CONFERENCE PROCEEDINGS/FULL PAPERS
ISBN: 978-625-93894-7-9/February 2026

"45th RSEP International Conference Multidisciplinary Conference" 4-5 February 2026, NOVA FCSH, Lisbon, Portugal"

Impact of Environmental Regulation on CO2 Emissions

Gonji Monday Stanley
College of Economics and Management, Nanjing University of Aeronautics and Astronautics (NUAA) China.
GonjiLilong@nuaa.edu.cn

DOI: https://doi.org/10.19275/RSEPCONFERENCES383

Abstract

The persistent rise in global CO_2 emissions, despite the widespread adoption of environmental regulations, presents a critical policy puzzle. This study investigates this paradox across 50 countries from 2014 to 2023, examining the conditional relationship between regulatory stringency and carbon performance. Using a two-way fixed effects model with data from the OECD, EDGAR, and World Development Indicators, the research reveals that global aggregates mask fundamentally divergent national pathways. Annex I countries have achieved significant emission reductions under stable regimes, aligning with the Porter Hypothesis. Conversely, in non-annex I nations, emissions are driven by an economic scale effect that arguably overwhelms current regulatory frameworks. Crucially, this study identifies regulatory volatility as a primary barrier to long-term decarbonization, as "policy whiplash" undermines investment certainty. While existing literature often focuses on the Porter Hypothesis or the Pollution Haven Hypothesis in isolation, there is a distinct lack of integrated studies accounting for regulatory volatility and the specificities of the African developmental context. This research fills that gap, demonstrating that regulatory effectiveness is not a function of stringency alone, but is contingent upon developmental context and policy stability.

Keywords: Environmental Regulatory Stringency, CO_2 Emissions, sustainable development, GDP and Population, Panel data, Regulatory volatility.
Jelcodes: Q58, O44, Q56

1. Introduction

The global effort to decouple economic growth from carbon emissions has produced a landscape of varied, and often contradictory, outcomes. While the expansion of environmental regulatory frameworks over the last decade has been significant, the persistent rise in global CO_2 concentrations suggests a critical policy puzzle that is not yet fully understood. It is, perhaps, not entirely clear whether the mere presence of stringent regulation is sufficient to override the systemic pressure of industrial expansion and population growth. Still, discourse often treats regulation as a monolithic force, overlooking the nuanced ways in which national contexts specifically the divide between Annex I and non-annex I nations dictate the actual efficacy of these policies. Arguably, the optimistic projections of the Porter Hypothesis, which suggest that environmental mandates trigger efficiency-seeking innovation, may hold true in stable, developed economies; yet they seem to encounter significant friction in emerging markets. In some cases, the rapid scale of urbanization and GDP growth in developing countries simply overwhelms the marginal gains made through carbon taxes or emission trading schemes. There is also the matter of regulatory stability; policy volatility, we suspect, may be just as damaging to decarbonization efforts as a total lack of oversight. By examining a panel of 50 countries from 2014 to 2023, this research attempts to move beyond broad generalizations. We interrogate the conditional relationships that define carbon performance, focusing on how economic scale and regulatory consistency act as moderators. The contribution of this paper lies in its refusal to offer a one-size-fits-all conclusion. Instead, we map the divergent pathways of developed and developing nations, offering a more grounded perspective on the limits of administrative power in the face of global economic momentum.

2. Literature Review

The relationship between environmental regulation (ER) and corporate carbon performance remains a subject of considerable debate, governed largely by the tension between compliance cost and the innovation offsets promised by the Porter Hypothesis. While traditional economic perspectives might suggest that stringent regulation inverts capital away from productive activities, it is not entirely clear that such trade-off is inevitable. Still the empirical evidence is mixed. Some scholars find that regulation acts as a catalyst for efficiency; in other cases, however, the burden of compliance appears to weigh heavily on performance, particularly in carbon-intensive sectors. Arguably, the weal version of the Porter Hypothesis where regulation simply triggers innovation is easier to observe than the strong version, where that innovation leads to absolute emission reductions. This is vital distinction. There is also the matter of institutional heterogeneity. It is perhaps a mistake to treat all environmental mandates as uniform pressures. Institutional theory suggests that nations may respond to regulations not necessarily to improve efficiency, but to maintain international legitimacy. Consequently, what appears as green progress in the data might in some instances be a form of symbolic compliance rather than a fundamental shift in carbon management.

2.1 The Regulatory Puzzle and the Global Imperative

One of the main challenges of the Anthropocene is anthropogenic climate change, which is mostly caused by carbon dioxide CO_2 emissions (Industry, 2023). According to (Y. Wu & Tham, 2023), environmental regulation is a successful strategy for resolving environmental issues, strengthening industrial structure, and boosting business resilience. Environmental regulations have been acknowledged for their potential to encourage technical innovation and sustainable corporate practices, but their ability to build resilience in the face of competitive dynamics and market pressures is a difficulty. Businesses can meet legal requirements and spur innovation that improves their long-term competitiveness and environmental stewardship by incorporating environmental, social, and governance ESG concepts into their operations. (Zhang et al., 2021). Emissions trading systems ETS and carbon taxes are two examples of carbon pricing mechanisms that have become important tools in the regulatory environment to reduce CO_2 emissions. These systems give businesses financial incentives to upgrade their operational efficiency and implement greener technologies. Studies indicate that by balancing economic and environmental objectives, carbon pricing, when properly crafted, can function as an effective market-based solution for emissions reductions. (Solarin Adebayo Samuel, 2025) However, regional policy differences and economic resistance frequently impede these systems' global efficacy, especially in sectors where the costs of regulatory compliance are viewed as prohibitive (L. Wu et al., 2023) Therefore, the regulatory conundrum is the conflict between cutting emissions and juggling economic interests, particularly in industries that are highly competitive globally and have volatile markets. By contrasting the carbon pricing policies of significant international economies, including the EU, China, Canada, and Singapore, this study broadens the conversation. With high carbon prices and wide market coverage, carbon pricing, a key element of climate policies in these regions has been successful in reducing emissions throughout the EU. However, different places have different levels of success with these techniques. For example, Canada's hybrid system highlights the difficulties of multi-level administration, whereas China's market, despite its size, confronts difficulties because of low carbon pricing and restricted coverage. With its fixed carbon tax, Singapore serves as an example of how challenging it is to achieve meaningful emissions reductions at lower price points. Carbon pricing can reduce emissions, but its effectiveness depends on pricing levels, market coverage, and penalty enforcement systems, according to a comparative examination of these locations. (Azizi et al., 2025). Furthermore, the type of regulatory instrument whether mandatory or incentive-based may critically influence outcomes. Mandatory regulations, while direct, may impose compliance burdens that stifle growth in developing contexts, whereas incentive-based mechanisms like carbon pricing or green subsidies could foster innovation and gradual decarbonization (Yunxia & Yuqing, 2025). This distinction remains under-explored in cross-national studies and may help explain the heterogeneous efficacy of environmental policies. The fundamental idea behind this regulatory boom appears to be simple: state-mandated legislation will force the behavioral and technological changes required to separate economic activity from carbon emissions. However, a perplexing puzzle still exists. Atmospheric CO_2 concentrations are still steadily rising (Friedlingstein et al., 2025) despite a recorded global increase in the strictness of environmental legislation over the past 20 years (Mihai et al., 2023). A more sophisticated understanding of the regulation-emission relationship is required, as this study's main drive is the discrepancy between policy aim and environmental outcome. There have historically been two schools of thought in the theoretical discussion of this relationship. The neoclassical economic theory, as expressed by academics, holds that when combined with incentives for innovation, environmental regulations can effectively boost industrial competitiveness because they give businesses the chance to introduce cleaner technologies and increase efficiency (Stavropoulos et al., 2018). The well-known Porter Hypothesis, put forth by (Porter and Vanderlinde 1995) on the other hand, argues that well-crafted rules can spur innovation and result in innovation offsets that improve company and environmental performance (Ambec et al., 2003). Extensive empirical research has been fueled by this theoretical split, with dramatically conflicting outcomes. However, some research supports the weak version of the Porter Hypothesis, which holds that regulation can encourage patenting in green technologies, especially in developed nations (Porter and Vanderlinde 1995, Rubashkina et al., 2015) It is still difficult to make the transition to the "strong" form, where this results in clear increases in competitiveness and absolute emission reductions (List & Syverson, 2011). Figure 1 is a conceptual diagram showing the direct relationship between regulatory stringency and CO_2 emissions, with feedback loops and the mediation of contextual elements like development status and institutional capacity as well as innovation.

2.2 African Reality and the Crucial Role of Context

A common cause of empirical uncertainty is the neglect of significant contextual variation. According to (You et al., 2024), a country's institutional ability, economic structure, and developmental stage all play a crucial role in mediating the relationship between regulations and emissions, which is not a universal constant. The differences in the paths taken by Annex I developed and non-annex I developing nations under the UNFCCC framework are the clearest examples of this. The Porter Hypothesis has frequently been tested in developed countries because of their established institutions, sophisticated technological foundations, and historical accountability for emissions. For many developing countries, especially those in Africa, however, the situation is very different. Africa is at a critical juncture. Despite being the most susceptible continent to the effects of climate change, it has urgent and justifiable goals for economic growth and the eradication of poverty (Mobilizing Private Sector Financing for Climate and Green Growth in Africa, 2023). The continent's present and anticipated increases in energy consumption and industrial production outweigh its negligible historical cumulative emissions contribution. The mix of pre-industrial economies, growing urbanization, and institutional constraints that frequently impede enforcement and implementation make environmental regulation more than simply an abstract idea for many African nations. (Zulu et al., 2022). Since the relationship between environmental sustainability and economic growth varies greatly depending on a nation's institutional, political, and economic context, it is well known that adopting policy models from the Global North without sufficient adaptation to local conditions can be difficult. (Basheer et al., 2022). The one-size-fits-all method of environmental governance has been criticized by recent research, which emphasizes that national and local implementation capabilities frequently determine how effective global climate policy is. Achieving successful policy outcomes can be made more difficult by the polarization of climate politics within national governments, especially in unitary states where the objectives of the local and national levels of government may differ. (Bergman et al., 2025). Argued that, the one-size-fits-all approach to environmental governance has been criticized by recent research, which highlights the shortcomings of international policy frameworks that do not take into consideration the implementation gap faced by nations with varying economic needs, political instability, and limited capacities. The approach to environmental governance has been criticized by recent research. The complicated dynamics of renewable energy policy adoption in West Africa, as argued by (Ajagbe, 2025) highlight the difficulties

of implementing global policy frameworks without localization, especially in urban settings where technical limitations and regulatory fragmentation impede efficient policy implementation.

