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CLIMATE CHANGE VULNERABILITY & INEQUALITY: A STUDY ON SOUTH MEDITERRANEAN COUNTRIES

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FORUM EUROMÉDITERRANÉEN DES INSTITUTS DE SCIENCES ÉCONOMIQUES

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CLIMATE CHANGE VULNERABILITY & INEQUALITY: A STUDY ON SOUTH MEDITERRANEAN COUNTRIES

CONTENTS

ABSTRACT

Climate change is one of the defining challenges of our time, marked by its complexity and evolving nature. While the effects of climate change on economic output and poverty have been widely studied, the relationship between climate change and within-country income inequality has garnered less attention. This paper provides new insights into the link between climate vulnerability and income inequality by analyzing data from sixteen South Mediterranean countries from 1995 to 2021. Our findings reveal that increased vulnerability to climate change is positively associated with rising income inequality. Specifically, by examining the six components of the composite climate vulnerability index—food, water, health, ecosystem services, human habitat, and infrastructure—we found that food vulnerability had a significant and positive coefficient. This suggests that vulnerability in the food sector is a primary driver of increasing inequality. We also explored the interaction between employment in the agricultural sector and institutional quality. The results indicate that institutional quality does not mitigate the negative impact of climate change on income inequality. Moreover, given that agriculture is one of the key channels through which climate change exacerbates inequality, our analysis highlights its crucial role in this dynamic.

Keywords: Climate change, climate vulnerability, inequality, panel data, ND-Index.

RÉSUMÉ

Le changement climatique constitue l'un des défis majeurs de notre époque, caractérisé par sa complexité et son évolution constante. Si les effets du changement climatique sur la production économique et la pauvreté ont été largement étudiés, la relation entre le changement climatique et les inégalités de revenus au sein des pays a suscité moins d'attention. Cet article apporte de nouveaux éclairages sur le lien entre la vulnérabilité climatique et les inégalités de revenus en analysant des données couvrant seize pays du Sud de la Méditerranée sur la période 1995–2021. Nos résultats montrent qu'une vulnérabilité accrue au changement climatique est positivement associée à une augmentation des inégalités de revenus. Plus précisément, en examinant les six composantes de l'indice composite de vulnérabilité climatique — alimentation, eau, santé, services écosystémiques, habitat humain et infrastructures — nous constatons que la vulnérabilité alimentaire présente un coefficient positif et significatif. Cela suggère que la vulnérabilité du secteur alimentaire constitue un facteur déterminant dans l'accroissement des inégalités. Nous avons également analysé l'interaction entre l'emploi dans le secteur agricole et la qualité des institutions. Les résultats indiquent que la qualité institutionnelle ne permet pas d'atténuer l'impact négatif du changement climatique sur les inégalités de revenus. En outre, étant donné que l'agriculture représente l'un des principaux canaux par lesquels le changement climatique exacerbe les inégalités, notre analyse met en évidence son rôle crucial dans cette dynamique.

Mots-clés: changement climatique, vulnérabilité climatique, inégalités, données de panel, ND-Index.

الملخّص

يُعدّ تغيّر المناخ أحد أبرز التحديات في عصرنا، حيث يتميّز بتعقيده وطبيعته المتغيّرة باستمرار. وعلى الرغم من أنّ آثار تغيّر المناخ على الناتج الاقتصادي والفقر قد دُرست على نطاق واسع، فإن العلاقة بين تغيّر المناخ وعدم المساواة في الدخل داخل البلدان لم تحظَ بالاهتمام الكافي.

تقدّم هذه الدراسة رؤى جديدة حول العلاقة بين قابلية التعرّض للمخاطر المناخية وعدم المساواة في الدخل من خلال تحليل بيانات ستة عشر بلداً من بلدان جنوب البحر الأبيض المتوسط خلال الفترة 1995–2021. وتُظهر نتائجنا أن زيادة قابلية التعرّض لتغيّر المناخ ترتبط بشكل إيجابي بارتفاع عدم المساواة في الدخل. وعلى وجه التحديد، ومن خلال دراسة المكوّنات الستة لمؤشر قابلية التعرّض المناخي المركّب — الغذاء، والمياه، والصحة، وخدمات النظم البيئية، والموائل البشرية، والبنية التحتية — تبيّن أن قابلية التعرّض في قطاع الغذاء تحمل معاملاً موجباً ودالاً إحصائياً، مما يشير إلى أن هشاشة قطاع الغذاء تُعدّ عاملاً رئيسياً في زيادة عدم المساواة.

كما قمنا بدراسة التفاعل بين التوظيف في القطاع الزراعي وجودة المؤسسات، وأظهرت النتائج أن جودة المؤسسات لا تخفّف من التأثير السلبي لتغيّر المناخ على عدم المساواة في الدخل. وعلاوة على ذلك، وبالنظر إلى أن الزراعة تمثل إحدى القنوات الرئيسية التي يفاقم من خلالها تغيّر المناخ عدم المساواة، فإن تحليلنا يسلّط الضوء على دورها الحاسم في هذه الديناميكية.

الكلمات المفتاحية: تغيّر المناخ، قابلية التعرّض المناخي، عدم المساواة، بيانات السلاسل الزمنية المقطعية (Panel Data)، مؤشر ND.

INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) has unequivocally stated in its reports that human activities are the primary drivers of global warming, with global surface temperatures rising by 1.1°C over the past decade compared to the period from 1850 to 1900. This warming has led to rapid and profound changes across the atmosphere, oceans, cryosphere, and biosphere, causing significant losses and damages to both natural systems and human communities. Vulnerable populations—those who have historically contributed the least to climate change—bear a disproportionate share of these impacts. The Mediterranean region stands out as one of the most climate-vulnerable areas in the world, grappling with water scarcity, desertification, rising sea levels, and increasing temperatures. These shared environmental challenges underscore the urgent need for regional cooperation on climate adaptation and mitigation.

However, the effects of climate change are not evenly distributed among citizens. Certain groups, such as rural, low-income communities and women, face disproportionately severe consequences. Several factors explain this inequality. First, the unequal spatial and sectoral distribution of economic activities and climate-related risks means that poorer households are more exposed to climate shocks than wealthier ones. Second, low-income communities, particularly the poorest households, often experience greater income and wealth losses due to climatic events. Third, many lack the capacity and financial resources needed to respond to or adapt to climate challenges. While between-country inequality has been widely studied, within-country inequality has received comparatively less attention. Most existing research has focused on poverty or aggregated inequality trends, with econometric studies addressing within-country inequality emerging only recently. These studies often group countries into developed and developing categories, failing to account for the diversity and heterogeneity within developing nations.

This study aims to examine the impact of climate vulnerability on within-country inequality, with a particular focus on South Mediterranean countries. By utilizing the climate vulnerability index developed by the Notre Dame Global Adaptation Initiative (ND-GAIN), this research contributes to the literature by capturing the nuanced ways climate change exacerbates or mitigates vulnerabilities.

Our analysis covers a panel of 16 Euro-Mediterranean countries to explore whether climate vulnerability explains rising inequality. Additionally, we investigate the interaction between climate vulnerability and two critical transmission channels: employment in the agricultural sector and institutional quality.Using a Feasible Generalized Least Squares (FGLS) one-way fixed effects model, this study provides new insights into these dynamics.

The findings reveal a positive correlation between climate vulnerability and rising income inequality, even after controlling for economic and demographic factors. Further analysis shows that the significant share of agricultural employment in many South Mediterranean countries amplifies this inequality, as the agricultural sector is particularly susceptible to climate change. Similarly, institutional quality in these countries does not effectively mitigate the adverse effects of climate change on the most vulnerable populations, due to factors such as weak anti- corruption controls, ineffective judicial systems,inadequate regulatory frameworks, and political instability.

The results of this researchhave important policyimplications. Climate change and vulnerability disproportionately affect the poorest and most disadvantaged communities in South Mediterranean countries. Climate policies that fail to account for inequality during their design and implementation may inadvertently worsen the burdens on these populations. Thus, addressing climate change from ecological, economic, and inequality perspectives is essential.

The remainder of this paper is organized as follows: Section 1 reviews the related literature, Section 2 describes the data and introduces the econometric model,and Section 3 presents the empirical results and policy implications.

LITERATURE REVIEW

CLIMATE CHANGEAND INEQUALITY

In recent years, numerous studies have highlighted the detrimental impact of global warming on GDP (Ciscar et al., 2011, 2012; Bosello et al., 2012; Sussman et al., 2014; Bosello and De Cian, 2014; OECD, 2015; Steininger et al., 2015; Dellink et al., 2017). Moreover, the correlation between rising temperatures and productivity losses has long been established (Montesquieu, 1750; Marshall, 1890; Huntington, 1915). Further research has uncovered significant connections between temperature and mortality(e.g., Curriero et al., 2002; Deschenes and Moretti, 2007; Deschenes and Greenstone, 2007), temperature and crime (e.g., Field, 1992; Jacob et al., 2007), and drought and conflict (Miguel et al., 2004), all of which directly or indirectly influence economic activity.

Conversely, colder countries may initially benefit from rising temperatures. Leppänen et al. (2017) found that an increase in temperature leads to reduced public expenditures. While it is true that cold countries will also experience a decline in GDP if warming continues, the immediate impacts are felt more strongly by warmer countries. Kahn et al. (2019) discovered that when a poor (hot) country experiences a 1°C increase in temperature, its income growth decreases by 1.2 percentage points in the short to medium term, whereas a similar increase in a wealthier country has minimal impact on economic activity. Moreover, many of these warmer countries contribute relatively little to global CO2 emissions, underscoring the unequal dynamics of climate change. This highlights the role of climate change in exacerbating inequality between countries. While between-country inequality has received significant attention, the same cannot be said for within-country inequality.

Islam et al. (2017) provided a theoretical explanation for how climate change worsens inequality, outlining three main channels through which disadvantaged groups are disproportionately affected. First, these groups are more exposed to climate hazards. Evidence suggests that disadvantaged communities often reside in areas more vulnerable to climate effects, such as flood-prone regions, due to financial constraints preventing them from living in safer areas.

Neumann et al. (2015)highlighted that a significant proportion of populations in developing regions live in "low-elevation coastal zones," which are especially vulnerable to sea-level rise. Additionally, disadvantaged individuals often work in jobs that are more exposed to weather conditions, such as outdoor labor. Second, disadvantaged groups are more vulnerable to the negative impacts of climate change. Wodon et al. (2014) observed that in some Middle Eastern and North African (MENA) countries, the poorest households suffered greater income losses, crop damage, and livestock depletion compared to wealthier households. Moreover, these groups face greater susceptibility to diseases and higher financial costs due to climate hazards, often exacerbated by inadequate housing. Third, disadvantaged groups have fewer resources to cope with and recover from climate disasters, such as floods, due to a lack of insurance and savings. This inability to recover further widens the gap between socioeconomic classes, perpetuating inequality.

