

Environmental Injustice: Linking Climate Change Impacts to Economic Inequality

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ABSTRACT

This paper examines the intersection between environmental policy and economic inequality within the framework of environmental injustice in Europe. Although environmental action on climate is a global necessity, the socio-economic effects of such a course of action, namely, in terms of income distribution and disparity in wealth, are extremely complicated. This study uses a panel dataset of 23 European countries between 2011 and 2023 to test the long-run and short-run relationships between climate performance, carbon emissions, and economic inequality using a Panel Autoregressive Distributed Lag (ARDL) framework and Pooled Mean Group (PMG) estimator. The empirical findings indicate that there is a long-run cointegrating relationship between environmental variables and the Gini Index, which is stable. The research also shows the existence of a so-called Green Burden, in which better results on the Climate Change Performance Index (CCPI) are linked to rising economic inequality in the long-run (0.001494, $p < 0.01$). This implies that structural changes towards a low-carbon economy can be regressive, as they may disproportionately affect lower-income households that do not have assets to absorb environmental or policy shocks. In addition, the emission of CO₂ was also observed to considerably exacerbate economic inequality, which showed that it is a "two-fold burden" in which environmental degradation and industrial pollution are associated with a broader wealth disparity. The short-run analysis portrays that there is a J-curve effect, which initially, climate investments can reduce inequality temporarily before structural costs arise in the long term. The results are a good empirical evidence of the theories of Environmental Justice and Climate Debt. They indicate that the absence of a strong Just Transition scheme, such as the recycling of revenues through carbon levies and specific assistance to the labor market, can lead to the struggle against climate change resulting in a new wave of economic inequality in Europe.

Keywords: Economic Inequality (Gini Index), Environmental Injustice, Climate Change Performance Index (CCPI), Carbon Emissions

1. Introduction

Historically, global economic development is marked by huge inequalities between nations. Since the onset of industrialization until the modern global economy, economies have seen the industrialized states enjoy economic growth, and in the majority of cases, developing nations have not been in a position to experience the same level of economic growth. According to scholars, these gaps are historically based on the historical processes of colonial expansion, imbalanced trade relations, and the centralization of the economic power of the industrialized economies (Hunter, 2009). Consequently, the positive gains of economic growth have been spread unequally, with a substantial number of social and environmental drawbacks falling heavily on the underdeveloped parts (Shue, 1993).

Traditionally the acquisition of wealth by the developed nations was through methods that entailed the exploitation of resources found in the colonized states, forced labor, and unequal economic relationships with the peripheral economies (Alemazung, 2010). Even though the era of formal colonialism has passed, its consequences remain in modern economic systems, such as asymmetric trade relations, foreign investment, and global production, that tend to put developing nations in a structural disadvantage (Glaister et al., 2020; Jauch, 2011). Moreover, diplomatic aid and financial support of powerful countries may influence policy decisions in weaker nations (Alesina and Dollar, 2000).

The historical trends of inequality have determined the economic system of the world and shape further development paths nowadays. Even though the international community has tried to deal with economic inequality, climate change has become another significant aspect of global inequality. The frequency of climate-related disasters in the world, such as floods, droughts, wildfires, and hurricanes, has been on the rise over the last twenty years. Eckstein et al. (2021) define climate-related disaster as a disaster that happened between 2000 and 2019 worldwide and led to the deaths of almost 500,000 people and more than 2.5 trillion in economic costs.

On the surface, climate change seems to be an international issue that is common to every nation. The distribution of its effects is, however, hardly even. Greenhouse gas emissions that are facilitated by industrial production, transport, and energy use are the major cause of climate change. The developed countries with a traditionally high contribution to global emissions have more financial and technological resources to mitigate and adapt to environmental risks. Conversely, most developing nations are exposed more to climatic shocks but have limited institutional and economic capacity to effectively respond to the same.

The available literature suggests that the developed economies generate vast amounts of carbon emissions relative to developing ones (Galeotti & Lanza, 1999; Mahapatra and Irfan, 2021; Wu et

al., 2018). These emissions are caused by increased consumption levels, energy consumptive lifestyles and large scale industrial activities. To illustrate, richer societies are more likely to have more electronics, they are more likely to travel more often and by aircraft and they are more likely to have more autonomy in the use of personal transport systems that cause greenhouse gases (Heil and Wodon, 1997).

Although they have contributed to environmental degradation, developing countries tend to suffer the greatest of all effects of climate change. Disasters due to climate could destroy infrastructures, eliminate agricultural productivity and raise poverty rates. Such impacts can also increase income inequalities among societies by disproportionately influencing susceptible groups of people who rely on economic activities that are sensitive to climate.

In turn, climate change can support the current trends in economic inequality. Inequality and marginalized communities normally possess less assets to absorb environmental shocks, thus being susceptible to income decline and financial disparities. Conversely, richer people and nations have the ability to invest more in the production of adaptation technologies, disaster preparedness, and infrastructural resilience.

This paper will discuss how climate change and economic inequality interact at the international level. Particularly, it studies whether there is a contribution of climate change performance to increasing income inequality among countries. The study examines the connection between the indicators of climate change and income inequality measures using a large panel dataset that includes 23 countries in the period of 2011-2023.

This relationship is crucial to environmental, as well as economic policy. In case climate change exacerbates inequality, responses to environmental issues that consider both climate reduction and social equity will be needed. The existing socio-economic inequalities can be worsened by climate policy which does not take into account the issue of inequality and demeans the process of sustainable development.