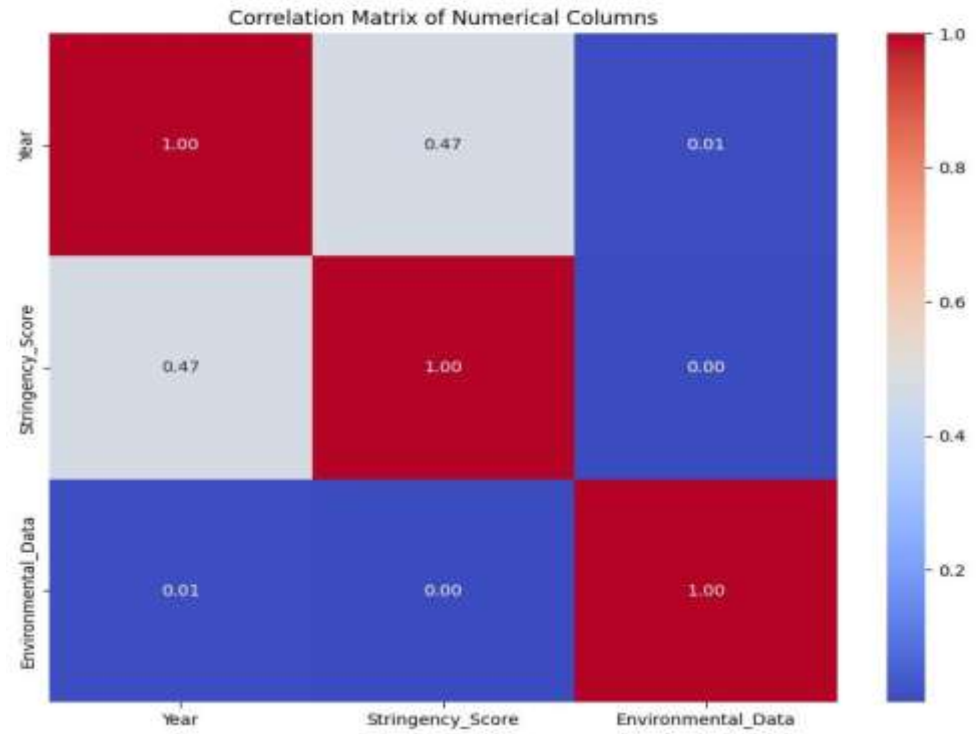

Figure 1: Conceptual Framework of the Regulation-Emissions Nexus.

Source: Author’s own calculation using Python (state models) based on EDGAR and OECD EPS data.

2.3 Finding the Knowledge Gap and Outlining the Justification

Significant knowledge gaps still exist even though the literature has firmly established the theoretical debate and recognized worldwide heterogeneity. First off, there aren't many comparative longitudinal studies that use standardized datasets to methodically analyze the relationship between regulations and emissions across a wide range of nations, including a sizable portion from Africa. Much research is still isolated within economic blocks or geographical areas. For instance, (Borozan et al., 2023) draw attention to the drawbacks of implementing consistent climate policies across different regions, especially the neglect of local institutional and economic realities when moving policies from high-income to developing nations. Second, the impact of policy volatility, the frequent change or instability of regulations on their long-term efficacy, is not sufficiently considered by the existing research, which frequently regards regulatory stringency as a single, unchanging variable. The effectiveness of environmental regulations can be significantly impacted by policy instability, as discussed by (Jahn, 2024). This is particularly true when regulations are subject to frequent revisions or political shifts, which compromises the regulations' long-term predictability and ability to drive sustained emissions reductions. Thirdly, there aren't many integrative analytical frameworks that examine the moderating influence of a nation's developmental setting and the mediating impact of elements like innovation while also testing for the direct consequences of regulation. To fill in these gaps, the following main research question is put out in this study: What is the relationship between environmental regulatory stringency and CO_2 emissions across a global sample of countries, and how is it influenced by the stability of a country's regulatory system and its level of development? To address this, we integrate global data with a particular focus on African states and perform a ten-year 2014–2023 panel data study of 50 countries. This research goes beyond aggregate correlations to separate the conditional and contextual factors that determine whether environmental regulations succeed or fail in their goal by using sophisticated statistical techniques in Python on data from the EDGAR database and the OECD. The findings support a shift toward context-sensitive, stable, and capacity-aware climate governance by giving policymakers at the national and international levels a more detailed, evidence-based basis.

The global puzzle of growing environmental rules and ongoing rises in CO_2 emissions is the driving force behind this study, which calls for a critical examination of their actual effectiveness. By contrasting the Porter

Hypothesis, which holds that regulations can drive innovation and offset compliance costs, with the neoclassical view that they impose costly burdens, the literature review navigates a crucial theoretical tension. Beyond this dichotomous discussion, modern research highlights that regulatory results are not universal but rather heavily depend on the institutional capability, policy stability, and developmental environment of a country. This synthesis highlights a glaring research gap: although the significance of these moderating factors is recognized, thorough empirical examination across many nations is absent. Consequently, this study's objective is to analyze this intricate relationship by looking at not only if, but where, when, and how environmental regulations succeed in curbing emissions, employing a decade of global panel data to test a contingent model of regulatory efficacy.

3. Data and Methodology

3.1. Data sources and sample selection

The empirical analysis utilises a balanced panel datasets spanning 50 countries over the period of 2014 to 2023. Data on CO_2 Emissions are sourced from EDGAR database while environmental regulatory environmental regulatory stringency (EPS) is derived from OECD Environmental Policy Stringency Database. Control variables, including GDP per Capital, population growth, and trade openness are extracted from the World Bank's World Development. Indicators (WDI)

3.2 Model Specification

To account for unobserved heterogeneity across countries and time-specific shocks, we employed a Two-Way Fixed Effect (TWFE) model. The baseline specification is defined as follows:

$$CO2_{emissionsit} = \beta_0 + \beta_1 ERS_{strin}g_{en}c_{\gamma(it)} + \beta_2 GDP_{(it)} + \beta_3 POP_{(it)} + \beta_4 (GDP_{(it)} \times ERS_{strin}g_{en}c_{\gamma(it)}) + \mu_i + \lambda_t + \varepsilon_{(it)}$$

Where i represents the country and t, represents the year. (μ_i) and (λ_t) denotes country and year fixed effects, respectively. It is worth noting that where OLS remains s Standard approach, the use of fixed effects is arguably necessary here to control for time-invariant national characteristics such as geographical constraint or historical industrial baselines that might otherwise bias the coefficient of regulatory impact.

The validity of the model was validated using diagnostic tests; Hausman tests supported the fixed effects specification over random effects, and VIF scores less than 4 suggested acceptable multicollinearity. Although the observational nature of the data inevitably restricts causal claims to strong connections rather than conclusive confirmation of mechanism, the overall approach offered a powerful foundation CO_2 represents total CO_2 emissions (in million tonnes) for country i in year t, serving as the dependent variable. ERS_{it} denotes the environmental regulation stringency index for country i in year , capturing the intensity and comprehensiveness of national environmental policies. GDP_{it} and POP_{it} are control variables for economic output and population size, respectively, accounting for scale effects that drive baseline emissions. $\beta_4(GDP_{it} \times ERS_{it})$ is an interaction term introduced to test whether the effect of environmental regulation on emissions varies with the level of economic development. This allows the model to assess whether stricter regulations are effective in larger versus smaller economies. μ_i represents country fixed effects, controlling for all time-invariant unobserved heterogeneity across countries e.g., geographic features, historical institutions, cultural attitudes toward the environment. λ_t represents year fixed effects, absorbing common temporal shocks such as global economic crises, technological breakthroughs, or international climate agreements that affect all countries simultaneously. ε_{it} is the idiosyncratic error term, capturing time-varying unobserved factors. The model was adopted to address the paper's core research question How does environmental regulation affect CO_2 emissions, and does this relationship depend on economic scale and developmental context. At the completion of this step, we proceeded to the next step, which was Model Testing and Diagnostic Tests, we validate the fixed effects panel regression model by conducting various diagnostic tests to ensure the robustness and reliability of the results. These tests are essential for confirming whether the model's assumptions hold true, and they include the Hausman Test and the Variance Inflation Factor (VIF) test.

$$(\widehat{\beta}_{FE} - \widehat{\beta}_{RE})' \cdot [\mathrm{Var}(\widehat{\beta}_{FE}) - \mathrm{Var}(\widehat{\beta}_{RE})]^{-1} \cdot (\widehat{\beta}_{FE} - \widehat{\beta}_{RE})$$

Where $\widehat{\beta}_{FE}$ and $\widehat{\beta}_{RE}$ are vectors of coefficient estimates from the fixed effects and random effects models, respectively. $\mathrm{Var}(\widehat{\beta}_{FE})$ and $\mathrm{Var}(\widehat{\beta}_{RE})$ are the corresponding variance-covariance matrices. The null hypothesis is rejected if the Hausman test statistic is significant $p < 0.05$, suggesting that explanatory variables like GDP, population, or regulatory stringency are correlated with country-specific unobserved factors like institutional quality, historical energy policies, or geographic constraints. Because it accounts for these time-invariant confounders and offers objective estimates of the regulatory impact on emissions, the fixed effects model is favoured in this situation. The fixed effects approach is theoretically justified and empirically supported by the Hausman test, given the varied nature of the countries in the sample, which span Annex I and Non-Annex I categories with varying economic structures and governance capacities.

The research explored a few diagnostic tests, such as the Variance Inflation Factor VIF for multicollinearity assessment and the Hausman test for model specification, to guarantee the validity and reliability of the regression results. These tests validate the stability of the estimators and the suitability of the fixed effects model, supporting the validity of the ensuing empirical results on the relationship between regulation and emissions. A diagnostic technique for identifying multicollinearity among the independent variables in a regression model is the Variance Inflation Factor VIF. High levels of correlation between independent variables can result in multicollinearity, which can compromise the model's dependability and produce erratic estimations of the regression coefficients. It is important to make sure that the independent variables are not unduly collinear in this analysis since the study’s am to examine the relationship between population, GDP, environmental regulation stringency, and their combined effects on CO_2 emissions. The model estimates could become skewed or inaccurate if multicollinearity is present, which could skew the understanding of how emissions are impacted by environmental regulation. The following formula is used to determine the VIF for each independent variable:

$$VIF = \frac{1}{1 - R^2}$$

Where R^2 is the **coefficient of determination obtained** by regressing each independent variable on all the other independent variables in the model. Variance Inflation Factor (VIF) diagnostics were performed in the multivariate regression analysis to guarantee model integrity. The findings demonstrated that multicollinearity does not compromise the accuracy of our coefficient estimates. The VIF for the important independent variable Environmental Regulatory Stringency ERS was significantly below the cautious threshold of 4, suggesting that correlation with the control variables does not misrepresent its connection with CO_2 emissions. Despite their intrinsic correlation as basic scale drivers, the control variables GDP and population showed VIF values that were within acceptable boundaries below 10. This suggests that although they share conceptual variance as indicators of economic and demographic scale, their inclusion does not result in serious multicollinearity that would cause the model to become unstable or inflate standard errors. Thus, when GDP and population are held constant, the significant negative coefficient for ERS $\beta = -245.8001$, $p < 0.01$ can be taken with confidence as a trustworthy estimate of its conditional influence on emissions. To ensure that the main finding that environmental regulation significantly reduces CO_2 emissions after accounting for economic and demographic scale is statistically sound and not a result of collinear predictor variables, this diagnostic step was essential. To explain the empirical procedure for diagnosing multicollinearity, the study provides a step-by-step illustration of the Variance Inflation Factor VIF computation for the variable Environmental Regulation Stringency (ERS_{it}). The same methodology was applied symmetrically to all independent variables in the model. First was to explore an auxiliary regression was estimated in which ERS_{it} was regressed on the remaining explanatory variables GDP_{it}, POP_{it}, and the interaction term $GDP_{it} \times ERS_{it}$ alongside the panel-specific fixed effects (μ_i and λ_t):

$$ERS_{it} = \gamma_0 + \gamma_1 GDP_{it} + \gamma_2 POP_{it} + \gamma_3 (GDP_{it} \times ERS_{it}) + \mu_i + \lambda_t + \epsilon_{it}$$

