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The Drivers of Ecological Sustainability: Climate Policy, Institutions, and Renewable Energy

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ABSTRACT

Aim of the Study: This research examines the relationship between climate policy strength, institutional quality, renewable energy use, and ecological sustainability among a sample of (selected developed and developing) countries between 2007-2021.

Methodology: The analysis will use the fixed effects, random effects, and system GMM estimators to analyze the effect of structural, policy, and governance variables on environmental performance based on the Environmental Kuznets Curve and the institutional theory.

Findings: Descriptive statistics indicate that there is a high cross-country heterogeneity in the ecological pressure, innovation and policy performance. Empirical evidence continues to indicate that the use of renewable energy sources has a significant, negative impact on ecological footprint, thus highlighting its high importance in alleviating degradation. Climate policy performance similarly exhibits a strong negative association with ecological pressure, which indicates the need to have coherent and well-imposed policy frameworks. In the fixed effects model, the negative association between institutional quality and ecological footprint is also substantial, which proves that the presence of a better system of governance leads to better environmental performance. On the other hand, the impacts of economic growth, innovation and demographic pressures are complex and specific.

Conclusion: The results conclude that policy ambition, the effectiveness of governance, and the structural economic dynamics influence the environmental sustainability. Long-term ecological stability can be achieved through comprehensive policy interventions comprising of strict climate policy, sound institutional structures, and long-term renewable energy changeovers.

Keywords: Climate Policy Effectiveness; Ecological Footprint; Institutional Quality; Environmental Kuznets Curve; Renewable Energy Consumption.

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1. INTRODUCTION

The issue of sustainable use of the environment has become one of the most significant of the 20th century, and the exhaustion of resources, increased emissions, and environmental vulnerability become a challenge to long-term developmental trends in countries (Suprayitno et al., 2024; Awewom et al., 2024). The concept of sustainable development underlines that the current consumption trends, in particular, the further use of non-renewable resources are incompatible with the ecological threshold to preserve the welfare of the future generations (Freedman, 2018; Osabohien et al., 2025). The rapid growth of the world population complicates all these problems even more because it imposes more pressure on the ecosystem and aggravates the environmental degradation, particularly in those countries with poorly organized institutional structures (Israilova et al., 2023). Environmental sustainability requires the need to focus on enhancing ecological resilience and in protecting economic growth, social welfare, and intergenerational fairness (Fatah et al., 2025). As a result, there is a growing pressure on developed and developing countries to reconcile development goals and sustainability commitments, even though their institutional capabilities, types of governance, and ecological requirements differ enormously (Hosseini, 2023).

The efficiency of the institutional framework is also a critical aspect of making sure that the climate policies are aligned with the Sustainable Development Goals (SDGs) because an appropriate system of governance enables countries to develop, implement, and enforce similar environmental policies (Pandey and Bharti, 2024; Radtke, 2025). The developed economies have developed advanced infrastructure and regulatory systems, which guarantee integrated climate governance and the evidence-based decision-making process (Pandey and Bharti, 2024; Radtke, 2025). Instead, emerging countries tend to encounter hard organizational bureaucracies, resource scarcity, and political administrative pressures that make inter-sector coordination difficult, which in effect hamper the effectiveness of the climate efforts and exposes them to increased risks of environmental damage (Pandey & Bharti, 2024; Radtke, 2025). Such differences affect the process of policy promises being transformed into feasible results and determine the degree to which climate policies can bring the benefits of sustainable development in various settings (Adanma and Ogunbiyi, 2024; Banso et al., 2023).

The previous literature is becoming increasingly focused on the interconnection of climate policy, governance, and environmental performance, still there are considerable differences in the potential of counties to take climate action and adopt policies (Erbil, 2025; Hariram et al., 2023). Although strong institutional structures may lead to better policy coherence and strengthen environmental policies, most developing nations encounter conflicting priorities including poverty reduction, economic diversification and energy security, making it harder to enforce climate policies and plan over the long term (Hariram et al., 2023). Nevertheless, international environmental regulations have still been progressing with international agreements despite the unequal performance of these systems because of differences in national capacities, political motivation, and institutional congruence (Cirkovic & Wood, 2025; Hernandez Guzman and Hernandez Garcia de Velazco, 2024). Examples of how these experiences relate to the country in which they occur, like the experience of Indonesia and Pakistan, show that the domestic development agenda, sectoral requirements, and political ambitions influence climate policy outcomes more than international expectations do (Sembiring, 2025). Equally, experiences of Mexico demonstrate that national institutions and governance priorities often trump international standards on the course of national climate action (Kamil & Karlsson-Vinkhuyzen, 2023).

The latter points to the significance of evaluating the interaction between climate policy and governance structures in their impact on environmental sustainability, particularly in those settings in which institutional capacities differ significantly (Haque and Ntim, 2018; Abbas et al., 2022). The research analyzes the meaning of climate policy and governance in environmental sustainability in both developed and developing economies with an analysis of how institutional quality, policy design, and environmental performance are interrelated (Abbass et al., 2022; Smith et al., 2020; Patil et al., 2024). The analysis does not present a comparative approach to the study of the impact of socio-economic structures, governance arrangements, and policy instruments on environmental trajectories, but instead, both developing and developed countries are taken in a single equation on the idea that an increase in income or a change in characteristics across countries will have some specific implications in environmental pressure across countries. it investigates the existing knowledge, posing a critically important question: how each of these elements contributes to climate governance, facilitating or hindering sustainability transitions (Kaklauskaite and Streimikiene, 2024; John et al., 2025; Simon and Munoz, 2025). According to this view, the study would contribute to the knowledge of how climate policy influences development priorities to promote ecological resilience, which would involve coherent institutional frameworks that combine environmental, economic, and social factors in long-term sustainability policies (Pandey and Bharti, 2024; Radtke, 2025). Current research examines the question of whether any dynamic relationship between climate policy strength, institutional quality, renewable energy consumption, and ecological sustainability exists across multiple countries. If so, is it a linear relationship or a nonlinear relationship? This investigation will be a helping hand in policy making process and progress. The scope of the study is restricted to the selected 32 economies, randomly selected based on consistent data availability.