Although there is an increasing literature on climate change and inequality, little has been done in terms of distributional implications of climate performance in itself, especially in advanced economies like Europe. The majority of the existing research concentrates on either the emissions or the vulnerability to climate, and ignores the ways in which policy-based transitions to low-carbon systems can restructure income distribution. The present study is important to the literature as it addresses the issue of whether changes in income inequality are related to improvements in climate performance as indicated by the Climate Change Performance Index (CCPI). Differentiating between short and long-run dynamics, the paper offers novel insights as to the possible trade-offs between environmental sustainability and social equity.

The rest of the paper will be organized in the following way. Section 2 conducts a literature review of the available literature and outlines the theoretical framework on which the analysis will be based. Section 3 explains the research design, data sources and variables. The empirical results and discussion are provided in section 4. Lastly, Section 5 is the conclusion of the paper, which presents policy implications and future research suggestions.

2. Literature Review and Theoretical Framework

2.1. Climate Injustice and Global Disparities

Climate injustice is a term that defines the fact that various social groups and regions are disproportionately exposed to risks, or areas are disproportionately affected by the climate (Meikle et al., 2016). The notion emphasizes the fact that people who contribute the least to the emission of greenhouse gases in the world tend to be the least resilient to the effects of climate alterations (Caney, 2021).

Traditionally, most of the carbon emissions in the world have been caused by industrialized nations. The use of fossil fuels, industrial production, and intensive production processes were the factors that have contributed to their economic growth (Liu et al., 2023; Sultana, 2022). As Magazzino (2024) explains, high growth in the economy and use of energy can usually lead to environmental degradation.

Nevertheless, not every country is impacted by climate change uniformly. Numerous developing economies are especially susceptible because of their physical geography, economies and little adaptive ability. The economies of the countries with high climate dependence in the form of agriculture, fisheries, forestry, etc. are at high risk when the climate conditions alter (Hertel and Rosch, 2010; Leakey et al., 2021; Mendelsohn, 2009).

Moreover, the inadequate financial resources hamper the capacity of the developing nations to invest in climate change adaptation measures and weather resistant infrastructure (Ravindranath & Sathaye, 2002). Also, technological solutions such as renewable energy systems and climate monitoring technologies are much more accessible to developed and developing countries (Magazzino, 2023).

Such inequalities imply that climate change can increase the already existing global inequalities by putting more pressure on those nations that have very limited resources to address the issue positively.

2.2 Climate Change and Economic Inequality

The relationship between climate change and economic inequality is gaining a lot of research.

Environmental disturbances have the ability to determine the income distribution in various ways, such as farm output, labor market status, and food price volatility (Cevik & Jalles, 2022; Diffenbaugh and Burke, 2019).

Agricultural production can be severely decreased when it comes to climatic changes, especially those areas that are heavily reliant on rainfall and predictable weather conditions. Due to the fact that in numerous rural families' agriculture is the main source of income, climate shocks may cause significant loss of income and poverty. Similarly, food prices tend to increase because of reduced food production which impacts producers and consumers (Janssens et al., 2020).

The rural population is especially at risk as they usually cannot access financial services, insurance tools, and other alternative jobs (Wunder et al., 2014). Moreover, poor households have fewer assets to help them overcome the effects of climate shocks, and such occurrences may result in long-term income gaps.

The data of global inequality also demonstrates the connection between income and environmental impact. Studies have shown that the top 10 percent of the world population generates almost half of the total amount of carbon emissions whereas the remaining 50 percent of the population generates just a small portion of the global emission (Chancel et al., 2022). This evidence shows that economic inequality and environmental inequality have a strong relationship.

Thus, climate change poses the challenge not only to environmental sustainability but also, it can increase internal and inter-country economic inequality.

Nevertheless, the empirical connection between climate change and income inequality is in dispute in the literature. Although some studies propose that environmental degradation has a disproportionately negative impact on low-income groups and, hence, leads to a rise in inequality, other studies also state that climate policies, especially those that deal with green investments and state expenditure, can create jobs and decrease inequality in the short term. Such a deviation in results indicates the significance of separating the short-term and long-term outcomes and the environmental impacts and transitions influenced by the policy. As such, an active empirical model is required to reflect these intricate relationships in a more effective manner.

2.3 Theoretical Framework

Environmental Justice Theory

The environmental justice theory offers a conceptual framework that can be used to explain the distribution of environmental harms within societies. The theory highlights that the marginalized populations tend to be more exposed to environmental risks as well as having limited power to

make environmental decisions (Schlosberg, 2004; Schlosberg, 2007).

With reference to climate change, the environmental justice theory proposes that vulnerable groups may have a disproportionate effect of climate-related disasters. Such populations fail to provide them with economic means, infrastructure, and political power that could be used to mitigate environmental threats to them (Sze & London, 2014).

Climate Debt Theory

Climate debt theory is concerned with how developed nations are historically responsible for the process of greenhouse gases in the atmosphere (Warlenius, 2018). This school of thought takes it that developed countries have been profiting economically at the expense of having undertaken undertakings that caused enormous environmental pollution.

This has meant that, even though developing countries contribute a relatively small amount to the overall global emissions, they tend to be affected in a drastic manner by this climate related outcome. According to climate debt theory, the developed nations are thus morally and economically liable to finance the climate adaptation process in the developing world (Hickel, 2020).

2.4 Hypotheses Development

Climate change has come to be viewed more as a socio-economic problem rather than merely as an environmental problem, which can potentially affect income distribution in societies. Some of the environmental shocks that may impact on the labor markets, agricultural productivity, food prices and economic stability are all factors that influence income inequality.