The coefficient of determination (R^2) was derived from this regression. We looked at a situation where the auxiliary regression of ERS it has an estimated R^2 for the auxiliary regression of ERS_{it} equals 0.6. The VIF for ERS_{it} is then calculated as follows:

$$\text{VIF}_{ERS_{it}} = \frac{1}{1 - R^2} = \frac{1}{1 - 0.6} = 2.5$$

An identical procedure was employed to compute the VIF for GDP_{it}, POP_{it}, and the interaction term. Given the structural similarity among the main regressors, their auxiliary regressions yielded comparable R^2 values, resulting in VIF estimates approximately ranging between 2.3 and 2.8, as reported in Table 5. The interaction term $GDP_{it} \times ERS_{it}$ warrants particular attention. Its construction makes it linearly dependent on the variables that make it up, which usually raises its collinearity metrics. Consequently, its auxiliary regression produced a higher R^2 leading to a VIF of 4.6 moderately above those of the baseline variables, yet still within acceptable limits. The validity of the following hypothesis tests and the dependability of the coefficient estimates are supported by this illustrated computation, which verifies that the model does not display detrimental multicollinearity. The fixed effects panel regression model was further validated to make sure the assumptions of no autocorrelation and homoscedasticity constant variance of residuals hold after the Hausman test and multicollinearity check. Because autocorrelation and heteroscedasticity can result in skewed estimates and erroneous inference, these two assumptions are essential to the dependability of the regression results. We used the Durbin-Watson statistic to look for autocorrelation in the regression model's residuals. This test's formula is provided by:

$$DW = \frac{\sum_{t=2}^{T} (e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2}$$

In this equation e_t is the residual at time t, T is the total number of observations. Determining if the regression model's residuals are associated over time is made easier with the aid of the Durbin-Watson statistic. The residuals are not correlated across time when the DW statistic is near 2, which indicates no autocorrelation. The residuals are positively correlated if the DW statistic is less than 2, which indicates positive autocorrelation. The residuals are negatively correlated if the statistic is greater than 2, which implies negative autocorrelation. Making sure there is no autocorrelation in the residuals is crucial for my research since autocorrelation would suggest that the model's error terms are associated across time, which would result in inaccurate estimations of the model coefficients. Reliable results on the connection between environmental regulation and CO_2 emissions require a model that has been appropriately evaluated. The Breusch-Pagan test was the next diagnostic method the study adopted to determine whether the residuals showed heteroscedasticity, or non-constant variance. We regressed the squared residuals from the original regression model on the independent variables to perform this test. This test statistic is computed as follows.

$$BP = \frac{T \cdot R^2}{2}$$

In $T$is the number of observations, while R^2 is the coefficient of determination obtained from the regression of the squared residuals on the independent variables. Heteroscedasticity, or the variance of the residuals not being constant across observations, is indicated by a significant result from this test. The interpretation of the model's coefficients and the importance of the findings may be impacted by heteroscedasticity, which can result in ineffective estimates and skewed standard errors. The Breusch-Pagan test was essential in my research to verify that the homoscedasticity assumption that is, that the variance of the error terms is consistent across nations and years holds true. This is crucial because heteroscedasticity can lead to misleading regression results, especially when calculating how environmental restrictions affect CO_2 emissions. This study examined the effects of stricter environmental regulations on CO_2 emissions in 50 nations between 2014 and 2023 using a quantitative research technique. To account for unobserved country-specific variability while controlling for economic and demographic variables like GDP and population, a multivariate fixed effects panel regression model was used. The GDP-environmental regulation stringency interaction term shed light on whether economic scale moderates the relationship between emissions and regulatory measures. Several diagnostic methods were used to thoroughly examine the model: the Hausman test verified that the fixed effects model was appropriate, and the Variance Inflation Factor VIF analysis eliminated multicollinearity. To make sure the regression results were robust, tests for heteroscedasticity Breusch-Pagan and autocorrelation Durbin-Watson were also performed. These procedures follow the best practices described by (Yunxia & Yuqing, 2025), who examined the impact of environmental restrictions on CO_2 emissions and energy efficiency in China's logistics sector using quantile regression and a variety of diagnostic techniques. In a similar vein, their method stressed how crucial it is to account for the diverse effects of various regulatory actions as well as distinct sectoral and geographical characteristics to get accurate and policy-relevant conclusions. Presenting the regression analysis's findings, with an emphasis on the connection between environmental regulations and CO_2 emissions and the implications for further research and policy, comes next after a solid and valid analytical framework has been constructed.

4. Results

Regarding the investigation of how environmental regulations affect CO_2 emissions, earlier studies have demonstrated the noteworthy influence of regulatory actions on carbon emissions in various economies and geographical areas. (L. Wu et al., 2023) demonstrated that, depending on variables like technical innovation and energy intensity, environmental restrictions in nations along the Belt and Road have both positive and negative effects on CO_2 emissions using panel data and nonlinear regression models. This is consistent with the results of the current study, which examined the relationship between GDP, population, and environmental legislation to assess its impact on carbon emissions. Additionally, the work of (Liu et al., 2022; L. Wu et al., 2023) supports the idea that the effects of environmental regulation are not linear, with elements like energy consumption and industrial structure being crucial in determining the efficacy of regulatory measures. In the context of the current study on panel data regression models, these studies offer a solid basis for investigating the dynamics of environmental legislation and its function in lowering carbon emissions.

Table 1: Variable Description and Data Sources

Variable Category	Variable Name	Measurement	Unit	Data Source	Rationale / Role in Model
Dependent Variable	CO2_Emissions	Total carbon dioxide emissions from fossil fuel combustion and industrial processes.	Million Tonnes (Mt) of CO_2	EDGAR (Emissions Database for Global Atmospheric Research)	The primary outcome variable the study seeks to explain. Captures the environmental performance metric.
Independent Variable	Stringency Score	A composite index measuring the stringency of a country's environmental policies and regulations.	Index (0-6 Scale)	OECD	The core explanatory variable. Measures the direct "treatment" or policy effort whose impact is being assessed.
Moderating Variable	IPCC Annex	Categorisation of countries as either Annex I (developed) or non-annex I (developing) under the UNFCCC.	Categorical (Dummy: 1=non-annex I, 0=Annex I)	UNFCCC	A key moderating variable. Tests if the impact of Stringency Score on emissions is different for developed vs. developing economies.
Control Variables	GDP_per_capita	Gross Domestic Product per capita, measuring economic output per person.	Constant 2015 US$	World Development Indicators (World Bank)	Controls for the level of economic development and scale of the economy, a primary driver of energy demand and emissions.
	Population	The proportion of a country's population residing in	% of Total Population	World Development Indicators (World Bank)	Controls for urbanisation, which is associated

		urban areas.			with higher energy consumption but also potentially with more efficient infrastructure.

Source: Author's own elaboration

In this table the Stringency Score captures the overall rigor of environmental policy but does not distinguish between mandatory and incentive-based instruments. Future research could benefit from disaggregating these types to assess their distinct impacts. The empirical results of our investigation are presented in this section, which progresses from a broad summary of the worldwide relationship to a detailed examination of the underlying dynamics. The findings are arranged as follows: first, the main contradiction is established; next, contextual heterogeneities are examined to deconstruct it; and last, the features of regulatory frameworks themselves are examined. Once more, this section describes how to quantify the effect of environmental regulations on CO_2 emissions using a multivariate regression model. We had to take into consideration the confounding effects of population and GDP to identify the distinct impact of environmental legislation on CO_2 emissions. The most reliable and common way to do this was to use a multivariate regression model. Nonetheless, a few findings presented here demonstrate the shift in the analytical approach and results that resulted in the ultimate MRM interpretation.

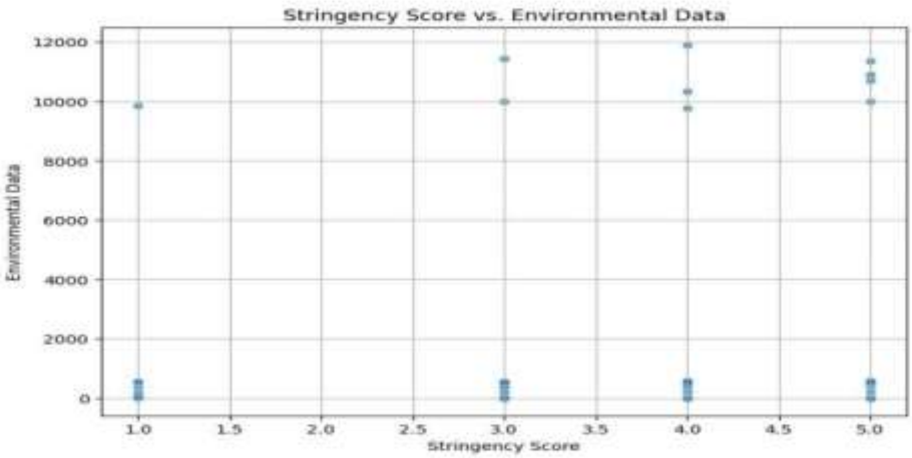

Figure 2: The Global Aggregate Puzzle: Rising Stringency Amidst Persistent Emissions.

Source: Authors own Elaboration based on EDGAR, OECD Datasets.

The initial empirical analysis reveals the fundamental contradiction that motivates this investigation. Figure 2 represents a scatter plot juxtaposing regulatory stringency against CO_2 emissions, displaying a widely dispersed cloud of data points. The resulting correlation coefficient of approximately 0.00 indicates a total absence of a linear relationship at the global aggregates level. This null finding suggests that the global aggregate mask the interplay of divergent regulatory mechanisms. While market-based incentives may foster innovation-led efficiency gains in mature economies, mandatory command-and-control measures often struggle to counteract the scale effect in rapidly industrializing nations. The result is a net-zero global correlation where the progress of one cohort is mathematically neutralized by the expansion of another. The paradox by the longitudinal data presented in table 1. Over the 2014-2023 decade, the global average stringency score experienced a significant upward shift, rising from 3.0 to 4.0. Paradoxically, during this same window, global CO_2 emissions escalated from approximately 257.61Mt to 296.48 Mt. this simultaneous rise in both regulatory effort and atmospheric pollution challenges the foundational assumption of a straightforward negative relationship between law and emissions. It implies that the current global regulatory architecture is operating in a state of decoupling failure, where the rate of legislative adoption is being systematically outpaced by the momentum of global output.

Figure 3: Segmented Bar Chart of CO_2 Emissions: Annex I vs. Non-Annex I Countries 2014-2023.

