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CLIMATE CHANGE AND INCOME INEQUALITIES

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Abstract

The relationship between climate warming and associated socio-economic development is a central question for environmental economists and social scientists. The scientific literature focusing on the economic effects of climate change is mainly based on the cross-sectional impact of temperature and precipitation on GDP growth. However, little is known about the effects of climate variations on income inequality. This paper aims at filling this gap by exploring the relationship between climate and income inequality. We use two different country-level panel datasets on income inequality: i) the Standardized World Income Inequality Database (Solt, 2016), which provides the GINI index, and ii) the World Income Inequality Database (Wider, 2008), which provides the share of income held by different classes of the population. We then match the two-income inequality indices with annual climate data for 165 countries from 1960 to 2010. Our analysis suggests a significant ∩-shaped relationship between inequality indices and annual mean temperature.

Keywords: Income Inequality, climate change, GINI index, income distribution

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1. Introduction

Understanding the drivers of income inequality is a crucial task for economists and social scientists.

Economic literature has extensively addressed this topic by focusing on the effects of climate change, mainly on the GDP at a national level (Diffenbaugh and Burke, 2015, 2019). The general conclusion of these studies suggests that historical increases in temperatures substantially reduce economic growth (Dell et al., 2009, 2012; Deryugina and Hsiang, 2014). This is especially the case for developing countries. Nevertheless, establishing the channels through which climate warming might affect economic development is a complicated task. The reason is that there exists a variety of impacts of temperature and precipitation shocks. Jones and Thornton (2003) have first focused on the reduction of maize output caused by the increase in surface temperatures in Africa and Latin America. On the other hand, Deschênes and Greenstone, 2007 focusing on the U.S., have concluded that climate change will increase annual profits by four percentage points. Burke et al. (2015) first, and Bosetti et al. (2020), more recently instead, have shown how climate change might exacerbate political instability, causing local conflicts and poverty.

Furthermore, Casey et al. (2019) have shown how temperature variations directly affect fertility rates. Finally, Lindsay and Birley (1996) and Gething et al. (2010) have suggested that small increases in temperature at low temperatures may substantially increase the risk of transmission of vector-borne diseases such as malaria. This conclusion is significant since poor communities characterized by the absence of efficient health services that are currently not affected by vector-borne diseases might be at increased risk of future outbreaks.

However, little is known about the relationship between climate and income inequality. In this paper, we combine spatial time series data at the national level on temperature together with two different indexes of income inequality to shed light on the possible relationship between temperature variations and income inequality within nations.

A similar study is by Diffenbaugh and Burke (2019), in which the authors differentiate the economic effects of climate warming in poor and wealthy parts of the population. A significant difference between Diffenbaugh and Burke (2019) and this paper is that while the first focuses on the GDP per capita, the present study concentrates on the impact of climate warming on the GINI index as a proxy of income inequality. Another study in line with the present one is Dasgupta et al. (2020). This study builds on the literature above, considering inequality and poverty at the sub-national level rather than standard GDP measures. They show a significant ∪-shaped relationship between inequality/poverty indices and local mean temperature.[1] However, while Dasgupta et al. (2020) focus on South Africa, we enlarge the analysis on the whole world and differentiate the effects of climate warming on different population classes (i.e., from the poorest quintile to the wealthiest 1% of the population).

This paper contributes to filling the gap of the existing literature on the estimation of the relationship between climate change and income inequality at a global scale by providing a country-level analysis using two different measures of the income distribution, i.e., the Standardized World Income Inequality Database (Solt, 2016), and the World Income Inequality Database (Wider, 2008). The SWIID provides the GINI index, while the WIID provides the share of income held by different population classes. We then match the two-income inequality indices with annual climate data for 165 countries from 1960 to 2010.

Our analysis suggests that overall income inequality exhibits a non-linear relationship with the annual mean temperature across countries. Overall, we conclude that an increase in one-degree Celsius in annual temperature is associated with an increase of 0.45 points in the GINI index (i.e., more income inequality) and a reduction of 0.49% of the share of income owned by the bottom 40% of the population, and at the same time, an increase of 0.94% in the share of income owned by the top 10% of the population. However, our estimates do not show a statistically significant differential effect on income inequality of developing countries compared to more advanced economies.

The rest of the paper is organized as follows. We first describe the annual data used to measure income inequality. Section 2 presents the data used to estimate the empirical relationship between climate and global income inequality. We then present the country-level time series climate variables used in the analysis, i.e., the average annual precipitation levels and surface temperature. In section 3, we describe the empirical procedure. Section 4 reviews the evidence regarding climate's effects on country-level income inequality. Finally, section 5 concludes.

[1] Dasgupta et al. (2020) also find that inequality tends to be lowest at moderate temperatures (11°C-17°C).