Despite the literature that currently investigates climate policy, institutional quality, renewable energy, and environmental performance, most of them consider these factors individually and use a fixed approach, which provides a little information on the dynamic and interactive impacts of these variables across the heterogeneous nations. Also, there is limited evidence on the comparative mechanisms of nonlinear sustainability, especially when considering ecological footprint as a holistic measure. The given study addresses this gap as it uses dynamic panel techniques and simultaneously evaluates the mutually affecting role of policy strength, governance, and renewable energy in 32 economies between 2007 and 2021. Incorporating institutional, policy, and energy aspects into a single framework, the study will be a contribution to existing literature that will use strong comparative evidence and offer policy-makers practical lessons on how to design coordinated, context-specific policies that will empower governance, facilitate renewable energy transitions, and lead to long-term ecological sustainability.

This research is based on Environmental Kuznets Curve and institutional theory that collectively describe the relationship between economic growth, the quality of governance, and the efficacy of policies and their impact on the environment. Environmental Kuznets Curve postulates that the environmental degradation at first grows with the growth of income and then starts to fall above a certain level of development whereas institutional theory stresses on the importance of the powerful governance to guarantee the desirable implementation of policies. Based on these insights and combined with the energy transition framework, this paper conceptualizes climate policy power, institutional effectiveness, and renewable energy demand as primary sources of ecological sustainability, which can influence the performance of countries in the long term both economically and institutionally.

1.1 Objectives of the Study

The current undertaken the following research objectives to be achieved:

- To examine the dynamic relationship between climate policy strength, institutional quality, renewable energy consumption, and ecological sustainability across selected countries from 2007 to 2021.
- To assess the individual and combined effects of policy, governance, and energy-related factors on ecological footprint.

1.2 Research Questions

- How do climate policy strength, institutional quality, and renewable energy consumption individually and jointly influence ecological sustainability across selected countries during the period 2007–2021?

- To what extent do nonlinear and heterogeneous effects shape the relationship between governance, energy transitions, and environmental performance, and how can these insights inform the design of effective and context-specific environmental policies?

2. LITERATURE REVIEW

2.1 Theoretical Foundations of Climate Policy and Governance

The theoretical basis of climate policy and governance dynamics is mostly based on two closely interconnected theories the Environmental Kuznets Curve (EKC) hypothesis and the institutional theory (Haque and Ntim, 2018; Kamil and Karlsson-Vinkhuyzen, 2023). According to the EKC hypothesis, the relationship between economic growth and environmental degradation is inverted U-shaped, meaning that ecology is more deteriorated in the initial developmental phases, but then it begins to decrease as countries achieve higher income growth and use cleaner technology (Sarkodie, 2018). The recent empirical studies confirm the existence of this inverted U-shaped trend, but they also put more emphasis on the role of climate policy uncertainty as a mediating variable that conditions the environmental outcomes (Bousnina et al., 2025; Erbil, 2025). This kind of framework provides analytical insight into why various countries have divergent success rates of policy effectiveness at different stage of development, which demonstrates that the gains of the environment are determined by the state of economic maturity within the country and the level of institutional capability within the country.

The institutional theory builds on an exclusively economic viewpoint, like that provided by the Environmental Kuznets Curve (EKC), and argues that the connection between economic development and environmental outcomes is not strictly or directly determined, but instead actively mediated by the governance system of a given country. This framework changes the emphasis of macroeconomic output variables to the micro-foundations of political and administrative effectiveness, which underlines that such variables as the stringency of regulations, the fair application of the rule of law, temporal consistency of policy are not just contextual variables but the main determinants of environmental performance (Awewomom et al., 2024; Mehmood and Kaewsaeng-on, 2024). Stokke (2018) suggests that the governance structure is the gateway transmission belt and thus transforms economic potential into environmental action. Strong institutions, defined by low levels of corruption, high levels of bureaucratic capability, and independent judiciaries, are the key to aligning the frequently differing interests of the state and non-state actors, credibly committing to long-term climate goals, and to a realization mechanism of accountability that makes environmental governance work (Huang et al., 2024).

The critical implementation of this theory, however, has to struggle with its complexities and limitations as well. To start with, there is a tendency to the relationship to be endogenous: whereas strong institutions allow fostering better policy, the political desire to establish strong institutions may be also a result of the same economic development patterns that also trigger environmental degradation. Second, the fact that the theory focuses on the quality of institutions may make one forget that institutions are not apolitical space; they are the space where politics occur. A regulatory design that is considered to be very strong may only be effective in terms of entrenching the interest of the incumbent industries to give rise to a phenomenon of capture whereby the rules of law will protect the polluters at the expense of the environment. The ability to "align" state and non-state entities, as described by Huang et al. (2024), turns out to be politically contentious--it takes not only institutional power, but the allocation of power that does not give priority to economic rent-seeking in the short run but the environmental protection.

The comparison between the institutional theory and the EKC frame proposed by Tang (2021) is especially informative when it comes to the interpretation of the dissimilar environmental performance of states that share certain resemblances in terms of their economic profile. As the EKC hypothesizes an inverted U-shaped relationship between income and pollution, the institutional theory is used to explain the deviations to the curve. As an example, low quality of governance in a high-income country (e.g., high corruption, volatile policies) can make it worse in the environment as compared to a middle-income country with good, progressive regulatory institutions. This is a bitter paradox, in that economic development holds the capacity to offer the means to conserve the environment, but unless there is institutional capacity to utilize these means prudently and avoid political pressures, it may lead to further exploitation of the environment. Thus, the interdependence between economic growth, policy structures and institutional strength is not a harmonious congruence but an active contention. Climate policy performance is not determined by the wealth of a country or the policies that have been written down but by the mundane, everyday aspects of implementation, where the institutional theory reminds us that the rule of law is not a structural attribute but a living, breathing practice of enforcement.