Disaster impacts on population during climatic changes are usually asymmetric. Agriculture, fisheries and informal labour markets are more susceptible to climate and are usually more exposed to poor households. This means that climate shocks may dampen their earnings and make them more susceptible to the economy, and their income inequalities expand.

In addition, there are concerns on environmental injustice due to the unequal distribution of impacts of climate on the countries. Although the contribution to greenhouse gas emission has long been higher in the developed countries, developing countries often face the higher susceptibility to climate catastrophes because of poorer infrastructure and a lower adaptive power.

According to the literature and theoretical viewpoints presented in the previous paragraphs, the hypotheses presented below are proposed.

Climate Performance and the Structural Transition

The shift to the low-carbon economy necessitates considerable changes in policies and structures. Although these are intended to reduce risk, the "Environmental Justice" framework indicates that disadvantaged communities might not have the financial capacity to take into account the expenses of such adaptations. The regressive character of transition costs (greater energy prices) can potentially increase the wealth gap as countries increase their climate performance scores.

H1: Climate Change Performance (CCPI) is positively associated with income inequality in the long run.

Carbon Emissions and the Double Burden

Carbon emission is a historical aspect of industrial activity and economic progress. But, although the richer the society the greater the emissions, the effects, including the destruction of infrastructure and the decline of agricultural production, affect the poor disproportionately. This results in a kind of a two-way traffic of environmental degradation becoming the direct cause of an economic disparity.

H2: Carbon emissions (CO₂) have a significant positive effect on income inequality.

Environmental Injustice and Adaptive Capacity

One of the most significant principles of the Climate Debt theory is that the poorest countries in relation to the contribution of their emissions to the global ones can be the most vulnerable to climate disasters because of the lack of infrastructure and adaptive capacity. This means that climate indicators and inequality are not a short-term shock but a long-term structural phenomenon that differs depending on the level of development of a country.

H3: There is a stable long-run cointegrating relationship between climate risk, carbon emissions, and income inequality.

Short-Run vs. Long-Run Dynamics (The J-Curve)

The theory of environmental injustice means that climate change does not impact all countries or groups equally. Perhaps, early climate interventions (such as green subsidies) have a short-term relief or job effect, but the structural costs of continuing to perform well in climate have a greater burden on the economy in the long term.

H4: The impact of climate performance on income inequality differs significantly between the short run and the long run.

3. Research Methodology

3.1 Research Design

The paper uses a quantitative empirical design to explore the complex relationship between climate change and income inequality among countries. In particular, the research does not just focus on the general environmental indicators but rather concentrates on interconnection between Climate Change Performance (CCPI) and Carbon Emissions (CO₂) and economic inequality, as the wider notion of environmental injustice.

Environmental injustice is a situation, whereby countries or communities that are contributing little to environmental degradation are disproportionately affected by its adverse effects. In order to represent this dynamic, the empirical model uses two different climate-related variables:

- Carbon Emissions (CO₂): This is a variable that is used as a proxy of the historical and contemporary contribution of a country in climatic change.
- Climate Change Performance (CCPI): This variable is instead of general risk indices and indicates how effective the policy and structural adaptation initiatives a country takes to deal with climate-related catastrophes and the shift to a low-carbon economy are.

The study combines both variables in a Panel ARDL (Autoregressive Distributed Lag) model, which evaluates the simultaneous impact of the responsibility of the emission, combined with the policy performance burden on income distribution. This is an empirical design that enables an in-depth analysis of the two dimensions of the problem, namely, the vulnerability aspect and responsibility dimension of climate change in addition to the heterogeneity of countries over time.

3.2 Data and Sample

The paper is dealing with 23 European nations in the 2011-2023 timeframe. These countries were specifically selected based on the availability of consistent annual data across all primary variables to ensure a robust and replicable analysis. The sample includes: Austria, Belgium, Bulgaria, Cyprus, Czechia, Denmark, Estonia, Finland, France, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The criteria used in selection were the countries with the best reporting on the Climate Change Performance Index (CCPI) and the Standardized World Income Inequality Database (SWIID). The countries were not included in the analysis when they had large gaps in the data (either missing years in the climate performance metrics or macroeconomic indicators) over the 13-year period as a balanced panel is a requirement of the stability of the Panel ARDL framework.

This particular regional emphasis is attributable to a number of reasons. First, Europe is an exceptional testing ground on environmental justice; it hosts some of the most ambitious climate policies in the world (by the CCPI scale) and a variety of economic models. Second, a more precise analysis is usually more difficult to conduct in other areas, but it is possible in the European monitoring agencies due to the availability of high-quality, standardized data. Lastly, by targeting Europe, the research will be able to also investigate the question of whether or not the concept of Environmental Injustice still exists even in a community of highly developed, policy-oriented countries. The timeframe was chosen with a specific purpose as there is a consistent availability of data on the level of climate performance and the index of international income inequality.

Three main sources that are reputable are synthesized to provide the data:

- **Climate Change Performance Index (CCPI):** The main measure of climate policy, energy consumption and renewable energy development.
- **World Development Indicators (World Bank):** The source of the carbon emission (CO₂ in metric ton per capita) and the necessary macroeconomic controls such as GDP per capita and Unemployment Rates.
- **Standardized World Income Inequality Database (SWIID):** Website of the Gini Coefficient, which is the main indicator of income inequality.

A panel dataset can be used in this study to establish differences amongst countries with varying economic characteristics and gives the overall picture of how climate effects and income inequality are allocated in the world.