The limited studies on the subject suggests that climate change exacerbates the Gini index, the most commonly used measure of within-country inequality, thus increasing inequality over the long run. Cevik and Jalles (2022) used a panel of 158 countries from 1995 to 2019 and found that a 1% increase in climate vulnerability, as measured by the ND-GAIN index, is associated with a 1.5% deterioration in income inequality. Similarly, Paglialunga et al. (2022) found that increases in temperature and precipitation anomalies have significant negative effects on within- country inequality. Using fixed-effect and GMM models, they demonstrated that a 1% increase in temperature leads to a rise of about 0.5 percentage points in the Gini index. Hai-Anh et al. (2023) extended this analysis by studying 134 countries from 2010 to 2019, finding that a 1°C increase in temperature leads to an increase of 0.8% in the Gini index and 1.4% in the Theil index. They estimate that climate change has reversed approximately 1.2 years of progress in reducing income inequality.

Castells-Quintana et al. (2023) employed a different approach, analysing temperature changes over 5-year intervals to capture short-to medium-term effects on inequality. They found that a 1°C increase in average temperatures over this period is associated with a 1.3 percentage point rise in the Gini coefficient, consistent with previous findings.

Islam (2017) identified two ways climate change affects inequality—economic and political. Economically, it limits resources for disadvantaged groups,making recovery harder,especially in unequal societies. Agriculture is centralto this, as Hallegatte and Rozenberg (2017)and Rao et al. (2017) noted.It drives incomes,provides jobs, and supports the environment, particularly in Africa, where many rely on farming.

Politically, powerful groups often influence policies, delaying climate protections and favoring their own interests. Adaptation efforts may also benefit them more. Political economy theories link concentrated power to environmental harm and slow action. In southern Mali,for example, fire policies driven by international pressure to fight deforestation left rural communities more vulnerable to fires and increased the country's debt, showing how mitigation effortscan deepen inequality.

METHODOLOGY

DATA OVERVIEW

The primary variable of interest in this study is the ND-GAIN Vulnerability Index, which measures a country's current vulnerability to climate disruptions and its capacity to adapt through private and public sector investments. However, since the ND-GAIN Readiness Index incorporates inequality as one of its components, we have opted not to use the readiness score in our analysis to avoid potential endogeneity issues. Thus, the focus will be exclusively on climate vulnerability.

In contrast to traditional measures of climate impacts, such as temperature and precipitation, the ND-GAIN Vulnerability Index offers a more comprehensive assessment by examining the specific ways in which climate change affects different sectors. As discussed in the literature review, climate change can exacerbate inequality through three primary channels:(a) increasing the exposure of disadvantaged groups to climate hazards; (b) making them more susceptible to the damage caused by these hazards; and (c) reducing their capacity to recover from these impacts (Islam et al., 2017).

The ND-GAIN Vulnerability Index adopts a similar framework, but with greater granularity. Rather than presenting a singular score for a country's overall vulnerability, it disaggregates vulnerability into six key sectors: food, water, health, ecosystem services, human habitat, and infrastructure. This sectoral breakdown allows for a more detailed analysis of how different dimensions of climate vulnerability contribute to inequality, providing a more nuanced understanding than is possible with aggregate measures like temperature or precipitation alone.