2.2 Empirical Evidence on Climate Policy Instruments

The effectiveness of climate policy instruments has been empirically measured through assessments of the instruments in terms of their effectiveness across country settings, policy designs, and institutional settings (Smith et al., 2020). The academic literature on carbon taxation shows that when designed correctly, such policies result in macroeconomic benefits and avoid economic distortions, when the revenues are reinvested into the economy via household transfers or other forms of focused fiscal stimulus (Kok et al., 2015; Cohen et al., 2021). Quantitative studies suggest that carbon taxes can attain up to 35 percent of reduction in emissions and promote labor income, output, and consumption with minimal negative impacts on unemployment (Freedman, 2018; Awewomom et al., 2024). These findings discredit the current belief about the high prices of the climate mitigation policies and instead suggest that well-adjusted carbon pricing frameworks can prioritize both the ecological and economic objectives.

The efficacy of climate policy instruments is also established by endogenous responses to technology and corporate innovation processes on the corporate level (Capelle, 2023). Studies on the incorporation of firm entry, technology adoption and innovation decisions reveal that carbon tax may prompt engineers to use green technologies that promote the establishment of environmentally focused investments and cleaner production processes to generate both environmental and economic advantages (Khurshid et al., 2023). According to empirical evidence, climate policies can create mutually reinforcing outcomes whereby when the emission is cut, productivity is increased and long-term competitiveness is achieved (Liu and Zhu, 2024; Abbas et al., 2022; Ruggerio, 2021). They raise the question of the necessity to focus on technological change and behavioral adjustment when analyzing climate policy tools, especially where companies can switch to low-carbon technologies.

2.3 Governance Indicators and Environmental Outcomes

Governance indicators analyse invariably shows that institutional quality and environmental sustainability are closely related in a variety of national contexts (Azimi et al., 2023). Multiple studies on governance aspects, including regulatory capacity, coordination mechanisms, financial transparency, and accountability of the public sector, indicate that the quality of institutions is the key predeterminer of the success of climate mitigation and adaptation policies (Shabir et al., 2023). Coordination institutions may facilitate the streamlining of climate action at the government levels, and the laws of climate frameworks offer binding commitments which enhance policy consistency and reduce political discontinuities that sabotage long-term environmental aspirations (Adanma & Ogunbiyi, 2024). Evidence-based policy practices are also advocated by the independent climate advisory bodies, which ensure that the climate targets are scientifically consistent and implementable (Awewomom et al., 2024; Janicke, 2017).

The efficacy of governance is not confined to the institutional arrangements but may comprise the comprehension of larger aspects of state ability and performance of regulation. Studies show that planning at national levels, financial systems and procurements activities must be aligned with the environmental objectives to enable policy coherence, as well as conversion of sustainability pledges into action programs (Ediagbonya & Tioluwani, 2023). Similarly, state-owned companies should be made to follow a set of regulations to make sure that the climate objectives are implemented in the major sectors, such as energy, transport, and water, particularly in those economies where the state-owned business represents the leading one (Miao and Nduneseokwu, 2025). These findings indicate that institutional capacity building (through governance reforms such as transparency enhancing measures) are preconditions to success of climate policy implementation, especially where the administrative capacity is weak as is the case with the developing economies.

2.4 Institutional Interaction and Policy Synergies

The literature on the interactions of institutions in global environmental governance states that the interaction between policy frameworks can lead to a complementary or antagonistic effect on climate outcomes (Birchall and Bonnett, 2021). Comparative analysis of the institutional designs shows that there are three significant methods of interaction that influence the environmental governance: synergy, where the institutions are reinforced by one another; conflict, where the institutional mandates are pitted against each other; and interference, where the overlapping jurisdictions impede coordination and effectiveness (Banso et al., 2023). These processes are essential to understand how to grow coherent institutional setups that would minimize the policy fragmentation and maximize its returns to the environment (Bhuiyan et al., 2023).

Several examples of case studies with varying environmental regimes including Convention on International Trade in Endangered Species (CITES), the Convention on Biological Diversity (CBD), and United Nations Framework Convention on Climate Change (UNFCCC) show that synergistic interactions are usually more prevalent than the institutional tensions when the relations between the governance systems are configured appropriately (Schulze, 2021). This is also to suggest that the proposed institutional linkages with the purpose of enhancing environmental governance can build mutually strong policy frameworks that facilitate the effectiveness of implementation (Abbass et al., 2022). However, the complexity of the overlapping nature of environmental demands means that coordination systems, institutional complementarity, and governance structure have to be targeted purposely in the up-and-coming economies where there may be limited capacity to effectively manage the institutional interaction due to the lack of resources (Haftel and Lenz, 2022; Stokke, 2018). Combined, the evidence provided above points to the fact that the outcomes of environmental sustainability are not only determined by the tools in the individual policies but also by the institutional framework and its capacity to facilitate or suppress the coherence of climate action (Cabral et al., 2022; Kabir et al., 2023).

3. DATA AND RESEARCH METHODOLOGY

3.1 Description of Variables and Data Sources

Empirical research involves the use of the annual data of 32 countries (panel of developed and developing) between the year 2007-2021. The variables included in the study are environmental sustainability, climate policy, institutional quality, innovation activity, population dynamics, and economic performance. The Global footprint Network (GFN) carbon footprint and biocapacity indices give the standard indices of ecological demand and resource supply, namely global hectares per capita, to determine ecological sustainability. The consumption of renewable energy, population density and GDP growth rates are obtained through the World Development Indicators (WDI), which allows them to be consistent and comparable across countries. The number of accepted patent applications is a proxy of innovation, obtained through the Global Innovation Index (GII), and is indicative of technological activity in the field of environmental transitions. The Worldwide Governance Indicators (WGI) measure institutional quality by summing up the dimensions of core governance that are fundamental to policy implementation. The strength of climate policy is comprised of the Climate Change Performance Index (CCPI), a compilation of country-specific assessments of policy ambition and implementation compiled by German watch. All these indicators together are a balanced set that can be used to analyze the interaction of economic, institutional, and environmental variables in both developed and developing economies.

