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A Study of Income Inequality Amidst Climate Change in the MENA Region

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Abstract

There is extensive literature examining the effect of climate change on income inequality globally. However, there is limited literature focusing on this issue with respect to the MENA region, an area particularly vulnerable to the adverse effects of the climate crisis. This paper examines some of the climatic factors that affect income inequality using panel data, including 19 countries over 28 years, from the year 1995 to 2023. Recent studies have highlighted the urgency of addressing climate-induced income disparities, emphasizing the need for context-specific interventions supported by understanding socio-economic contexts and vulnerabilities of the targeted region. Consequently, this research is dedicated to exploring these dynamics and recommending evidence-based policies aimed at reducing climate-induced income disparities in the MENA region. This paper examines the relationship between the Gini index and various variables, including temperature, precipitation, vulnerability, and resilience. The results presented are based on a static panel model created using data retrieved from Standardized World Income Inequality Database (SWIID), World Income Inequality Database (WIID) and World Development Indicator (WDI) for the inequality and macroeconomic variables. The climate-related variables are retrieved from the Climate Change Knowledge Portal (World Bank Group) and Notre Dame Global Adaptation Initiative (ND-GAIN). The data revealed that resilience and temperature increases have a negative effect on the Gini index, indicating wider income gaps. Thus, it was recommended to study the root causes of the factors that negatively affect the Gini index, as well as invest in climate-resilient infrastructure, renewable energy resources, and education. Future research regarding this topic could focus on regional differences or integrate gender disparities within the model.

Keywords: Climate Change, Income Inequality, Vulnerability, MENA Region

I. Introduction

Climate change is a significant and growing challenge to economies, societies, and ecosystems worldwide, with its impacts disproportionately affecting vulnerable populations, such as the MENA region. The region's unique climatic and economic conditions render it particularly vulnerable given the rise of extreme weather events, prolonged droughts, and rising temperatures, all of which have far-reaching implications for agricultural productivity, water availability, health complications, and livelihoods. These climate conditions disproportionately impact low-income populations who lack the resources and infrastructure to adapt, thus widening the income inequality gap. The extent to which a country is affected by climate related events depends on the size of its economy and its capacity to adapt and mitigate climate change. The conceptual framework that examines this relationship focuses on globalization, technology, and demographics. To elaborate further, some countries face greater exposure to climate change threats compared to their wealthier counterparts, partially due to the uneven distribution of economic activities and climate-related hazards across regions and sectors. Additionally, lower-income countries tend to experience more significant income and wealth losses in response to climate shocks and generally don't have the capacity or financial resources to weather these challenges.

While there have been extensive studies on consequences of climate change globally, there is considerably less focus placed on the implications of its effect on income inequality in the MENA region. Additionally, climate studies generally focus on temperature, precipitation, and humidity as they are the most well-known climate indicators, neglecting vulnerability and resilience. Recent literature emphasizes the importance of addressing the multifaceted impacts of climate change on income inequality, specifically in terms of context-specific interventions which considers the complex relationship between socio-economic dynamics and climate vulnerabilities (Mabey, 2017; Scoville-Simonds, 2020; Fellmann, 2012; Birkmann et al., 2022). By understanding how climate change exacerbates income inequality, policymakers can develop effective responses that promote both climate sustainability and social equity. For that reason, this paper aims to explore the effect of climate change on income inequality in the MENA region using panel data in 19 countries[1] between the years of 1995 and 2023. In this study, income inequality is measured using the Gini index, while climate change is measured by temperature and precipitation anomalies, as well as vulnerability and resilience indices. By analyzing the data, the researcher will propose recommendations on how to reduce income disparities and promote sustainable and inclusive growth in the MENA region.

The remainder of this paper is organized as follows. Section II provides an overview of the related literature outlining the theoretical and empirical frameworks relevant to

[1] Algeria, Bahrain, Egypt, Iran, Iraq , Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, and United Arab Emirates

climate change and income inequality. Section III covers the stylized facts presenting income inequality trends, climate change impact, and existing policy implications in the MENA region. Section IV describes the data and method used in the empirical analysis. Section V presents the empirical results and their analysis. Finally, Section VI offers concluding remarks with policy implications.

II. Literature Review

Amidst global challenges, the impact of climate change on income inequality emerges as one of the most prominent challenges facing vulnerable populations. Climate change-induced challenges, such as resource scarcity, loss of livelihoods, and increased vulnerability to natural disasters, can disproportionately affect marginalized and economically disadvantaged populations that have a limited capacity to adapt. The review analyzes the theoretical and empirical frameworks, which examine the ways in which climate change impacts income inequality, encompassing disruptions in agriculture, shifts in employment patterns, and uneven distribution of climate adaptation and mitigation measures.

1. Theoretical Framework

Theoretical frameworks have been used to explain the relationship between climate change and income inequality. Generally, the literature on inequality originates from Kuznets' (1955) research in which he explained that a country's income distribution tends to become less equal during the early stages of economic development. Accordingly, a higher level of inequality is achieved as a result of surpassing a specific threshold for income per capita. This phenomenon is known as Kuznets inverted U-shaped curve, where developing countries must go through a period of increasing inequality in order to reach the optimum point of reduced inequality during the later stages of development (Cevik & Jalles, 2023). Cappelli et al. (2021), Acheampong (2023) and Abdelfattah and AlAzzawi (2024) identify a positive correlation between growth and income inequality in their studies. On the other hand, Amar and Pratama (2020) and Newell et al. (2021). find no clear relationship between income inequality, growth, and climate change.

Beyond Kuznets's findings, Boyce (2020) serves as an inaugural contributor to the idea that climate implications of income distribution exist. To further elaborate, the fundamental premise of Boyce's hypothesis, known as the political economy approach, analyzes the interconnectedness between political and economic factors in shaping climate change regulations and adaptation policies (Mabey, 2017). This approach argues that when the political influence of the rich faction in a society surpasses that of the poor, this unequal distribution of power leads to more intensified climate challenges, in contrast to the reverse scenario. This unequal distribution of power is mirrored through several channels, including globally differentiated responsibility, uneven vulnerability, and unequal representation in decision making regarding adaptation and mitigation initiatives (Scoville-Simonds, 2020). According to Boyce (2007), this happens in three ways; first, through cost–benefit analysis, involving variations in purchasing power among individuals, groups, and classes in their willingness to pay to mitigate pollution; second, through disparities in political power, which relate to variations in political influence among individuals, groups, and classes in shaping climate change policies; finally, through impacts on the rate of time preference, highlighting the inclination to trade present benefits for future costs (Boyce, 2007; 2021). The findings of Boyce align with climate injustice[2] literature claiming that countries with a high level of economic and political inequality tend to cause more climate damage than those with less inequality (Keohane, 2019).

