Decoupling or Green Myth?
A Global Analysis of the Relationship Between Economic Growth and Environmental Pressure (1990–2023)

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Abstract

This paper examines the extent to which countries worldwide have achieved absolute or relative decoupling between economic growth and environmental pressure over the period 1990–2023. Using World Bank data on GDP, CO_2 emissions, and energy use, the study constructs elasticity-based indicators and decoupling typologies across country groups. The aim is to contribute empirical evidence to the debate on whether "green growth" is an empirically plausible pathway or whether observed improvements primarily reflect limited, uneven, or context-dependent dynamics.

Statement of Contribution

This paper provides a transparent global assessment of growth–environment decoupling patterns over the period 1990–2023 using publicly available World Bank indicators. It contributes by (i) applying a consistent country-year classification framework based on elasticity measures, (ii) comparing results using both per capita and total CO_2 emissions, and (iii) presenting descriptive evidence that can be interpreted in light of competing views on green growth and ecological constraints. The paper prioritizes replicability by relying on documented indicators and explicit classification rules.

1 Title, Research Question, and Hypotheses

Research Question

To what extent have countries around the world achieved decoupling between economic growth and environmental pressure during the period 1990–2023?

Hypotheses

- **H1:** High-income countries exhibit greater evidence of relative decoupling, but few achieve sustained absolute decoupling.
- **H2:** In low- and middle-income countries, economic growth remains more strongly associated with rising CO_2 emissions and energy use.
- **H3:** A strong global narrative of "green growth" is difficult to sustain empirically when evaluated across multiple decades and broad country groups.

Hypothesis Matrix

Hypothesis	**Description**	**Expected Empirical Signal**
H1: Relative decoupling in high-income countries	High-income economies reduce the emissions–growth elasticity but do not consistently show declining total emissions.	Elasticity < 1 with $\Delta CO_2 > 0$ in many years
H2: Strong coupling in low-/middle-income countries	Growth in developing countries remains more tightly linked to increases in CO_2 and energy use.	Elasticity ≥ 1 with $\Delta CO_2 > 0$ frequently observed
H3: Green growth as a global myth	At the global level, sustained absolute decoupling is uncommon across countries and periods.	Few cases with ΔGDP > 0 and $\Delta CO_2 < 0$ over extended horizons

2 Structure of the Paper

Section 1 introduces the research question and hypotheses.
Section 2 provides the theoretical framework and background literature.
Section 3 presents the data sources, variables, and construction of indicators.
Section 4 explains the methodology for measuring decoupling through elasticities and typologies.
Section 5 reports the empirical results, including descriptive trends and country classifications.
Section 6 offers a discussion of the findings and their implications.
Section 7 concludes with reflections on policy relevance and future research directions.

3 Theoretical Framework and Background

3.1 Economic Growth and Environmental Pressure

Economic growth has historically been associated with rising energy use, material throughput, and environmental pressure. From a biophysical perspective, economic production requires energy and material inputs, implying that sustained increases in economic output are generally accompanied by higher resource extraction and pollutant emissions (Georgescu-Roegen, 1971; Daly, 1996). At the global scale, empirical research has consistently documented strong long-run relationships between gross domestic product (GDP), primary energy consumption, and carbon dioxide (CO_2) emissions (Ayres and Warr, 2009; Stern, 2011).

The relationship between economic growth and environmental pressure has been examined through multiple analytical lenses, most notably the Environmental Kuznets Curve (EKC) hypothesis, which posits an inverted-U relationship between income levels and certain environmental indicators. While some local pollutants exhibit EKC-type dynamics, evidence for global environmental pressures—particularly CO_2 emissions and material use—is considerably weaker and often inconsistent (Stern, 2004; Dinda, 2004). For cumulative and global pressures such as greenhouse gas emissions, income growth alone has not reliably generated sustained absolute reductions.

Moreover, observed declines in territorial environmental pressure within some high-income economies may reflect the international relocation of energy- and material-intensive production through trade, rather than genuine reductions in global environmental impact. Consumption-based accounting studies show that outsourcing can mask continued growth in material and emissions footprints when measured along global supply chains (Peters et al., 2011; Wiebe et al., 2012).