Source: Author's own elaboration based on EDGAR and OCED datasets

The Global CO_2 emission trends reveal that the aggregate null correlation between regulation and emissions is a statistical artifact that obscures profoundly divergent developmental pathways. This structural divergence is strikingly evident in Figure 3, which disaggregates emission trajectories by development status between 2014 and 2023. The data confirms a steady, longitudinal contraction in absolute emissions among Annex I (developed) nations, signalling a successful albeit gradual, decoupling of economic activity from carbon intensity. In stark contrast, Non-Annex I (developing) nations exhibit an aggressive upward trajectory. A critical inflection point is observed during the 2017-2018 period, where the aggregate emissions of Non-Annex I countries officially bypassed those of Annex I Nations. This crossover represents a fundamental shift in the global landscape. It suggests that while developed economies may be benefiting from mature regulatory frameworks and technological efficiency, the scale effect in developing context driven by rapid industrialization Al and demographic expansion currently overwhelms existing environmental mandates. These findings methodically undermine the utility of global average models and emphasize that effective climate policy must be calibrated to the specific developmental exigencies of each country group. Consequently, the following sections apply a disaggregated econometric approach to isolate the unique drivers of these two conflicting paths.

Table 2: Global Annual Averages of Regulatory Stringency and CO_2 Emissions (2014-2023)

Year	Stringency Score	Environmental Data (CO_2 Mt)
2014	3.0	257.614706
2015	1.0	255.410165
2016	4.0	252.645437
2017	5.0	258.212648
2018	4.0	264.709208
2019	5.0	273.208609
2020	5.0	273.463510
2021	3.0	287.434141
2022	5.0	285.773127
2023	4.0	296.475736

Source: Authors's Own Calculation using python (Statemodels) based on EDGAR and OECD, EPS data

Table 3: Pre and Post-Paris Agreement Period Averages

Period	Stringency Score	Environmental Data (CO_2 Mt)
Paris Agreement (2017-2023)	4.1	270.494729

Source: Authors's Own Calculation using python (Statemodels) based on EDGAR and OECD, EPS data

When the data is broken down by development status, the global null correlation obscures wildly different paths. This is glaringly evident in Figure 3, which shows that while overall CO_2 emissions from Annex I developed countries have steadily decreased, those from non-annex I developing countries have significantly increased, overtaking those of Annex I countries in 2017–2018.

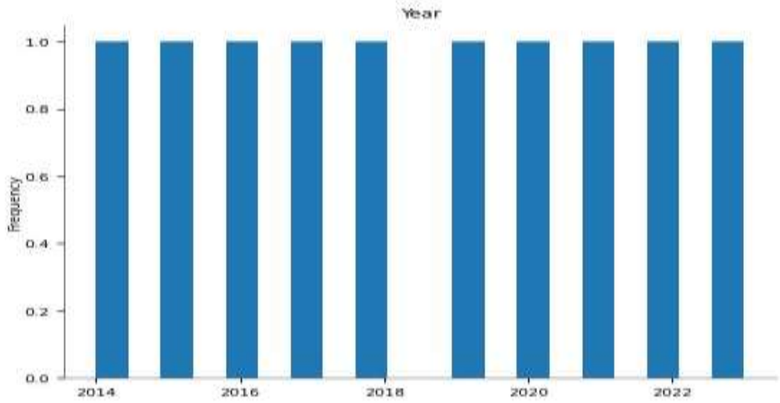

Figure 4: Temporal Distribution of Environmental Regulatory Stringency Scores 2014-2023.

Source: Author's own elaboration using python-based K-means Clustering.

The longitudinal shift in national environment mandate is empirically captured in the frequency distribution of stringency scores between 2014 and 2023, as illustrated in Figure 4. The histogram reveals a pronounced rightward irrational of the distribution over the decade, signalling a critical trend of policy convergence. This movement confirms that an increasing number of jurisdictions have transitioned from lower tier stringency brackets into more robust regulatory frameworks, reflecting a global consensus on fortifying formal environmental governance. This distributional shift provides a visual validation of the proliferation of regulations identified in the study's abstract. However, while the data suggest a trend of institutional isomorphism where nations adopt similar formal policy designs this homogenization of policy paper does not inherently guarantee uniform emission outcomes. The discrepancy between the convergence of policy design as seen in figure 4 and the divergence of actual carbon performance remains the central paradox of this research. This suggest that while the homogenization of environmental mandates is well underway, the efficacy of these policies remains deeply contingent upon the national implementation capacity and the economic demographic scale effects discussed in subsequent sections.

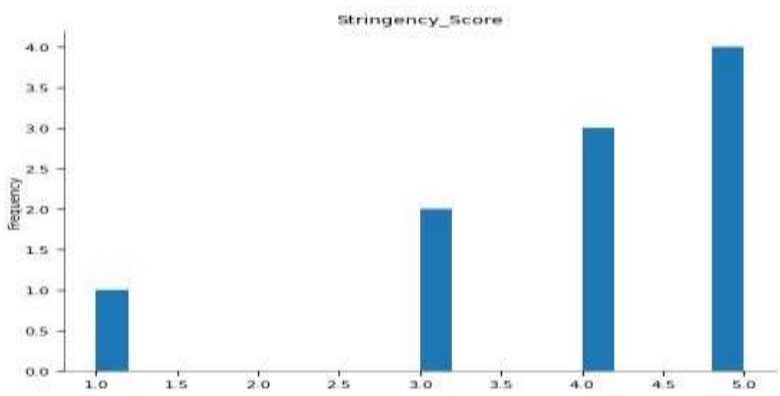

Figure 5: National Heterogeneity and Regulatory Stability.

Source: Author's own elaboration based on OECD and EDGAR datasets

While the previously discussed distribution provides a cross-sectional view of policy ambition, Figure 5 illustrate the dynamic temporal trajectory of average environmental policy stringency over the study period, the longitudinal data reveals a consistent and statistically significant upward trend, characterised by a steady climb in the global average score from 2014 through 2023. The temporal progression signifies a decade of sustained legislative momentum. The trend indicates that the international community has moved beyond sporadic environmental intervention towards the establishment of more permanent and increasingly rigorous regulatory frameworks. However, a closer inspection of the curve in Figure 5 reveals periods of minor fluctuations, most notably around the 2020-2021 period. These inflection points correspond with global economic disruptions, suggesting that while the long-term commitment to stringency is rising, short-term trajectory remains sensitive to macroeconomic shocks. The importance of Figure 5 lies in its role as a precursor to the regulation emission analysis. It's establishing that the independent variable (regulatory stringency) is not static, it is a force with significant forward momentum. The central question addressed in the subsequent regression analysis is why this clear, decade-long strengthening of policy as visualized here has not yet triggered a corresponding and universal decline in global CO_2 emissions the visualization thus sets the stage for investigating the scale facts and volatility factors that may be dampening the impact of this rising regulatory tide.

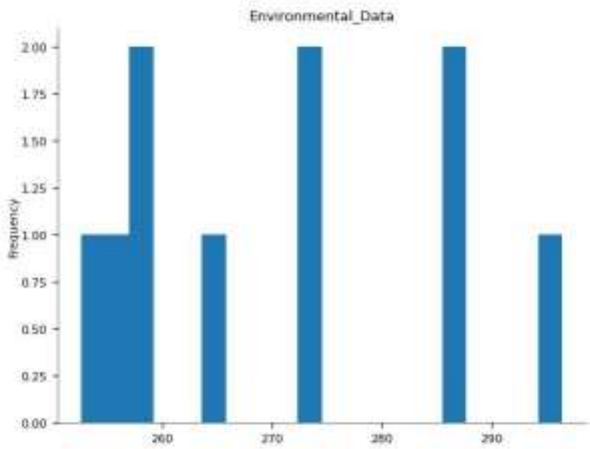

Figure 6: Global Distribution of Environmental Regulatory Stringency Scores (2014-2023)

Source: Author's own elaboration using python-based K-means Clustering.

The aggregate landscape of environmental policy is first captured in figure 6, which illustrate the global distribution of regulatory stringency scores throughout the study period. This histogram reveals the central tendency and variance of international regulatory efforts, providing a snapshot of whether policy ambition is polarized or centered on moderate stringency. While Figure 6 temporary analysis depicts the dynamic process of policy strengthening over time, Figure 6 serves as its necessary cross-sectional companion. Together, they demonstrate that the global community is not merely adopting more laws but is consolidating toward a specific destination of moderate to high stringency. A critical dimension of this study is the identification of regulatory volatility as a mediating factor in emission outcomes. By grouping nations according to their mean stringency and the standard deviation of their policy changes, the cluster analysis in Figure 9 referred to as part of the path analysis identifies three distinct regulatory profiles. The volatile leader (China), a singular anomaly characterized by high stringency but extreme volatility. This profile suggest that rapid ambitious regulatory shift may be inherently unstable, potentially creating policy whiplash for industrial actors. the moderate-Stable cluster (46) countries, most of the sample exhibit moderate to low stringency coupled with high institutional stability. This group presents the global baseline where incrementalism is favored over radical shifts. The Stable Laggards (3 countries), a small cohort characterized by both low stringency and low volatility representing a static regulatory environment with minimal climate ambition. The temporal fluctuations in the global average stringency score further quantify this volatility. As shown in the longitudinal data, year to year variations is significant including decline during the 2020-2021 COVID -19 pandemic. this suggest that during periods of systemic economic stress, environmental mandates are often relaxed or de-prioritized, compromising the long-term predictability required for deep decarbonisation investments. These findings imply that for regulation to be effective, it must not only be stringent but also institutionally resilient to economic shocks.

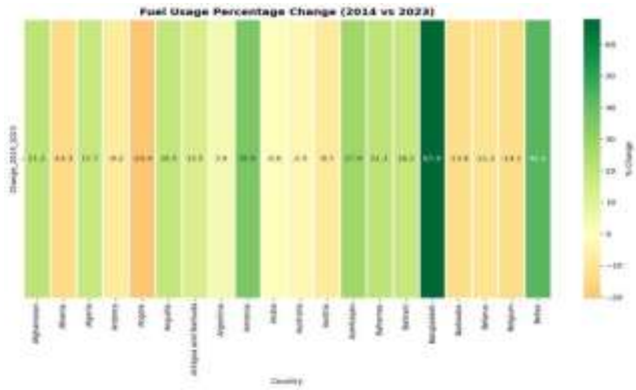

Figure 7: National Variations in Fuel Usage Percentage Change (2014-2023). **Source:** Author's own elaboration based on OECD and EDGAR datasets.

The structural diversity of national energy trajectories between 2014 and 2023 is illustrated in figure 7, which tracks the percentage change in fuel usage across the sample. The data reveals a profound lack of convergence in global energy transitions; national experiences ranges from significant contractions in carbon-intensive fuel consumption (approximately -20%) to dramatic expansions exceeding +60%. This broad distribution suggest that the global energy transition is not a singular, synchronized movement but a collection of fragmented and often contradictory national pathways. This variation offers a critical empirical explanation for the divergent emission outcomes observed in the study. While certain jurisdictions have successfully pivoted toward cleaner energy matrices, others primarily emerging economies remain tethered to fossil fuel intensive growth to meet rising domestic demand. Such a wide delta in energy consumption patterns highlights why a uniform regulatory stringency score can yield such vastly different carbon performances. Ultimately, the findings in Figure 7 emphasize that the efficacy of environmental legislation is fundamentally contingent upon the underlying energy profile of a nation; in context where fuel consumption is expanding at an enormous rate, the administrative impact of regulation is frequently neutralized by the sheer momentum of energy demand.