Conversely, Hailemariam et al. (2020) and Wolde-Rufael and Idowu (2017) challenge the political economy approach presented by Boyce by emphasizing that greater income inequality may not necessarily lead to an increase in climate change. The political economy theory posits that the distributional outcomes of climate change are not merely a consequence of environmental forces but are also influenced by power relations, political structures, and economic systems. In other words, the theory examines how existing inequalities in political power and economic resources can exacerbate the disparities in vulnerability and adaptive capacity to climate change (O'Hara, 2009). Wealthier individuals and powerful interest groups may have the ability to influence policy decisions, resource allocation, and the distribution of the costs associated with climate change mitigation and adaptation. This influence can lead to outcomes that disproportionately favor the well-off and contribute to an increase in income inequality (Paterson & P-Laberge, 2018).

Similar to the idea of disparities between high and low-income groups, the human development theory examines another perspective on the matter. The Human Development Theory as articulated by Amartya Sen (1990) through the capability approach examines human development based on individuals' capability to attain valuable functioning. In this context, functioning refers to aspects that individuals find meaningful such as good health, education, social interactions, and political engagement. This theory emphasizes the significance of having the freedom to pursue the functioning that align with an individual's values. Evidently, this shifts the focus from purely economic indicators to a broader understanding of well-being and development, considering social, political, and cultural factors that impact people's lives (Grasso, 2007; Martins, 2020). In the context of climate change and income inequality, this framework would examine how climate change impacts basic human capabilities, contributing to disparities in well-being. Vulnerable populations, often characterized by lower incomes, may encounter elevated risks due to limited adaptive capacities in the face of climate change (Eriksen et al., 2021). Events related to climate, such as extreme weather events or disruptions in agriculture, may disproportionately hinder the capabilities of individuals with lower incomes, limiting their choices and opportunities (Wasito, 2023). For instance, shifts in weather patterns may influence access to clean

[2] Climate injustice refers to the situation wherein specific communities suffer a disproportionate and inequitable share of the detrimental consequences of climate change, notwithstanding their minimal contribution to the underlying causes (Levy et al., 2024).

water and agricultural productivity, directly affecting the health and food security of populations, particularly those already struggling with economic challenges (Fellmann, 2012; Anderson et al., 2020).

Accordingly, the development economic theories emphasize that the development-inequality nexus can exacerbate existing inequalities and create new ones, negatively affecting the overall trajectory of development, inevitably affecting income inequality (Faus Onbargi, 2022; Coveri et al., 2020; De Roeck et al., 2018).

2. Empirical Framework

There is a growing body of literature examining the economic repercussions of climate change. There exists an inherent challenge in identifying the effects of variations in climatic conditions, yet researchers discovered that elevated temperatures lead to a significant decline in economic growth, particularly in developing countries (Kotz et al., 2021). This finding is corroborated by many who assert that temperature increases exert more substantial damage on countries situated in regions with hotter climates (Erkan & DİKEN, 2020). This is supported through empirical evidence that demonstrates that the long-term macroeconomic impact of weather anomalies varies across countries, with economic growth responding nonlinearly to temperature changes. In other words, low-income countries are unable to adapt due to geographical and institutional constraints (Cevik & Jalles, 2023).

a. Rising Temperature and Income Distribution

The rise of global temperatures has played a role in augmenting global economic disparities. According to historical discrepancies between rich and poor countries, global warming has disproportionately benefited wealthy nations at the expense of poorer countries, as high-income countries not only directly gained from fossil fuel use but also accumulated more wealth due to the presence of global warming. This dynamic reflects an uneven distribution of the climate-related consequences associated with industrial activities, with wealthier countries avoiding the direct impact of greenhouse gas emissions while potentially affecting less wealthy countries, leaving them vulnerable to the consequences (Ash et al., 2013; Khan et al, 2020; Eriksen et al., 2021).

Conversely, lower-income countries have not shared the advantages of energy consumption and have, in relative terms, faced economic decline linked to the energy consumption patterns of wealthier countries. Accordingly, it is projected that the income gap between the highest and lowest deciles is expected to be 25% greater today in comparison to a scenario where global warming does not exist (Diffenbaugh & Burke, 2019). Moreover, climate change significantly contributes to inequality, particularly in regard to the associated damages that hinder the economic convergence between low-income and high-income countries. Furthermore, policymakers tend to face a tradeoff between the adverse effects of climate change that disproportionately affect poorer countries, impeding their growth and development, against the costs of climate change mitigation, which could also potentially impede the economic development of poorer countries (Taconet et al., 2020).

b. Economic Sector Vulnerabilities

Climate change vulnerability refers to the extent to which a system is prone to and unable to manage the adverse impacts of climate change, encompassing climate variability and extremes. It is determined by the nature, magnitude, and pace of climate change and variations to which a system is exposed, along with its sensitivity and adaptive capacity (Fellmann, 2012; Birkmann et al., 2022). Some economic sectors, such as agriculture, fisheries, and the energy sector, are more vulnerable to climate change than other sectors.

Many developing countries experience severe climate and environmental changes that disproportionately harm vulnerable populations that heavily depend on the aforementioned sectors to generate income, thus, disrupting their livelihoods, which is further exacerbated by socio-economic and political inequalities (Ngcamu, 2023). For instance, agricultural vulnerability in terms of climate change can be characterized by factors such as exposure to increased temperatures, the responsiveness of crop yields to elevated temperatures, and the farmers' capacity to adapt to these effects and sensitivities (Fellmann, 2012; Schilling et al., 2020). The effects of climate change on the agricultural sector have been attributed to three main factors, namely changes in precipitation patterns, rise of extreme climate events, such as floods and droughts, and changes in air temperatures (Malhi et al., 2021). In regard to air temperatures, an increase leads to increased transpiration, resulting in reduced productivity of food crops, accelerated ripening of fruit/seeds, higher water consumption, diminished crop quality, and the proliferation of crop-damaging pests. Studies examining the impact of rising air temperatures on crop production indicate that a temperature increase of 1°C can lead to a 5-7% decrease in overall crop production (Eka Suranny et al., 2022).

