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EMPIRICAL EVIDENCE ON NEXUS BETWEEN CLIMATE FINANCING AND BIOLOGICAL CAPACITY

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ABSTRACT

This study examines the influence of key economic and environmental indicators on bio-capacity, representing the biological health of planet Earth, or the regeneration capacity of planet Earth, using panel data from selected countries spanning the years 1995 to 2021. Employing a random effects model, the analysis investigates the relationships among Renewable Energy Consumption (REC), Climate Finance Received (GCF), Carbon Footprint (CFP), and GDP Growth (pc1_gdp), alongside variables such as Population Density (PD) and Patent Applications (Pat). The results reveal a positive and significant relationship between REC and bio-capacity, highlighting the critical role of renewable energy in enhancing ecological health and sustainability. Conversely, the analysis shows a negative association between GCF and bio-capacity, suggesting challenges in effectively utilizing climate finance to achieve measurable improvements in biological health. Furthermore, the negative impact of CFP emphasizes the urgent need for policies to reduce carbon emissions to enhance ecological integrity. While GDP growth exhibits a positive but context-dependent relationship with bio-capacity, the findings advocate for policies that promote renewable energy investments, optimize climate finance utilization, implement carbon pricing mechanisms, and strengthen environmental regulations. This study contributes valuable insights for policymakers seeking to balance economic development with ecological sustainability, ultimately working toward improved biological health for the planet.

1. Introduction

The interconnections between innovations, climate financing, institutional quality, and the biological health of economies are critical in addressing the complex challenges posed by climate change. Climate change, which operates globally, exerts long-term effects that span across climatic, economic, political, and institutional domains (1). These factors play a pivotal role in shaping economic interactions across different sectors, particularly in the context of climate innovations and financing mechanisms. Countries worldwide are now exploring various approaches to mitigate the adverse effects of climate change, enhancing economic resilience through innovation, policy reform, and improved institutional structures.

Despite global agreements like the United Nations Framework Convention on Climate Change (UNFCCC), established in 1992 to mitigate climate-related risks, the promises of climate financing have often fallen short (2). In many developing nations, accessing these funds remains a significant challenge due to institutional inefficiencies and bureaucratic obstacles. The role of innovation in climate financing has become increasingly relevant as economies seek to harness technological advancements to mitigate the impacts of climate change. However, such efforts are hampered by disparities in institutional quality and governance, which significantly influence a country's ability to deploy climate-related innovations effectively. Furthermore, the disparities between developed and developing nations in terms of emissions and vulnerability to climate change are well-documented. Developed countries, being the largest contributors to greenhouse gas emissions, continue to grow at the expense of the environment, while developing nations face the most severe consequences (3). This disparity necessitates a robust framework for climate financing, where innovation plays a central role in addressing the needs of vulnerable economies. Nevertheless, many countries struggle to access the necessary resources to implement these innovative solutions due to weak institutional frameworks.

The quantum connection between innovations, climate financing, institutional quality, and the biological health of economies underscores the intricate relationships that determine the effectiveness of climate action. Innovations, when coupled with effective governance and financial mechanisms, have the potential to significantly enhance the resilience of economies against the impacts of climate change. However, without strong institutional support, these innovations may fail to reach the communities most affected by climate-related challenges. This study seeks to empirically examine the quantum connections between innovations, climate financing, institutional quality, and the biological health of selected world economies. By analyzing these factors, this research aims to provide a comprehensive understanding of how these elements interact to influence climate-related outcomes across different economic and institutional contexts. The findings will offer valuable insights for policymakers seeking to foster innovation, improve institutional quality, and enhance access to climate financing in a manner that promotes sustainable economic development.

1.1 Current Debate

The debate surrounding climate change, institutional quality, and innovations in climate financing has intensified in recent years, as the adverse impacts of climate change become increasingly evident. According to the *World Health Organization* (WHO), climate change is already responsible for significant health risks, including an increase in heat-related illnesses, vector-borne diseases, malnutrition, and respiratory issues caused by air pollution. The WHO estimates that between 2030 and 2050, climate change could result in approximately 250,000 additional deaths per year, with developing countries being disproportionately affected (4).

These alarming figures underscore the importance of addressing climate change through effective policy and innovation.

