveness of CO₂ emission changes to output changes and is expressed as follows:

$$DI_{it} = \frac{\Delta CO_{2it}/CO_{2i,t-1}}{\Delta GDP_{it}/GDP_{i,t-1}} \quad (1)$$

where, ΔCO_{2it} and ΔGDP_{it} denote the annual changes in total CO₂ emissions and real GDP, respectively, while CO_{2it-1} and GDP_{it-1} represent their corresponding values in the previous year.

Table 2. Classification of the Tapio decoupling index

Decoupling Status	ΔGDP	ΔCO_2	Decoupling Index
Strong decoupling	> 0	< 0	< 0
Weak decoupling	> 0	> 0	0–0.8
Recessive decoupling	< 0	< 0	> 1.2
Recessive coupling	< 0	< 0	0.8–1.2
Expansive coupling	> 0	> 0	0.8–1.2
Weak negative decoupling	< 0	< 0	0–0.8
Expansive negative decoupling	> 0	> 0	> 1.2
Strong negative decoupling	< 0	> 0	< 0

Adapted from Tapio [4].

Note: ΔGDP denotes the annual change in real GDP, while ΔCO_2 denotes the annual change in CO₂ emissions.

The Tapio classification divides the growth–emissions relationship into eight states by considering whether real GDP and CO₂ emissions increase or decrease, together with the value of the decoupling index, as presented in Table 2. For the empirical analysis, strong and weak decoupling are coded as decoupling outcomes, while the remaining Tapio categories are coded as non-decoupling outcomes. This binary classification is appropriate because the analysis focuses on the conditions associated with achieving CO₂ emission decoupling, rather than distinguishing among all Tapio categories. Strong and weak decoupling both occur under economic expansion, where CO₂ emissions either decline or grow more slowly than real GDP [4]. In contrast, the

remaining categories reflect proportional or faster emission growth, adverse emission–output dynamics, or economic contraction. Therefore, grouping the Tapio categories into decoupling and non-decoupling outcomes provides a clear basis for estimating the probability of CO₂ emission decoupling using a binary response model.

3.3 Model specification

Since the dependent variable is binary, this study employs a binary logit model to estimate the probability that a country achieves CO₂ emission decoupling. The dependent variable is the CO₂ decoupling outcome, denoted by D_{it} . It takes the value of 1 if country i in year t is classified as experiencing strong or weak decoupling, and 0 otherwise. Let $P_{it} = \Pr(D_{it} = 1)$ denote the probability that country i records a CO₂ decoupling outcome in year t . The baseline binary logit model is specified as follows:

$$\ln\left(\frac{P_{it}}{1 - P_{it}}\right) = \beta_0 + \beta_1 \ln RE_{it} + \beta_2 \ln GI_{it} + \beta_3 \ln TO_{it} + \beta_4 IQ_{it} + \beta_5 \ln GDPC_{it} + \beta_6 FDI_{it} + \beta_7 \ln UB_{it} + \gamma_t \quad (2)$$

where, RE denotes renewable energy consumption, GI denotes green innovation, TO denotes trade openness, and IQ denotes institutional quality. The control variables include GDP per capita (GDPC), foreign direct investment inflows (FDI), and urbanization (UB). The term γ_t captures year effects, which control for common time-specific shocks across countries. The notation $\ln$ indicates the natural logarithm.

Since logit coefficients are expressed in log-odds, average marginal effects are estimated to facilitate interpretation in terms of changes in the probability of achieving a CO₂ decoupling outcome. Discrete changes in predicted probabilities are also calculated by comparing the predicted probability when selected variables move from the 25th percentile to the 75th percentile, while holding other variables constant.

Given the panel structure of the data, pooled logit and random-effects logit specifications are compared using a likelihood-ratio test of the panel-level variance component. A fixed-effects logit model is not used as the main specification because the conditional logit estimator relies on within-country variation in the binary outcome and may exclude countries with no variation in decoupling status over time, thereby reducing the usable sample and removing cross-country variation central to this study [35]. In addition, an unconditional fixed-effects logit model may suffer from the incidental parameters problem in panels with limited time periods [36]. Country-clustered robust standard errors are applied to address heteroskedasticity and within-country error correlation [37].

3.4 Robustness tests

To evaluate the robustness of the main findings, this study employs seven alternative and extended specifications. First, a probit model is used as an alternative binary response specification to examine whether the results are sensitive to the choice between logit and probit models [38]. Second, both logit and probit models are estimated using one-year lagged explanatory variables to allow for delayed effects on the CO₂ decoupling outcome and to reduce concerns about

contemporaneous reverse causality, although this approach does not fully eliminate endogeneity [38].