Additionally, the energy sector is also vulnerable to the effects of climate change. Climate change has been seen to affect renewable energy sources such as hydropower, solar energy, biofuels, and wind power (Yalew et al., 2020; Kang et al., 2020). For instance, the presence and consistency of wind power are contingent on weather and climate circumstances. The energy density within the wind is influenced by the global energy balance and the atmospheric motion derived from it. Global climate change predominantly affects wind energy resources through alterations in the geographical distribution and variability of wind speed. The former results in diverse impacts on wind resources across various regions, while the latter, not only determines the economic viability of harnessing wind resources but also impacts the reliability of electricity generation (Schaeffer et al., 2012; Martinez & Iglesias, 2024). Similar effects apply for various sources of renewable energy.

To reiterate, climate change effects on vulnerable sectors contribute to greater income inequality. For example, reduced crop yields and extreme weather events result in income loss for farmers, exacerbating income inequality between small and larger, more resilient agricultural enterprises within a country, as well as overall inequality between countries that are heavily dependent on agriculture and countries that are more industrialized (Maja & Ayano, 2021). Additionally, poorer countries have limited access to resources that equip them to recover from such shocks (Anderson et al., 2020). Similarly, the adverse effects of climate change on energy sources leave regions that are heavily dependent on the affected resources to experience shortages. With developing countries already being poorer, vulnerable populations will face the challenges of accessing affordable and reliable energy sources, leaving them worse off (Jafino et al., 2021; Reidpath et al., 2023).

c. Damage Function

Recent studies have been using the damage function as an econometric representation of the relationship between the magnitude of a stressor on economic or social damages. In the context of this research, the damage function quantifies the impact of climate change on an economic factor, namely income inequality. A climate damage function is a simplified representation of economic consequences, encompassing both positive and negative effects, determined by climate inputs, including temperature and precipitation changes. These functions are derived from regression analyses that utilize the damage output from more complex sectoral models. These detailed models are designed to encompass complex structural, biological, physical, and economic relationships, illustrating the pathways through which climate change influences economic impacts (Neumann et al., 2020).

III. Stylized Facts

1. Income Inequality Trends

Observing income inequality trends is crucial for understanding how climate change affects different regions, allowing policy makers to design inclusive and equitable interventions to climate challenges. It provides significant analysis on how climate change exacerbates existing disparities in income and wealth, as well as the disproportionality of climate related burdens.

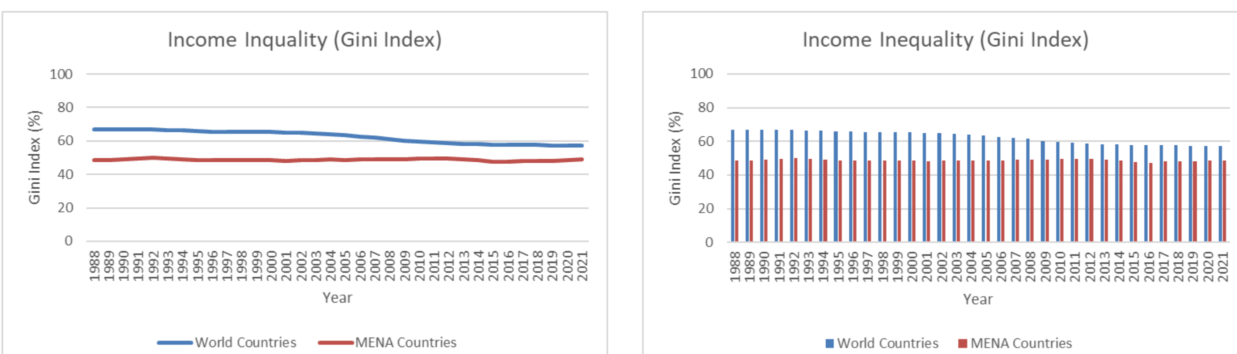


Figure 1: Income Inequality - Global vs. MENA region

Source: Constructed by author based on data retrieved from Darvas (2019)

Figure 1 uses GDP per capita at purchasing power parity as a mean income indicator, retrieved from the IMF World Economic Outlook dataset (Darvas, 2019). The data shows the Gini index, which assesses the level of income or consumption inequality within an economy, with 0 indicating perfect equality and 100 indicating perfect inequality. It is computed by comparing the Lorenz curve, which illustrates income distribution, against a line indicating perfect equality. This metric is derived from household surveys, adjusted for household size (Hasell & Roser, 2023).

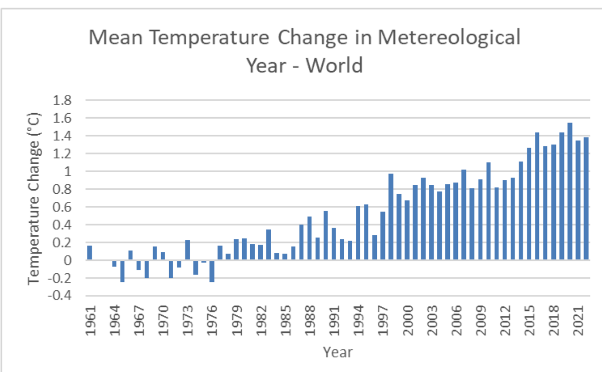
Figure 1 compares income inequality trends in 145 countries against MENA countries. The graphs reveal that there was a slight decrease in income inequality worldwide between 1988 and 2021, with the Gini coefficient in 1988 accounting for 66.79% and 57.29% in 2021. This observation can be attributed to the rapid growth of initially poor countries, reducing income inequality between countries. Many developing countries, particularly in Asia, have experienced rapid economic growth over the past few decades. This growth has lifted millions out of poverty and increased incomes for large segments of the population, narrowing the income gap between rich and poor countries (UN Wider, 2019). Another major factor that has positively contributed to the reduction of inequality are the international cooperation and development assistance programs that have supported initiatives aimed at improving living standards, promoting human rights, and reducing income disparities in various countries. Since the development of the global development agenda, as articulated in the United Nations' Sustainable Development Goals (SDGs), focus has shifted towards reducing poverty and inequality worldwide. While there is still much to be achieved, there has been positive progress (Cernev & Fenner, 2020).

On the other hand, the graphs reveal that income inequality has been consistent in MENA countries. This can be attributed to the uneven distribution of resources, lack of economic diversification, youth unemployment, corruption, and economic instability (Moshrif, 2022; Alverdo et al., 2018; Matallah, 2020). To elaborate further, the MENA region is characterized by substantial inequality, mainly driven by Gulf countries, which significantly contribute to regional disparities. Moreover, this disparity predominantly arises from within-country inequities rather than between-country inequalities. The region can be split into two categories: the oil-rich Gulf countries and the more densely populated non-Gulf nations. The Gulf countries' abundant oil resources and lower population density lead to unique dynamics in wealth and income distribution, thus distinguishing them from the non-Gulf countries (Moshrif, 2022). The substantial gap in average income is primarily a result of the geographic distribution of oil ownership and the conversion of oil revenues into financial endowments. This results in a significant discrepancy between Gulf countries and other countries in the region (Alverdo et al., 2018). Generally, the gulf countries are faced with the concept of the resource curse, which illustrates a situation where the abundance of natural resources correlates with poor economic performance. This is mainly due to the over-reliance on natural resources, adverse effects on other economic sectors due to real exchange rate appreciation from resource exports, short-term increase in inflation, reduced consumption in response to high commodity prices, ineffective control over public spending, and widespread corruption (Matallah, 2020).