Table 1: *Variable Description*

Important Variables, Measurement Units, and Sources			
CFP	Carbon foot Print	Gha	GFN
REC	Renewable Energy Consumption	% of Total Consumption	WDI
Bio Cap	Biocapacity	Hectares per person	GFN
GDP	Gross Domestic Product	Annual Growth	WDI
CP	Climate Policy	Taken as the index score CCPI	German Watch
PD	Population density	People per sq. km of land area	WDI
Pat	Patent	Number of Applications Approved	GII
INST	Institutional Quality	The index is an aggregated score of governance indicators for six dimensions of governance	WGI

The variables, measurement units and source of data utilized in the empirical study are summarized in Table 3.1. The carbon footprint is calculated in global hectares (gha), renewable energy consumption is calculated as a ratio of total energy consumption, biocapacity is the available ecological resources per capita, and GDP is the rate of yearly economic growth. The composite index is used to depict institutional quality, and patent applications are used to indicate national innovation capacity. Both population density and population policy power are quantified based on standardized scores of CCPI. The dataset, therefore, combines the indicators of the environment, economy, demography, and governance to obtain a holistic analysis of the effectiveness of climate policy.

3.2 Model Specification

The empirical approach explores the factors affecting environmental sustainability and the way climate policy, the quality of governance, and associated macroeconomic factors affect ecological performance. The analysis will use the panel data estimation methods to capture both the cross-sectional and time variation in the data, which commences with the fixed effects (FE) model. The FE methodology provides a control over the unobserved time-invariant country-specific heterogeneity that otherwise can cause biases in coefficient estimates, which guarantees that the coefficients obtained represent time-varying within-country dynamics (Wooldridge, 2006). The overall form of the fixed effects model is as it is:

$$CFPit = \beta 0 + \beta 1GDPit + \beta_2 GDPPC_{it}^2 + \beta 3RECit + \beta 4Instit + \beta 5CPSit + \beta 6Popdenit + \beta 7Anovatit + \beta 8Biocapit + \beta 9[IntractCPS * INST]it + \mu it + \epsilon it \quad (1)$$

The Carbon Footprint (CFP) defines the amount of carbon consumed, renewable energy consumption (REC) defines the amount of renewable energy consumed, economic growth (GDP) defines the amount of economic growth, biocapacity (BIOCAP) defines the amount of biocapacity, population density (PD) defines the amount of population density, patent activity (PAT) defines the amount of patent activity, institutional quality (INST) defines the amount of institutional quality, and climate policy strength (CPS). Country-level fixed effects are also included in the error term to cover unobserved heterogeneity.

3.3 Dynamic Modeling: Generalized Method of Moments (GMM)

The study uses the dynamic panel Generalized Method of Moments (GMM) estimator to deal with possible endogeneity due to reverse causality, discounted variables, or simultaneity between explanatory variables and environmental outcomes. The GMM method applies lagged levels and differences of endogenous variables as internal instruments, which eliminates endogeneity biases in panel datasets. The estimator is especially appropriate when the dependent variable has persisted over time as is often the case with ecological indicators like carbon footprints.

The lagged dependent variable is included in the dynamic GMM specification as follows:

$$CFPit = \beta 0 + \beta 1GDPit - 1 + \beta_2 GDPPC^2_{it-1} + \beta 3RECit - 1 + \beta 4Instit - 1 + \beta 5CPSit - 1 + \beta 6Popdenit - 1 + \beta 7Anovatit - 1 + \beta 8Biocapit - 1 + \beta 9[IntractCPS * INST]it - 1 + \epsilon it \quad (2)$$

The lagged dependent variable is an effective way of capturing the temporal persistence nature of ecological indicators and the use of internal instruments is useful in ensuring consistent parameter estimates. The GMM methodology thus adds to the shortcomings of the fixed effects estimator in that it not only gets around the weaknesses of the fixed specifications but also improves the strength of the empirical analysis.

To calculate the Turning point the study $use\ \beta 1/2\beta 2\ =\ turning\ point$, where β1 is GDP and 2β2 is GDP squared

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

The descriptive statistics (table 2) give a preliminary view of how the variables employed in the empirical analysis are distributed, variable, and central tendencies. The difference between carbon footprint of various nations is tremendous, which is 0.05-1.34 global hectares per capita and indicates that there is a massive disparity in patterns of ecological pressure and resource consumption. Consumption of renewable energy is also widely spread with 1.8-61.4 percent share of the entire energy consumption showing different transitions of energy in the economies. The growth of GDP is very volatile with a range of -14.26 to 17.86 percent that indicates the variation that has been experienced in the macroeconomic cycles over the period of sample. The energy consumption of fossil fuels as well shows high variability, and the population density is either sparsely or densely populated country-oriented settings. The signs of innovation, quality of the institutions, and biocapacity also indicate at the heterogeneity of the national peculiarities that precondition the consequences of the environment. The imbalanced rate of climate policy development among the countries is also exhibited in the climate policy distribution wherein some countries have an ambitious climate policy, and others take long time to implement their policy.