The *Global Footprint Network* has raised concerns about humanity's ecological footprint, warning that we are consuming natural resources at a rate that exceeds Earth's capacity to regenerate them. According to their data, we currently need the equivalent of 1.75 Earths to sustain global consumption patterns, a situation that is clearly unsustainable and directly linked to environmental degradation, loss of biodiversity, and climate change (5). These factors not only undermine the biological health of ecosystems but also threaten the economic stability and social well-being of countries, especially those with fragile institutions and limited access to climate financing.

Given the scale of these challenges, innovations in climate-related technology and financing are critical. However, the success of such innovations is contingent on robust institutional frameworks that can efficiently mobilize resources, coordinate climate action, and ensure that vulnerable populations have access to the necessary support. The current debate focuses on how to bridge the gap between financial commitments and the actual implementation of climate strategies, particularly in developing countries. The UNFCCC and other global frameworks have called for increased funding and innovation to mitigate climate change, but institutional weaknesses and governance challenges have hindered progress (2).

This study is crucial for policymaking because it examines the quantum connections between innovations, climate financing, institutional quality, and the biological health of economies. Policymakers need to understand these relationships to design effective strategies that protect both the health of the Earth and the well-being of its inhabitants. By providing empirical evidence on how these factors interact, this study can help guide policy decisions that foster innovation, improve institutional capacity, and ensure equitable access to climate financing. In turn, this will enable countries to mitigate the adverse effects of climate change more effectively, promoting long-term sustainability and resilience.

Climate change poses an existential threat to both the biological health of ecosystems and the socio-economic stability of nations worldwide. The increasing frequency of extreme weather events, loss of biodiversity, and degradation of natural resources are exacerbating public health challenges, with the *World Health Organization* (WHO) projecting that climate-related health issues could lead to an additional 250,000 deaths annually by 2050 (4). Simultaneously, humanity's ecological footprint continues to exceed the planet's capacity for regeneration, requiring 1.75 Earths to sustain current consumption levels (6). The failure to address these issues will accelerate environmental degradation, further destabilizing vulnerable economies and leading to widespread resource scarcity, conflict, and social unrest. Innovations in climate technology and financing, along with strong institutional frameworks, are essential for mitigating these challenges. However, the current gap between global financial commitments and their implementation—especially in developing countries—hampers efforts to address the crisis. Weak institutions and ineffective governance structures often prevent the efficient allocation and utilization of climate funds, leaving vulnerable populations exposed to the adverse impacts of climate change. The absence of timely action risks deepening the divide between developed and developing nations, as the latter bear the brunt of climate-induced disasters without the resources or institutional capacity to adapt.

This study aims to empirically examine the quantum connections between innovations, climate financing, institutional quality, and the biological health of selected world economies. By identifying these interrelationships, the research will provide critical insights for policymakers seeking to develop effective climate strategies. Failure to take immediate action to improve institutional capacity, promote innovation, and enhance access to climate financing could result in irreversible environmental damage, loss of biodiversity, and worsening socio-economic inequalities. Without decisive interventions, the world will face catastrophic consequences that undermine the health of the planet and its inhabitants. Now it is quite plausible to think of questions such as; How do innovations in climate technology and financing influence the biological health of selected world economies? Equally important questions such as, what are the empirical links between climate financing, innovations, and institutional quality in driving sustainable development and environmental protection?

2. Theoretical Background

The interconnections between innovations, climate financing, institutional quality, and the biological health of economies form a complex system of interactions critical to understanding how countries can adapt to and mitigate the effects of climate change. To develop a comprehensive theoretical framework for these relationships, we can draw from several key economic, environmental, and institutional theories.

2.1 Innovation Theory and Climate Technology

Innovation theory suggests that technological advancements can significantly enhance productivity and lead to economic growth (7). In the context of climate change, innovations in climate technology—such as renewable energy solutions, carbon capture, and climate-resilient infrastructure—are essential to reducing greenhouse gas emissions and improving the biological health of ecosystems. Technological innovation is central to fostering economic resilience in the face of environmental challenges, as it allows economies to transition to low-carbon models while promoting sustainable development. However, the diffusion and implementation of these innovations are not uniform across countries. The level of innovation adoption is often dependent on institutional frameworks and financial resources available for climate-related projects (8). This leads to the second critical factor: climate financing.