As the figures reveal, as there is a decline in global inequality, but consistent inequality in the MENA region, both started converging in recent years. The persistence of income inequality in MENA countries amid global progress highlights the need for tailored and context-specific strategies to address underlying structural challenges and foster inclusive growth.

2. Climate Change Impacts

Studying climate change trends globally is essential for understanding its wide-ranging impacts and identifying effective strategies to address them. By examining patterns and trends on a global scale, researchers can assess risks, make informed policy decisions, and promote international cooperation. Additionally, in the context of the MENA region, global climate trends can help identify commonalities or disparities in climate change effects, as well as assess how broader climate-related factors, such as temperature increases or changes in precipitation patterns, may exacerbate or mitigate existing income inequalities within the MENA region. This understanding is essential for developing targeted policies and interventions to address climate-induced income disparities and promote socio-economic resilience in the face of climate change. Ultimately, a comprehensive understanding of climate change at the global level is critical for protecting ecosystems, economies, and societies around the world.



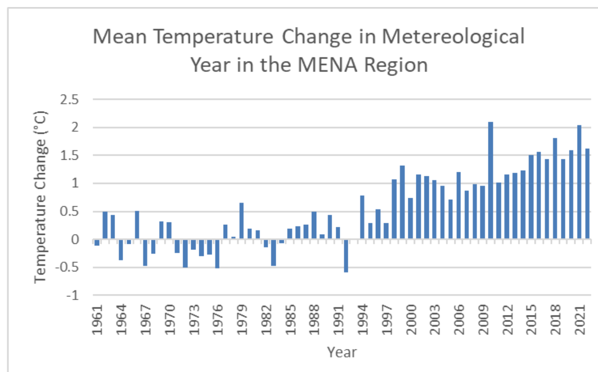


Figure 2: Annual Surface Temperature - Global vs. MENA Region

Source: Constructed by author based on data from FAOSTAT and GISTEMP data from NASA GISS

Figure 2 represents the mean surface temperature change during the period 1961-2022. This data is retrieved from the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) and is based on publicly available GISTEMP data from the National Aeronautics and Space Administration Goddard Institute for Space Studies (NASA GISS) (IMF Climate Change Dashboard, 2023). The data reveals a clear trend of rising temperatures both globally and in the MENA region with the highest temperature change of 2.1 °C in 2010 in the MENA region and 1.5 °C in 2020 globally. While temperature increases have not occurred equally worldwide, the overall upward trajectory in the average temperature change indicates that a greater number of regions are experiencing warming rather than cooling (Lindsey & Dahlman, 2020).

In the last decade, the MENA region has witnessed higher temperature changes than the rest of the world. The vulnerability to climate change varies from one region to another and is closely intertwined with the socio-economic and ecological characteristics of each region. The MENA region exhibits a high degree of political instability and low levels of economic freedom, often enduring decades of war, whether through invasion or civil conflict. Despite being rich in oil and gas reserves, with approximately 57% of the world's oil reserves and 41% of natural gas resources, the region faces significant challenges due to its poor renewable water resources. The region currently exhibits the highest per capita rates of freshwater extraction globally. According to The World Water Development Report, water scarcity serves as a primary challenge for the economies of MENA countries. Approximately 1% of GDP in Egypt, Jordan, Lebanon, and Morocco, and nearly 3% of GDP in Iran, is allocated to addressing health damages and loss of products induced by water scarcity. If water scarcity persists, it could lead to severe economic devastation in these countries (Namdar et al., 2021). Furthermore, the population of MENA is growing rapidly, with the most significant population growth forecasted to take place in Egypt, followed by Algeria, which will likely exacerbate the already limited water resources (Schilling et al., 2020).

In addition, developed countries prefer locating their production plants in less developed, low-income countries. As part of the MENA region is characterized by low-income, developing countries, firms outsource their production overseas for cost efficiency. This has implications for climate change, particularly regarding temperature and precipitation changes, as relocation of production to countries with lower labor costs and fewer environmental regulations often results in increased emissions, contributing to global warming and alterations in precipitation patterns. Countries with relaxed environmental regulations may emit higher levels of greenhouse gasses per unit of production compared to those in more regulated regions. Consequently, outsourcing production to such locations exacerbates the overall warming trend, intensifying the impacts of climate change (Dai, 2021). Thus, the effect of climate change is more dire on developing countries than developed countries, even though developed countries are contributing more to its exacerbation through industrialization.

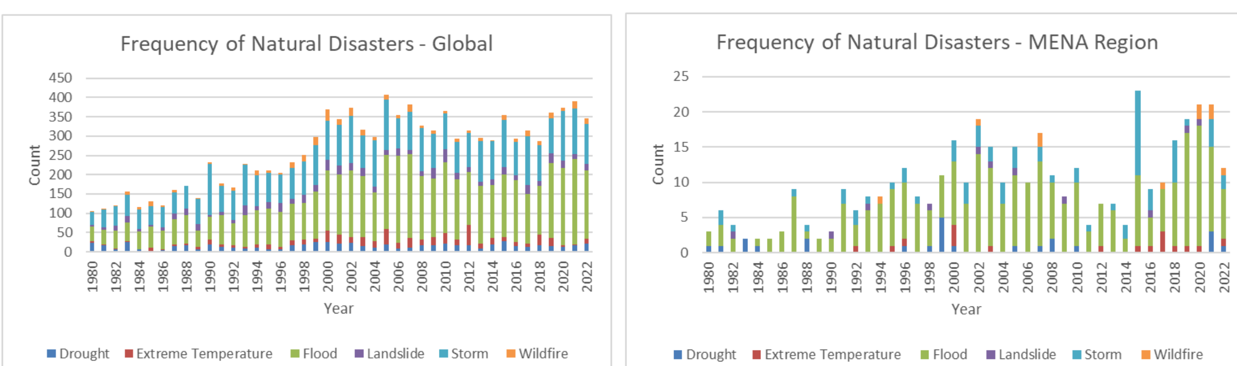


Figure 3: Climate-related Disasters Frequency - Global vs. MENA Region

Source: Constructed by author based on data retrieved from EM-DAT

Figure 3 represents the total annual climate-related disasters, namely drought, extreme temperatures, floods, landslides, and wildfires during the period 1980-2022. This data is retrieved from the Emergency Events Database (EM-DAT) by the Center for Research on Epidemiology of Disasters (IMF Climate Change Dashboard, 2023). The graph showing global data reveals that the frequency of climate disasters has been increasing over the years, with floods and storms accounting for the highest number of occurrences. This has resulted in severe repercussions that are expected to get worse if this trend continues.