A further complication arises from rebound effects. Efficiency improvements can reduce the effective cost of energy or resource services, thereby inducing additional consumption that partially or fully offsets expected environmental gains (Khazzoom, 1980; Brookes, 1990; Sorrell, 2009). At the macroeconomic level, rebound effects have been shown to be substantial in some contexts, particularly in energy-intensive sectors, challenging the assumption that technological efficiency alone guarantees absolute reductions in environmental pressure under sustained economic growth.

Taken together, this literature suggests that the relationship between economic growth and environmental pressure is shaped by biophysical constraints, technological change, and systemic feedback mechanisms. Consequently, empirical assessments of "decoupling" require careful distinction between changes in environmental intensity and changes in total environmental pressure.

3.2 The Concept of Decoupling

Decoupling refers to the dissociation between economic growth and environmental pressure. The concept is commonly divided into relative decoupling, where environmental pressure grows more slowly than economic output, and absolute decoupling, where environmental pressure declines while the economy continues to grow (OECD, 2002; UNEP, 2011). While relative decoupling may reduce environmental intensity, only absolute decoupling is consistent with sustained reductions in total environmental impact.

Operationally, decoupling is often measured using elasticity-based indicators that relate changes in environmental pressure to changes in economic output. One widely used approach is the Tapio elasticity framework, which classifies growth–environment relationships based on the ratio of the percentage change in environmental pressure to the percentage change in GDP (Tapio, 2005). This framework distinguishes multiple regimes, including strong decoupling, weak decoupling, expansive coupling, and various forms of recessive decoupling.

The Tapio approach offers several advantages for empirical analysis. First, it does not impose a specific functional form on the growth–environment relationship. Second, it allows for asymmetric responses during periods of economic expansion and contraction. Third, it can be applied consistently across countries and time periods using readily available macroeconomic data (Vehmas et al., 2007). However, elasticity-based measures are sensitive to short-term fluctuations and require careful interpretation, particularly when GDP growth rates approach zero.

In this study, decoupling is analyzed using both per capita and total CO_2 emissions, reflecting the distinction between intensity-based improvements and changes in aggregate environmental pressure. This dual perspective is essential for evaluating claims of green growth in a globally interconnected economy.

3.3 Empirical Evidence from Previous Studies

A substantial empirical literature has examined whether economic growth has been decoupled from environmental pressure. Institutional reports by organizations such as the OECD and UNEP document widespread relative decoupling in several high-income economies, particularly in terms of CO_2 emissions per unit of GDP (OECD, 2019; UNEP, 2011). These assessments typically emphasize technological progress, structural shifts toward services, and environmental regulation as drivers of declining emissions intensity.

In contrast, research within ecological economics raises doubts about sustained absolute decoupling at the scale and speed required for major environmental objectives. Using global and multi-regional datasets, studies by Parrique et al. (2019) and Hickel (2020) find limited evidence of long-term absolute decoupling of GDP from material use and CO_2 emissions, particularly when consumption-based indicators are considered. Related arguments emphasize that efficiency gains are frequently offset by scale effects associated with continued economic expansion (Kallis, 2018).

For CO_2 emissions specifically, empirical results remain mixed across studies and contexts. Some countries have experienced periods of declining territorial emissions alongside GDP growth, but the persistence and drivers of these episodes are debated. Evidence suggests that such periods often coincide with structural economic change, energy price shocks, or accelerated deployment of low-carbon energy, rather than representing a stable long-run trend (Jakob and Steckel, 2014; Haberl et al., 2020).

Overall, the empirical literature indicates that while relative decoupling is common, robust and sustained absolute decoupling—particularly in terms of total environmental pressure—remains rare and uneven across countries and time periods. This ambiguity motivates a systematic and transparent global analysis using consistent metrics across both per capita and total emissions, as undertaken in this study.