Additional robustness checks address specific measurement and specification concerns. Because the binary outcome classifies only strong and weak decoupling as decoupling outcomes, observations with negative real GDP growth are assigned to the non-decoupling category, including cases in which emissions decline. This classification may mechanically affect the measured incidence of decoupling during contractionary periods. To assess the sensitivity of the results to this coding, the baseline logit model is first re-estimated using only observations with positive real GDP growth. As an additional check, the baseline logit model is re-estimated after excluding the major global crisis years of 2009 and 2020.

Green innovation is alternatively measured using a population-normalized indicator, calculated as the number of environment-related technology patents divided by total population and multiplied by 1,000,000. The resulting measure represents environment-related patent intensity per million inhabitants and is used to account for differences in country size and the concentration of absolute patent counts across countries. In this robustness specification, the baseline logit model is re-estimated by replacing the original green innovation measure with the corresponding population-normalized measure. Finally, the baseline logit model is re-estimated with industry share included as an additional control to examine the sensitivity of the institutional-quality coefficient to differences in industrial structure. All specifications include year effects and robust standard errors clustered at the country level.

3.5 Income-group heterogeneity

To examine whether the relationships between the main explanatory variables and CO₂ emission decoupling differ across income subgroups, an additional heterogeneity analysis is conducted. The sample consists of six lower-middle-income economies and 23 upper-middle-income economies. A binary dummy variable, D_i , is constructed to distinguish the two groups, taking the value of 1 for lower-middle-income economies and 0 for upper-middle-income economies. Upper-middle-income economies therefore serve as the reference group.

The baseline logit model is extended by interacting D_i with the four main explanatory variables, namely renewable energy consumption, green innovation, trade openness, and institutional quality. The baseline control variables, namely GDP per capita, FDI inflows, and urbanization, are retained without interaction terms. The model specification for the heterogeneity analysis is expressed as:

$$\ln\left(\frac{P_{it}}{1 - P_{it}}\right) = \beta_0 + \beta_1 \ln RE_{it} + \beta_2 \ln GI_{it} + \beta_3 \ln TO_{it} + \beta_4 IQ_{it} + \beta_5 \ln GDPC_{it} + \beta_6 FDI_{it} + \beta_7 \ln UB_{it} + \delta D_i + \theta_1 (\ln RE_{it} \times D_i) + \theta_2 (\ln GI_{it} \times D_i) + \theta_3 (\ln TO_{it} \times D_i) + \theta_4 (IQ_{it} \times D_i) + \gamma_t \quad (3)$$

where, P_{it} denotes the probability that country i achieves CO₂ emission decoupling in year t . The interaction coefficients θ_1 to θ_4 test whether the relationships of renewable energy consumption, green innovation, trade openness, and institutional quality with CO₂ emission decoupling differ

between the two income groups. The interaction terms are evaluated both individually and jointly to assess income-group heterogeneity. The individual tests examine whether the relationship associated with each main explanatory variable differs between lower-middle-income and upper-middle-income economies, while the joint Wald test evaluates whether the four interaction coefficients are collectively equal to zero. The interaction approach is preferred to separate subgroup regressions because the lower-middle-income subgroup contains only six economies, which limits the reliability of country-clustered inference in split-sample estimation. The specification retains year effects and robust standard errors clustered at the country level.

4. RESULTS

4.1 CO₂ emission decoupling status results

This section reports the CO₂ emission decoupling status derived from the Tapio index. As shown in Table 3, the growth–emissions relationship varies considerably across the sampled middle-income economies. Weak decoupling is the most frequent category, accounting for 27.93% of the sample, followed by strong decoupling at 19.48%. Together, these two categories account for 47.41% of country-year observations, indicating that nearly half of the sample shows some degree of CO₂ emission decoupling. However, carbon-intensive growth remains substantial, as expansive negative decoupling and expansive coupling account for 25.17% and 16.90% of the sample, respectively. These patterns suggest that CO₂ emission decoupling has emerged in middle-income economies, but it is not yet dominant. Table 4 summarizes the classification of decoupling and non-decoupling outcomes used in the econometric analysis.