For instance, droughts, characterized by prolonged periods of low precipitation, have become more frequent and severe in many regions, leading to water shortages, crop failures, and ecological damage. Additionally, extreme temperatures, marked by heatwaves and record-high temperatures, have become more common, resulting in heat-related illnesses, agricultural losses, and strain on energy resources. Similarly, floods, resulting from excessive rainfall or rapid snowmelt, have been leading to devastating infrastructure damage and loss of life. Moreover, landslides, triggered by heavy rainfall or seismic activity, have also increased in frequency, posing risks to communities living in hilly or mountainous regions. Finally, wildfires, exacerbated by prolonged droughts, heatwaves, and land-use changes, have been causing widespread destruction of forests and habitats, as well as air pollution and health hazards for nearby populations (OECD, 2023). Accordingly, the trend of climate-related disasters worldwide underscores the urgent need for comprehensive mitigation and adaptation efforts to address the impacts of climate change and build resilience in vulnerable communities.

The MENA region, serving as a vulnerable community to the implications of climate hazards, has been widely affected by storms as the most frequent climate-related disaster. The region's vulnerability is attributed to the fact that it emerges as a climate change hotspot, as shown by climate models forecasting temperatures approximately 20% higher than global norms. Moreover, it is currently recognized as the most water-scarce region worldwide. Thus, projections indicate that rising temperatures will likely cause more frequent and severe drought occurrences, among other hazards in the region. Climate change is not merely a distant threat for the MENA region; rather, it is an existing threat evidenced by intense heat waves and water scarcity. Moreover, climate change coupled with environmental degradation and resource scarcity, is actively impeding development efforts in the region. These factors are exacerbating existing inequalities, eroding social cohesion, and introducing new challenges to public health and security (UNFCCC, 2023).

IV. Methodology

This paper investigates the impact of climate change on income inequality within the MENA region. The paper uses panel data retrieved from the Standardized World Income Inequality Database (SWIID), World Income Inequality Database (WIID) and World Development Indicator (WDI) for the inequality and macroeconomic variables.

The climate-related variables are retrieved from the Climate Change Knowledge Portal (World Bank Group) and Notre Dame Global Adaptation Initiative (ND-GAIN). While it may have its drawbacks, panel data allows economists to control variables that cannot be observed, such as cultural factors and behavioral responses to climate change. Additionally, it also accounts for individual heterogeneity, which could be in terms of demographic parameters that may have not been accounted for. The main drawback of panel data, specifically for macro panels, is cross-country dependency, which means there is a correlation between countries included in the dataset. When dealing with panel data, economists can run fixed or random effects models. This is determined by the nature and objectives of the model and is verified using the Hausman test. To elaborate further, if there are no omitted variables or if the omitted variables are not correlated with the explanatory variables in the model, then a random effects model is suitable as it provides unbiased coefficient estimates, uses all available data, and yields the smallest standard errors. On the other hand, if omitted variables are correlated with the variables in the model, fixed effects models may help mitigate bias, assuming that variables do not change over time and have consistent effects across time periods. Additionally, if there is minimal variability in the dataset, a fixed effects model will be ineffective because the standard errors will be too large. Conversely, random effects models will often have smaller standard errors, but the coefficients are more likely to be biased (Williams, 2018). If the assumptions hold, the random effects model is more efficient than the fixed effects model because it uses both within-country and between-country variation. The Hausman test is used to determine which model is more suitable and will produce more accurate estimates for the dataset by using the coefficients of both fixed and random effects models. This method is used instead of OLS as OLS is often inadequate for panel data due to its inability to account for unobserved heterogeneity and omitted variable bias that can lead to biased results.

This paper runs a static panel data regression using the following model:

Static Panel Model: $GiniIndex = \alpha + \beta\ Climate_{it} + \gamma X_{i,t} + \varepsilon_{it}$

In this model, income inequality is measured by the Gini index as our dependent variable, which is taken from the Standardized World Income Inequality Database (SWIID). Climate represents the measures of temperature and precipitation anomalies, as well as vulnerability and resilience indices and the X is a vector of control variables including total population, GDP per capita, rule of law index and each respective country’s income level denoted using a dummy variable. The temperature and precipitation anomalies were calculated using data retrieved from the Climate Change Knowledge Portal (World Bank Group). Temperature anomalies refer to the difference between the observed temperature in a given year and the average temperature of the reference period, which in this case is through the years of 1995 to 2023. Precipitation anomalies are similar to temperature anomalies but in terms of rainfall, snow, etc. Climate change vulnerability and resilience, as measured by the ND-GAIN indices, reflect a country's overall susceptibility to climate-related disruptions and its capacity to manage the consequences of climate change, respectively. Vulnerability is based on 36 variables calculated through a systematic assessment process that assigns a weight for each variable based on its relevance and significance in determining vulnerability. Once the variables are weighted, the final index falls between 0 and 1. Resilience index is based on 9 variables calculated using the same method as the vulnerability index. Finally, ε is the statistical error term.

The following information provides a reasoning behind the inclusion of each of the four main explanatory variables, as well as the expectation of how each affects overall income inequality in the MENA region. First, positive temperature anomalies indicate that the observed temperature is warmer than the average for the reference period, while negative temperature anomalies indicate cooler temperatures. Temperature anomalies are crucial for monitoring climate change because they provide a standardized measure of temperature variations over time. By examining long-term trends in temperature anomalies, policymakers and researchers can understand the magnitude of temperature changes and their impact on economies, societies, and ecosystems. Second, positive precipitation anomalies indicate that observed precipitation is greater than the average for the reference period, while negative precipitation anomalies indicate less precipitation. Similar to temperature anomalies, precipitation anomalies are used in climate communication to illustrate changes in precipitation patterns in a more accessible way than absolute precipitation values. Third, the vulnerability index falls between 0 and 1, with the higher scores indicating higher levels of vulnerability, meaning that the observed country is more susceptible to the adverse impacts of climate change. Conversely, lower scores indicate lower vulnerability and greater resilience or adaptive capacity to climate-related crises. The vulnerability index is widely used in climate change research and policymaking, as it allows for the prioritization of resource allocation. In other words, higher vulnerability scores may signal the need for targeted interventions and investments to enhance adaptive capacity and reduce vulnerability, while lower scores may indicate areas of relative strength that can be leveraged for resilience-related initiatives. Finally, the resilience index also falls between 0 and 1, with the higher scores indicating higher levels of resilience, meaning that the country being assessed has greater capacity to withstand and adapt to climate-related challenges. Conversely, lower scores indicate lower resilience and greater vulnerability to climate change impacts. Similar to the vulnerability index, the resilience index provides insights into countries' capacity to cope with climate change, thus, directing interventions to countries at risk. All the aforementioned variables were well thought of and related to income inequality, thus, their inclusion in the model was essential.