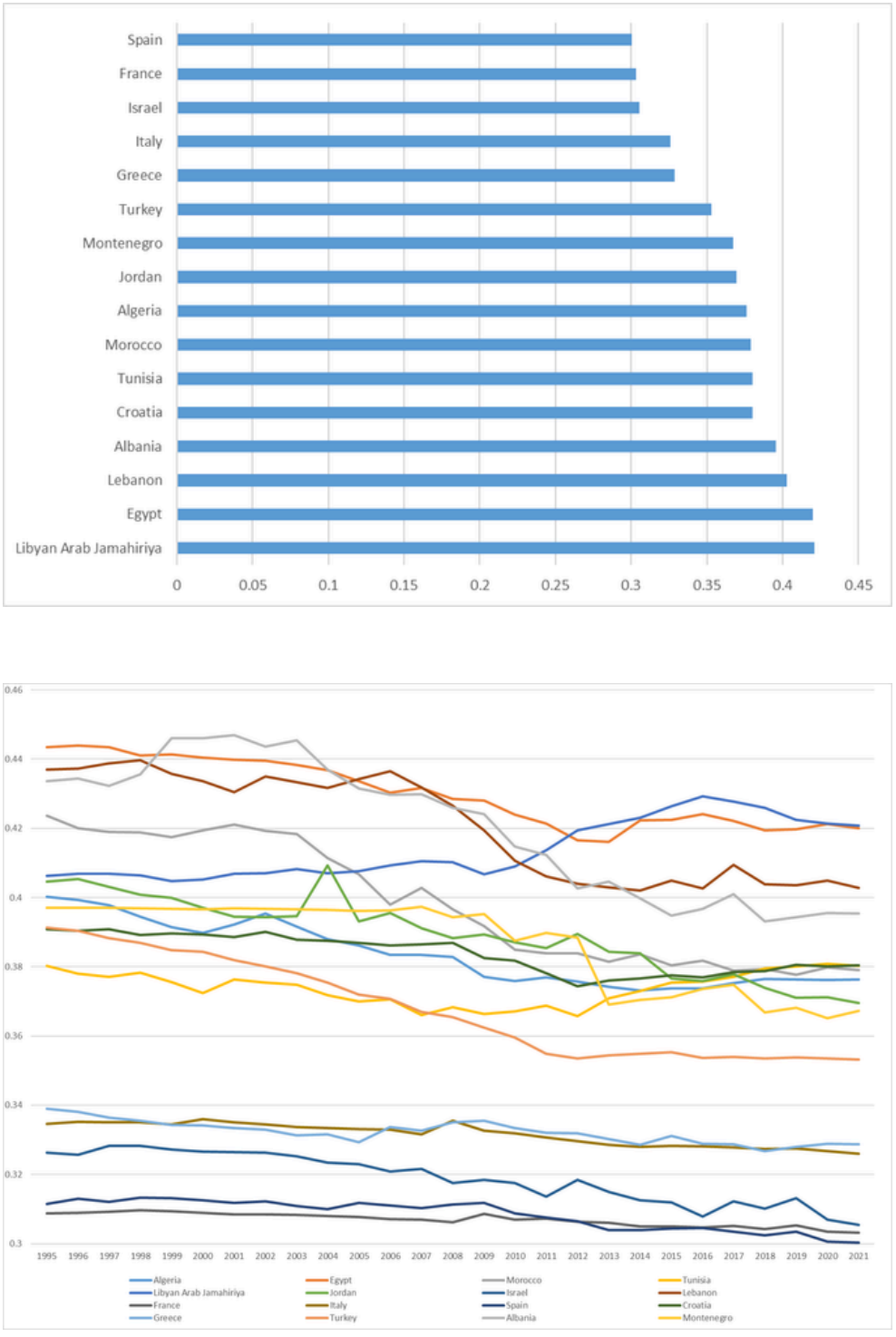

Figure 2.1.1: Vulnerability across countries of our sample

Source: Authors' calculations

Figure 2.1.1 shows that Israel, France and Spain have the lowest vulnerability to climate change, while Libya and Egypt rank highest, facing severe threats from floods and tornadoes. Although countries like Morocco and Algeria were already less vulnerable than Egypt and Libya in 1995, they have experienced further reductions by 2021. For example, Morocco successfully reduced its vulnerability from over 0.42 in 1995 to less than 0.38 in 2021.This improvement was largely due to a decrease in its sensitivity score, which dropped from 0.34 in 1995 to 0.30 in 2021. The reduction in sensitivity can be attributed to efforts to lessen the country's dependence on food imports, which fell from 0.3 in 1995 to 0.2 in 2021, as well as a significant decline in the proportion of the population living in slums, from over 0.35 to 0.10 by 2021. Although Morocco's reliance on imported energy has increased, unlike Algeria, this did not lead to a rise in the sensitivity score.

When examining the impact of climate change on inequality, most studies rely on the Gini Index as a measure of inequality. The Gini Index's advantage lies in its ability to summarize the inequality of an entire income distribution into a single, easy-to-interpret statistic that ranges from 0 to 1, facilitating comparisons among countries with varying population sizes. Additionally, Gini Index data is widely accessible.

However, the Gini Index has faced significant criticism. Thomas Piketty, founder of the World Inequality Lab, argues in his book *Capital in the 21st Century* [1] that it is impossible to encapsulate the multidimensional nature of inequality within a unidimensional index without substantial oversights. Atkinson and Bourguignon (2015) also point out that a lower Gini Index does not necessarily indicate a more equitable income distribution, as the Lorenz curves of two countries may intersect, reflecting different income structures. Furthermore, multiple countries can share the same Gini Index value while exhibiting different levels of inequality when considering the incomeshares held by the richestand poorest segments. For instance, according to 2015 World Bank data, Greece and Thailand both had a Gini Index of 0.360, yet the ratio of the income share of the richest 10% to that of the poorest 10% was 13.8 in Greece and 8.9 in Thailand.

[1] Piketty, T., & Goldhammer, A. (2014). Capital in the Twenty-First Century. Harvard University Press. http://www.jstor.org/stable/j.ctt6wpqbc

Piketty further highlights in his book, the beauty of deciles and centiles is precisely that they enable us to compare inequalities that would otherwise be incomparable, using a common language that should in principle be acceptable to everyone" [2](p. 252). This rationale led us to opt for a ratio using deciles rather than relying on the Gini Index. Consequently, we chose to measure inequality by examining the ratio of the income of the richest 10% (the "upper class") to that of the bottom 50% (the "lower class") of the population.

The figure below shows the correlation in 2021 between climate vulnerability and inequality. We observed a strong positive correlation: higher vulnerability to climate change is generally associated with higher inequality. This finding aligns with the literature, which suggests that countries highly vulnerable to climate change tend to experience significant income losses among poorer households. These households are also less equipped to cope with climate shocks, which exacerbates inequality.