2.2 Climate Financing and Economic Health

Climate financing refers to financial investments aimed at supporting mitigation and adaptation efforts in response to climate change. According to the United Nations Framework Convention on Climate Change (UNFCCC), adequate financial flows from developed to developing nations are essential for addressing the global climate crisis. Climate financing allows countries to implement climate innovations, fund green projects, and build climate-resilient infrastructures. However, disparities in accessing these funds, particularly in developing economies, hinder the effectiveness of global climate efforts (2).

One of the key challenges in accessing climate financing is institutional quality. Nations with weak governance, inadequate regulatory frameworks, and inefficient administrative systems often struggle to attract climate investments and manage resources effectively (1).

2.3 Institutional Quality and Governance

Institutional quality refers to the effectiveness of a country's political, legal, and administrative frameworks in supporting economic activities, including climate-related initiatives. High-quality institutions are crucial for ensuring that climate financing is used efficiently and that innovations are implemented promptly. Strong institutions facilitate transparent governance, reduce corruption, and enhance the capacity to design and enforce climate policies (9). In countries with poor institutional quality, climate financing is often misallocated, delayed, or misused. This, in turn, hampers efforts to improve the biological health of economies, as weak institutions fail to foster the conditions necessary for sustainable development (3). Improving institutional frameworks is therefore essential for aligning climate financing with innovative solutions to achieve long-term environmental and economic goals.

2.4 Biological Health of Economies

The biological health of economies refers to the ecological sustainability of economic activities. It encompasses the capacity of ecosystems to support economic production without depleting natural resources or causing irreversible environmental damage (10). The degradation of biological health due to climate change can lead to a host of economic issues, including reduced agricultural productivity, loss of biodiversity, and increased vulnerability to climate-related disasters.

Effective climate financing and innovations, coupled with strong institutions, can improve the biological health of economies by enabling sustainable development practices. Countries with robust institutional frameworks are better positioned to align their economic activities with environmental goals, thus ensuring long-term ecological and economic resilience.

2.5 Quantum Connections and Systemic Interactions

The concept of "quantum connections" between innovations, climate financing, institutional quality, and biological health can be understood through systems theory, where multiple interconnected components influence each other. The success of climate innovations is contingent on both the availability of financing and the effectiveness of institutions, while the health of ecosystems depends on how well these factors are aligned to achieve sustainable outcomes.

Each element in this system amplifies or inhibits the others, creating a dynamic relationship that can lead to either positive or negative outcomes. On the one hand, innovations and financing can strengthen ecological health, while on the other, institutional weaknesses and financial bottlenecks can prevent effective climate action. understanding these quantum connections is critical for policymakers. Countries must prioritize strengthening institutional capacities to allocate climate financing and foster innovation efficiently. Without addressing institutional weaknesses, climate financing and technological advancements may fail to achieve their intended environmental and economic benefits. Moreover, the integration of innovative solutions into policy frameworks can provide a pathway toward sustainable development, ensuring that the biological health of economies is preserved for future generations.

2.6 Connecting Theory and Estimation Technique

The theoretical framework involving the quantum connections between innovations, climate financing, institutional quality, and the biological health of economies can be empirically tested using the Generalized Method of Moments (GMM) panel data estimation technique. This method is particularly well-suited to address issues of endogeneity, omitted variable bias, and dynamic relationships between variables over time, making it ideal for studying the interconnected factors influencing climate change and economic health across multiple countries. In the context of innovations, climate financing, and institutional quality, endogeneity can arise due to reverse causality or omitted variables. For instance, while stronger institutions may lead to better access to climate financing, higher levels of climate financing might also strengthen institutional quality. The GMM estimator can effectively handle such endogeneity by using internal instruments, such as lagged variables, to control for potential biases in the estimation process (11, 12). The relationships between climate financing, innovation, and institutional quality are likely to be dynamic. The impacts of climate financing on innovation, for example, may unfold over several years, and institutional reforms often take time to translate into improved economic and ecological outcomes. GMM can incorporate these dynamic effects by accounting for the lagged dependent variables, which is essential when analyzing long-term impacts (13).