V. Results and Discussion

This paper uses panel data in order to examine the effect of the explanatory variables, representing climate and economic indicators, on income inequality represented by the Gini index in 19 countries in the MENA region. Table 1 displays a summary of the descriptive statistics, including the mean, standard deviation, minimum, and maximum. The table displays the aforementioned statistics for the dependent variable, the Gini index, and for the explanatory variables. Based on the calculations derived from the table below, the mean Gini index is 38.56, with the lowest index of 26 in United Arab Emirates in the years 2004 and 2018 and the highest index of 53.1 in Sudan in 2010. In terms of climate change indicators, the lowest vulnerability index is 0.35 which was estimated for Turkey in 2023, while the highest is 0.61 for Sudan in 1995. This suggests that Sudan faced high risk of climate consequences in the given year, whereas Turkey is currently experiencing a low level of risk. For the resilience indicator, the lowest is 0.22 for Syria in 2020, while the highest is 0.58 for United Arab Emirates in 2015. These results coupled with those of the Gini index indicate that United Arab Emirates implemented effective social policies and infrastructure, fostering socioeconomic stability and enhancing the population's ability to adapt in adverse conditions. This is evident given a low level of income inequality within the observed period and high level of resilience, allowing them to adequately adapt to the effects of climate change.

Table 1 – Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Giniindex	551	38.567	5.187	26	53.1
TemperatureAnomalies	551	4.38e-16	.421	-1.349	1.568
PrecipitationAnoma~s	551	1.18e-14	49.005	-295.724	282.436
Vulnerability	551	.423	.064	.353	.615
Resilience	551	.372	.079	.224	.586
lnGDPpercapita	551	8.808	1.135	6.859	11.084
RuleofLaw	551	-.307	.744	-2.092	1.128

ln pop	551	16.255	1.355	13.149	18.533
ConsumerPriceInfla~n	551	11.94	31.791	-16.117	387.311
lowermiddleincome	551	.365	.482	0	1
uppermiddleincome	551	.285	.452	0	1
highincome	551	.278	.448	0	1

Table 2 shows whether there is a relationship between the regressors in the model. Most values in the matrix are below 0.70 indicating an acceptable level of multicollinearity. The matrix also indicates that some of the explanatory variables have inverse relationships with one another. However, a few variables were highly collinear. For instance, the rule of law index is highly correlated to the resilience index. This made sense because both indices measure aspects of institutional strength and governance quality. In other words, effective governance is crucial for implementing and enforcing policies and regulations that enhance climate resilience.

Table 2: Pairwise Correlation

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Giniindex	1.000								
(2) TemperatureAno~s	-0.021	1.000							
	(0.618)								
(3) PrecipitationA~s	-0.021	-0.067	1.000						
	(0.626)	(0.116)							
(4) Vulnerability	0.374	-0.064	-0.009	1.000					
	(0.000)	(0.136)	(0.837)						
(5) Resilience	-0.063	0.162	-0.050	-0.490	1.000				
	(0.14	(0.00	(0.23	(0.00					

	1)	0)	8)	0)					
(6) lnGDPpercapita	-0.124	0.056	-0.006	-0.486	0.662	1.000			
	(0.004)	(0.190)	(0.891)	(0.000)	(0.000)				
(7) RuleofLaw	0.028	-0.040	-0.039	-0.475	0.786	0.634	1.000		
	(0.506)	(0.351)	(0.358)	(0.000)	(0.000)	(0.000)			
(8) ln_pop	0.159	0.086	-0.002	-0.011	-0.332	-0.519	-0.446	1.000	
	(0.000)	(0.043)	(0.954)	(0.796)	(0.000)	(0.000)	(0.000)		
(9) ConsumerPriceI~n	0.098	-0.102	0.104	0.219	-0.267	-0.206	-0.292	0.212	1.000
	(0.022)	(0.016)	(0.014)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

We ran a static panel regression model, once with fixed and once with random effects to determine the significance of the explanatory variables in relevance to the Gini index. Table 3 displays the outcome of the Hausman test that determines if a random or fixed model should be used. Based on the p-value, we did not reject the null hypothesis, thus, a random effects model was applied. To ensure that the application of the random effects model was suitable, we ran the Breusch-Pagan Lagrange multiplier (LM) test. According to table 4, we reject the null hypothesis and conclude that random effects model is appropriate, as there is evidence to suggest that there are significant differences across countries.

Table 3: Hausman Test

	Coef.
Chi-square test value	11.19
P-value	0.2630

Table 4: Breusch-Pagan Lagrange multiplier (LM)

Estimated results:

	Var	sd = sqrt(Var)
Giniindex	26.90967	5.187453
e	4.028829	2.007194
u	24.10301	4.909482

Test: Var(u) = 0

chibar2(01): 5576.32

Prob > chibar2 = 0.0000

Using a random effects model, we ran the regression displayed in table 5. Overall, the model can be seen as significant for various reasons. Generally, the Prob > Chi2 indicates whether there is statistical significance between the dependent and independent variables. It should be lower than 0.05 in the case of a 95% confidence level in order to show significance. In this model, this value is 0.00, indicating that the independent variables can significantly predict the dependent variable. Additionally, the overall r-squared explains the variance in the dependent variable explained by the independent variables. In this model, the four climate indicators and the control macroeconomic indicators explain around 27% of the variance in the Gini index. This is considered a rather low figure; however, this can be explained by the presence of endogeneity between the Gini index and the GDP per capita. To elaborate further, high income inequality negatively affects economic growth and development through reduced investment and overall instability. On the other hand, economic growth, as measured by GDP per capita, can affect income inequality in both directions. From one perspective, if the benefits of economic growth are disproportionately distributed among certain segments of the population, then income inequality is expected to increase. On the other hand, if economic growth is complemented by policies that promote inclusive growth, such as investment in education and healthcare or social welfare programs, then income inequality is expected to decrease. This two-way relationship suggests complex dynamics between income inequality and economic growth that have caused an endogeneity problem in the model. Furthermore, the t-values of each explanatory variable implies their significance in the model, except for precipitation anomalies, vulnerability, and population. This could be due to the idea that there is little variation in precipitation levels within the MENA region, therefore, the model would be unable to detect a significant relationship between precipitation and income inequality. As for vulnerability and total population, this can be attributed to the high correlation between them and other variables in the model.