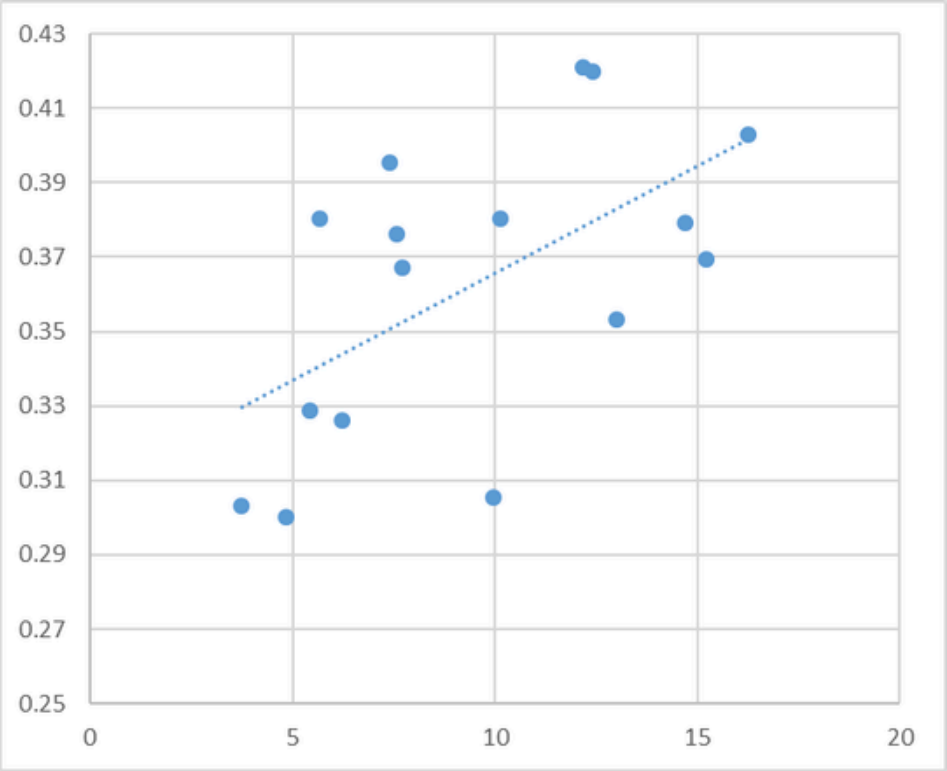

Figure 2.1.2: Vulnerability and income inequality (2021)

Source: Authors' calculations

[2] Piketty, T., & Goldhammer, A. (2014). Capital in the Twenty-First Century. Harvard University Press. http://www.jstor.org/stable/j.ctt6wpqbc

EMPIRICAL METHODOLOGY

Drawing on existing literature, this study investigates the empirical relationship between climate change and income inequality while controlling for conventional determinants of income disparities, using a panel dataset of eight[3]South Mediterranean countries from 1995 to 2021. Tests using R Studio showed that for our analysis, we need to use the Feasible Generalized Least Squares (FGLS) method instead of the usual Ordinary Least Squares (OLS) method, given that FGLS accommodates heteroscedasticity and serial correlation present in our dataset.

Furthermore, we use a fixed effect one-way (individual) effect model. Moreover, a test to check for endogeneity indicated that the one-way(individual) effect within the FGLS model is the most optimal. The regression model we employ is as follows:

$$Inequality_{it} = \alpha Vulnerablity_{it} + \beta X_{it} + \eta_i + \varepsilon_{it} \quad (1)$$

In this model, the top 10/bottom 50 ratio is our dependent variable, with data sourced from the World Inequality Database (WID).Our primary independent variable is vulnerability, with data available from the Notre Dame University website.[4]The vector X_{it}represents our control variables, including real GDP growth, trade openness, population, population density, employment in agriculture (as a percentage share of total employment), and quality of institutions (measured by the Worldwide Governance Indicators from the World Bank).[5] The data we use are from the IMF dataset, the World Bank, and the ND-GAIN dataset. η_i is the individual fixed effect of our model, and ε_{it} is our idiosyncratic error term.

[3] There is no available data on climate vulnerability for Palestine

[4] https://gain.nd.edu/our-work/country-index/

[5] These indicators include corruption control, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability.

Building on the literature review, we recognize that people's increased exposure and vulnerability to climate hazards are significantly influenced by a combination of economic, political, and social factors that both create and exacerbate inequalities. To better understand this dynamic, we explore the interaction between a country's vulnerability, employment in agriculture, and the quality of its institutions (i.e., vulnerability * employment in agriculture,[6] vulnerability * quality of institutions).[7] This in-depth analysis aims to provide a more comprehensive understanding of the complex nature of climate vulnerability and its impact on inequality. Accordingly, we proceed to estimate equations (2) and (3):

$$Inequality_{it} = \alpha(Vulnerablity_{it} * quality\ of\ institutions_{it}) + \beta X_{it} + \eta_i + \varepsilon_{it} \quad (2)$$

$$Inequality_{it} = \alpha(Vulnerablity_{it} * employment\ in\ agriculture_{it}) + \beta X_{it} + \eta_i + \varepsilon_{it} \quad (3)$$

[6] Hallegatte and Rozenberg (2017) and Rao et al. (2017) suggest that agriculture is one of the primary channels through which climate change impacts poverty and income inequality.

[7] The quality of institutions significantly affects the allocation of resources and opportunities among domestic social groups, ultimately shaping the distributive patterns of countries (Chong & Gradstein, 2007; Levy & Temin, 2007; Ostry et al., 2018).

RESULTS

Table 3.1.1 presents the results of equations (1), (2), and (3), estimated using a Feasible Generalized Least Squares (FGLS) individual within model. All three modelsshow an R-squared value of over 0.75, indicating that the selected variables explain more than 75% of the variation in income inequality.