Table 3. Distribution of Tapio decoupling status

Decoupling status	Frequency	Percentage (%)
Strong decoupling	113	19.48
Weak decoupling	162	27.93
Expansive coupling	98	16.90
Expansive negative decoupling	146	25.17
Recessive decoupling	30	5.17
Recessive coupling	4	0.69
Strong negative decoupling	12	2.07
Weak negative decoupling	15	2.59

Table 4. Decoupling and non-decoupling classification

Decoupling Status	Frequency	Percentage (%)
Decoupling	275	47.41
Non-decoupling	305	52.59

At the country level, Table 5 shows substantial variation in decoupling frequency. Uzbekistan records the highest frequency, followed by China, Colombia, Mexico, and Moldova. By contrast, Algeria records the lowest frequency, followed by Argentina, Brazil, El Salvador, and Guatemala. This contrast indicates that the ability to weaken the growth–emissions link differs considerably across middle-income economies, possibly reflecting differences in energy structure, technological capability, institutional conditions, and dependence on carbon-intensive activities [12, 16].

Figure 1 shows that the annual share of countries achieving decoupling fluctuates considerably over time, indicating that CO₂ emission decoupling among middle-income economies remains episodic rather than sustained. The highest share occurs in 2008, while the lowest is observed in 2020, with a relatively low value also recorded in 2009. The low values in 2009 and 2020 may reflect major macroeconomic disruptions related to the global financial crisis and the COVID-19 pandemic, respectively. Because the Tapio index is based on relative changes in CO₂ emissions and GDP, these annual patterns should not be interpreted solely as evidence of environmental improvement.

Table 5. Countries with the highest and lowest decoupling frequencies

Rank	Highest	Years	Lowest	Years
1	Uzbekistan	15	Algeria	3
2	China	13	Argentina	6
3	Colombia	13	Brazil	6
4	Mexico	12	El Salvador	7
5	Moldova	12	Guatemala	7

Notes: 1. Years indicate the number of country-year observations classified as strong or weak decoupling during 2002–2021. 2. “Highest” and “Lowest” refer to countries with the highest and lowest decoupling frequencies, respectively.

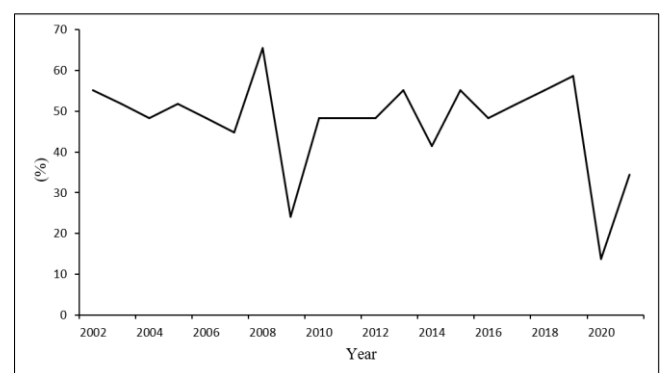


Figure 1. Annual share of countries achieving decoupling

4.2 Descriptive statistics

Table 6 presents the descriptive statistics of the variables included in the baseline model. The results show substantial variation across the 29 middle-income economies. Green innovation displays the largest dispersion, indicating that environment-related patenting activity is concentrated in a limited number of countries. Renewable energy consumption, trade openness, institutional quality, GDP per capita, FDI inflows, and urbanization also differ considerably across the sample.

4.3 Correlation matrix

Table 7 presents the pairwise Pearson correlation matrix for the variables included in the baseline binary response model. Most correlations are low to moderate, with the highest correlation observed between GDP per capita and urbanization at 0.732, which remains below the commonly used threshold of 0.80. These results indicate that the explanatory variables do not exhibit serious pairwise multicollinearity.

Table 6. Descriptive statistics

Variables	RE	GI	TO	IQ	GDPC	FDI	UB
Mean	19.792	967.731	68.644	-2.116	5,285.607	3.027	60.779
Median	15.050	20.571	60.533	-2.031	4,408.744	2.329	62.718
Maximum	67.400	65,330.100	210.374	0.650	14,040.620	43.912	92.229
Minimum	0.100	0.000	22.106	-5.260	793.616	-37.173	28.244
Std. Dev.	16.470	5,879.918	33.023	1.081	3,071.745	3.860	15.170
Kurtosis	3.041	81.067	4.776	3.277	3.023	53.379	2.158
Skewness	0.832	8.566	1.220	0.004	0.905	1.967	-0.065