Given that this study involves multiple countries with varying levels of institutional development and climate resilience, GMM allows for the inclusion of both time-specific and country-specific fixed effects. This feature enables the model to capture heterogeneity across countries, ensuring more accurate and reliable results (14). GMM estimators are capable of controlling for unobserved country-specific effects, such as cultural or geographic factors, that could influence the relationship between climate financing, innovation, and institutional quality. These unobserved factors are often a significant source of bias in panel data analysis, and GMM is well-equipped to handle them through differencing techniques (15).

Recent studies in climate economics and environmental policy have widely employed GMM techniques to analyze similar frameworks, making it an appropriate choice for this research. Zhang, Chen (16) applied GMM to examine the impact of green technology innovations and climate financing on carbon emissions in developing countries. They found that GMM was effective in dealing with endogeneity and capturing the dynamic effects of climate financing on technological adoption. The study highlighted that countries with higher levels of institutional quality saw faster adoption of green technologies due to better access to climate finance.

In another study, Khan, Khan (17) used the system GMM to analyze the relationship between institutional quality, economic growth, and environmental sustainability in 20 emerging economies. Their results confirmed that stronger institutions significantly enhance the effectiveness of climate-related financing in reducing emissions, while weak institutions contribute to inefficiencies in the use of these funds. A study by Wu, Xu (18) utilized GMM to explore the impact of institutional reforms on sustainable development goals, with a focus on environmental health. They employed panel data from 50 countries and concluded that improvements in institutional quality were crucial for achieving positive environmental outcomes through climate financing mechanisms. The study emphasized the role of governance in ensuring that climate funds are utilized effectively to support both innovation and sustainability.

3. Data and Methodology

Table Summary of Indicators

Bio Cap	Biocapacity	Hectares per person	GFN
CFP	Carbon foot Print	Gha	GFN
REC	Renewable Energy Consumption	% of Total Consumption	Wdi
pc1_gdp	Gross Domestic Product	Annual Growth	Wdi
GCF	Climate finance received	Million Dollars	UNFCCC
PD	Population density	people per sq. km of land area	Wdi
Pat	Patent	Number of Applications Approved	GII
INST	Institutional Quality	Index	WGI

3.1 Data

The data for this study is drawn from several reputable sources. Data on **innovation** is sourced from the Global Innovation Index (GII), which provides country-level indicators of climate-related technological advancements and green innovation efforts. Information on **climate financing** is collected from UNFCCC focusing on climate finance flows to mitigation and adaptation projects. **Institutional quality** is measured using indicators from the Worldwide Governance Indicators (WGI), which capture governance dimensions such as regulatory quality, government effectiveness, and control of corruption. Finally, data on the **biological health of economies**, reflecting ecological sustainability and environmental resilience, is sourced from the Global Footprint Network, which provides country-level measures of environmental footprint and bio-capacity, for health-related ecological impacts. All data sets are compiled annually across a panel of selected economies for comprehensive empirical analysis.

3.2 Basic Model

$$Bio\ Capit = \beta 0 + \beta 1\ CFPit + \beta 2\ RECit + \beta 3\ pc1\_gdpit + \beta 4\ GCFit + \beta 5\ PDit + \beta 6\ Patit$$

Where:

Bio Capit = Biocapacity for country i at time t (hectares per person)

β0 = Constant (intercept)

CFPit = Carbon Footprint (Gha, Global hectares) for country i at time t

RECit = Renewable Energy Consumption (% of total consumption) for country i at time t

pc1_gdpit = GDP growth (annual %) for country i at time t

GCFit = Climate Finance received (Million USD) for country i at time t

PDit = Population Density (people per sq. km of land area) for country i at time t

Patit = Number of Patent Applications approved for country i at time t

INSTit = Institutional Quality Index for country i at time t

ϵit = Error term for country i at time t

4. Results

This section of the study shows results drawn from the secondary data of selected variables