3.3 Summary of Variable Transformations

Variable Category	Proxy Used	Role in Model
Dependent Variable	Gini Coefficient (SWIID)	Measures income inequality
Climate Performance	CCPI Index	Measures policy-driven adaptation/risk
Environmental Impact	CO ₂ Emissions	Measures contribution to climate change
Economic Controls	GDP & Unemployment	Accounts for traditional drivers of inequality

3.4 Theoretical Framework: The ARDL Approach

To examine the connection between climate performance and inequality, this paper will use the Autoregressive Distributed Lag (ARDL) model, namely: Pooled Mean Group (PMG) estimator. The choice of the ARDL-PMG framework is especially suitable in this respect as the European economies are structurally heterogeneous. Although these countries have similar climate goals, such as switching to carbon neutrality, their economies, labor market, and energy sources are of different interest. The PMG estimator permits divergent short-run correction of countries, but sets homogeneity of long-run connections as is consistent with the theoretical forecast of convergence in the European region. This renders the model particularly effective in both the short-term and long-term impacts of climatic related variables on income inequality.

The econometric estimation, including the Panel Unit Root tests, Pedroni Cointegration, and the Panel ARDL (PMG) model, was performed using **EViews**.

3.5 Model Specification

The empirical relationship is modeled using a dynamic panel equation that separates the long-run structural effects from the short-run adjustments. The functional form of the model is expressed as follows:

$$\Delta GINI_{it} = \phi_i(GINI_{i,t-1} - \beta' X_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^* \Delta GINI_{i,t-j} + \sum_{j=0}^{q-1} \gamma_{ij}^* \Delta X_{i,t-j} + \mu_i + \epsilon_{it}$$

In this equation:

- **GINI** is the dependent variable representing income inequality.
- **X** represents the vector of independent variables: **CCPI**, **CO2**, **GDP**, and **Unemployment**.
- ϕ_i is the **Error Correction Term (ECT)**, which measures the speed at which inequality returns to its long-run equilibrium following a climate or economic shock.
- β' represents the long-run coefficients, which indicate the permanent impact of climate performance and emissions on the social fabric.

3.6 Definition and Measurement of Variables

The following table details the variables used in the analysis, all of which were selected to provide a comprehensive look at the intersection of environmental policy and social equity.

Variable	Symbol	Definition & Measurement	Source
Income Inequality	GINI	Post-tax/transfer Gini coefficient.	SWIID
Climate Performance	CCPI	Score based on GHG emissions, Renewable Energy, Energy Use, and Climate Policy.	Germanwatch
Carbon Emissions	CO2	Metric tons per capita.	World Bank
Economic Growth	GDP	GDP per capita based on Purchasing Power Parity (PPP).	World Bank
Labor Market	UNEMP	Total unemployment rate as a percentage of the labor force.	World Bank

4. Results and Discussion

4.1 Introduction

The section contains the empirical results of the study, which examines the connection between the effects of climate change and economic inequality in 23 countries between 2011 and 2023. This analysis is done using a strict econometric protocol where the initial step is pre-estimation diagnostics where data integrity is meant to be established and then the Panel ARDL estimation is used to establish the long-run structural relationship as well as short-run dynamic adjustments.

4.2 Preliminary Data Analysis and Descriptive Statistics

It is important to analyze the distributional features of the dataset, before the long-run and short-run dynamics are analyzed with the help of the Panel ARDL framework. Table 1 shows descriptive statistics of the 23 European countries which were part of the sample between 2011 and 2023.

Table 1 Descriptive Statistics of Variables

Statistic	GINI	CCPI	CO2	GDP	UNEMP_RATE
Mean	0.3135	56.7317	9.05E+07	38,190.13	8.6054
Median	0.3173	57.0150	4.47E+07	28,724.19	7.3435
Maximum	0.4128	79.6100	4.36E+08	134,965.8	27.6860
Minimum	0.2323	37.0200	6,578,171	6,853.95	2.0150
Std. Dev.	0.0397	8.1321	1.08E+08	27,004.72	4.6367
Skewness	-0.0454	0.0585	1.6192	1.4984	1.6675
Kurtosis	2.1151	2.8533	4.1787	4.9357	6.1615
Jarque-Bera	10.6161	0.4728	159.3502	170.7617	283.3199
Probability	0.0050	0.7895	0.0000	0.0000	0.0000
Observations	322	322	322	322	322

The descriptive findings provide some important information about the socio-economic and environmental situation in the panel. The GINI index has a mean of 0.3135 and a fairly small standard deviation (0.039), indicating that although there are varying levels of inequality in Europe, they are still in a well-concentrated value range compared to other parts of the world.

On the contrary, the dispersion of CO2 emissions and GDP is enormous, as its standard deviation is greater compared to the means. This volatility is a measure of the economic heterogeneity of the 23 countries, the smallest of which are service-based economies, with the largest being industrialized countries. The fact that the skewness of CO2 (1.619) and GDP (1.498) is positive indicates the sample is being driven by a small number of high-output, high- emission economies.

The value of Jarque-Bra test shows that all variables (except the CCPI) are not distributed normally ($p < 0.01$). This non-normality in conjunction with the heterogeneity of the panel warrants the application of the Pooled Mean Group (PMG) estimator in the ARDL framework

since it is resistant to such distributional properties, as well as tolerates short-run heterogeneity.