Table 7. Pearson correlation matrix

Variables	lnRE	lnGI	lnTO	IQ	lnGDPC	FDI	lnUB
lnRE	1.000						
lnGI	0.084	1.000					
lnTO	-0.199	-0.258	1.000				
IQ	0.347	0.242	0.280	1.000			
lnGDPC	-0.089	0.291	-0.030	0.468	1.000		
FDI	-0.057	-0.126	0.278	0.172	0.030	1.000	
lnUB	-0.221	0.069	-0.057	0.321	0.732	0.071	1.000

4.4 Model selection

Before estimating the main model, a likelihood-ratio test of the panel-level variance component is conducted to assess whether a random-effects logit specification is warranted relative to pooled logit. The null hypothesis states that the panel-level variance component is equal to zero. Because the null hypothesis places the variance component at the boundary of the parameter space, the test is evaluated using the chi-square distribution. As reported in Table 8, the test yields $\chi^2(01) = 0.17$ with a p-value of 0.339. Therefore, the null hypothesis cannot be rejected, and the pooled logit specification is retained as the main estimation approach.

Table 8. Likelihood-ratio test

Model Comparison	Chibar ² (01)	p-Value
Pooled logit vs random-effects logit	0.17	0.339

4.5 Estimation results

Table 9 presents the binary logit estimation results, Table 10 reports the corresponding average marginal effects, and Table 11 shows the discrete changes in predicted probabilities to complement the interpretation of the estimated effects.

Table 9. Binary logit estimation results

Variables	Coeff.	Std. Error	z-stat.	p-Value
lnRE	0.211*	0.115	1.84	0.066
lnGI	0.103**	0.045	2.26	0.024
lnTO	0.657***	0.207	3.18	0.001
IQ	-0.398***	0.134	-2.97	0.003
lnGDPC	0.090	0.165	0.55	0.586
FDI	0.036*	0.019	1.89	0.059
lnUB	0.464	0.410	1.13	0.257

Notes: 1. Robust standard errors clustered at the country level are reported.
2. Year effects are included but not reported. 3. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Renewable energy consumption has a positive coefficient of 0.211 and is significant at the 10% level. The marginal effect suggests that a 1% increase in renewable energy consumption raises the probability of decoupling by about 0.049 percentage points. The predicted probability increases from 0.442 to 0.524

when renewable energy consumption moves from the 25th percentile to the 75th percentile, equivalent to an 8.2 percentage-point increase.

Green innovation also shows a positive coefficient of 0.103 and is significant at the 5% level. This indicates that stronger green innovation capacity is linked to a higher likelihood of achieving a CO₂ decoupling outcome. The marginal effect implies that a 1% increase in green innovation raises the probability of decoupling by about 0.024 percentage points. When green innovation moves from the 25th percentile to the 75th percentile, the predicted probability increases from 0.435 to 0.511, equivalent to a 7.6 percentage-point increase.

Table 10. Average marginal effects of the binary logit model

Variables	dy/dx	Std. Error	z-stat.	p-Value
lnRE	0.049*	0.026	1.87	0.061
lnGI	0.024**	0.010	2.29	0.022
lnTO	0.151***	0.046	3.28	0.001
IQ	-0.092***	0.030	-3.02	0.003
lnGDPC	0.021	0.038	0.55	0.586
FDI	0.008*	0.004	1.91	0.056
lnUB	0.107	0.094	1.14	0.255

Notes: 1. Robust standard errors clustered at the country level are reported.
2. Year effects are included but not reported. 3. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Trade openness shows a positive coefficient of 0.657 and is significant at the 1% level. The average marginal effect suggests that a 1% increase in trade openness raises the probability of decoupling by approximately 0.151 percentage points. When trade openness moves from the 25th percentile to the 75th percentile, the predicted probability increases from 0.428 to 0.526, equivalent to a 9.9 percentage-point increase.

Institutional quality shows a negative coefficient of -0.398 and is significant at the 1% level. Its average marginal effect of -0.092 implies that a one-unit increase in institutional quality lowers the probability of achieving a CO₂ decoupling outcome by 9.2 percentage points. When institutional quality moves from the 25th percentile to the 75th percentile, the predicted probability decreases from 0.533 to 0.423, equivalent to an 11.0 percentage-point decline.