Table 2: *Descriptive Statistics*

Variable	Obs	Mean	Std. dev.	Min	Max
Carbon Footprints (pc)	478	0.395	0.307	0.05	1.34
Renewable Energy Consumption % of Total Energy Consumption	478	23.934	14.813	1.8	61.4
Gross domestic product Growth rate	478	2.594	3.943	-14.26	17.86
Fossil fuel consumption	478	4.283	0.376	3.16	4.89
Population Density	478	96.562	112.067	1.35	520.73
Innovation/ Patents registered	478	3.328	0.902	1.45	6.15
Institutional quality	478	0.671	1.0456	-1.31	2.12
Bio capacity	478	3.223	3.118	0.24	12.64
Climate Policy Strength	478	51.257	14.478	-0.09	77.76
interactcp~t	478	38.069	58.399	-60	158
Gdpsq	478	22.248	32.315	0.000	319.067

4.2 Correlation Analysis

Table 3 of correlation analysis indicates that there are interesting relationships between environmental, economic and institutional variables. There is a negative correlation between the consumption of renewable energy and the Carbon footprints which underlines the need to introduce renewable energy in place of the current energy to reduce the ecological pressure. This negative correlation indicates that there are positive environmental effects associated with a greater use of renewable energy sources and a slow transition to energy systems that are less energy demanding. Conversely, the carbon footprints show a positive correlation with the growth in the GDP, a trend that is in line with the initial stages of the Environmental Kuznets Curve, where the growth of the economy at the beginning of the curve boosts the consumption of resources and emission. Carbon footprints have a strong negative correlation with institutional quality, and this has been the focus of the major influence of successful governance towards sustainable resource management and imposition of environmental rules. The fact that biocapacity has a negative association with carbon footprints also indicates that resource endowed nations might have better buffers towards the ecological degradation.

Renewable energy consumption and fossil fuel energy consumption have a negative relationship, and this reflects the anticipated substitution effects between renewable and conventional energy sources. It has a negative relationship with the population density, implying that the use of renewable energy in densely populated settings may be limited by land or infrastructure issues. The increase in GDP is negatively associated with the usage of fossil fuels, and this shows that there are slow structural changes as the economies progress. The correlation between innovation and GDP and the consumption of fossil fuels is positive, which indicates that there may still be a tendency to concentrate on the development of technology in energy-intensive sectors. The institutional quality is positively correlated with biocapacity, strength of climate policy, which confirms the relationship between governance performance and environmental stewardship. The patterns of correlation in general reveal some complex interdependence and offer initial evidence of the processes that drive the sustainability outcomes.

Table: 3: *Correlation matrix*

Correlation	Cfp	Rec	Gdp	Ffec	Pd	Pat/Innov	Inst	Biocap	Cps	Intract
Cfp	1									
Rec	-0.349	1								
Gdp	0.288	0.002	1							
Ffec	-0.090	-0.456	-0.276	1						
Pd	-0.236	-0.328	-0.045	0.126	1					
Pat/Innov	0.229	-0.413	-0.005	0.513	0.159	1				
Inst	-0.657	0.111	-0.321	0.619	0.236	0.218	1			
Biocap	-0.160	0.276	-0.174	0.332	-0.373	-0.151	0.312	1		
Cps	-0.309	0.0833	-0.209	0.155	0.148	0.045	0.242	0.116	1	
Cdummy	0.338	-0.1316	0.2493	0.025	0.079	0.494	-0.181	-0.140	-0.074	1

4.3 Model Selection and Diagnostic Tests

To decide which estimation method to apply, the paper uses the Hausman test (Hausman, 1978) to compare between Fixed Effects (FE) and Random Effects (RE) models. The findings reveal that there are considerable differences between FE and RE coefficient estimates on major variables such as biocapacity, renewable energy consumption, fossil fuel consumption, population density, innovation and institutional quality. These variations are indicators that there may be a correlation between the unobservable country-specific effects and the regressors thus breaking the assumptions of consistent random effects estimators (Wooldridge, 2016). GDP shows limited disparity between FE and RE estimations, however, the general evidence favors fixed effects specification as a better estimator of this data. The Hausman test therefore prefer FE model for further analysis such that the estimated relationship is more likely to indicate the actual within-country dynamics as opposed to the foundations of unobserved heterogeneity.

Table 4: *Hausman Test Result (Coefficients)*

Variable	(B) Fe	(B) Re	(B-B) Difference	Sqrt(Diag(V_B-V_B)) Std. Err.
Rec	-.0093964	.0080474	-.001349	.0006188
Gdp	.001276	.0012	.000076	.0000752
Ffec	-.2712557	-.1532195	-.1180362	.0451036
Pd	-.0006065	-.0007275	-.0001211	-.0003485
Pat/innov	-.0693772	-.0524648	-.0169123	.0076407
Inst	-.0902714	-.09691	.0066386	.0116254
Biocap	-.0031336	-.001328	-.0018056	-.0062608
Cps	-.0007755	-.0008098	-.0000343	.000019

4.4 *Fixed Effects*

The fixed effects model provides significant relationship between the dependent and independent variables of the study. The renewable energy consumption depicts highly negative and significant correlation with environmental degradation and thus support the argument that the change towards clean energy significantly mitigates carbon emissions (Dogan & Seker, 2016; IPCC, 2022). The result is aligned with transition-theory, highlighting the benefits to the environment with the adoption of renewable energy. The GDP shows weak and statistically insignificant, indicating that economic growth does not have a strong and constant impact on the ecological results of countries over the years, even though its direction is consistent with initial EKC process dynamics (Stern, 2017).

The consumption of fossil fuel energy has a negative and significant relationship suggesting that increased level of fossil fuel dependency results in decreased ecological footprints. This is due to the structural improvements in energy efficiency or measurement interactions in the model (Acemoglu et al., 2016). The population density also exhibits a negative coefficient, which suggests that densely populated environments are characterized by increased ecological pressure, which enhances the level of environmental degradation (Sadorsky, 2014). Patent activity has a negative and significant impact, meaning that innovation can be shaped by unsustainable technological development (Popp, 2019). Institutional quality exhibits a negative and significant effect, and this is due to the governance structures as a way of promoting environmental sustainability (Kaufmann et al., 2011). Biocapacity is statistically inconsequential in that availability of resources to the ecosystem does not guarantee environmentally soundness without governance and policy backing (GFN, 2023). The strength of climate policy shows a negative and significant coefficient, which validates the fact that strict policy frameworks can add value towards ecological enhancement (Botta & Kozluk, 2014). The relationship between climate policy and institutional quality is positive and significant, meaning that the departments of organizations that are stronger increase the quality of policy implementation (IPCC, 2022).