In equation (1), the coefficient for climate vulnerability is positive and statistically significant at the 5% level (refer to column 1 of table 3.1.1). This suggests that an increase in climate vulnerability leads to a rise in income inequality. Specifically, a one-unit increase in a country's vulnerability in period t−1 results in a 0.3143% increase in the income inequality gap between the top 10% and the bottom 50% of the population. This finding is consistent with the results of Cevik and Tovar Jalles (2021), who also used the ND-GAIN vulnerability index in their analysis.

	Dependent variable:		
	log(inequality)		
	(1)	(2)	(3)
lag(vulnerability)	0.704*** (2.2e-16)		
lag(log(empagr))		0.028403*** (8.9e-14)	
lag(log(tradopeness))	-0.05701*** (0.0000002)	-0.06165*** (2.2e-16)	-0.05533*** (2.2e-16)
lag(governance)	0.4132*** (0.00000022)		0.38138*** (2.2e-16)
lag(log(pop))		-0.01355*** (0.000098)	-0.012766*** (0.0000592)
lag(rgdpgrowth)	0.00101*** (0.00021)	0.00067** (0.0000000059)	0.0006462*** (0.00000000247)
lag (vulnerability * governance)		0.891094*** (2.2e-16)	
lag (vulnerability * log(empagr))			0.1075*** (2.2e-16)
lag(log(pop density))	-0.01023***	0.0129***	0.0144***
	(0.000001)	(0.000077)	(0.0036)
Observations	431	431	431
Fixed effects	Yes	Yes	Yes
Multiple R-squared:	0.95304	0.9535	0.95391

Table 3.1.1: Results of oneway (individual) effect Within FGLS model

Note: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1
This table presents the estimation results for Equations (1). The interaction of vulnerability and institutional quality on income inequality is examined in the specification (2). The interaction of vulnerability and institutional quality is added in the specification (3).

We further estimate equation (1) by incorporating the six constituent components of the composite vulnerability variable: food, water, health, ecosystem services, human habitat, and infrastructure (refer to the appendix). The results indicate that the food component has the largest significant and positive coefficient, suggesting that climate vulnerability in the food sector primarily contributes to rising income inequality. Upon examining food vulnerability within our sample of countries, we found that they exhibit a high food vulnerability rating. This elevated rating can be attributed to the agricultural dependence of most countries in the region.

Additionally, the Global Food Insecurity Index shows that South Mediterranean countries have relatively high food insecurity scores compared to European countries (IMF,2022) (see Figure 3.1.1). This vulnerability is worsened by the region's dependence on food imports, a lack of resilience to climatic events, and excessive government intervention, all of which render food supplies and prices particularly sensitive to climate change.(Refer to Tanyeri-Abur, A. (2015)[8] for more info)

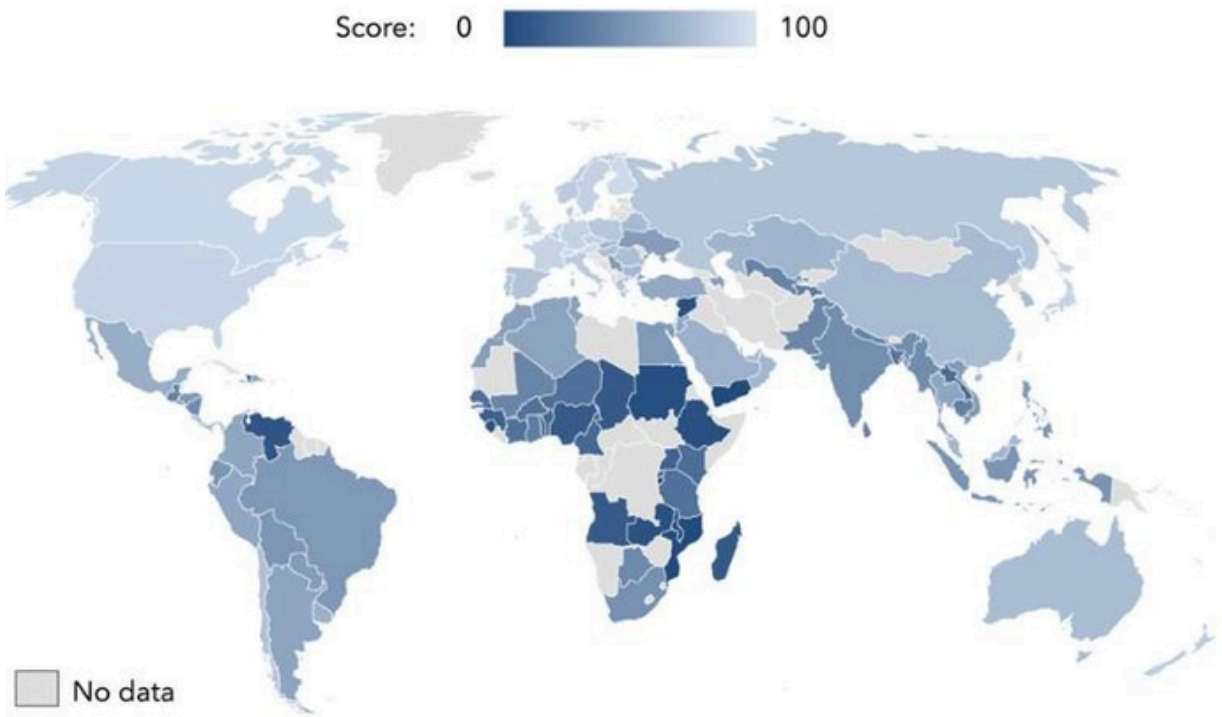

Figure 3.1.1: Hanger metrics

Source: Global Food insecurity index2021 and IMF calculations

[8] Tanyeri-Abur, A. (2015).Food Security in the SouthernMediterranean/North Africa. In: Vastola, A. (eds) The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin. Springer, Cham. https://doi.org/10.1007/978-3-319-16357-4_1