Among the control variables, FDI inflows show a positive coefficient of 0.036 and are statistically significant at the 10% level. The average marginal effect of 0.008 suggests that a one

percentage-point increase in FDI inflows raises the likelihood of decoupling by about 0.8 percentage points. When FDI inflows move from the 25th percentile to the 75th percentile, the predicted probability increases from 0.460 to 0.479, equivalent to a 2.0 percentage-point increase. GDP per capita and urbanization are statistically insignificant. Although both coefficients are positive, the estimates do not provide sufficient evidence that these variables explain the CO₂ decoupling outcome in the sampled middle-income economies. Overall, the baseline estimation results support H1, H2, and H3. H4 is also supported, as institutional quality is significantly associated with CO₂ emission decoupling, although the estimated relationship is negative.

4.6 Robustness test results

Table 12 reports the baseline model and seven alternative robustness and extended specifications. Model (1) represents the baseline logit specification. Model (2) uses a probit specification, while Models (3) and (4) employ one-year lagged explanatory variables using logit and probit estimators, respectively. Model (5) restricts the sample to observations with positive real GDP growth, and Model (6) excludes the major crisis years of 2009 and 2020. Model (7) replaces the original green innovation measure with a population-normalized measure (lnGIpc), while Model (8) includes industry share (lnIND) as an additional control. All specifications include year effects and country-clustered robust standard errors.

Renewable energy consumption retains a positive

coefficient across all specifications, although its statistical significance varies. It remains statistically significant in the probit specification, the positive-growth sample, the specification excluding 2009 and 2020, and the population-normalized green innovation model. However, it is not statistically significant in the lagged specifications or in the extended specification controlling for industry share. These results indicate that the positive association between renewable energy consumption and CO₂ emission decoupling remains consistent in direction but is more sensitive to specification changes than the associations of the other main explanatory variables.

Green innovation remains positively associated with CO₂ emission decoupling and is statistically significant across specifications. Its coefficient remains significant under the probit and lagged specifications, as well as in the positive-growth sample, the specification excluding 2009 and 2020, and the extended specification controlling for industry share. When green innovation is alternatively measured using a population-normalized green innovation measure, the coefficient also remains positive and statistically significant. Trade openness also remains positive and statistically significant across all alternative specifications. This result remains consistent under the probit and lagged models, the recession-related sample restrictions, the population-normalized green innovation specification, and the additional industry-share control. This consistency suggests that the positive association between trade openness and CO₂ emission decoupling is robust across alternative estimators, sample treatments, and model specifications.

Table 11. Discrete changes in predicted probabilities

Variables	Predicted Probability at P25	Predicted Probability at P75	Difference	p-Value
lnRE	0.442	0.524	0.082*	0.060
lnGI	0.435	0.511	0.076**	0.022
lnTO	0.428	0.526	0.099***	0.001
IQ	0.533	0.423	-0.110***	0.002
FDI	0.460	0.479	0.020*	0.057

Notes: 1. The table reports changes in predicted probabilities when each variable moves from the 25th percentile to the 75th percentile. 2. Predicted probabilities are based on the main logit model with year effects. 3. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 12. Robustness test results

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)	Model (7)	Model (8)
lnRE	0.211* (0.115)	0.129* (0.071)	0.166 (0.119)	0.101 (0.075)	0.236* (0.128)	0.236** (0.105)	0.215** (0.105)	0.177 (0.114)
lnGI	0.103** (0.045)	0.063** (0.028)	0.117** (0.046)	0.073** (0.029)	0.112** (0.045)	0.099** (0.040)	-	0.124*** (0.047)
lnGIpc	-	-	-	-	-	-	0.545*** (0.157)	-
lnTO	0.657*** (0.207)	0.401*** (0.127)	0.704*** (0.233)	0.432*** (0.145)	0.763*** (0.240)	0.728*** (0.205)	0.487** (0.190)	0.732*** (0.202)
IQ	-0.398*** (0.134)	-0.248*** (0.080)	-0.373*** (0.129)	-0.233*** (0.078)	-0.424*** (0.151)	-0.353*** (0.133)	-0.452*** (0.135)	-0.430*** (0.128)
lnGDPC	0.090 (0.165)	0.061 (0.102)	0.108 (0.159)	0.068 (0.099)	-0.024 (0.179)	0.017 (0.148)	-0.072 (0.147)	0.160 (0.188)
FDI	0.036* (0.019)	0.023* (0.012)	0.040* (0.024)	0.025* (0.015)	0.025 (0.019)	0.029 (0.020)	0.036* (0.019)	0.034* (0.018)
lnUB	0.464 (0.410)	0.267 (0.249)	0.256 (0.400)	0.145 (0.247)	1.094** (0.440)	0.740* (0.408)	0.477 (0.390)	0.397 (0.456)
lnIND	-	-	-	-	-	-	-	-0.633 (0.476)
Observations	580	580	551	551	519	522	580	580