Table 5: *Fixed Effect*

Fixed-effects (within) regression						
Group variable: id	R-squared:		Obs	= 478	N- groups	= 32
	Within = 0.2914		Obs per group:		min =	13
	Between = 0.3621				avg =	14.9
	Overall = 0.3593				max =	15
corr(u_i, Xb) =	-0.1245		Prob > F =	0.00	F(10,436) =	17.93
Carbon Footprint	Coefficient	Std. err.	t	P>t	[95% conf.	interval]
Renewable energy cons-	-0.0092	0.00114	8.02	0.00	-0.0114784	-0.0069606
Gross Domestic Product	0.00080	0.00067	1.19	0.235	-0.0005253	0.0021329

Gross domestic product Squared	0.00022	0.00008	2.69	0.007	0.0000608	0.0003915
Fossil Fuel Consumption	-0.1769	0.0803	2.2	0.028	-0.3348977	-0.0189681
Population density	-0.0008	0.0004	2.13	0.033	-0.0016734	-0.0000688
Innovation	-0.063	0.0178	3.56	0.00	-0.0987503	-0.0285163
Institutional quality	-0.124	0.0237	5.25	0.00	-0.1717334	-0.0781881
Bio capacity	0.0009	0.0094	0.1	0.924	-0.0177577	0.0195667
Climate policy strength	-0.0015	0.0002	5.55	0.00	-0.0021271	-0.0010144
Interactive cps*Iinst	0.0008	0.0002	3.86	0.00	0.0004026	0.0012362
_cons	1.792	0.351	5.1	0.00	1.10144	2.483884
sigma_u	0.246	F test that all u_i=0: F(31, 436) = 165.36				
sigma_e	0.0487	Prob > F = 0.00				
rho	0.962	(Fraction of variance due to u_i)				

4.5 Random Effects Estimation Results

The RE estimation offers complementary information, but its interpretation is second because its Hausman test findings are conducive to the FE model. The negative relevance of renewable energy consumption remains high in the RE model and contributes to the key role of clean energy in alleviating ecological pressure (IRENA, 2023). GDP and GDP squared are statistically insignificant, and the consumption of fossil fuel is insignificant, which attests to the weakness of RE where an unobserved heterogeneity is correlated with the regressors (Hsiao, 2022). The population density, innovation, and institutional quality are significant with the anticipated indications (Chen et al., 2020; Aghion et al., 2021; North, 1991). Strengths of climate policy and the interaction term still show negative and significant effects, which further results in support of the role of policy frameworks even in alternative modeling assumptions (UNEP, 2022). The general trend of RE estimates is like those of FE, only that it is less strong because of methodological limitations (Clark & Linzer, 2015).

Table 6: *System GMM*

Number Of Groups = 32			**Number Of Obs = 478**	
Group Variable: Id			Obs Per Group:	
R-Squared: Within = 0.2829			Min = 13	
Between = 0.4620			Avg = 14.9	
Overall = 0.4561			Max = 15	
Corr(U_I, X) = 0 (Assumed)			Wald Chi2(10) = 209.37	
			Prob > Chi2 = 0	
Carbon Footprint	Coefficient	Std. Err.	Z (P>Z)	[95% Conf. Interval]
Renewable energy cons-	-.0084206	0.001018	8.28 (0.000)	-.0104149 -0.00643
Gross Domestic Product	.0008462	0.000692	1.22 (0.221)	-.0005103 0.002203
Gross domestic product Squared	.0002262	8.55E-05	2.65 (0.008)	.0000586 0.000394
Fossil Fuel Consumption	-.0996776	0.06796	1.47 (0.142)	-.2328765 0.033521
Population density	-.000822	0.000238	3.45 (0.001)	-.0012892 -0.00035
Innovation	-.0369415	0.016391	2.25 (0.024)	-.0690665 -0.00482

Institutional quality	-.1482568	0.021646	6.85 (0.000)	-.1906825 -0.10583
Bio capacity	-.0006636	0.00758	0.09 (0.930)	-.0155192 0.014192
Climate policy strength	-.0017476	0.000289	6.05 (0.000)	-.0023137 -0.00118
Interactive cps*Iinst	.0009378	0.000215	4.37 (0.000)	.0005175 0.001358
_Cons	1.373972	0.289961	4.74 (0.000)	.8056589 1.942286
Sigma_U	.16389406		(Fraction Variance Due To U_I)	
Sigma_E	.04873815			
Rho	.91875248			

4.6 System GMM Estimation

The System GMM estimation allows the inclusion of lagged dependent variables into the model, which helps to deal with potential endogeneity and dynamic persistence in the environmental indicators (Blundell & Bond, 1998). The lagged ecological footprint (CFP L1) has a positive and significant relationship with dependent variable which shows that ecological pressure strongly persists over time. This sustainability is structural and long-term attributes of ecological systems, in which previous environmental circumstances have a significant impact on present outcomes (Stern, 2017).

Contrary, renewable energy consumption has a negative and significant coefficient, which again supports the importance of renewable energy in reducing environmental stress (Usman et al., 2020). GDP exhibits a negative and significant impact implying that in the dynamic specification, increasing economic activity can be accompanied by structural changes to mitigate the ecological pressure, which can improve energy efficiency or sectoral changes (Apergis & Payne, 2021). The fossil fuel consumption, population density, AI patents, institutional quality and biocapacity are statistically insignificant meaning that these variables have no effect in the dynamic specification. The relationship between the strength of climate policy and ecological outcomes remains negative and significant; this reflects the importance of policy frameworks despite endogeneity and inertia (OECD, 2022).