Based on table 5, if all climate and macroeconomic indicators have no effect on the Gini index, then the inequality level will be 25.7, indicating an adequate level of equality in the MENA region. Delving deeper into the meaning behind each coefficient will indicate if our previously stated expectations were correct, as well interpreting the effect of the significant explanatory variables on the Gini index. The Gini index has a significant relationship with temperature anomalies and the resilience index. First, as temperature anomalies increase by 1°C, the Gini index increases by 0.677 points. This is because an increase in temperatures can disrupt economic activities that contribute to the livelihoods of many individuals in the MENA region. Additionally, it can cause negative effects on the health of vulnerable communities. With limited resources, lower-income countries can severely suffer from disproportionate access to basic necessities, potentially widening the income gap. Second, as the resilience index increases by 1 point, the Gini index increases by 6.8 points. This is applicable in the situation where resilience-building efforts disproportionately benefit wealthier individuals, which can lead to a further concentration of resources and opportunities among those who are already better off, exacerbating income inequality.

The analysis in table 5 included fixed effects, random effects, and pooled models. Despite using different modeling approaches, the coefficients obtained from each model appear consistent with one another. This consistency across models suggests that the relationships between the variables remain stable regardless of the model specification used. Despite these observations, the discussion and analysis are centered on the random effects model, as it is the most suitable, as determined by the results of the Hausman test.

Table 5: Static Panel Regression Results – Pooled, Fixed and Random Effects Models

	Random Effects Model				Fixed Effects Model			
Giniindex	Coef.	St.Err.	t-value	p-value	Coef.	St.Err.	t-value	p-value
TempAnomalies	.677	.325	2.08	.037	.649	.289	2.24	.025
PrecipAnomalies	-.002	.001	-1.43	.154	-.002	.002	-0.96	.339
Vulnerability	18.293	21.684	0.84	.399	17.988	12.03	1.50	.135
Resilience	6.815	3.59	1.90	.058	7.002	3.074	2.28	.023
lnGDPpercapita	-.92	.443	-2.08	.038	-1.035	.312	-3.32	.001
RuleofLawEstimate	-1.468	.661	-2.22	.026	-1.704	.424	-4.02	0
ln_pop	.828	.702	1.18	.239	1.149	.562	2.04	.041
ConsumerPriceInfla~n	-.007	.001	-4.86	0	-.007	.003	-2.32	.021
lowermiddleincome	-1.901	.601	-3.16	.002	-1.835	.461	-3.98	0
uppermiddleincome	-1.527	.943	-1.62	.105	-1.489	.629	-2.37	.018
highincome	-1.587	1.205	-1.32	.188	-1.78	.864	-2.06	.04
1995b	0	.	.	.	0	.	.	.
1996	-.412	.465	-0.89	.375	-.408	.587	-0.70	.487
1997	-.103	.279	-0.37	.712	-.116	.586	-0.20	.844

1998	-.754	.423	-1.78	.074	-.736	.614	-1.20	.231
1999	-.571	.438	-1.30	.192	-.561	.617	-0.91	.363
2000	-.655	.486	-1.35	.178	-.654	.591	-1.11	.269
2001	-.632	.458	-1.38	.167	-.612	.625	-0.98	.328
2002	-.611	.41	-1.49	.136	-.605	.606	-1.00	.318
2003	-.479	.475	-1.01	.313	-.474	.617	-0.77	.443
2004	-.859	.539	-1.59	.111	-.857	.612	-1.40	.162
2005	-.543	.511	-1.06	.288	-.565	.616	-0.92	.36
2006	-1.35	.792	-1.71	.088	-1.392	.626	-2.22	.027
2007	-1.248	.698	-1.79	.074	-1.292	.637	-2.03	.043
2008	-1.582	.84	-1.88	.06	-1.632	.648	-2.52	.012
2009	-1.924	1.104	-1.74	.081	-1.967	.663	-2.97	.003
2010	-2.044	1.189	-1.72	.086	-2.084	.758	-2.75	.006
2011	-1.292	.916	-1.41	.158	-1.382	.674	-2.05	.041
2012	-1.4	1.056	-1.33	.185	-1.489	.694	-2.15	.032
2013	-1.356	.994	-1.36	.173	-1.469	.696	-2.11	.035
2014	-2.679	1.184	-2.26	.024	-2.796	.71	-3.94	0
2015	-2.465	1.121	-2.20	.028	-2.598	.72	-3.61	0
2016	-2.122	1.019	-2.08	.037	-2.262	.734	-3.08	.002
2017	-2.403	.918	-2.62	.009	-2.55	.733	-3.48	.001
2018	-2.742	1	-2.74	.006	-2.881	.759	-3.80	0
2019	-2.723	.945	-2.88	.004	-2.877	.738	-3.90	0
2020	-2.746	1.031	-2.66	.008	-2.911	.728	-4.00	0
2021	-2.832	1.095	-2.59	.01	-3.009	.729	-4.13	0
2022	-3.978	.848	-4.69	0	-4.161	.731	-5.69	0
2023	-3.625	1.233	-2.94	.003	-3.81	.734	-5.19	0
Constant	25.736	13.657	1.88	.06	21.596	11.6	1.86	.063

Mean dependent var	38.567	SD dependent var	5.187	Mean dependent var	38.567	SD dependent var	5.187
Overall r-squared	0.086	Number of obs	551	R-squared	0.276	Number of obs	551
Chi-square	184.64	Prob > chi2	0.000	F-test	4.808	Prob > F	0.000
R-squared within	0.274	R-squared between	0.068	Akaike crit. (AIC)	2215.2	Bayesian crit. (BIC)	2387.692