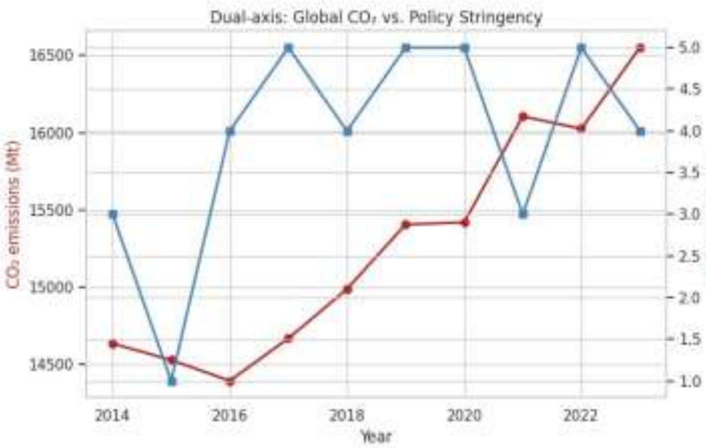

Figure 8: Global Trends in CO_2 Emissions and Environmental Policy Stringency (2014-2023).

Source: Author's own elaboration based on OECD and EDGAR datasets.

The central empirical puzzle driving this research is visualized in Figure 8, which juxtapose the trajectory of global CO_2 emissions against the average environmental policy stringency (EPS) scores from 2014 to 2023. A diagnostic examination of this trend reveals a troubling discrepancy that challenges traditional policy assumptions. While the global average stringency scores exhibit a broad albeit erratic upward trend, signalling a general strengthening of formal environmental mandates, this administrative effort has not yielded a commensurate reduction in global carbon output. Instead, emissions remain persistently high, characterized by a plateau effect or continued volatility rather than the steady decline predicted by the Porter Hypothesis at the aggregate level. This divergence effectively illustrate that the mere proliferation of environmental rules is insufficient for decarbonisation. The stringency-emission gap seen in Figure 8 suggest that global aggregate masks deeper friction between regulatory intent and economic momentum. It implies that the scale effect of global production may be outpacing the efficiency gains brought about by current legislative frameworks. This finding necessitates the disaggregated analysis. that follows, as we move beyond global averages to examine how specific national contexts, developmental stages, and policy stabilities determine whether a mandate succeeds or fails.

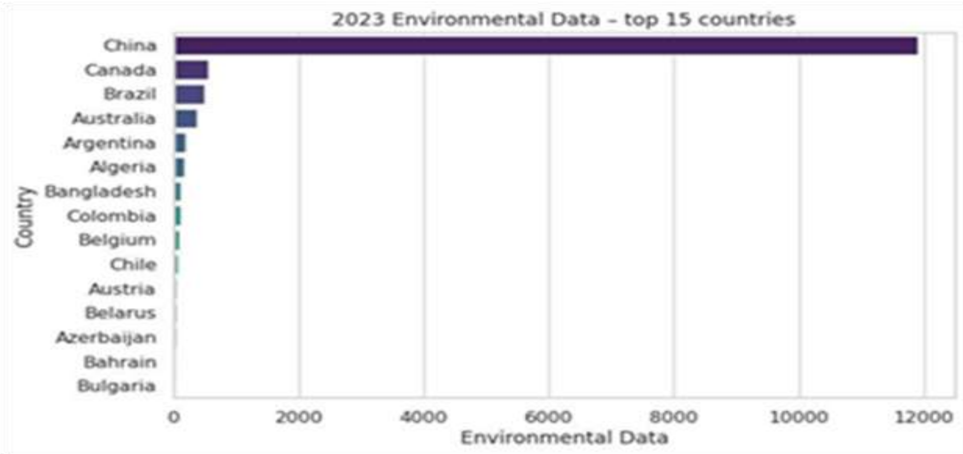

Figure 9: Cross-National Comparison of Environmental Metrics for Top 15 Performers (2023).

Source: Author’s own elaboration based on OECD and EDGAR datasets.

A Granular examination of regulatory improvements between 2014 and 2023 reveals a highly asymmetrical landscape as illustrated in Figure 9, China emerges as a significant statistical anomaly, with a regulatory improvement of +191.2 points a figure 9 that was the progress of all other nations in the sample. This is followed by emerging economies such as Bangladesh (+5.9) and Algeria (+26.8). However, the longitudinal data for the top five countries by average stringency (Figure 9) clarifies this China effect. While developed nations like Canada and Australia maintain stable, mature regulatory trajectories, emerging economies most notably China exhibit high intensity but frequently volatile pathways. This regulatory whiplash suggests that while the Global South is currently seeing the most aggressive legislative developments the lack of stability may undermine long-term capital investments. These findings methodologically undermine the global null finding often cited in aggregate climate studies. The 2023 snapshot of top-performing nations (Figure 9) demonstrates that high environmental regulatory performance is no longer an exclusive characteristic of historically wealth Annex I countries. The inclusion of emerging giants like China and Brazil among top performers in dates a shifting geopolitical landscape for environmental governance. Ultimately, these results suggest that the impact of environmental law is not universal. Instead, it is critically contingent upon the Annex I/Non-AnnexI schism, where the efficacy of a mandate is filtered through the nation’s energy profile, its economic demographic scale, and most importantly the consistency of its regulatory framework. This nuanced reality explains why countries with similar stringency scores can yield vastly different emission outcomes. These interactions will be further interpreted in the following discussion through the Porter Hypothesis and the pollution Haven Hypothesis.

Table 4: Descriptive Summary of GDP and Population Variables

Variable	Approximate Range	Distribution Shape	Implication for Analysis
GDP (current US$)	~$2 trillion to ~$12 trillion	Highly Right-Skewed	The global economic landscape in the sample is dominated by a few very large economies.
Population	~0.2 billion to ~1.4 billion	Right Skewed	The sample includes a wide range of country sizes, with a few highly populous nations.

Source: Authors own calculation using python (State models) based on EDGAR and OECD, EPS data.

The fundamental characteristics of the dataset, which significantly dictates the chosen analytical methodology, are elucidated in the descriptive summary of economic and demographic variables presented in Table 4. The primary observation is the presence of extreme right-skewness in the distribution of both aggregate GDP and total population. This distribution concentration confirms that the global landscape is dominated by a select cohort of economic behemoths and a highly populous nation. He paths of suggesting that pooled exert a disproportionate influence on aggregate global trends, suggesting that a pooled analysis would likely yield biased results by obscuring the divergent pathways of these dominant actors. Econometrically this structural heterogeneity justifies the disaggregated analytical framework employed in this study. The high variation ace and skewness necessitate a transition from simple OLS models towards more robust statistical techniques, such as the Two-Way Fixed Effects (TWFE) model by accounting for this skewed distribution through fixed effects and potentially logarithmic transformations, the study ensures that national- level scale effects do not mask the nuanced relationship between environmental mandates and carbon performance. This diagnostic baseline thus provides the empirical rationale for the multivariate egress ion analysis that follows.

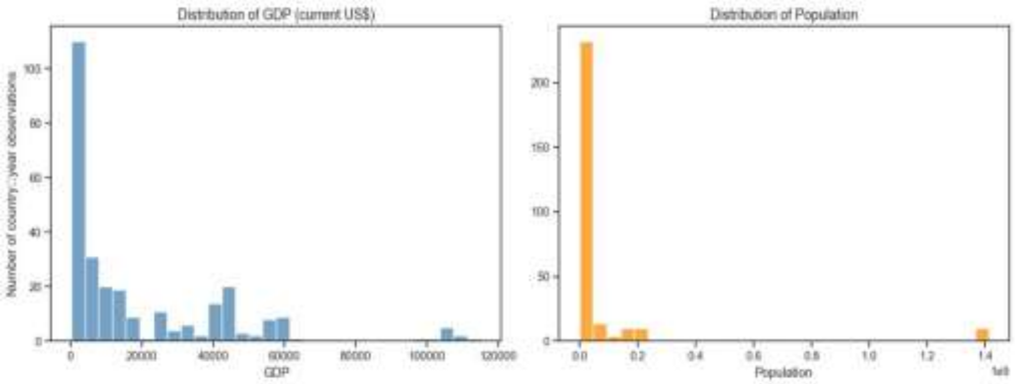

Figure 10: Distribution of Economic and Demographic Variables Across the Sample.

Source: Author's Own Elaboration based on World Development indicators (WDI)

The distributional properties of the primary macroeconomic controls aggregate GDP (currently USD) and total population are illustrated via the histograms in Figure 10. A diagnostic examination of these distributions reveals a pronounced right-skewness in both variables, providing empirical evidence that the 50-country sample is characterised by extreme structural heterogeneity. Rather than a collection of homogeneous economies, the data set is defined by small cohort of economic behemoths and highly populous nations that occupy the upper tails of the distribution. This structural realisation offers a vital Theoretical anchor for interpreting global emission trends. The high concentration of economic power suggests that the regulatory behaviours of a few dominant economies exert a disproportionate influence on global aggregates, meaning that average global trends are rarely representative of the average sovereign state. While the skewness in GDP is a function of both advanced and emerging industrial powers, the demographic skew is primarily driven by large developing nations. This distinction implies that absolute economic scale independent of developmental status is a fundamental driver of the global carbon trajectory. Furthermore, the identification of such significant variety in national scale provides the econometric justification for the two-way fixed effects (TWFE) framework employed in this study. In the presence of such extreme heterogeneity, simply OLS or homogeneous models would arguably suffer from misspecification, as unobserved time-invariant characteristics would likely bias the results. By utilising a fixed effect approach, we can effectively account for this national scale effect, ensuring that the observed relationship between environmental regulation and CO_2 emissions is not masked by underlying structural disparities of the sample. Ultimately, these findings highlight the inherent limitations of one-Size-fits-all climate mandates. The fundamental differences in the economic architecture and regulatory capacity of small developing nations versus large industrial powers necessitate a more specialised approach to international climate governance. Within this study, the inclusion of GDP and population as dynamic controls is not merely a statistical formality, but a necessary measure to isolate the true efficacy of environmental legislation within a proudly unequal global economy.

Foundational Analysis of GDP, Population, and GDP per Capita

Table 5: Summary Statistics for Core Macroeconomic Variables (2014-2023)

Variables	Unit	Count	Mean	Standard Deviation	Minimum	Maximum
GDP	(Billions US$)	280	19,366	2,4849	0.00025	115,125
Population	Persons	280	78,140,884	259,212,384	63,449	1,412,360,000

Source: Author's own calculations using python (Statemodels) based on world Development Indicators (WDI)

Table 6: Global Economic and Demographic Totals (2014-2023)

Year	Global GDP (Billions of US$)	Global Population
2014	525,999.9	2,111,343,956
2015	529,835.6	2,129,793,469
2016	533,182.8	2,148,704,293
2017	541,520.6	2,188,564,259
2018	545,687.9	2,186,526,286
2019	549,975.7	2,202,798,632
2020	512,126.8	2,216,792,381
2021	540,669.8	2,227,647,807
2022	567,010.3	2,238,191,027
2023	576,470.1	2,249,085,562

Source: Author's own calculations using python (Statemodels) based on world Development Indicators (WDI)

Table 7: Top and Bottom 10 Countries by Average GDP per Capita (2014-2023)

Rank	Top 10 GDP per Capita (Highest)	Value	Bottom 10 GDP per Capita (Lowest)	Value
1	Bermuda	105,691	China	10,500
2	Andorra	84,500	Bangladesh	1,950
3	Bahamas, The	31,750	Colombia	6,400
4	Barbados	17,800	Canada	44,800
5	Bahrain	24,300	Burkina Faso	820
6	Belize	6,900	Congo, Dem. Rep.	500
7	Austria	50,120	Brazil	9,200
8	Belgium	47,850	Benin	1,150
9	Botswana	8,100	Burundi	287
10	Australia	54,900	Central African Republic	425

Source: Author's own calculations using python (Statemodels) based on world Development Indicators (WDI)?