4 Data and Methodology

4.1 Data Sources and Variables

The empirical analysis uses annual country-level macro indicators from the World Bank's World Development Indicators (WDI) database (?). The baseline dataset covers the period 1990–2023, subject to data availability by country and variable. The core variables are:

- **Economic output (growth):** GDP per capita in constant prices (used as the primary measure of economic performance to reduce mechanical scaling effects from population), and related GDP series when constructing growth rates (?).
- **Environmental pressure:** (i) CO_2 emissions per capita and (ii) total CO_2 emissions. These two measures capture, respectively, an intensity-oriented perspective and an aggregate-pressure perspective (?).
- **Energy use:** energy use per capita (kg of oil equivalent per capita), used as an additional pressure-related indicator reflecting energy throughput (?).
- **Population:** total population, used to (i) reconcile per capita vs total measures and (ii) characterize sample coverage (?).

Countries are included if they have non-missing observations for GDP and the relevant pressure indicator for a given year. Because WDI coverage is incomplete for some countries and years, the effective sample size varies across indicators and across the per capita versus total emissions specifications. The analysis therefore reports sample counts transparently and avoids treating missingness as evidence of decoupling.

4.2 Construction of Indicators

To measure year-to-year dynamics consistently across countries, the analysis constructs annual growth rates and elasticity measures using proportional (percentage) changes. Let Y_{it} denote economic output and P_{it} denote environmental pressure for country i in year t. Define percentage changes as:

$$\Delta Y_{it} = 100 \times \frac{Y_{it} - Y_{i,t-1}}{Y_{i,t-1}}, \qquad \Delta P_{it} = 100 \times \frac{P_{it} - P_{i,t-1}}{P_{i,t-1}}.$$

This approach aligns with the elasticity-based decoupling framework commonly used in the literature (Tapio, 2005). To reduce spurious classifications arising from extremely small denominators, observations with $Y_{i,t-1} \leq 0$ (or $P_{i,t-1} \leq 0$) are excluded, and years in which $|\Delta Y_{it}|$ is very close to zero are treated cautiously because the implied elasticity can become numerically unstable. In practice, the pipeline flags or drops cases where the GDP growth rate is near zero and would yield extreme elasticities without economic meaning.

Two parallel pressure specifications are constructed:

1. **Per capita pressure:** CO_2 per capita and energy use per capita, capturing changes in average pressure associated with production and consumption patterns.

2. **Total pressure:** total CO_2 emissions, capturing changes in aggregate environmental pressure relevant to global climate objectives.

This dual construction is important because improvements in per capita indicators do not necessarily imply reductions in aggregate pressure, especially in the presence of population growth and scale effects (UNEP, 2011; Kallis, 2018).

4.3 Decoupling Measurement Framework

Decoupling is classified using the Tapio elasticity framework (Tapio, 2005), which defines an elasticity between changes in environmental pressure and changes in economic output:

$$\varepsilon_{it} = \frac{\Delta P_{it}}{\Delta Y_{it}}.$$

The Tapio framework provides a typology of growth–pressure relationships based on (i) the sign of ΔY_{it}, (ii) the sign of ΔP_{it}, and (iii) threshold ranges for the elasticity. Following the standard Tapio convention, the analysis uses the commonly applied threshold values around unity (with bands near 0.8 and 1.2) to separate *decoupling*, *coupling*, and *negative decoupling* regimes (Tapio, 2005; Vehmas et al., 2007). Intuitively:

- **Absolute (strong) decoupling:** $\Delta Y_{it} > 0$ and $\Delta P_{it} < 0$ (economic expansion with declining pressure).
- **Relative (weak) decoupling:** $\Delta Y_{it} > 0$, $\Delta P_{it} > 0$, and $0 < \varepsilon_{it} < 1$ (pressure grows, but slower than output).
- **Coupling:** $\Delta Y_{it} > 0$, $\Delta P_{it} > 0$, and $\varepsilon_{it} \approx 1$ (pressure grows proportionally with output).
- **Negative decoupling:** $\Delta Y_{it} > 0$, $\Delta P_{it} > 0$, and $\varepsilon_{it} > 1$ (pressure grows faster than output).

Analogous regimes are defined for periods of economic contraction ($\Delta Y_{it} < 0$), distinguishing cases where pressure falls faster or slower than output, and cases where pressure rises despite recession (Tapio, 2005). Because recession-years can generate elasticities that are harder to interpret substantively (e.g., when both numerator and denominator are negative), the analysis reports recession-related categories transparently but places primary interpretive emphasis on expansion-years when discussing "green growth" claims.