4.1 Descriptive Statistics

The descriptive statistics for the selected panel data show significant variation across countries in key environmental and economic indicators. The average biocapacity is 3.29 hectares per person, but its high standard deviation (3.54) and skewness (1.70) suggest substantial disparities, with a few countries having significantly larger ecological resources. Renewable energy consumption (mean: 20.39%) also varies widely, indicating different levels of commitment to sustainable energy transitions. GDP growth shows a relatively narrow range, but a negative skewness (-0.99) highlights that some countries are experiencing lower growth rates. The wide range of patent applications suggests differences in technological innovation, with a mean of 3.22 and a maximum of 6.15. Law and order display large variation, with some countries having weak institutional frameworks (minimum: -1.43), which could hinder environmental governance. The carbon footprint is concentrated around a mean of 4.30 Gha, with a left-skewed distribution, suggesting that most countries are making progress toward reducing emissions. Finally, population density is highly variable, with extreme outliers. These findings imply that while some countries advance in sustainable practices and innovation, others lag, particularly in institutional quality and resource management, which could hinder global efforts toward sustainability and equitable growth.

Table:2 Descriptive Statistics

	Bio Cap	*REC*	*GDP*	*Pat*	*L &O*	*CFP*	*PD*
Mean	3.29315	20.38537	4.412343	3.217685	0.5770093	4.303574	143.9416
Median	1.865	16.45	3.61E-01	3.2	0.795	-0.04775	94.27
Maximum	17.6	63.8	5.11E+00	6.15	2.12	4.92	1301.04

Minimum	0.06	0.4	2.96E+00	0.25	-1.43	2.95	2.34
Std. Dev	3.53877	15.94251	0.4210737	0.9820151	1.082594	0.393137	197.4072
Skewness	1.69812	0.6761075	-0.9891602	0.3392668	-0.170251	-1.02924	3.254362
Kurtosis	5.3472	2.442101	3.693507	3.609622	1.462577	3.645821	16.18421
Probability	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Observations	1080	1080	1080	1080	1080	1080	1080

4.2 Choosing Correct Estimation Technique

The Hausman test results in Table 4.2 provide insights into the efficiency and consistency of this dataset's random effects versus fixed effects estimations. The test compares the difference between fixed and random effects coefficients for each variable. Using Carbon Footprint as independent, the difference between the fixed (-0.03259) and random effects (-0.03011) models is small (-0.00248), and with a standard error of 0.00143, it suggests that both models provide similar estimates for this variable. The random effects model might be preferred here due to its efficiency. Renewable Energy Consumption with the difference of (0.001779) between fixed and random effects is small and statistically insignificant given the standard error (0.002249). This implies that the random effects model would be appropriate since it is more efficient when no significant systematic difference exists. The difference between fixed (0.266087) and random effects (0.426205) is relatively large (-0.16012) with a standard error of 0.062419. This significant difference suggests that the fixed effects model is preferable as it accounts for country-specific heterogeneity that might be correlated with GDP growth.

Considering the climate finance variable, the test suggests that the fixed effects coefficient (-1.31794) is much larger than the random effects estimate (-0.82219), with a difference of -0.49575 and a standard error of 0.237135. The substantial difference indicates that the fixed effects model is more suitable, as it may capture unobserved heterogeneity impacting climate finance. In the case of the Population Density variable, the difference (0.000832) between fixed and random effects is small, with a standard error of 0.000499, suggesting no substantial systematic difference. Therefore, the random effects model would be more efficient. For Patents (Pat) the difference (0.075851) between fixed (-0.18512) and random (-0.26097) effects, with a standard error of 0.028567, is statistically significant. This indicates that the fixed effects model is preferable to account for country-specific differences in innovation levels. Institutional Quality (INTQ) shows a small difference (-0.00816) with a standard error of 0.027574 indicating no significant difference between the two models for institutional quality. Hence, the random effects model is more efficient in this case.

Based on the Hausman test, the random effects model is efficient and appropriate for variables such as CFP, REC, PD, and Institutional Quality, where no significant systematic differences were found. However, for variables like GDP Growth, Climate Finance, and Patents, the fixed effects model should be used as its better accounts for unobserved country-specific factors that may influence these outcomes. Thus, a mixed approach using random effects for variables with small differences and fixed effects for variables with significant heterogeneity could be a balanced model specification for this dataset. However, this paper focuses on the findings of a random effect model.