Equation (2) (refer to column 2 of Table 3.1.1) indicates that the interaction between climate vulnerability and the quality of institutions is positive and significant at the 0.1% level. This suggests that, within our panel of countries, the combined effect of vulnerability and institutional quality increases income inequality. While studies[9] in other regions have shown that improving institutional quality can reduce inequality and mitigate the adverse effects of climate change on income distribution, our analysis reveals that institutions quality widen the income gap between the top 10% and the bottom 50% of the population.

Equation (3) (refer to column 3 of Table 3.1.1) shows that the interaction between climate vulnerability and employment in the agricultural sector is positive and significant at the 0.1% level. This result was anticipated, as the agricultural sector plays a critical role in the link between climate change and inequality. A higher proportion of employment in agriculture intensifies the effect of rising temperatures on income inequality. Specifically, agricultural households are more likely to experience revenue losses due to climate change, which amplify income disparities.

Additionally, trade openness exhibits a significant and negative impact on inequality across all three equations. This result supports the Stolper-Samuelson theorem (Stolper & Samuelson, 1941), which posits that trade openness increases inequality in developed countries but reduces it in developing countries. Empirical studies in developing countries have consistently found this negative relationship (e.g., Dorn[10] et al., 2021). Through our analysis, we demonstrate the significant role of climate vulnerability in exacerbating inequality in South Mediterranean countries, corroborating findings from various studies across different country panels. Furthermore, we examined the relationship between climate vulnerability and two key channels of climate change impact: institutional quality and the agricultural sector. Our findings reveal that the interaction between climate vulnerability and employment in the agricultural sector positively influences inequality within countries. This is because agriculture is one of the sectors most susceptible to climate change impacts, affecting the income of those employed within it and widening income disparities.

[9] Chong and Gradstein (2007),Carmignani (2009), Ezcurraet al. (2014) and Cong and Hong (2024).

[10] Dorn, Florian and Fuest,Clemens and Potrafke, Niklas, Trade Openness and Income Inequality: New Empirical Evidence (2021). CESifo Working Paper No. 9203, Available at SSRN: https://ssrn.com/abstract=3892627 or http://dx.doi.org/10.2139/ssrn.3892627

ROBUSTNESS ANALYSIS:

To test the robustness of ourresults, we utilizedthe Gini Index as an alternative measure of inequality. The resultsconsistently show a positive relationship between climate vulnerability and inequality. Although the coefficient differs from the ratio used previously (which compared the income share of the top 10% to the bottom 50%), this difference is expected since the Gini Index considers the entire distribution of income. Specifically, our analysis indicates that an increase in a country's vulnerability raises the Gini Index by 0.04%. This finding aligns with the results of Cevik and Jalles (2022), who used a similar vulnerability measure.

Additionally, we conducted the same estimations across different panels of countries, and the results remained consistent. This further supportsthe robustness of our findings,reinforcing the observed relationship between climate vulnerability and income inequality.

CONCLUSION

his study demonstrates that climate change consistently amplifies within-country inequality, a finding that aligns with the broader literature. Robustness analyses reinforce these conclusions, showing that the observed outcomes remain stable across different measures of income inequality. Furthermore, the unequal distribution of climate impacts highlights the necessity of policies that not only accelerate climate action but also promote sustainability and equity. By exploring how inequality shapes and is influenced by climate vulnerability, this research contributes to the broader goal of designing equitable climate policies, a vital element of climate action in the Euro med region.

A critical limitation of this study lies in the inconsistency of data availability across countries. For example, missing data on dam capacity for Israel, access to reliable drinking water for Egypt, and natural capital dependency for Lebanon may affect the accuracy of vulnerability measures, emphasizing the need for caution when interpreting the results. Additionally, aggregating data at the national level may hide significant intra-country disparities, such as regional variations in weather conditions, disaster exposure, and socioeconomic inequality. This issue is particularly relevant for developing countries, which are often characterized by diverse climates and risks. The analysis also reveals that water vulnerability—unlike other components—has a negative and significant coefficient, suggesting it may reduce inequality. This result could be attributed to specific interventions, such as Morocco's water desalination programs aimed at mitigating drought and water scarcity.

It is also important to recognize that future impacts of climate change on income, inequality, and poverty will not depend solely on the nature and magnitude of climate changes but also on evolving socioeconomic contexts (Kelly & Adger, 2000; Hallegatte & Rozenberg, 2017). These contexts—shaped by socioeconomic and technological trends, policies, and collective action— are highly uncertain and critical to understanding future outcomes. In summary, this study highlights the significant impact of climate vulnerability on income inequality, emphasizing the need for further research using more granular data and refined methodologies. Addressing these limitations will be essential for advancing our understanding and informing more effective, equitable policy responses to climate change.