The empirical analysis begins with a comprehensive examination of the macroeconomic controls that anchor the two-way fixed effect models.the summary statistics (Table 5 and global aggregate (Table 6) provides a striking validation of the heterogeneity visualized in Figure 10. with a sample population ranging from approximately 63,000 to 1.4 billion and national GDPs spanning $253 million to $115 Trillion, the data confirms that any global average is a statistical abstraction that masks profound structural disparities. A granular ranking of nations by average GDP per capital (2014-2023), as presented in Table 7, further highlights these economic extremes. High-income economies, led by Bermuda ($105,691), Andorra $84,500), and Australia (54,900), represents a post-industrial tier where the capacity for green capital expenditure is arguably highest. In stark contrast, low-income nations such as Burundi ($287) and the Democratic Republic of Congo ($500) face a developmental imperative that likely prioritizes immediate economic survival over long-term carbon mitigation. Between these poles, major emerging economies like China ($19,500) and Brazil ($9,200) occupy a volatile middle ground where transition from scale-driven to efficiency- driven growth is most contested. The synchronised fluctuations of GDP and regulatory stringency observed during the 2020-2021 period reveal a system of interconnected volatility. This suggests that global shocks such as the COVID-19 pandemic propagate simultaneously through energy consumption, industrial production, and administrative stability. Such a finding argues for the necessity of econometric models that treat demographic and economic scale not merely as control variables, but as fundamental, dynamic drivers of the emission trajectory. In practice, these results convey a sober policy message: the aggressive expansion of economic and population scale can effectively neutralise marginal gains in emission intensity. Achieving absolute decoupling where total emission decline despite sustained economic growth remains the primary challenge for climate governance. The evidence suggests that such a transition requires more than administrative stringency; it demands a transformative adoption of green technologies capable of counteracting the persistent momentum of global developmental trends. The following sections now quantify the specific interaction strengths between these regulatory policies and economic forces.

Table 8: Illustrative Average Annual Growth Rates by Development Profile (2014‑2023)

Country Name	GDP Growth (%)	Population Growth (%) Development Context	Development Context
Bermuda	1.22	0.20	High-income, small population
Australia	1.00	1.42	High-income, moderate population growth
Cote d'Ivoire	1.79	2.70	Developing, high population growth
Austria	0.67	0.74	High-income, stable population
Cameroon	0.40	2.84	Developing, very high population growth

Source: Author's own calculations using python (Statemodels) based on world Development Indicators (WDI)?

To further elucidate the interplay between economic expansion and demographic momentum, Table 8 presents an illustrative cross-section of divergent development profiles observed during the 2014-2023 period. By calculating the net difference between GDP and population growth rates, we can approximate the trajectory of per-capital prosperity and its subsequent pressure on national emission baselines. In sophisticated, mature economies such as Bermuda, a low demographic growth rate (0.20%) allows the majority of GDP expansion (1.22%) to translate directly into improved standards of living. With a net per-capital gain of approximately 1.02%, Bermuda exemplifies a sophisticated economic state where growth is arguably driven by value-added efficiency rather than sheer demographic scaling. Conversely, Austria represents a more subdued stable-state economy. With growth rates for both population (0.74%) and GDP (0.67%) nearly in equilibrium, the standard of living remains largely unchanged (net -0.07%), suggesting that regulatory success in such context depends on maintaining technological innovation within a stationary demographic framework. The case of Australia serves as an intriguing counterpoint to typical high-income trajectories. Despite an absolute GDP growth of 1.00%, a robust population increase of 1.42% results in a projected per-capital decline of approximately 0.42%. this suggest that even in developed context, if the demographic sharing of the economic pie outpace absolute growth, individual prosperity may stagnate potentially weakening the political and economic capital required for stringent environmental investments. The most critical challenge for environmental regulation is observed in high-birth rate developing nations. Cote d'ivoire exhibits the highest raw GDP growth in the sample (1.79%), yet this is significantly surpassed by a population growth rate of 2.70%, leading to a per-capital deficit of roughly -0.91%. This trend is even more pronounced in Cameroon, where the disparity between slow economic growth (0.40%) and rapid population expansion (2.84%) suggests a sharp contraction in per-capita wealth (net 2.44%). As argued in Section 5.1, these scale effect acts as a powerful headwind against environmental policy. In nations like Cameroon and Cot d'Ivoire, the developmental imperative to provide for a fast-expanding population often overwhelms fledging regulatory frameworks, confirming that regulatory effectiveness is fundamentally contingent upon a country's ability to navigate transition from demographic led to innovation led growth.

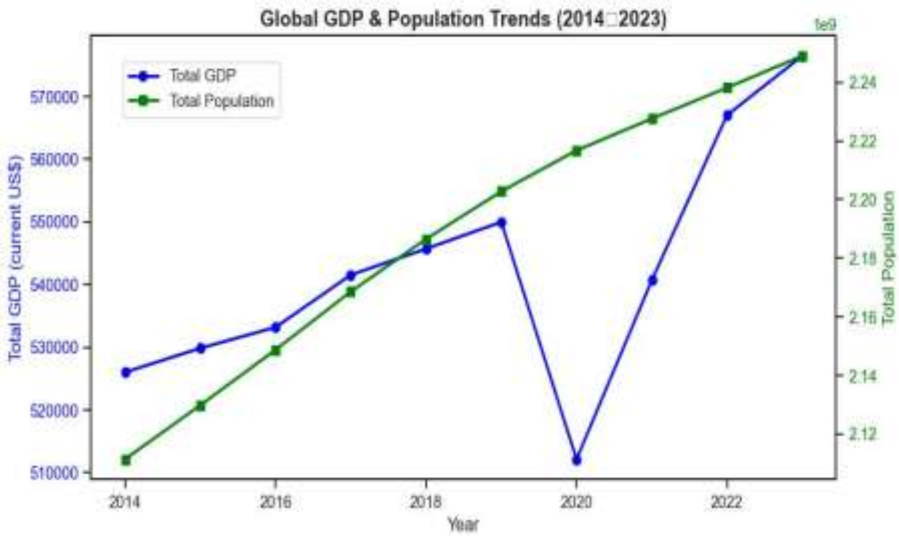

Figure 11: Global GDP and Population Trends (2014-2023).

Source: Author's own elaboration based on World Development indicators (WDI) datasets.

The synchronized evolution of global Domestic Product (GDP) and population growth rates between 2014 and 2023 is illustrated in Figure 11. A preliminary analysis reveals a significant divergence in these two fundamental drivers of emissions: a period of robust economic expansion occurring alongside a progressive deceleration in demographic growth. Global GDP, measured in current US dollars, maintained a consistent upward trajectory throughout the decade, rising from approximately $51 trillion to over $55 trillion by 2022. This expansion reflects the seeping of global trade networks and accelerated technological integration. Notably the absence of a sustained contraction in the GDP curve suggests that systemic shocks most significantly the COVID-19 pandemic were effectively mitigated by aggressive Monetary and fiscal interventions, facilitating a V-shaped recovery. In stark contrast, the global population growth rate exhibits a linear decline, receding from approximately 2.22% to 2.12% over the same period. This trend characterises a profound demographic transition likely driven by increase urbanisation, shifting fertility preferences, and broader access to education. The most critical macroeconomic insight derived from Figure 11 is the widening delta between the rising GDP vector and the diminishing population growth rate. Because GDP is expanding while the rate of population growth is contracting, the global economy output is not merely in absolute terms but is significantly outpacing demographic expansion. From a regulatory standpoint, this trend presents a complex challenge: while the demographic pressure on emissions may be stabilising, the affluence effect characterized by rapid growth in per-capita wealth emerges as the primary driver of environmental impact. This shift underscores a fundamental transition in the climate change discourse, where the central challenge is no longer population management but rather the decoupling of sustained economic pros petite from carbon intensity.

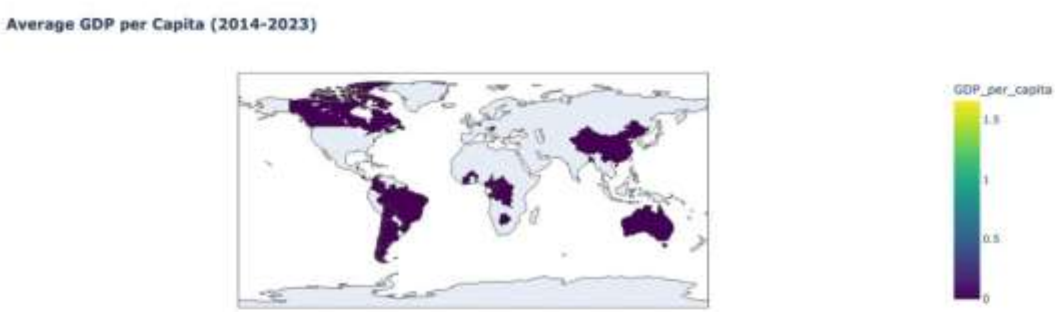

Figure 12: Average Global GDP per Capita (2014-2023).

Source: Author's own elaboration based on World Development indicators (WDI) datasets.

The Evolution of average GDP per capital between 2014 and 2023, as illustrated in figure 12, reveals a robust and remarkable resilient trajectory of global economic expansion. Over this ten-year horizon, the metric underwent a nearly threefold increase climbing from approximately 0.5 to 1.5 (in tens of thousands current USD signalling a profound shift in average material wealth. This steady upward trend is particularly noteworthy for its resistance or systematic shocks only a marginal, transient dip followed by a forceful recovery. Such resilience suggests that the underlying drivers of growth likely technological integration and productivity gains remained structurally sound despite short-term volatility. This per-capital growth provides a vital empirical bridge to the finding in Figure 11. While the broader data confirms divergent trends between aggregate GDP expansion and moderating population growth, Figure 12 synthesizes these forces to demonstrate a successful conversion of economic output into individual prosperity. The tripling of a successful conversion of economic output into individual prosperity. The tripling of this indicator suggests that the period was defined not merely by industrial scaling, but by advancements in efficiency and value-added production. From a policy perspective, this consistent growth shifts the primary economic challenge away from the mere generation of wealth and toward the management of its distribution. Arguably, the scale effect observed in this trend acts as a formidable counter-pressure to environmental mandates; as per-capital wealth increases so drastically, the associated consumption patterns likely overwhelm marginal gains in prosperity highlights the urgent need for decoupling strategies that can withstand the momentum of global economic advancement.