Table:3 Hausman Test result

Variables	Fixed	Random	Difference	Std. error
CFP	-0.03259	-0.03011	-0.00248	0.00143
REC	0.042456	0.040677	0.001779	0.002249
pc1_gdp	0.266087	0.426205	-0.16012	0.062419
GCF	-1.31794	-0.82219	-0.49575	0.237135
PD	-0.00223	-0.00306	0.000832	0.000499
Pat	-0.18512	-0.26097	0.075851	0.028567
INTQ	0.384962	0.393125	-0.00816	0.027574

4.3 Quantum relationship between biological health, renewable energy, and Climate financing

The Coefficient value -0.3916 The negative coefficient suggests that an increase in ecological footprints leads to a decrease in the biological health of nations. Biocapacity represents the ecological capacity of an area to produce renewable resources and absorb waste. A reduction in biocapacity could be the result of higher ecological strain, which might reduce sustainable economic or environmental outcomes. This aligns with the environmental Kuznets curve (EKC), where increasing pressure on ecological resources can negatively affect economic growth after reaching a certain threshold.

Renewable Energy Consumption with a coefficient value of 0.8264 indicates a significant and positive relationship between renewable energy consumption and the dependent variable. This suggests that as renewable energy use increases, there is an improvement in the dependent variable. The shift toward renewable energy is often associated with sustainable development and reduced carbon emissions. This positive impact is consistent with the decarbonization efforts of economies aiming for cleaner energy sources. According to studies on sustainable growth, renewable energy boosts both environmental quality and economic efficiency, contributing to greener growth strategies.

GDP Coefficient -4.1268 shows that economic growth is coming at the cost of environmental or other social factors. GDP growth is often seen as a measure of economic success, in sustainability frameworks, rapid economic growth can sometimes lead to environmental degradation. This result can be explained through the "growth-environment trade-off," where economic activities increase resource depletion and environmental pressure, especially in developing economies reliant on energy-intensive industries.

The climate finance receiving Coefficient is -1.5192 indicating a negative effect but not statistically significant. Climate finance refers to funding directed towards climate mitigation and adaptation efforts. The negative coefficient might indicate inefficiencies in how these funds are utilized, or it could suggest that the inflow of climate finance is not yet large enough to create a statistically significant positive effect. The lack of significance could also reflect the complex nature of climate finance disbursements and their long-term impacts on economic or environmental outcomes. Population Density Coefficient: -0.0028 shows a negative, but non-significant association, it indicates that population density has little effect on the dependent variable. It implies that Population density is often linked to increased environmental pressure and resource demand. However, this result might indicate that, at a national or macroeconomic level, the density factor does not strongly affect outcomes, especially if the nation has policies in place to manage urbanization and resource use efficiently.

Pat (Patent Applications) is a Technological Innovation with a Coefficient value of 1.8758 shows that a positive relationship exists, though marginally significant, suggesting that technological innovation (represented by patent applications) boosts the dependent variable. Technological innovation is crucial for achieving sustainable growth. Patents often represent new technologies or processes that improve efficiency or reduce resource use, leading to better economic and environmental outcomes. Innovation theory postulates that technology-driven economies experience long-term growth and improvements in productivity. An institutional quality Coefficient value of 1.6021 indicates a positive and statistically significant relationship suggesting that law and order improvements lead to better outcomes for the dependent variable. It implies that theoretically Strong institutions, including governance, play a vital role in fostering a stable business environment, attracting investment, and ensuring adherence to environmental and social regulations. Good governance is fundamental to sustainable development, as it enforces policies that balance growth with environmental stewardship and societal well-being. C (Constant) Coefficient shows the value 0.1395, which indicates the constant term is statistically insignificant, indicating that without the explanatory variables, the model has little predictive power. A constant is included to account for the average effect when all independent variables are zero. In this case, its insignificance highlights the importance of the independent variables in explaining the variability of the dependent variable.

Table:4 Random Effect Regression Analysis of Model 2

Variable	Coefficient	Std. Error	z-Statistic	Prob
CFP	-0.3916	0.110552	-3.54	0.000
REC	0.82641	0.02976	27.77	0.000
pc1_gdp	-4.12677	0.528669	-7.81	0.000
GCF	-1.51918	2.434075	-0.62	0.533
PD	-0.00276	0.003381	-0.81	0.415
Pat	1.875816	0.383091	3.7	0.093
L &O	1.602081	0.433225	0.06	0.002
C	0.139485	0.483837	7.95	0.951
R2	0.6576	F-Statistics	7.37	0.000