POLICY IMPLICATIONS & RECOMMENDATIONS

The findings of this study highlight the need for climate policies that are explicitly designed with distributional impact in mind. This means that mitigation and adaptation measures should be systematically assessed in terms of their effects on income inequality and the welfare of vulnerable groups, rather than focusing solely on aggregate emissions reductions. Effective climate policies should consider social and economic disparities to ensure a just and inclusive transition to a sustainable future. Furthermore, given the significant role of food vulnerability in driving inequality, governments should prioritize investments in climate- resilient agricultural practices, such as drought-resistant crops, improved irrigation systems, and localized food production initiatives. Reducing reliance on food imports through enhanced agricultural productivity can also strength food security and stabilize incomes for rural communities.

Additionally, the strong link between institutional quality and inequality underscores the urgency of strengthening governance frameworks in the region. In practice, this requires improving the transparency and targeting of climate-related public spending, strengthening anti-corruption mechanisms in the allocation of climate funds and reinforcing the capacity to ensure that adaptation and mitigation programs effectively reach vulnerable populations. Policymakers must prioritize the establishment of transparent and equitable resource allocation systems, and ensure that decision- making processes are inclusive, with particular attention to the needs of the most vulnerable communities. An example given by SenGupta, Swapnanil and Atal, Aakansha (2024),[11] highlights the importance of designing climate change mitigation policies that address fairness.

They suggest measures such as carbon taxes and the removal of fossil fuel subsidies, paired with direct cash transfers to protect low-income households from rising energy costs. Additionally, they recommend expanding access to education, subsidizing green energy, promoting environmental awareness, and encouraging sustainable practices through behavioural incentives. These actions, supported by green taxation on wealthier groups, could effectively tackle both income inequality and climate change.

[11] SenGupta, Swapnaniland Atal, Aakansha, Income Inequality in the Face of ClimateChange: An Empirical Investigation on Unequal Nations, Vulnerable Regions and India (May 16, 2024). Available at SSRN: https://ssrn.com/abstract=4831042 or http://dx.doi.org/10.2139/ssrn.4831042

Furthermore, regional cooperation, specially within the Euro-Mediterranean framework, should be strengthened to addressshared challenges such as water scarcity and infrastructure vulnerability. In this context, initiatives under the EU-Mediterranean cooperation framework, supported by international organizations such as the IMF, the Word Bank, and also regional development banks, can play a central role in financing and coordinating climate adaptation efforts. For example, collaborative initiatives may focus on large-scale water desalination projects, cross-border renewable energy integration, and regional disaster preparedness programs. By transforming these findings into actionable strategies, policymakers and international partners can more effectively address the dual challenges of climate vulnerability and inequality, fostering a more equitable and sustainable future for the region.

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APPENDIX

Table A-1: Estimation of the components of vulnerability

One-way (individual) effect Within FGLS model

pggls(formula = vul, data = PDATA2, effect = "individual", model = "within") Unbalanced Panel: n = 16, T = 26-27, N = 431

Residuals:

Min.	1st Qu.	Median	3rd Qu.	Max.
-0.324548385	-0.059028388	-0.007550531	0.056757285	0.305025523

Coefficients:

	Estimate	Std. Error	z-value	Pr(>|z|)	
lag(health)	1.6557e-04	2.0101e-02	0.0082	0.9934	
lag(ecosystems)	6.8704e-01	3.1891e-02	21.5434	< 2.2e-16	***
lag(water)	-8.9454e-01	2.8025e-02	-31.9197	< 2.2e-16	***
lag(infrastructure)	-3.8136e-01	2.0612e-02	-18.5016	< 2.2e-16	***
lag(habitat)	-3.8437e-01	4.8029e-02	-8.0028	1.216e-15	***
lag(food)	1.0490e+00	2.4411e-02	42.9740	< 2.2e-16	***
lag(log(tradopeness))	-2.9150e-02	3.7801e-03	-7.7115	1.244e-14	***
lag(governance)	5.1818e-01	1.3211e-02	39.2226	< 2.2e-16	***
lag(rgdpgrowth)	1.1216e-04	7.7846e-05	1.4408	0.1496	
lag(log(popdencity))	3.9890e-02	1.5462e-03	25.7986	< 2.2e-16	***

Signif. codes : 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 Total Sum of Squares: 96.972

Residual Sum of Squares: 4.2285 Multiple R-squared: 0.95639

Table A-2: ND-GAIN Vulnerability Indicators

Sector	Exposure component	Sensitivity component	Adaptive Capacity component
Food	-Projected change of cereal yields -Projected population change	-Food import dependency -Rural population	-Agriculture capacity (fertilizer, irrigation, pesticide, tractor use -Child malnutrition
Water	-Projected change of annual runoff - Projected change of annual groundwater recharge	- Fresh water withdrawal rate - Water dependency ratio	- Access to reliable drinking water - Dam capacity
Health	- Projected change of deaths from climate change induced diseases - Projected Change in Vector Borne Disease	- Slum population - Dependency on external resource for health services	- Medical staffs (physicians, nurses, and midwives) - Access to improved sanitation facilities
Ecosystem services	- Projected change of biome distribution - Projected change of marine biodiversity	- Dependency on natural capital - Ecological footprint	- Protected biomes - Engagement in international environnement conventions
Human Habitat	- Projected change of warm period - Projected change of flood hazard	- Urban concentration - Age dependency ratio	- Quality of trade and transport-related infrastructure - Paved roads
Infrastructure	- Projected change of hydropower generation capacity - Projected change of sea level rise impacts	- Dependency on imported energy - Population living under 5m above sea level	-Electricity access -Disaster preparedness

Source: Chen et al. (2015)

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