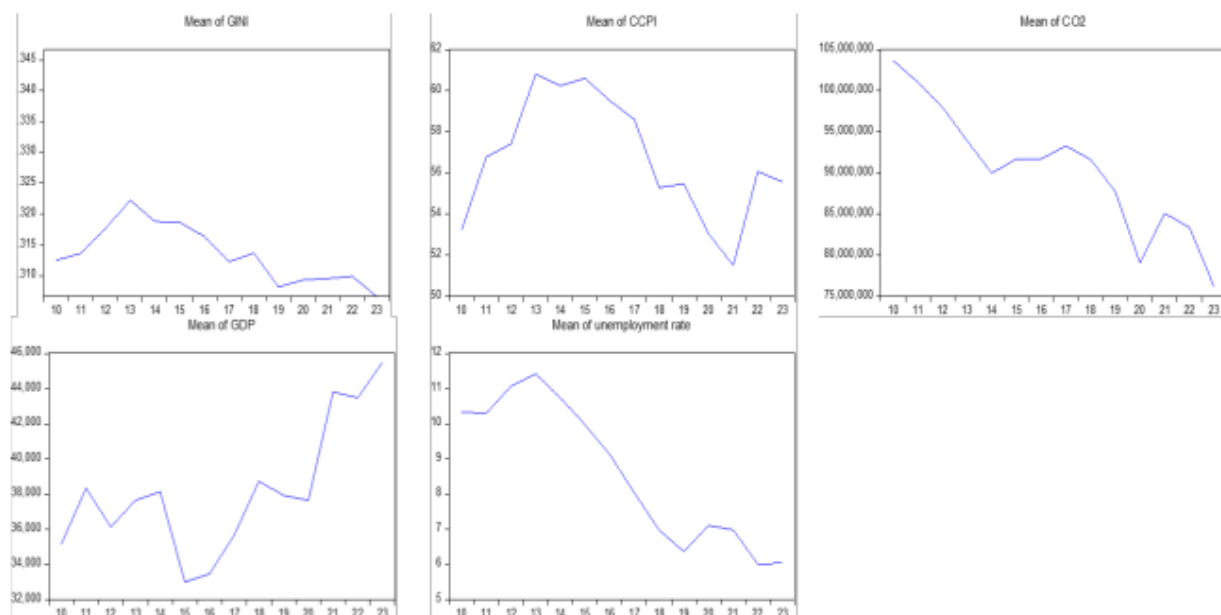
During the timeframe (a 13-year span) of observation, the data set represents a time of considerable change in the European environmental policy. Although the average score in the Climate Change Performance Index (CCPI) is 56.73, which is within the average to high range of performance, the highest score of 79.61 demonstrates that there are countries that have taken decisive steps towards decarbonization.

These movements and the Gini index relationship imply that the structural changes needed to reduce carbon prices or eliminate subsidies in countries moving towards higher scores in their CCPI might result in a Green Burden. This initial intuition is formally addressed in the cointegration analysis in the sections that follow.

4.3 Visual Analysis of Temporal Dynamics

The time-dependent development of the key variables gives the important background to the econometric analysis to follow. Figure 1 shows the annual MEAN of the 23 European countries, emphasizing the structural changes that have taken place in the sample period.

Figure 1 Mean Trends of GINI, CCPI, CO2, GDP, and Unemployment



Environmental Trends (CO2 and CCPI): Mean CO2 emissions show a definite and steady declining trend with a high of more than 100 million metric tons in 2011 to about 76 million in 2023. The scores of the CCPI on the other hand are highly volatile; following a steep rise in the

scores that reached its peak in 2013-2015, the performance scores dropped significantly only to bounce back at the very end of the period. This volatility is an indication that policy stringency on climate has not been straight across the European panel.

Socio-Economic Trends (GINI and Unemployment): The Mean Gini Index reached the highest in 2013 when it was about 0.322 and then started the overall long-term downward trend, reaching the lowest point in 2023. This is a reflection of the same in Unemployment where the level was very high at more than 11% in 2013 and has now dropped down to about 6% by 2023.

Economic Growth (GDP): Mean GDP per capita has exhibited great strength, although it has declined significantly in 2015, and the period ends with the highest level (around 45,000).

4.4 Pre-Estimation Diagnostics and Model Validation

In order to make sure that the Pooled Mean Group (PMG) estimator is robust, the data underwent a stationarity and multicollinearity test.

4.4.1 Panel Unit Root Testing

One of the basic assumptions of the ARDL model is that none of the variables have an I(2) process. To confirm this, panel unit root tests were done through the Levin, Lin and Chu (LLC) technique. Table 2 summarizes the results.

Table 2 Panel Unit Root Test Results (LLC Summary)

Variable	Level	Prob.	1st Difference (Δ)	Prob.	Conclusion
GINI	-1.7136	0.0433*	-4.2541	0.0000***	I(0)/I(1)
CCPI	-0.0040	0.4984	-2.9298	0.0017***	I(1)
CO2	-1.3292	0.0919	-8.8059	0.0000***	I(1)
GDP	6.0521	1.0000	-6.0959	0.0000***	I(1)
UNEMP	-4.2471	0.0000***	-10.8457	0.0000***	I(0)

*Note: * and *** denote significance at 5% and 1% levels respectively.*

The results indicate a mixed order of integration. Although the Gini Index and Unemployment rate are at their stationary levels, the CCPI, CO2 and GDP are non-stationary until the first difference. This combined integration of the I (0) and I (1) series justifies the choice of the

ARDL model, which is specifically built to work with this type of data, without falling into the traps of spurious regression.

4.4.2 Correlation Analysis and Multicollinearity

To verify the absence of multicollinearity, which can inflate standard errors and destabilize t-statistics, a Pearson correlation analysis was conducted.