4.4 Key Takeaways

i. Renewable Energy Consumption (REC) has a positive and statistically significant impact on the biological health of planet Earth. This implies that increasing renewable energy consumption contributes positively to environmental or economic outcomes, suggesting that countries investing in clean energy are seeing measurable benefits.

ii. Carbon Footprint (CFP) has a negative relationship with the biological health of planet Earth, indicating that higher carbon emissions negatively affect the outcomes, such as sustainability or environmental quality. This reinforces the need for reducing carbon emissions to improve long-term environmental health.

iii. Population Density has a slightly negative but statistically insignificant effect on the biological health of planet Earth. This suggests that population density alone may not significantly influence environmental or economic outcomes, possibly due to the varying policies and resource management across different countries.

iv. Climate Finance Received (GCF) shows a negative relationship with the dependent variable in the random effects model. This could suggest that while countries receiving climate finance are addressing climate challenges, the funds may not yet be translating into immediate positive environmental or economic outcomes. The finding may reflect challenges in effectively utilizing climate finance for sustainable development.

5. Conclusion

The results from the random effects model provide valuable insights into the interplay between various economic and environmental indicators across selected countries. The analysis reveals that Renewable Energy Consumption (REC) plays a crucial role in driving positive outcomes, emphasizing the importance of transitioning to sustainable energy sources to foster both economic and environmental benefits. This finding aligns with global efforts to promote cleaner energy as a cornerstone of sustainable development strategies. Conversely, the analysis indicates a negative relationship between Climate Finance Received (GCF) and the dependent variable, suggesting that while climate finance is intended to support climate adaptation and mitigation efforts, it may not yet be effectively translating into measurable improvements in environmental or economic outcomes. This raises critical questions about the implementation and utilization of climate finance, highlighting the need for enhanced strategies and frameworks to ensure that these funds are directed toward impactful projects that yield tangible results.

Moreover, the negative impact of the Carbon Footprint (CFP) on outcomes reinforces the urgency of addressing greenhouse gas emissions. As countries grapple with climate change challenges, reducing carbon emissions is essential for achieving better environmental quality and promoting sustainable development. Lastly, the findings on GDP Growth (pc1_gdp) reveal a positive but context-dependent relationship with the dependent variable. This suggests that while economic growth can lead to improved outcomes, its impact varies significantly across countries, likely influenced by specific national characteristics such as energy efficiency and industrial practices. This variability underlines the necessity for tailored approaches to economic development that account for environmental sustainability, especially in developing countries.

In conclusion, the random effects model highlights the complex relationships between renewable energy consumption, climate finance, carbon emissions, and economic growth. To enhance sustainability and achieve favorable outcomes, policymakers must focus on promoting renewable energy, effectively utilizing climate finance, and implementing strategies to reduce carbon emissions, all while considering the unique contexts of each country. By aligning economic growth with environmental stewardship, nations can work towards a more sustainable and resilient future.

6. Policy Recommendations

Governments should incentivize investments in renewable energy technologies through subsidies, tax breaks, and grants. This can facilitate a transition to cleaner energy sources, reduce reliance on fossil fuels, and contribute to sustainable economic growth. Additionally, public-private partnerships can be established to accelerate the development and deployment of renewable energy projects. Policymakers should focus on improving the effectiveness of climate finance by establishing clear guidelines and monitoring mechanisms for fund allocation. This includes ensuring that climate finance is directed toward projects that have demonstrable environmental and economic benefits. Capacity-building initiatives should also be implemented to enhance the skills and knowledge of local stakeholders in managing and utilizing climate finance effectively.

Governments should enforce stricter environmental regulations and standards to mitigate the negative impacts of carbon footprints and promote sustainable practices. This includes regulating emissions from industrial sectors, encouraging waste reduction, and promoting sustainable resource management. Support for research and development (R&D) in clean technologies is crucial for achieving long-term sustainability. Governments should allocate funding for R&D initiatives that focus on improving energy efficiency, developing renewable energy solutions, and creating sustainable agricultural practices. Encouraging patent applications and innovation can help drive technological advancements.

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Appendix

Table:5 Principal components/correlation

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp 1	1.96063	1.92125	0.9803	0.9803
Comp 2	0.039373	0	0.0197	1