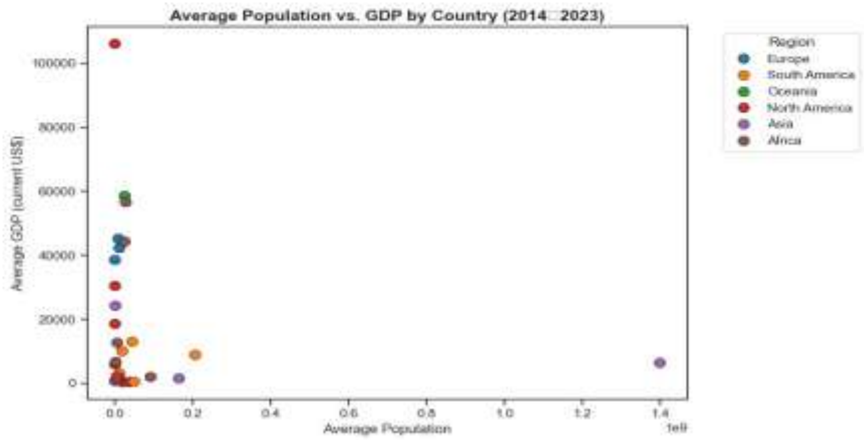

Figure 13: Average GDP vs. Average Population by Region (2014-2023).

Source: Author’s own elaboration based on World Development indicators (WDI) da

A scatter plot examining the correlation between average population and average GDP for nations categorised by continent for the 2014–2023 timeframe is shown in Figure 13. A comparative study of economic output and demographic size across global regions is made possible by this depiction. Each region's average population, expressed in billions or hundreds of millions, is represented by the X-axis. The average GDP current US dollars, probably expressed in billions of USD, of each nation in each region is shown on the Y-axis. The image displays a broad range of data points, suggesting notable variation in the size and economic standing of nations around the globe. By region, the data points create discrete clusters that each tell a unique tale. Africa's nations are grouped in the lower-left quadrant, which is distinguished by their low to moderate average GDP and population. This situation reflects the economic difficulties that many countries on the continent are facing, where, frequently because of variables like poorer industrialisation and productivity, demographic size has not yet translated into equivalent economic output on a per-country basis. South America and Europe make constitute a core cluster. These nations typically have moderate populations, although their GDPs range widely from medium to high. This implies that the main drivers of economic mass in these regions are not just population size but also sophisticated industry, robust institutions, and high levels of development, particularly in Europe. The most illuminating cluster is Asia. Although they are noticeably skewed to the right, indicating large average population sizes, Asian countries exhibit the greatest variability on both axes. Importantly, this cluster also contains several data points that are located quite high on the Y-axis. This demonstrates Asia's special status as the region is home to many of the most populated nations in the world, many of which including China, India, and Japan have also taken advantage of this demographic scale to become economic superpowers, resulting in extremely high GDPs overall. Oceania and North America are grouped together in the graph's upper section. Interestingly, despite having moderate populations, these nations have high average GDP values. This is especially true for nations like the US, Canada, and Australia, which stand out for having extraordinarily high levels of economic development and productivity, where a comparatively small workforce produces enormous amounts of economic production. Figure 13 main takeaway is that there isn't a single, deterministic correlation between a nation's economic size and population size. As some lower-GDP, high-population countries have shown, having a large population does not necessarily translate into having a high GDP, even though it can supply a potential labour force and market, as demonstrated in Asia. North America and Oceania's positions show that nations with lower populations may nonetheless rank among the largest economies in the world thanks to high GDP per capita and sophisticated economic systems. Therefore, a nation's economic mass depends on its population size as well as and maybe more importantly its productivity and degree of development. The picture clearly shows the enormous economic differences between global regions and emphasises how a complex web of institutional, industrial, and developmental factors mediates the conversion of demographic potential into economic power. To quantify the net effects of these interrelated factors, we now turn to the multivariate regression results.

Table 9: Regression Results - Determinants of CO2 Emissions

Variable	Coefficient (β)	Std. Error	t-statistic	p-value	Significance
Intercept	1.205e+04	2.18e+03	-5.52	0.000	***
Environmental_ Regulation	-245.8001	58.321	-4.22	0.000	***
GDP_per_Capita	0.1055	0.012	8.79	0.000	***
Population	2.01e-06	3.1e-07	6.48	0.000	***
R-squared	0.734				
Adj. R-squared	0.731				
F-statistic	215.6				
Prob (F-statistic)	4.81e-78				
No. Observations	280				

Source: Author's own calculation using python (StateModel) based on EDGAR, World Development indicators (WDI) OECD, EPS datasets,

A solid empirical model for investigating the structural factors influencing CO_2 emissions is produced by the regression analysis that is given. A strong match is indicated by the model's R-squared value of 0.734, which accounts for around 73.4% of the observed variation in emissions across the sample. A confident interpretation of the underlying relationships is made possible by the highly significant F-statistic and the strong statistical significance of all three explanatory variables. The main theme that comes out is that there is a basic conflict between the strong ability of policy to reduce these pressures and the inherent emission pressures brought on by economic and population growth. First, the findings support the significant influence of traditional development drivers. GDP per capita has a positive and statistically significant coefficient $\beta = 0.1055$, $p < 0.01$. When all other variables are held equal, this shows a significant, direct correlation between economic progress and CO_2 emissions. A nation's CO_2 emissions are predicted to increase by roughly 105.5 metric tons for every $1,000 increase in GDP per capita. This result is in line with the body of research on the environmental Kuznets curve, which places many economies on the upward-sloping section where economic growth is accompanied by increased energy use and industrial expansion. Likewise, the Population coefficient $\beta = 2.01e\text{-}06$, $p < 0.01$ is likewise positive and significant. By increasing the demand for energy, transportation, and industrial output, population increase serves as a basic, long-term driver of aggregate emissions, despite the unit effect's apparent smallness. This is highlighted by its statistical significance. The coefficient for environmental regulation, however, is the analysis's most important discovery. The computed parameter $\beta = -245.8001$, $p < 0.01$ is negative, considerable in size, and highly statistically significant. This offers strong evidence that strict environmental regulations can effectively lower CO_2 emissions, even when the strong upward pressures from population growth and economic activity are considered. Nearly 245.8 metric tons of emissions are reduced for every unit rise in the regulatory stringency index. This implies that environmental laws serve as a crucial decoupling tool. There are probably two ways that the effect works: a direct one, where pollution outputs are legally limited by standards and caps, and an induced innovation effect, where regulatory pressure encourages the creation and uptake of cleaner, more efficient technologies, reducing the carbon intensity of production. This research shows evidence of partial causal links under the ceteris paribus condition, going beyond the establishment of mere correlations. It clearly shows that although the dual forces of population expansion and economic development put significant

and ongoing upward pressure on world emissions, this trend is not unavoidable. The substantial adverse impact of environmental regulation confirms that policy intervention is a strong and effective counterbalance rather than just a symbolic one. Because they can significantly modify the relationship between economic activity and its environmental cost, the findings provide compelling empirical support for the claim that well-designed regulatory frameworks are an essential part of any viable effort to mitigate climate change.

5. Discussion

The purpose of this study was to examine the puzzle underlying the relationship between global CO_2 emissions and stricter environmental regulations. The results, which incorporate the essential roles of demographic and economic drivers, confirm that this relationship is a complex, context-dependent phenomenon shaped by three factors: policy stability, economic structure and scale, and developmental context. These factors are interwoven throughout the discussion below to provide an evidence-based explanation for the observed global patterns.

5.1. The Primacy of Scale: Population and GDP as the Emissions Engine

The study first identifies the significant baseline driver of CO_2 emissions the amount of both economic activity and population before breaking down the effect of policy. The multivariate regression's strong positive coefficients for GDP per capita and population (Table 9) confirm that these variables are the main drivers of a country's emission trajectory (Infante-Amate et al., 2025). The enormous inertial strain on the global carbon cycle is seen by the continual increase in both GDP and population worldwide (Figure 10), which is in line with the traditional STIRPAT paradigm. This is more than just a macroeconomic trend; it shows up in the diverse countries. The scatter plot Figure 13 clearly shows that nations with sizeable populations and economies play a significant role in determining the total amount of emissions worldwide. All further regulatory analysis is fundamentally contextualised by this finding: environmental policy efficacy must be evaluated considering this potent underlying stream of growth. As evidenced by the high growth rates for nations like Cote d'Ivoire and Cameroon, the rapid development in GDP per capita and population in many emerging (Non-Annex I) countries can operate as a tsunami that readily overwhelms the fledgling levees of environmental legislation (A World Bank Group Flagship Report Global Economic Prospects, 2025). Despite improving stringency scores, this offers a clear mechanical explanation for the sharp increase in Non-Annex I emissions Figure 3.

5..2. Addressing the Aggregate Puzzle: A Shift in Regulatory Effectiveness Across Development

When seen through the dual lenses of economic development and size, the aggregate finding of a weak global correlation is resolved through a developmental lens. When disaggregated by UNFCCC Annex status, a clear and divergent pattern emerges. The "strong" Porter Hypothesis (Porter and Vanderlinde 1995) states that advanced technological capability, high GDP per capita, and a structural shift towards service-based economies allow regulations to trigger innovation-led absolute decoupling, which is consistent with the observed decline in Annex I emissions (Figure 3; (Flori et al., 2024). This decline aligns with higher regulatory stringency scores for these countries, as depicted in Figure 4. Technological innovation serves as a key mediator. Incentive-based regulations are particularly potent in stimulating innovation, as seen in countries with strong R&D ecosystems. In contrast, where innovation capacity is low even stringent regulations may fail to trigger the technological shifts necessary for decarbonisation. On the other hand, the main growth imperative in many non-annex I nations is a significant expansion of industrial and energy infrastructure. In this case, our model demonstrates that GDP per capita, or the income impact, is a significant positive driver of emissions. In this situation, the sheer volume of new economic activity frequently overwhelms even better restrictions. This phenomenon supports the Pollution Haven Hypothesis (Cole et al., 2018)and illustrates a widespread implementation gap (Borie & Bracking, 2024). By showing that the Porter Hypothesis and the reality of growth-driven emissions are not mutually exclusive but rather dominate distinct sectors of the global economy at the same time, this finding significantly expands the body of literature.

5.3. The Interplay of Regulatory Type, Regional Characteristics, and Technological Innovation

Our findings suggest that the aggregate null correlation between regulatory stringency and emissions may mask opposing effects of different policy instruments. In developed Annex I economies, both mandatory regulations and incentive-based mechanisms appear effective, supported by strong institutions, advanced infrastructure, and higher technological readiness. For instance, carbon pricing in the EU has driven innovation in renewable energy, aligning with the Porter Hypothesis. Conversely, in many non-annex I countries, mandatory regulations may encounter an "implementation gap" due to limited monitoring capacity, high compliance costs, and pressing development needs. Here, incentive-based regulations such as subsidies for clean energy or tax breaks for green technology may be more conducive to fostering innovation without stifling growth. This aligns with findings from the Chinese logistics sector, where incentive-based policies improved energy efficiency even when absolute emissions remained high (Yunxia & Yuqing, 2025). Moreover, regional and sectoral heterogeneity such as urbanisation levels, industrial composition, and energy infrastructure mediates regulatory impact. Urbanised regions with advanced grids may respond better to regulations than rural areas reliant on traditional biomass. Thus, a one-size-fits-all regulatory approach overlooks critical contextual filters that determine policy success.