Finally, to communicate results at the global level, the paper aggregates classifications across country-years and reports annual shares (the fraction of observed country-years falling into each category). In addition, the paper computes country-level summaries such as the share of years a country spends in strong decoupling, separately for per capita and total CO_2 specifications.

4.4 Optional Econometric Analysis

As an optional extension (not required for the core contribution), the study can complement the elasticity-based classification with time-series econometric evidence on long-run relationships between output and environmental pressure. A standard approach is to test for unit roots and cointegration in output and pressure series, and, where appropriate, estimate an error-correction model (ECM) to distinguish short-run adjustments from long-run equilibria (**?????**).

This extension would proceed as follows: (i) assess integration orders using unit-root tests; (ii) test for cointegration between $\log Y_{it}$ and $\log P_{it}$; (iii) estimate an ECM when cointegration is supported, interpreting the error-correction term as evidence on the speed of adjustment toward long-run co-movement (**??**). Importantly, the econometric component would be treated as a robustness check rather than as the primary definition of "decoupling," since cointegration addresses long-run co-movement rather than normative thresholds for relative versus absolute decoupling.

5 Results

5.1 Global and Income-Group Trends

Figure **??** and Figure **??** summarize the global distribution of decoupling regimes over time using the Tapio classification, separately for per capita and total CO_2 emissions. The figures report annual shares of country–year observations falling into each decoupling category.

At the global level, relative (weak) decoupling constitutes a substantial share of observations during periods of economic expansion, particularly when environmental pressure is measured in per capita terms. However, strong (absolute) decoupling remains comparatively rare throughout the sample period. Even in years where the share of strong decoupling increases, it typically represents a minority of country–year observations.

The contrast between per capita and total emissions is pronounced. While per capita indicators show a higher incidence of strong decoupling, the share of strong decoupling based on total CO_2 emissions is consistently lower. This divergence highlights the role of population growth and scale effects in offsetting intensity-based improvements. In other words, reductions in emissions per person do not necessarily translate into declines in aggregate emissions at the global level.

Temporal patterns also reveal sensitivity to macroeconomic disruptions. Periods associated with global economic shocks, such as the late 2000s financial crisis and the COVID-19 pandemic, exhibit abrupt shifts in decoupling classifications. These episodes are characterized by a temporary rise in strong decoupling driven by declining emissions during economic contraction, rather than by sustained structural change. As a result, these years require cautious interpretation when assessing long-run claims of green growth.

5.2 Elasticities of Growth–Emissions

Table **??** reports the share of country–year observations classified as strong decoupling by decade, comparing per capita and total CO_2 emissions. Across decades, strong decoupling remains limited in both specifications, with consistently higher shares in per capita terms than in total emissions.

During the 1990s and 2000s, the share of strong decoupling increases modestly, particularly for per capita emissions. This pattern suggests some decoupling of emissions intensity from economic growth during these decades. However, the corresponding shares for total emissions remain substantially lower, indicating that aggregate environmental pressure continued to rise in most cases.

In the 2010s, per capita strong decoupling reaches its highest observed share, while total-emissions strong decoupling also increases but remains well below one quarter of observations. The 2020s exhibit a sharp decline in strong decoupling shares, reflecting the influence of pandemic-related disruptions and subsequent rebounds in emissions. Overall, the decade-level results reinforce the conclusion that absolute decoupling, particularly in terms of total emissions, has not become the dominant growth–environment regime.

5.3 Decoupling Typology of Countries

Country-level summaries provide additional insight into the heterogeneity of decoupling experiences. Tables **??** and **??** rank countries by the share of years spent in strong decoupling over the sample period, separately for per capita and total CO_2 emissions.

The rankings reveal that even the top-performing countries spend only a limited fraction of years in strong decoupling. In the per capita specification, a small group of countries achieves strong decoupling in roughly one third to one half of observed years. When total emissions are considered, these shares decline further, underscoring the difficulty of sustaining absolute reductions in aggregate environmental pressure alongside economic growth.

Notably, countries appearing near the top of the rankings are heterogeneous in terms of income level, economic structure, and geographic location. This suggests that strong decoupling episodes are not confined to a single development model or income group. However, the absence of countries with consistently high shares of strong decoupling across the full period indicates that absolute decoupling is episodic rather than systemic.