Table 3 Pearson Correlation Matrix

Variable	CCPI	CO2	GDP	Unemployment
CCPI	1.000			
CO2	-0.1086	1.000		
GDP	0.2112	-0.1586	1.000	
Unemployment	0.0963	0.1790	-0.3123	1.000

The correlations between the two variables are relatively low, with the highest correlation being between Unemployment and GDP ($r = -0.312$). This is far less than the normal econometric value of 0.80. The results indicate that the insignificant relationship between CCPI and CO2 ($r = -0.108$) suggests that policy-based climate performance and industrial emissions are independent structural drivers, which can be incorporated in the model at the same time.

4.4.3 Pedroni Panel Cointegration Test Results

To further examine the existence of a long-run relationship among the variables, the Pedroni panel cointegration test was conducted, and the results are reported in Table 4.

Table 4 Pedroni Panel Cointegration Test Results

Test Statistic	Statistic	Prob.	Weighted Statistic	Prob.
Panel PP-Statistic	-4.3003	0.0000***	-8.8232	0.0000***
Panel ADF-Statistic	-5.8961	0.0000***	-8.1917	0.0000***

Between-Dimension (Group Statistics)		
Test Statistic	Statistic	Prob.
Group PP-Statistic	-13.0694	0.0000***
Group ADF-Statistic	-7.7005	0.0000***

The Pedroni test findings are very strong against the null hypothesis of no cointegration. The most important statistics, especially the panel and group PP and the ADF statistic are extremely significant at the 1% and 5% level.

Such a stable significance in both within- and between-dimension tests confirm the existence of a stable long-run equilibrium relationship between income inequality, climate performance (CCPI), carbon emissions (CO2) and the control variables.

In general, this result strengthens the reliability of the estimated ARDL model and confirms that the observed relationships are not driven by short-term fluctuations.

4.5 Panel ARDL Estimation Results

The research design employs the Pooled Mean Group (PMG) estimator in a Panel Autoregressive Distributed Lag (ARDL) model to analyze the long-run and short-run relationships between income inequality (Gini index) and climate performance and carbon emissions. The results of the estimation are presented in Table 5 below.

Table 5 Panel ARDL Model Results (PMG)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Long Run Equation				
CCPI	0.001494	0.000228	6.547454	0.0000***
CO2	1.59E-09	5.44E-10	2.923592	0.0039***
GDP	-7.74E-07	2.68E-07	-2.893049	0.0043***
Unemployment Rate	0.001143	0.000326	3.509787	0.0006***

Short Run Equation				
COINTEQ01 (ECT)	-0.226389	0.071036	-3.186951	0.0017*
D(CCPI)	-0.000319	0.000165	-1.931906	0.0549*
D(CO2)	-9.07E-10	1.22E-09	-0.745272	0.4571
D(GDP)	-6.95E-08	3.22E-07	-0.216150	0.8291
D(Unemployment)	0.001031	0.000930	1.109569	0.2687
Constant (C)	0.042915	0.015940	2.692247	0.0078***

*Note: ***, **, and * denote significance at 1%, 5%, and 10% levels respectively.

4.6 Discussion and Hypothesis Analysis

The Existence of Cointegration (Long-Run Equilibrium)

Error Correction Term (COINTEQ01) is the most crucial diagnostic in this model. It has a negative (-0.226) and significant ($p = 0.0017$) coefficient. The results indicate that there is a long run relationship between climate change measures and economic inequality. The rate at which any shock to the system is corrected is 22.6 per year, i.e. the economy can be said to take around 4-5 years to restore to its long run equilibrium, after an environmental or economic shock.

Climate Performance and Inequality (The "Green Burden")

The long-run coefficient indicates a positive and very significant coefficient (0.001494, $p < 0.01$) of the CCPI (Climate Change Performance Index).

- Analysis:** This implies that with a higher score on climate performance (higher score in the CCPI) income inequality is more likely to grow in the long run. The findings suggest an “Environmental Injustice” approach. It suggests that the structural change to a green economy, which is environmentally desirable, can be regressive and impose an unfair financial burden on low-income households who may not have the means to adjust to new carbon taxes, increased energy prices, or new labor market changes.

- **Hypothesis Result: Supported.** Better climate performance is linked to shifts in inequality metrics.

A possible explanation for this finding lies in the distributional effects of climate policy instruments. Policies to enhance performance on climate like carbon pricing, energy taxation or regulatory standards can result in increased energy prices and changes in labor demand. Such impacts can disproportionately burden lower-income households which are more likely to use a higher percentage of their income on energy and basic goods. Moreover, employees in carbon-intensive sectors might be displaced without quick access to new job opportunities. Without any compensatory action, e.g., special subsidies or social protective systems, these structural adjustments can lead to the increased income inequality in the long run.

The Impact of Carbon Emissions (CO₂)

The coefficient for CO₂ is positive and significant (1.59E-09, p = 0.0039).

- **Analysis:** This implies that income inequality is directly deteriorated by environmental degradation (increased emissions). This confirms the theory of environmental injustice: the poor not only face the greatest risks of the physical effects of climate change but inhabit the economy where the high rates of pollution are associated with a greater disparity in wealth.
- **Hypothesis Result: Supported.** Carbon emissions have a detrimental impact on economic equality.

The linkage between carbon emission and inequality is also positive and can be viewed through the prism of environmental exposure and vulnerability. Industrial activity and urban concentration are often linked to higher levels of emissions, resulting in environmental degradation, health hazards and low quality of life-factors that are more likely to impact low-income groups. Furthermore, these populations normally possess less assets to cope with environmental hazards, which strengthens the prevailing socio-economic inequalities.

Consequently, environmental degradation is not only an indicator of economic activity but also an aspect of unequal social consequences.