**** p<.01, ** p<.05, * p<.1*

Pooled Model

Giniindex	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]
Temperature Anomalies	.675	.278	2.43	.015	.13	1.219
Precipitation Anoma~s	-.002	.002	-0.94	.347	-.005	.002
Vulnerability	18.235	10.04	1.82	.069	-1.443	37.912
Resilience	6.838	2.902	2.36	.018	1.15	12.525
lnGDPpercapita	-.929	.294	-3.16	.002	-1.506	-.352
RuleofLaw	-1.485	.397	-3.74	0	-2.263	-.707
ln_pop	.844	.462	1.83	.068	-.061	1.75
ConsumerPriceInfla~n	-.007	.003	-2.40	.016	-.012	-.001
lowermiddleincome	-1.896	.443	-4.28	0	-2.765	-1.027
uppermiddleincome	-1.524	.603	-2.53	.011	-2.706	-.342
highincome	-1.602	.825	-1.94	.052	-3.219	.015
1995b	0	.	.	.	.	.
1996	-.412	.565	-0.73	.466	-1.52	.696
1997	-.104	.564	-0.18	.854	-1.21	1.002
1998	-.753	.591	-1.27	.203	-1.911	.406
1999	-.57	.594	-0.96	.337	-1.734	.594
2000	-.654	.569	-1.15	.251	-1.77	.462
2001	-.63	.602	-1.05	.295	-1.81	.55
2002	-.61	.583	-1.05	.296	-1.753	.533
2003	-.478	.593	-0.81	.421	-1.641	.685

2004	-.857	.587	-1.46	.144	-2.007	.293
2005	-.543	.589	-0.92	.356	-1.697	.611
2006	-1.351	.598	-2.26	.024	-2.523	-.18
2007	-1.249	.607	-2.06	.039	-2.438	-.06
2008	-1.584	.615	-2.58	.01	-2.789	-.379
2009	-1.925	.629	-3.06	.002	-3.159	-.692
2010	-2.044	.722	-2.83	.005	-3.46	-.628
2011	-1.296	.633	-2.05	.041	-2.536	-.055
2012	-1.403	.652	-2.15	.031	-2.682	-.125
2013	-1.361	.652	-2.09	.037	-2.639	-.084
2014	-2.685	.668	-4.02	0	-3.993	-1.376
2015	-2.471	.675	-3.66	0	-3.795	-1.148
2016	-2.129	.688	-3.09	.002	-3.478	-.78
2017	-2.41	.685	-3.52	0	-3.754	-1.067
2018	-2.748	.712	-3.86	0	-4.144	-1.352
2019	-2.731	.69	-3.96	0	-4.083	-1.379
2020	-2.754	.68	-4.05	0	-4.086	-1.422
2021	-2.842	.679	-4.18	0	-4.173	-1.511
2022	-3.988	.68	-5.86	0	-5.321	-2.655
2023	-3.635	.682	-5.33	0	-4.972	-2.297
Constant	25.559	9.936	2.57	.01	6.085	45.032
Mean dependent var		38.567	SD dependent var			5.187
Number of obs		551	Chi-square			199.862

According to table 6, the p-value indicates that the data is stationary as we reject the null hypothesis, meaning that the data has no trend and its variance is consistent over time. We ran the unit root test for the dependent variable and the explanatory variables representing climate indicators to ensure that they are all stationary and fit for use in this model. According to the results, all variables are stationary. Finally, table 7 displays the Wooldridge test for autocorrelation, which indicates the absence of autocorrelation in the model.

Table 6: Unit Root Test for Stationarity

	Statistic	p-value
z	30.9771	0.0000

Table 7: Wooldridge Test for Autocorrelation

Wooldridge test for autocorrelation in panel data

H0: no first order autocorrelation

F(1, 18) = 1.335

Prob > F = 0.2631

The results regarding the effect of the explanatory variables on the Gini index are largely consistent with findings from earlier studies. The coefficients align with expectations and are well-supported by economic theories.

VI. Conclusion and Policy Implications

The paper presents a detailed examination of the factors that affect income inequality in 19 MENA countries from the year 1990 to 2022. We analyzed the effects of the temperature and precipitation anomalies, vulnerability, and resilience on the Gini index. Recent research papers focused on either temperature and precipitation or vulnerability and resilience as climate change indices. However, this paper integrates both, making the analysis more inclusive. The data suggests that resilience and temperature increases have a negative effect on the Gini index, indicating wider income gaps. Income inequality is a critical issue; therefore, we must work diligently to eliminate any challenges or problems that exacerbate inequality, striving towards a more equitable world.

Based on the econometric findings, significant policy implications can be proposed, specifically for developing countries that are more vulnerable to the risks of climate change. Countries in the MENA region can invest in infrastructure that can withstand climate-related disasters. This includes water management systems, heat-resilient structures, and smart grids and energy efficient infrastructure that can ensure protecting vulnerable populations by providing sustainable water and energy sources, reducing health risks, and maintaining economic productivity. To complement this, governments can ensure that all communities have access to clean water and sanitation facilities, which are crucial in adapting to higher temperatures and climate change. Furthermore, governments can work towards providing social safety nets, insurance plans, and support for vulnerable sectors by offering technical assistance for sustainable practices and introducing climate insurance schemes. By doing so, the government is ensuring financial stability for low-income households during and after climate-related disasters, preventing them from falling deeper into poverty. Moreover, investing in renewable energy projects that also create job opportunities for low-income communities would be an asset as it mitigates climate change and provides employment opportunities, thus addressing the two challenges at hand. This needs to be accompanied by enhanced educational programs and vocational training to equip individuals with skills needed for jobs in a climate-resilient economy. Finally, to align with the aforementioned recommendations, there needs to be policy reforms that promote climate justice. To achieve this milestone, policymakers need to identify the root causes of the existing inequalities and vulnerability to adequately design inclusive policies.

While this research is very insightful, it still has its limitations. For instance, the researcher had to exclude some countries from the model due to the limited availability of data. Those include Somalia, Yemen, and Palestine. Additionally, some macroeconomic variables were excluded from the model as there was high multicollinearity between the regressors, which negatively affected the significance of the model. The r-squared of the model was relatively low, indicating an issue with the model specification, which needs to be examined further. However, as mentioned, this was attributed to the endogeneity problem caused by including the Gini index and the GDP per capita, which have a two-way relationship. To resolve this, the researcher ran a panel IV model and a panel GMM model, however, the problem remained unresolved. Finally, the analysis did not reveal evidence of a Kuznets curve because both the GDP per capita and the squared term of GDP per capita coefficients were negative. In the context of a Kuznets curve, it is expected to see a positive coefficient for GDP per capita, indicating that inequality initially increases with income, and a negative coefficient for the squared term, indicating that inequality decreases after a certain level of income is reached. Thus, for future research, suitable solutions for these major issues needs to be identified. For instance, a use of a more suitable panel GMM model specification can be used to resolve the endogeneity problem. Future research regarding this topic could focus on regional differences or integrate gender disparities within the model.

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