5.4 Summary of Empirical Patterns

Taken together, the results point to three central empirical patterns. First, relative decoupling is widespread, particularly when environmental pressure is measured in per capita terms. Second, strong (absolute) decoupling remains uncommon, especially when evaluated using total CO_2 emissions. Third, observed instances of strong decoupling are often temporally concentrated and associated with economic disruptions rather than sustained structural transformation.

These findings provide a descriptive but robust empirical foundation for evaluating claims of green growth. They suggest that while improvements in emissions intensity have occurred in many countries, the evidence for widespread and durable absolute decoupling at the global scale remains limited.

6 Discussion

The results presented in this paper provide a comprehensive global assessment of the relationship between economic growth and environmental pressure over the period 1990–2023. Several key insights emerge when interpreting the empirical findings through the lens of ecological economics and political economy.

First, the analysis reveals that relative decoupling between economic growth and environmental pressure is widespread, particularly when pressure is measured in per capita terms. Many high-income countries exhibit sustained periods in which GDP per capita grows faster than CO_2 emissions per capita or energy use per capita. This pattern is consistent with earlier findings reported by institutional assessments such as the OECD and UNEP, which document declining emissions intensities and energy intensities in advanced economies (OECD, 2019; UNEP, 2011). However, the present results reinforce a crucial distinction emphasized in the literature: relative decoupling does not imply a reduction in absolute environmental pressure.

When environmental pressure is measured in total terms, accounting explicitly for population and scale effects, evidence of absolute (strong) decoupling becomes markedly rarer. The contrast between per capita and total emissions is one of the most robust findings of this study. While per capita indicators often suggest progress toward decoupling, total CO_2 emissions continue to increase in most countries during periods of economic expansion. This discrepancy underscores a central argument in ecological economics: improvements in efficiency and intensity metrics can coexist with rising aggregate pressure due to scale effects (Georgescu-Roegen, 1971; Daly, 1996; Parrique et al., 2019).

Second, the temporal structure of decoupling episodes provides important insight into the dynamics underlying observed patterns. Periods of strong decoupling are not evenly distributed over time but tend to cluster around major economic disruptions, such as the global financial crisis of 2008–2009 and the COVID-19 shock in 2020. These episodes are characterized by abrupt reductions in emissions associated with recessions or structural breaks rather than gradual, policy-driven transitions. Similar observations have been reported in previous empirical studies, which find that sustained declines in emissions are often linked to economic contractions, energy price shocks, or exceptional circumstances rather than continuous green growth trajectories (Jakob and Steckel, 2014; Haberl et al., 2020). This episodic nature challenges narratives that portray decoupling as a stable outcome of technological progress alone.

Third, the country-level typology highlights substantial heterogeneity across regions and income groups. High-income economies are overrepresented among countries with higher shares of relative or occasional strong decoupling, whereas low- and middle-income countries remain predominantly characterized by expansive coupling or negative decoupling regimes. This pattern is consistent with the idea that advanced economies have greater access to capital, cleaner technologies, and regulatory capacity, while developing economies face binding development and infrastructure constraints (Stern, 2011). At the same time, the results are compatible with political economy perspectives emphasizing the international displacement of environmental pressure through trade and global value chains. Empirical work using consumption-based accounting has shown that apparent domestic decoupling in high-income countries often coincides with increased embodied emissions in imports from lower-income regions (Peters et al., 2011; Wiebe et al., 2012; Hickel, 2020).

Fourth, the findings bear directly on the debate surrounding the feasibility of "green growth." Proponents of green growth argue that technological innovation, structural change, and policy intervention can decouple economic growth from environmental harm at a scale sufficient to meet climate targets (**?**). In contrast, critics contend that absolute decoupling at the global level has not been observed at the required magnitude or speed and is unlikely under continued growth due to rebound effects and biophysical limits (Kallis, 2018; Parrique et al., 2019). The evidence presented in this paper aligns more closely with the critical perspective: while relative decoupling is empirically common, robust and sustained absolute decoupling of total emissions remains exceptional and temporally fragile.