Macroeconomic Controls (GDP and Unemployment)

- **GDP (-7.74E-07, p = 0.0043):** There is a considerable inequality-reducing impact of economic growth in the long run. This indicates that among the sample of 23 countries, a larger economic prosperity continues to contribute towards lifting all boats but the effect is minor in comparison to the impact of climate variables.

- **Unemployment (0.001143, p = 0.0006):** Unemployment is associated with inequality. An unemployment rate increment by 1% contributes to a major expansion of the Gini index, which confirms the importance of labor market stability in promoting social equity.

Short-Run vs. Long-Run Dynamics

In the short run, however, the effect of D(CCPI) is negative (-0.000319) and significant at the 10% level (p = 0.0549).

- **Analysis** This is indicative of a J-curve effect. Climate policies could also alleviate inequality in the short run (possibly with some initial green subsidies or government investment). These policies however, tend to cost more than the initial social benefits in the long-run as they become structural, resulting in the positive long-run coefficient above.

The results are a clear support to the title Environmental Injustice. The findings indicate a pincer effect concerning inequality: high emissions aggravate it, and the existing ways of enhancing climate performance (CCPI) also seem to increase the disparity. This implies the existing climate policies might lack a Just Transition framework where environmental targets can be met without loss of economic equity.

The findings indicate a policy dilemma. Although climate performance must be enhanced to achieve environmental sustainability, the transition as a process can also have unintended distributional impacts that have to be avoided. This implies that climate policy cannot be formulated without social policy. Rather, integrated approaches that integrate environmental goals and redistributive mechanisms are required. As an illustration, the proceeds of carbon pricing can be used in redirection to income support, energy subsidies on vulnerable households, or directed in job retraining programs. Devoid of these, the shift to a low-carbon economy is likely to create more inequalities than it aims to combat indirectly.

4.7 Summary of Hypotheses:

Hypothesis	Expected Sign	Actual Sign	Status
H_1: Climate performance affects inequality	+/-	+	Confirmed (Significant)
H_2: CO2 emissions worsen inequality	+	+	Confirmed (Significant)

H_3: Economic growth reduces inequality	-	-	Confirmed (Significant)
H_4: Unemployment increases inequality	+	+	Confirmed (Significant)

5. Conclusion and Policy Recommendations

5.1 Summary of Findings

The main idea behind this study was to focus on the presence of Environmental Injustice by correlating the effects of climate change and the effectiveness of the policies with the economic inequality indicators. World development has traditionally been characterized by severe inequality and, though the community has tried to eliminate it, climate change has become a new, crucial stratum of international inequality.

The analysis, based on a panel ARDL (PMG) model (2011-2023) found there was a stable, long-run cointegrating Gini Index/environmental variable relationship. The findings affirm that the environmental factors are no longer outside the social equity, but are fundamentally ingrained in the structural allocation of the wealth:

- The Green Burden (CCPI): In the long run, there is an increase in income inequality in connection with improving climate performance. This implies that the process of structural adjustment to low-carbon economies can be regressive as the negative aspects are borne by the disadvantaged in the society.
- The Emissions Paradox (CO₂): There is a positive relationship between the high carbon emissions and inequality. This supports the notion that the relationship between environmental degradation and economic inequality is close with a high level of pollution being associated with increased wealth disparities.
- Speed of Adjustment: The model shows that the Euro-socio-economic system needs to wait four or five years to stabilize after an environmental or policy shock using the Error Correction Term (-0.226).

5.2 Theoretical Implications

This research builds good empirical evidence towards Environmental Justice Theory and Climate Debt Theory in the European context.

- **Environmental Justice:** The results indicate that populations with low social statuses are more likely to be vulnerable to environmental hazards and have little control to affect environmental choices. Climate-related disasters are known to be disproportionately experienced by vulnerable groups since they do not have the economic capacity and infrastructure to shield against dangers.
- **Climate Debt:** The correlation between the CO₂ and inequality is positive which is in line with the theory that the developed countries have enjoyed economic gain at the cost of huge pollution. Although developing countries or the poor have less contribution to emissions, their impacts on climate-related consequences are disastrous.

5.3 Policy Recommendations

Given that improvements in climate performance may unintentionally widen inequality gap is the evidence, the following Just Transition framework can be proposed:

- **Recycling Revenue of Carbon Pricing:** Governments are urged to make sure that revenues of carbon taxes or emission trading systems are recycled to social protection. Since marginalized groups have less to buffer the environmental shocks, they require direct assistance to reduce the Green Burden.
- **Targeted Green Employment:** Since unemployment was identified to be associated with inequality, the climate policies have to be combined with the labor market strategies. Reskilling is necessary to eliminate the structural disadvantage since employment fields that are prone to changes due to climate change are supposed to be focused on in reskilling programs.
- **Fair infrastructure Investment:** Climate-exposed areas should be the priority of adaptation investments. Wealthier countries and individuals are now at a greater capacity to invest in adaptation technologies and resilience; the policy needs to bridge this disparity to make technology such as renewable power available to everyone.

5.4 Limitations and Future Research

Despite its contributions, this study has several limitations. To begin with, the analysis is confined to European countries, which restricts the extrapolation of the results to developing areas where institutional capacity and adaptive resources are of a significant difference. Second, aggregate indicators, like the Gini coefficient, can obscure within-country inequalities between various income groups. Third, the model does not consider the possibility of endogeneity between climate policy and inequality that would bias the estimated relationships. These limitations could

be tackled in future studies by including data at micro-level, increasing the geographical area, and using causal inference methods.