Notes: 1. Robust standard errors clustered at the country level are shown in parentheses. 2. Year effects are included but not reported. 3. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Institutional quality remains negative and statistically significant across specifications. The negative coefficient persists in the probit and lagged models, the positive-growth sample, the specification excluding 2009 and 2020, the population-normalized green innovation specification, and the extended specification controlling for industry share. In particular, the coefficient remains negative and statistically significant after controlling for industry share, suggesting that the baseline association is not driven solely by differences in industry share. Nevertheless, this finding should be interpreted as a conditional association rather than a causal effect, since other potentially relevant structural factors are not explicitly included in the model.

The control variables show less consistent results across specifications. FDI inflows remain positive but lose statistical significance in the positive-growth sample and in the specification excluding 2009 and 2020. GDP per capita remains statistically insignificant across all alternative specifications. Urbanization is generally insignificant but becomes positive and statistically significant in the positive-growth sample and in the specification excluding 2009 and 2020. Overall, the robustness analysis indicates that the findings for green innovation, trade openness, and institutional quality remain consistent across specifications, including alternative estimators, sample restrictions, measurement choices, and additional controls. Renewable energy consumption retains a positive coefficient across all specifications, although its statistical significance is more sensitive to specification changes.

4.7 Income-group heterogeneity results

Table 13 reports the income-group heterogeneity results, with upper-middle-income economies serving as the reference group. None of the individual interaction terms is statistically significant. The p-values for the interactions of renewable energy consumption, green innovation, trade openness, and institutional quality are 0.660, 0.235, 0.383, and 0.115, respectively, indicating no statistically significant coefficient difference for any single determinant between the two income groups.

Table 13. Income-group heterogeneity estimation results

Variables	Coeff.	Std. Error	z-stat.	p-Value
lnRE	0.251***	0.090	2.79	0.005
lnGI	0.162***	0.037	4.43	0.000
lnTO	0.757**	0.313	2.42	0.016
IQ	-0.251**	0.108	-2.33	0.020
D	-3.054	4.250	-0.72	0.472
D × lnRE	-0.061	0.139	-0.44	0.660
D × lnGI	-0.153	0.129	-1.19	0.235
D × lnTO	0.634	0.726	0.87	0.383
D × IQ	-0.628	0.398	-1.58	0.115
lnGDPC	0.035	0.161	0.22	0.827
FDI	0.040**	0.018	2.21	0.027
lnUB	0.606	0.499	1.21	0.225

Joint Wald test: $\chi^2(4) = 22.25$, p -value = 0.0002

Notes: 1. Robust standard errors clustered at the country level are reported.
2. Year effects are included but not reported. 3. ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. 4. D = 1 for lower-middle-income economies and 0 for upper-middle-income economies.

However, the joint Wald test rejects the null hypothesis that the four interaction coefficients are jointly equal to zero ($\chi^2(4) = 22.25$, $p = 0.0002$), providing evidence of overall parameter

heterogeneity. Accordingly, the pooled baseline coefficients should be interpreted as full-sample associations rather than as evidence of identical relationships across both income groups. This result should nevertheless be interpreted cautiously because the lower-middle-income subgroup contains only six economies, which limits the strength of subgroup inference.

5. DISCUSSION

The Tapio results show that CO₂ emission decoupling has emerged in middle-income economies, but it remains neither dominant nor stable. Strong and weak decoupling coexist with expansive coupling and expansive negative decoupling, indicating that many middle-income economies have not consistently weakened the link between economic growth and CO₂ emission growth. This pattern is consistent with previous studies showing that decoupling tends to be intermittent in economies where industrial expansion, fossil-fuel dependence, and structural transformation remain ongoing [12, 16].

The positive and statistically significant effect of renewable energy consumption suggests that greater renewable energy use helps reduce the carbon intensity of economic expansion. This finding is in line with previous studies showing that renewable energy can reduce emission pressure and improve environmental performance when it becomes a meaningful part of the energy system [39, 40]. It is further supported by studies that examine the growth–emissions relationship more directly. Lundquist [14] shows that renewable electricity production increases the probability of strong CO₂ emission decoupling, while Wang et al. [20] show that increasing the share of renewable energy has a carbon-mitigation effect and can support a transition toward stronger CO₂ emission decoupling. However, the weaker robustness of this effect across specifications indicates that renewable energy consumption alone may not be sufficient to ensure decoupling unless it reaches a scale large enough to transform the overall energy mix. This interpretation is supported by evidence showing that the emission-reducing effect of renewable energy depends on threshold levels and its ability to substitute fossil energy effectively [41–43].