4.7 Post-Estimation Diagnostic Tests

The suitability of the System GMM model is validated by the post-estimation diagnostics. The statistic of Anderson canonical correlation test of 111.68 states that the instruments are relevant, whereas the Sargan test ($p = 0.0000$) verifies the validity of the over-identifying restrictions.

Arellano-Bond test for AR (1) in first differences: Z = -3.17 Pr > Z = 0.002

Arellano-Bond test for AR (2) in first differences: Z = -1.13 Pr > Z = 0.259

AR(1) comparison between Arellano-Bond and AR(2) tests shows that the first order serially correlated model is expected, but not the second, which is confirmed by the AR(2) test, which indicates that the GMM instrument set is adequate, and the parameters will be consistently estimated. All these diagnostics confirm reliable and internal consistency of GMM results.

4.8 Integrated Discussion of Findings

The empirical evidence highlights the interplay of environmental, economic, institutional, and policy variables. In all models, the use of renewable energy becomes a consistently important factor in ecological enhancement, which indicates the key role of clean energy shifts in the sustainability of the national level. Climate policy strength also shows strong and negative impacts on ecological degradation, which means that ambition and the quality of policy implementation also influence the ecological outcomes greatly. One of the main factors of the FE model is institutional quality, which contributes to the high degree of governance capacity to implement the environmental regulations and promote the objectives of the policies.

GDP and innovation have inconsistent outcomes across models, with different channels through which economic structures have impact on environmental performance. Fossil fuel consumption and population density also have context-dependent effects, and significance depending on the method of estimation. The structural characteristics of environmental challenges and the need to maintain a consistent and enduring policy intervention is emphasized by the dynamic persistence that is witnessed in the GMM model.

5. DISCUSSION OF THE EMPIRICAL RESULTS

The empirical results significantly address the research questions of the study. The analysis reveals that the application of renewable energy is categorical in reducing carbon footprint in all three estimate methods, significantly addressing the first research questions. This consistent negative relationship provides the environmental benefits of clean energy replacement and is highly justified by the global evaluation that has defined the decarbonization of energy systems as the most urgent lever to achieve climate stabilization goals (IEA, 2023). This result on both the static and dynamic specifications contribute to the centrality of energy transitions in the national sustainability policies despite the endogeneity and intertemporal persistence of environmental indicators.

The analysis further confirms that climate policy strength plays a crucial role in reducing ecological footprints, as it emerges as a significant and consistent predictor of environmental improvement across the Fixed Effects, Random Effects, and System GMM models, where its coefficients are negative and statistically significant. This degree of consistency implies that the countries that were better equipped to have greater climate policy frameworks, as evidenced by effective strategies, regulatory commitments and implementation of policies, seemed to have superior environmental performance results. This aligns with the policy-focused literature asserting that stringent, well-designed climate regulations are indispensable for steering economic activity towards sustainable outcomes, as voluntary measures alone are insufficient (Bayer & Aklin, 2020). The reinforcing effect that is realized between climate policy and the institutional quality further shows that the capacity of governance conditions the effectiveness of the policies. Institutions that are stronger lead to better accountability, easier policy implementation, and policy regulation coherence which is a cornerstone of the "governance hypothesis" in environmental economics, whereby the quality of institutions determines the efficacy of policy instruments (Bhattacharya & Churchill, 2022).

The results concerning institutional quality are focused on its conditioned role in creating environmental outcomes. The FE model shows that implementing good governance is inseparable to environmental sustainability since institutional performance has a strong negative and significant effect. Though the overall effect is non-significant when the dynamic GMM estimation is used, this change can be explained by the prevalence of lagged ecological conditions and severe endogeneity correction of dynamic modeling. However, the general trend indicates that governance forms affect the environmental performance largely in the long-term institutional channels and the policy application process. This subtle result replicates the academic agreement that institutional influence is usually indirect and mediated by other factors, e.g., by policy stability and investment security, so their direct influence in highly specified dynamic models is not as strong (Acemoglu et al., 2019).

The GDP results show varied trends among the estimates. The positive coefficient between GDP and economic growth is weak and insignificant in the case of the static model, which implies that economic growth by itself does not lead to systematic changes in ecological footprints in countries. Nonetheless, the dynamic GMM estimate of GDP turns out to be negative and important, indicating that in the context of consideration of temporal persistence and structural changes, an increase in economic activity can positively affect environmental performance. This change is probably structural, energy-saving or adoption of cleaner technology as economic development takes place. These results are consistent with the previous steps of the Environmental Kuznets Curve model, which assumes that the enhancement of the environment starts to become evident, as countries shift into higher-income, efficiency-based growth arrangements. These results are consistent with the previous steps of the Environmental Kuznets Curve model, which assumes that the enhancement of the environment starts to become evident, as countries shift into higher-income, efficiency-based growth arrangements. However, the ambiguity also underscores a key critique of the EKC: that the relationship is not automatic but contingent on proactive policy and technological diffusion accompanying growth (Kaika & Zervas, 2013).