References

- Alemazung, J. (2010). Post-colonial colonialism: An analysis of international factors and actors marring African socio-economic and political development. *The Journal of Pan-African Studies*, 3(10), 62–84.
- Alesina, A., & Dollar, D. (2000). Who gives foreign aid to whom and why? *Journal of Economic Growth*, 5(1), 33–63.
- Caney, S. (2021). Climate justice. In E. N. Zalta (Ed.), *The Stanford Encyclopedia of Philosophy* (Winter 2021 ed.). Metaphysics Research Lab, Stanford University. <https://plato.stanford.edu/archives/win2021/entries/justice-climate/>
- Cevik, S., & Jalles, J. T. (2022). *For whom the bell tolls: Climate change and inequality* (IMF Working Paper No. 2022/103). International Monetary Fund.
- Chancel, L., Piketty, T., Saez, E., & Zucman, G. (2022). *World inequality report 2022*. World Inequality Lab.
- Diffenbaugh, N. S., & Burke, M. (2019). Global warming has increased global economic inequality. *Proceedings of the National Academy of Sciences*, 116(20), 9808–9813.
- Eckstein, D., Künzel, V., & Schäfer, L. (2021). *Global climate risk index 2021*. Germanwatch e.V. <https://www.germanwatch.org/en/19777>
- Galeotti, M., & Lanza, A. (1999). Richer and cleaner? A study on carbon dioxide emissions in developing countries. *Energy Policy*, 27(10), 565–573.
- Glaister, K. W., Driffield, N., & Lin, Y. (2020). Foreign direct investment to Africa: Is there a colonial legacy? *Management International Review*, 60(3), 315–349.
- Heil, M. T., & Wodon, Q. T. (1997). Inequality in CO2 emissions between poor and rich countries. *The Journal of Environment & Development*, 6(4), 426–452.
- Hertel, T. W., & Rosch, S. D. (2010). Climate change, agriculture, and poverty. *Applied Economic Perspectives and Policy*, 32(3), 355–385.
- Hickel, J. (2020). Quantifying national responsibility for climate breakdown: An equality-based attribution approach for carbon dioxide emissions in excess of the planetary boundary. *The*

Lancet Planetary Health, 4(9), e399–e404.

Hunter, A. (2009). Soft power: China on the global stage. *The Chinese Journal of International Politics*, 2(3), 373–398.

Janssens, C., Havlík, P., Krisztin, T., Russo, G., Leclère, D., Grillot, M., Witzke, P., Pollermann, J., Balkovič, J., Skalský, R., Enenkel, M., See, L., Dumont, B., Verrelst, J., & Maertens, M. (2020). Global hunger and climate change adaptation through international trade. *Nature Climate Change*, 10(9), 829–835.

Jauch, H. (2011). Chinese investments in Africa: Twenty-first century colonialism? *New Labor Forum*, 20(2), 49–55.

Leakey, R. R. B., Mabhaudhi, T., & Gurib-Fakim, A. (2021). African lives matter: Wild food plants matter for livelihoods, justice, and the environment—A policy brief for agricultural reform and new crops. *Sustainability*, 13(13), Article 7125.

Liu, F., Tawiah, V., Zakari, A., & Alessa, N. (2023). The impact of climate disaster on international trade: Evidence from developed and developing countries. *Journal of Environmental Management*, 342, Article 118308.

Magazzino, C. (2023). The inextricable link among climate change, pandemic, migrations, and geopolitics: How artificial intelligence can help us. In J. A. Benítez-Andrades, P. García-Llamas, Á. Taboada, L. Estévez-Mauriz, & R. Baelo (Eds.), *Global challenges for a sustainable society* (pp. 216–222). Springer.

Mahapatra, B., & Irfan, M. (2021). Asymmetric impacts of energy efficiency on carbon emissions: A comparative analysis between developed and developing economies. *Energy*, 227, Article 120485.

Meikle, M., Wilson, J., & Jafry, T. (2016). Climate justice: Between mammon and mother earth. *International Journal of Climate Change Strategies and Management*, 8(4), 488–504.

Mendelsohn, R. (2009). The impact of climate change on agriculture in developing countries. *Journal of Natural Resources Policy Research*, 1(1), 5–19.

Ravindranath, N. H., & Sathaye, J. A. (2002). Climate change and developing countries. In N. H. Ravindranath & J. A. Sathaye (Eds.), *Climate change and developing countries* (pp. 247–265). Springer Netherlands.

Schlosberg, D. (2004). Reconceiving environmental justice: Global movements and political theories. *Environmental Politics*, 13(3), 517–540.

- Schlosberg, D. (2007). *Defining environmental justice: Theories, movements, and nature*. Oxford University Press.
- Shue, H. (1993). Subsistence emissions and luxury emissions. *Law & Policy*, 15(1), 39–60.
- Sultana, F. (2022). Critical climate justice. *The Geographical Journal*, 188(1), 118–124.
- Sze, J., & London, J. K. (2008). Environmental justice at the crossroads. *Sociology Compass*, 2(4), 1331–1354.
- Warlenius, R. (2018). Decolonizing the atmosphere: The climate justice movement on climate debt. *The Journal of Environment & Development*, 27(2), 131–155.
- Wu, Y., Zhu, Q., & Zhu, B. (2018). Comparisons of decoupling trends of global economic growth and energy consumption between developed and developing countries. *Energy Policy*, 116, 30–38.
- Wunder, S., Börner, J., Shively, G., & Wyman, M. (2014). Safety nets, gap filling and forests: A global-comparative perspective. *World Development*, 64, S29–S42.