The positive and statistically significant effect of green innovation indicates that technological capability plays an important role in making economic activity less emission-intensive. Green innovation may support this process by improving energy efficiency, promoting cleaner production, and reducing the carbon intensity of output [7, 21, 22]. Economies with stronger green innovation capacity may therefore be better positioned to expand production without generating proportional increases in CO₂ emissions. This result is consistent with previous studies showing that green technological innovation contributes to emission reduction and better environmental performance [11, 31]. It is also supported by Lundquist [14], who shows that green technologies increase the rate of emissions decoupling, and Wang et al. [44], who identify green transformation as an important factor in CO₂ emission decoupling.

The positive and statistically significant effect of trade openness on CO₂ emission decoupling suggests that external economic integration helps reduce the carbon intensity of economic activity. More open economies may gain access to cleaner technologies, energy-efficient capital goods, knowledge spillovers, and global environmental standards,

thereby supporting decoupling outcomes [9]. From this perspective, trade openness can promote decoupling when technology diffusion and technique effects outweigh scale effects [8]. This result is consistent with previous studies showing that trade openness can facilitate decoupling, particularly when trade integration is accompanied by technological upgrading and cleaner production structures [9, 30]. However, its environmental effect remains conditional rather than automatic, as the trade–emissions nexus may be nonlinear and heterogeneous across countries and development stages [30, 45, 46]. Therefore, in middle-income economies, trade openness is more likely to support CO₂ emission decoupling when accompanied by cleaner technology adoption, industrial upgrading, and stronger environmental standards.

The negative and statistically significant effect of institutional quality on CO₂ emission decoupling should be interpreted cautiously. It does not imply that stronger institutions necessarily worsen environmental outcomes. The negative coefficient remains statistically significant after industry share is included as an additional control, indicating that the estimated effect remains after accounting for differences in industry share. However, other potentially relevant structural factors, including fossil-fuel endowments, energy-price subsidies, and other country-specific characteristics, are not explicitly controlled for in the present analysis.

One possible explanation for the observed negative effect is that improvements in institutional capacity may initially strengthen growth-oriented functions, such as investment facilitation, trade expansion, industrial development, and administrative capacity, without immediately translating into stronger environmental enforcement, credible environmental regulation, or effective low-carbon policy implementation [47]. However, this interpretation remains a hypothesis rather than an empirically established mechanism. This interpretation may help explain why the present finding differs from some CO₂ emission-level studies showing that better institutional quality is associated with lower emissions through stronger regulation, policy enforcement, and environmental governance [6, 10, 11]. Unlike those studies, this study examines CO₂ emission decoupling status, which depends not only on emission levels but also on whether emissions decline or grow more slowly than economic output. Moreover, institutional quality may operate differently across governance dimensions, as some components may be associated with lower emissions while others may exhibit weaker or even counterintuitive relationships [47, 48]. These considerations suggest that the contribution of institutional quality to CO₂ emission decoupling may depend on the extent to which institutional capacity is translated into credible environmental regulation, effective policy enforcement, and low-carbon development priorities [49, 50]. Accordingly, the institutional-quality coefficient should be viewed as a conditional relationship within the sampled middle-income economies rather than as evidence of a causal effect.

The additional variables provide further insights into CO₂ emission decoupling. FDI inflows show a positive association with decoupling in the baseline specification, suggesting that foreign capital may support growth–emissions separation through technology transfer, managerial upgrading, and more efficient production processes [51]. However, the FDI estimate is less consistent across alternative specifications, and its environmental implications may depend on the origin,

sectoral allocation, technological content, and regulatory conditions of investment [52]. FDI may therefore support decoupling when directed toward cleaner and more technology-intensive activities, while investment concentrated in fossil-fuel-based or resource-intensive sectors may reinforce carbon lock-in.

GDP per capita and urbanization are not statistically significant in the baseline model. GDP per capita remains insignificant across the alternative specifications, whereas the urbanization estimate is less consistent across robustness checks. These results suggest that income level and urbanization alone may not systematically explain CO₂ emission decoupling in the sampled middle-income economies. Instead, decoupling may depend more on the characteristics of the growth process, including cleaner energy systems, technological capability, energy efficiency, and cleaner production structures [12, 13, 53].