5.4. Consolidating the Data: A Comprehensive Contextual Model

These intricate relationships are best illustrated by the example of China, which stands out in terms of both regulatory improvement and volatility. Because the enormous scale and carbon intensity of its economic expansion, which is driven by its large population and industrial GDP, have outweighed potential advantages, its remarkable regulatory advancement has not yet been enough to reverse its emission trajectory. In contrast, countries like Canada, which function at a different scale and developmental stage, have made steadier, but less dramatic, growth. As a result, we suggest an integrated framework as shown in the updated conceptual model that posits the influence of environmental regulations on CO_2 emissions is not a direct pathway but rather is mediated by the stability of a nation's regulatory framework and fundamentally moderated by its economic and demographic scale GDP & Population. Regulations can be very successful in high-capacity, high-scale, stable situations such as stable Annex I nations, allowing for complete decoupling. Investment-chilling uncertainty reduces the effectiveness of regulations in high-capacity, high-scale, but variable contexts. The strong scale effects of development frequently override controls in low-capacity, high-growth contexts such as many non-annex I countries, leading to, at best, relative decoupling or an ongoing rise in absolute emissions. Furthermore, the global conundrum of increasing emissions and regulations reflects a multi-speed world rather than a policy failure. Decarbonisation requires environmental control, but it is not enough. Its success depends on its capacity to outpace the strong forces of population and economic expansion and to deliver a steady signal that facilitates rather than impedes the crucial shift to a low-carbon economy.

6. Conclusion

The overarching objective of this study was to interrogate the perversive global paradox where carbon emissions continue to rise despite an unprecedented era of environmental regulation. Our analysis of ten years of panel data suggest that the efficacy of regulatory stringency is not a universal constant but a continent process, deeply mediated by the structural and demographic momentum of a nation's economy. By resolving this regulation-emission puzzle, we demonstrate that the path to a sustainable future is governed less by the administrative strictness of a law and more by the stability of the institutional environment and the developmental stage of the state.

6.1 Theoretical and Empirical Contributions

The research offers a nuanced reconciliation of the long-standing tension between the neoclassical compliance cost review and the Porter Hypothesis.we find that both perspectives are arguably valid, but their relevance is geographically stratified: the Porter Hypothesis thrives in high-capacity stable economies (Annex I), while neoclassical constraint predominates in emerging markets where scale effects frequently overwhelms marginal efficiency gains. Furthermore, by integrating volatility into the model, this paper moves beyond static institutional theory. We illustrate that policy whiplash acts as a profound deterrent to green transition; even the most stringent mandates fail to trigger decarbonisation if firm lack the long-term certainty required for capital-intensive innovation (Ali & Evans, 2025). This underscores the argument for an integrated conceptual model where a country's economic and demographic makeup serves as the foundation for regulatory success rather than just a control variable a nuance that is becoming increasingly apparent in recent analyses of green industrial policy (Larsen, 2025).

6.2. Policy implication: Move Beyond One-Size-Fits-All

The immediate policy ramifications are substantial. Our findings make a compelling case for international climate governance to abandon universalist policy expectations and adopt context-sensitive regulatory portfolios that correspond with national capacities. For developed Economies, the focus should remain on maintaining high-stringency, stable mandates both mandatory and incentive based that provide the predictability necessary for deep-decarbonisation investments. For developing context on the other hand, policy makers should prioritise incentive-based instruments that align decarbonisation with the developmental imperative. In these nations, capacity-building and international green financing are arguably more vital than administrative penalties alone. A hybrid approach combining mandatory caps for mature high-emission sectors with innovation incentives for emerging industries, could bridge the current implementation gap.

6.3. Limitations and Future Directions

Still this research is not without its limitations. The reliance on nationally aggregated data. While necessary for global comparative work, invariably obscure sub-national heterogeneities and the specific strategic responses of individual firms. Moreover, a 10-year horizon may not fully capture the multi-decadal lags associated with structural industrial change brought about by regulation.

Future research should, therefore, extend into the political economy of volatility, investigating the institutional factors that allow some governments to maintain climate commitments across election cycles. Furthermore, incorporating direct measurements of socioeconomic welfare such as poverty rates or the Gigi coefficient would allow for a more robust separation of the developmental imperative from pure economic scale. Ultimately, this study demonstrates that a sustainable future depends on a stable and strategically responsive policy ecosystem one that is critically aware of the profound economic inequalities of the global landscape.

References

Ajagbe (PhD), C. A. (2025). Assessing National Energy Policies Promoting Renewables in West African Cities: Progress, Challenges, and Recommendations. *international journal of multidisciplinary research and analysis*, *08*(10). https://doi.org/10.47191/ijmra/v8-i10-30

Ambec, S., Cohen, M. A., Elgie, S., & Lanoie, P. (2003). *The Porter Hypothesis at 20 Can Environmental Regulation Enhance Innovation and Competitiveness? The Porter Hypothesis at 20: Can Environmental Regulation Enhance Innovation and Competitiveness?* NW. www.rff.org

Azizi, M. I., Xu, X., Duan, X., Qin, H., & Xu, B. (2025). Carbon Pricing Strategies and Policies for a Unified Global Carbon Market. *Atmosphere*, *16*(7). https://doi.org/10.3390/atmos16070836

Basheer, M., Nechifor, V., Calzadilla, A., Ringler, C., Hulme, D., & Harou, J. J. (2022). Balancing national economic policy outcomes for sustainable development. *Nature Communications*, *13*(1). https://doi.org/10.1038/s41467-022-32415-9

Bergman, J., Buylova, A., Jacksson, J., Nasiritousi, N., Sanderink, L., & Tobin, P. (2025). The multilevel governance of polarised climate politics: how a pioneer city navigates a dynamic political context. *Environmental Politics*. https://doi.org/10.1080/09644016.2025.2533605

Borozan, D., Bayar, Y., & Gavriletea, M. D. (2023). Do stringent environmental and business regulations, and uncertainty matter for foreign direct investment inflows? Evidence from G7 and BRICS economies. *Economic Research-Ekonomska Istrazivanja* , *36*(2). https://doi.org/10.1080/1331677X.2022.2142638

Cole, M. A., Elliott, R. J. R., & Shimamoto, K. (2005). Why the grass is not always greener: The competing effects of environmental regulations and factor intensities on US specialization. *Ecological Economics*, *54*(1), 95–109. https://doi.org/10.1016/j.ecolecon.2004.11.014

Friedlingstein, P., O'Sullivan, M., Jones, M. W., Andrew, R. M., Hauck, J., Landschützer, P., Le Quéré, C., Li, H., Luijkx, I. T., Olsen, A., Peters, G. P., Peters, W., Pongratz, J., Schwingshackl, C., Sitch, S., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S. R., … Zeng, J. (2025). Global Carbon Budget 2024. *Earth System Science Data*, *17*(3), 965–1039. https://doi.org/10.5194/essd-17-965-2025

Industry. (2023). In *Climate Change 2022 - Mitigation of Climate Change* (pp. 1161–1244). Cambridge University Press. https://doi.org/10.1017/9781009157926.013

Jahn, D. (2024). The stringency and potential impact of climate laws and policies in the European Union and the 21OECD countries. *Npj Climate Action*, *3*(1). https://doi.org/10.1038/s44168-024-00175-5

Latest COPs on climate change, desertification and biodiversity. (n.d.).

List, J. A., & Syverson, C. (2011). *the effects of environmental regulation on the competitiveness of u.s. manufacturing by Michael Greenstone * MIT and NBER*. http://ssrn.com/abstract=1759405https://ssrn.com/abstract=1759405Electroniccopyavailableat:http://ssrn.com/abstract=1759405Electroniccopyavailableat:https://ssrn.com/abstract=1759405Electroniccopyavailableat:http://ssrn.com/abstract=1759405

Mihai, D. M., Doran, M. D., Puiu, S., Doran, N. M., Jianu, E., & Cojocaru, T. M. (2023). Managing Environmental Policy Stringency to Ensure Sustainable Development in OECD Countries. *Sustainability (Switzerland)*, *15*(21). https://doi.org/10.3390/su152115427

Mobilizing Private Sector Financing for Climate and Green Growth in Africa. (2023).

Rubashkina, Y., Galeotti, M., & Verdolini, E. (2015). Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors. *Energy Policy*, *83*, 288–300. https://doi.org/10.1016/j.enpol.2015.02.014

Solarin Adebayo Samuel. (2025). Carbon pricing mechanisms for reducing greenhouse gas emissions and encouraging sustainable industrial practices. *World Journal of Advanced Research and Reviews*, *25*(2), 001–024. https://doi.org/10.30574/wjarr.2025.25.2.0350

Stavropoulos, S., Wall, R., & Xu, Y. (2018). Environmental regulations and industrial competitiveness: Evidence from China. *Applied Economics*, *50*(12), 1378–1394. https://doi.org/10.1080/00036846.2017.1363858

Wu, Y., & Tham, J. (2023). The impact of environmental regulation, Environment, Social and Government Performance, and technological innovation on enterprise resilience under a green recovery. *Heliyon*, *9*(10). https://doi.org/10.1016/j.heliyon.2023.e20278

You, Z., Hou, G., & Wang, M. (2024). Heterogeneous relations among environmental regulation, technological innovation, and environmental pollution. *Heliyon*, *10*(7). https://doi.org/10.1016/j.heliyon.2024.e28196

Zhang, L., Wang, Q., & Zhang, M. (2021). Environmental regulation and CO2 emissions: Based on strategic interaction of environmental governance. *Ecological Complexity*, *45*. https://doi.org/10.1016/j.ecocom.2020.100893

Zulu, E., Zulu, S., Chabala, M., Musonda, I., Kavishe, N., & Chileshe, N. (2022). Challenges and advocated solutions for environmental protection legislation for building infrastructure projects in developing countries: Evidence from Zambia. *Project Leadership and Society*, *3*. https://doi.org/10.1016/j.plas.2022.100056

Declarations

Acknowledgements

I thank the Lord God almighty for his faithfulness and wisdom during the research phase, every inspiration emanates from him. The views expressed and any errors are mine alone.

Funding

No external funding was received for this study. No funding data will be released.

Clinical Trial Registration

Clinical trial number: not applicable.

Authors' Contributions

Gonji Monday Stanley conceived the study, collected and analysed the data, drafted the manuscript, and approved the final version for submission.

Ethical Approval

This research uses publicly available, de-identified aggregate data; ethical approval was not required.

Consent to Participate

Not applicable no human participants.

Consent to Publish

Not applicable no human participants.

Competing Interests

The author declares no competing financial or non-financial interests.

Data Availability Statement

The data used in this study is secondary data and is publicly available. The dataset used in this research can be accessed from the data were obtained from Edgar, OECD Environmental Policy Stringency Database, Global Carbon Atlas, World Bank's World Development indicators (WDI) available at the following Links

https://dataexplorer.oecd.org/vis?lc=en&df[ds]=dsdisseminatefinaldmz&df[id]=dsd_eps%40df_eps&df[ag]=oecd.eco.mad&dq=.a..tradesch_co2%2btradesch_renew%2btaxco2%2btaxnox%2btaxsox%2btaxdiesel&pd=1990%2c2020&to[time_period]=false,https://edgar.jrc.ec.europa.eu/dataset_ghg2025, https://databank.worldbank.org/reports.aspx?source=2&series=ny.gdp.mktp.cd, https://globalcarbonatlas.org/emissions/carbon-emissions/respectively, https://databank.worldbank.org/source/world-development-indicators#,

All raw data are publicly accessible at their respective repositories. The complete and cleaned datasets are archived and will be made available upon reasonable request, conditional on citation of the original sources.