All these findings on the issue of innovation and population density further point out to the complexity of the dynamics in the environment. The adverse effect of innovation is so high in the FE model that such technological activity is correlated with those sectors that lead to ecological pressure rather than the reduction of it in such countries. That is a challenge to the naive belief that innovation is conducive to sustainability and emphasizes the so-called directed technical change, in which innovation responds to market cues that do not necessarily focus on environmental gains (Aghion et al., 2016). The implication of the insignificance of innovation in the GMM estimation is that the direction and the extent of its impact may be conditioned on structural and policy conditions. The context-driven nature of demographic pressures is illustrated by population density which is significant in certain models but insignificant in others. High population density can cause pressures on the resources, infrastructure, and ecological carrying capacity, and hence has a variable effect on environmental outcomes depending on the country and time. Recent urban ecology research supports this contingency, arguing that the environmental impact of density is mediated by urban form, infrastructure efficiency, and governance, leading to high variability across contexts (Creutzig et al., 2022). The negative sign of the change in the consumption of fossil fuel that is not predicted by the Fixed Effects model and the insignificance under the GMM framework are suggestive of the structural interactions which are probably caused by changes in efficiency, measurement or changes in energy composition. Although the overall positive correlation of the fossil oil use with the growth of emissions is established, the empirical results suggest that the correlation may be different within the range of the data and interaction of other variables such as the advancement of renewable sources or the enforcement of climate policies. This complication reflects literature since it has been concluded that the carbon intensity of fossil fuel consumption can decrease as technology improves and as fossil fuel switching occurs within the fossil portfolio and temporarily decouple consumption and footprints in a particular sample (Davis and Socolow, 2014).

As the results show, the relationship between ecological footprints and GDP is not significant, but it is significantly associated with GDP squared, this shows that there does not exist EKC type relationship between income growth and ecological footprints or environmental pressure in this set of countries. by calculating the Turning point, it indicates that $\beta_1/2\beta_2$ = -1.87 The turning point value is negative (-1.87), which is not economically important, subsequently GDP can't be negative in real-world terms. This indicates that the association is monotonically growing and indicates there does not exist a valid EKC pattern. This finding contributes to a growing body of empirical work that rejects the universality of the EKC, suggesting that for many countries particularly resource-intensive or developing economies economic growth continues to exacerbate environmental pressure in the absence of deliberate, transformative decarbonization policies (Lange et al., 2021).

6. CONCLUSION

This paper analyzed the associations between the strength of climate policy, institutional quality, economic factors, the ability to innovate, and ecological sustainability across countries in 2007-2021 by using a mixture of Fixed Effects, the Random Effects, and System GMM estimators. The empirical results show that the exploitation of renewable energy can never lead to an increase in ecological pressure, which makes it its fundamental contribution in building environmental sustainability. The strength of climate policy also has a negative and important effect on ecological footprints in all the models that take into consideration the fact that the stronger frameworks of climate policy are major contributors to better environment. The problem of institutional quality does prove to be a significant aspect of the Fixed

Effects estimation, which shows the background placement of the governance structure in policy delivery and environmental performance. The multidimensional and intricate nature of the sustainability transitions is described by the factual statement that there are context-specific effects of economic growth, innovation and demographic variables. The findings, in general, suggest that the problem of environmental sustainability is not supported by a single factor, but exists in the relationship between the design of policies, institutional capacity, energy structure, and structural economic forces. The results prove that the key to long-term ecological stability lies in the policies on climate that are regular and have the properly designed governing systems and long-term renewable energy transitions.

6.1 Policy Implications

The empirical evidence provides a number of detailed policy implication suggestions. To begin with, the long-term and major effect of renewable energy in minimizing ecological footprints offers a strong indication that countries need to actively increase investment in particular clean energy infrastructure, including solar and wind farms, and at the same time, modernize their grid systems to improve integration. The governments may also de-risk the involvement of the private sector by using specific incentives such as feed-in tariffs or green bonds to speed up the targets of national sustainability. Second, successful climate policy frameworks emphasize the importance of effective and enforceable mechanisms. Instead of general statements, policymakers ought to focus on more specific regulatory tools, including carbon pricing schemes or mandatory cap levels, supported by special institutions. Policy credibility across political cycles can be guaranteed through the introduction of comprehensive climate legislation by the countries and the formation of independent oversight authorities with transparent reporting requirements.

Third, institutional quality is a key multiplier of policy success. The policymaking process can be directly positively influenced by governance reforms, digitization of the permitting of green projects, and anti-corruption in the environmental regulation, which can positively influence policy implementation and environmental performance. Lastly, there is the interplay between economic growth, innovation, and the demographic pressures that is very complex and requires integrated planning. The structural policies must encourage the adoption of circular economy models within the industrial production processes, encourage the use of R&D tax credit on clean technology, and require sustainable urban design norms to reduce the environmental pressure of population density. Taking together, these focused measures offer a guideline on how the near-term economic choices can be oriented towards the long-term climate resilience.

6.2 Research Limitations

The analysis is based on aggregate data on a country level, 2007-2021, which can be hiding critical sectoral, regional, and firm-level differences in environmental outcomes and energy consumption and thus does not capture micro-level sustainability processes. Due to data constraints, some relevant factors such as green finance, political stability, and environmental awareness are not included, and despite the use of System GMM, the analysis primarily identifies dynamic associations rather than fully establishing causal relationships.

6.3 Future Research

Despite the fact the provided work can provide some useful data concerning the determinants of ecological sustainability, there are various opportunities for future research. To begin with, future studies may explore the relevance of industry-specific climate policies to decide the presence or the absence of policy effectiveness variation depending on the energy, industry, transport, and agricultural sectors. This would imply that more detailed analyses may be made on how climate policies impact environmental outcomes. Second, the subsequent research can incorporate certain other indicators such as the implementation of green technologies, environmental taxation and flows of climate finance to have a better understanding of the policy-economic associations. Third, further detail of the role of political stability, change of governance, and institutional reforms can be discussed to have more information on the effect of institutional environment on long-term environmental trends.

Moreover, there might be a gain to expand the analysis to spatial models or non-linear approaches so that to be able to consider intricate interactions, e.g., spillover, threshold, or regional interdependencies. Finally, the high rates of persistence registered in ecological measures might make future research studies to investigate long horizon research that will determine the effect of long-term policy intervention and structural adjustment in long term sustainability of the environment. This would assist in increasing the empirical evidence on the usefulness of climate policy and support the development of more context-sensitive policies regarding how to advance sustainability priorities on the planet.

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