The income-group heterogeneity analysis indicates overall parameter heterogeneity between lower-middle-income and upper-middle-income economies, although no individual interaction term is statistically significant. Accordingly, the pooled estimates should be interpreted as full-sample associations rather than as identical relationships within both income subgroups, while the small number of lower-middle-income economies limits the strength of subgroup inference. Overall, the findings indicate that CO₂ emission decoupling in middle-income economies is associated with multiple dimensions, including energy structure, technological capability, trade integration, and institutional context.

6. CONCLUSION AND POLICY IMPLICATIONS

This study examined the determinants of CO₂ emission decoupling in 29 middle-income economies over the period 2002–2021. Using the Tapio framework, strong and weak decoupling were classified as decoupling outcomes and analyzed using binary response models. This approach allows the study to move beyond emission-level analysis by directly evaluating whether economic expansion occurs alongside declining or more slowly growing CO₂ emissions.

The findings show that CO₂ emission decoupling has emerged in middle-income economies, although it remains neither dominant nor stable. Renewable energy consumption is positively associated with the probability of decoupling, although its statistical significance is more sensitive across robustness specifications. Green innovation is positively and consistently associated with decoupling, highlighting the importance of technological capability in supporting lower-carbon growth. Trade openness is also positively and robustly associated with decoupling, indicating that trade integration may support cleaner technology diffusion, industrial upgrading, and more efficient production structures. A notable finding is the negative association between institutional quality and decoupling, which should be interpreted cautiously within the sampled middle-income economies. FDI inflows also show a positive association, although the estimates are less consistent across alternative specifications.

These findings provide several policy implications. First, renewable energy policy should go beyond capacity expansion by promoting the effective substitution of fossil-fuel-based energy use through grid modernization, energy storage, and broader clean energy adoption. Second, green innovation should be strengthened through support for green R&D,

environmental patents, clean production technologies, and energy-efficiency improvements. Third, trade openness and FDI inflows should be aligned with green industrial policy so that trade and foreign investment support cleaner technology diffusion, industrial upgrading, and low-carbon production rather than reinforcing carbon-intensive activities. Fourth, the findings suggest that institutional reform should place greater emphasis on environmental governance, including stronger regulation, monitoring, enforcement, transparency, and policy coordination.

The limitations of this study also point to several directions for future research. First, although the lagged specifications reduce concerns about contemporaneous reverse causality, they do not fully address potential endogeneity; therefore, the estimated relationships should be interpreted as associations rather than causal effects. Second, because observations with negative real GDP growth are classified as non-decoupling, the estimated decoupling probability remains conditional on this coding framework, although the results remain broadly consistent when using only positive-growth observations and when excluding the major global crisis years of 2009 and 2020. Third, the negative association between institutional quality and decoupling should be interpreted within the sampled middle-income economies and the 2002–2021 study period. Although the coefficient remains statistically significant after controlling for industry share, other potentially relevant structural factors, including fossil-fuel endowments and energy-price subsidies, are not explicitly modeled. Future research could examine these factors together with individual dimensions of institutional quality, sector-specific decoupling, and consumption-based CO₂ emissions.

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APPENDIX

Table A1. Sample countries by income classification

No.	Country	Income Classification
1	Algeria	Upper-middle-income
2	Argentina	Upper-middle-income
3	Bosnia and Herzegovina	Upper-middle-income
4	Brazil	Upper-middle-income
5	China	Upper-middle-income
6	Colombia	Upper-middle-income
7	Costa Rica	Upper-middle-income
8	Ecuador	Upper-middle-income
9	Egypt, Arab Rep.	Lower-middle-income
10	El Salvador	Upper-middle-income
11	Guatemala	Upper-middle-income
12	India	Lower-middle-income
13	Indonesia	Upper-middle-income
14	Iran, Islamic Rep.	Upper-middle-income
15	Kazakhstan	Upper-middle-income
16	Malaysia	Upper-middle-income
17	Mexico	Upper-middle-income
18	Moldova	Upper-middle-income
19	Mongolia	Upper-middle-income
20	North Macedonia	Upper-middle-income
21	Pakistan	Lower-middle-income
22	Peru	Upper-middle-income
23	Philippines	Lower-middle-income
24	South Africa	Upper-middle-income
25	Thailand	Upper-middle-income
26	Tunisia	Lower-middle-income
27	Türkiye	Upper-middle-income
28	Ukraine	Upper-middle-income
29	Uzbekistan	Lower-middle-income