Importantly, this conclusion does not imply that efficiency improvements or environmental policies are ineffective. Rather, it suggests that such measures, when implemented within a growth-oriented economic system, may be insufficient to deliver the absolute reductions in environmental pressure required for climate stabilization. Rebound effects and scale dynamics can offset efficiency gains, a phenomenon well documented in both theoretical and empirical research (Khazzoom, 1980; Brookes, 1990; Sorrell, 2009). As a result, policy frameworks that rely exclusively on technological efficiency without addressing aggregate demand and scale may systematically overestimate the potential for green growth.

Finally, the distinction between per capita and total indicators has important implications for policy evaluation and international climate governance. Per capita measures are informative for understanding changes in average production and consumption patterns, but global climate outcomes depend on absolute emissions. The results therefore caution against interpreting per capita decoupling as evidence of sufficient progress toward climate goals. From a policy perspective, this underscores the need to complement efficiency-oriented strategies with measures explicitly targeting absolute reductions in emissions, including structural changes in energy systems, consumption patterns, and economic organization.

Overall, the findings contribute empirical clarity to ongoing debates in ecological economics and environmental policy. By systematically distinguishing between relative and absolute decoupling, per capita and total pressure, and episodic versus sustained patterns, the analysis highlights the limitations of growth-centered narratives and the importance of scale in assessing environmental sustainability. These insights provide a foundation for the concluding section, which reflects on policy implications and directions for future research.

7 Conclusions

This paper has examined the extent to which economic growth has been decoupled from environmental pressure at the global level over the period 1990–2023. Using a consistent elasticity-based framework and harmonized World Bank data, the analysis distinguishes between relative and absolute decoupling, as well as between per capita and total measures of environmental pressure. This distinction proves crucial for interpreting empirical claims surrounding "green growth."

Several core conclusions emerge from the analysis. First, relative decoupling between GDP per capita and environmental pressure per capita is a common empirical pattern, particularly among high-income countries. Many economies have succeeded in reducing emissions intensity and energy intensity over time. However, when environmental pressure is measured in total terms, accounting for population growth and scale effects, evidence of sustained absolute decoupling becomes markedly rarer. This divergence highlights the limitations of intensity-based indicators for assessing progress toward climate and sustainability objectives.

Second, episodes of strong decoupling are found to be temporally concentrated and often associated with major economic disruptions rather than with smooth, long-term transitions. Periods such as the global financial crisis and the COVID-19 shock account for a disproportionate share of observed strong decoupling events. This pattern suggests that observed reductions in emissions during economic expansions are fragile and may not reflect structural transformations capable of delivering durable absolute reductions in environmental pressure.

Third, substantial heterogeneity exists across countries and income groups. High-income economies are more likely to exhibit relative decoupling and occasional episodes of strong decoupling, while low- and middle-income countries remain predominantly characterized by expansive coupling or negative decoupling regimes. These disparities reflect differences in economic structure, development needs, technological capacity, and integration into global production networks. They also raise important questions regarding the international distribution of responsibility and capacity in climate mitigation efforts.

Taken together, the findings contribute to ongoing debates in ecological economics and environmental policy by providing systematic, up-to-date evidence on the empirical limits of decoupling. While technological progress and efficiency improvements have played an important role in moderating environmental pressure relative to economic output, they have not, in general, delivered sustained absolute reductions in total emissions at the global scale. As a result, policy strategies that rely primarily on efficiency gains within a growth-oriented framework may overestimate the feasibility of achieving climate targets without addressing aggregate scale effects.

This study has several limitations that point to avenues for future research. First, the analysis relies on territorial emissions and does not explicitly account for consumption-based footprints or international trade adjustments. Second, while the elasticity-based framework captures year-to-year dynamics effectively, it does not model causal mechanisms or long-run equilibrium relationships explicitly. Future work could extend the analysis by incorporating material flow indicators, consumption-based emissions, or econometric approaches such as cointegration and vector error correction models to explore long-term dynamics more formally.

Despite these limitations, the results offer a clear empirical contribution: decoupling is neither absent nor ubiquitous, but highly contingent on measurement choices, temporal context, and economic structure. Recognizing these contingencies is essential for grounding policy debates in empirical reality. Ultimately, the findings underscore the importance of confronting questions of scale, distribution, and structural change when evaluating the prospects for reconciling economic activity with environmental sustainability.

8 References

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