2. Data

We construct a panel dataset comprising 165 countries covering the period between 1960 to 2010. Income inequality is generally measured with the Gini index. Its coefficient measures the inequality among levels of income and ranges from zero to one. A Gini coefficient of zero expresses perfect equality (in such a case, all individuals share the same annual income). A Gini coefficient of one expresses maximal inequality (in this case, one individual possesses the country's total income while all others have none).

For the present study, we consider two indices of income inequality: i) the World Income Inequality Database (WIID) constructed by Wider (2008)[2], and ii) the Standardized World Income Inequality Database (SWIID) developed by Solt (2016, 2020).

i) The World Income Inequality Database (WIID)

The UNU-WIDER World Income Inequality Database (WIID) collects and stores information on income inequality for developed, developing, and transition countries. In addition to the Gini coefficient reported by the source, a Gini coefficient calculated using a new method developed by Shorrocks and Wan (2008) is reported[3]. The WIID provides the Gini coefficient with quintile and decile shares, survey means, and medians, along with the income shares of the wealthiest 5% and the poorest 5%. It has a geographical coverage of 159 countries. Although the earliest data are from 1867, most country data are available for the period after 1960.

ii) The Standardized World Income Inequality Database (SWIID)

First proposed by Solt (2016), the SWIIS is based on WIID but with all observations multiply-imputed. In particular, the SWIID standardizes the World Income Inequality Database, the OECD Income Distribution Database, the Socio-Economic Database for Latin America and the Caribbean[4], and the World Top Incomes Database[5]. The data collected by the Luxembourg Income Study (LIS) is employed as the standard. The SWIID currently incorporates comparable

[2] Jenkins (2015) provides a detailed assessment of the two income iniequality indeces used in this paper.

[3] Source: http://www.wider.unu.edu/research/Database/en GB/database/ with emphasis in original.

[4] Generated by CEDLAS and the World Bank, Eurostat, the World Bank's PovcalNet, the UN Economic Commission for Latin America and the Caribbean

[5] In his original paper, Solt (2016) also used data provided by national statistical offices around the world.

Gini indices and net income inequality for 173 countries for as many years as possible from 1960 to the present. It also includes information on absolute and relative redistribution. A full explanation of the SWIID, the procedure used to generate it, and an assessment of the SWIID's performance in comparison to the available alternatives are presented in Solt (2020).

iii) Country-level climate variables

Historical annual data on temperature and precipitation per country are obtained from the new Climate Change Knowledge Portal (CCKP) of the World Bank. The Portal provides an online platform for comprehensive country data related to climate change and development. The CCKP consists of spatially and temporally referenced data which are available starting from 1950. More detail of this data can be found in the Appendix.

3. The Model

Using this data, we estimate the annual relationship between climate variables, represented by mean temperature and mean precipitation levels and the Gini index, i.e.,

$$I_{ct} = \beta_1 T_{ct} + \beta_2 T_{ct}^2 + \beta_3 Prec_{ct} + \beta_4 Prec_{ct}^2 + \beta_5 GDP_{ct} + \alpha_t + \alpha_t^2 + \gamma c + \varepsilon_{ct} \quad (1)$$

where I_{ct} is either the GINI index or the share of income of country c in year t. The GINI ranges from 0 (highest inequality) to 1 (no inequality in income distribution). The share of income also ranges from 0, meaning that the portion of the population we are referring to does not have any income, to 1, meaning that a single portion of the population possesses the country's entire income. In equation (1), we control for annual temperature T_{ct} and precipitation levels $Prec_{ct}$ and their squared terms T_{ct}^2 and $Prec_{ct}^2$ to capture potential non-linear effects. We estimate equation (1) using OLS. Standard errors are calculated clustering observations by state and year.

4. Empirical Estimates at National-Level

The results from estimating equation (1) are presented in Tables 1 and 2. Table 1 shows the relationship between annual climate variations and the GINI index. In contrast, Table 2 presents the effects of climate variations on the share of income held by different population classes.

As a benchmark, we begin in column 1 of Table 1 with a panel regression for the whole world. Specifically, we use all 165 countries in the WIID sample and calculate the GINI index reported in the database. The results are opposite to what was found in the environmental economics literature, which focused on GDP. For instance, Dell et al. (2009) found that an additional 1 degree Celsius is associated with a statistically significant reduction of 8.5 percentage points of per capita GDP. More recently, Diffenbaugh and Burke (2019) found that the GDP per capita has been reduced between 17 and 31 percentage points at the poorest four deciles of the population-weighted country-level per capita GDP distribution.

Results reported in column 1 of Table 1 show that each additional 1 degree C is associated with a statistically significant increase of 0.45 points of the GINI index, which translates to an increase in income inequality. We reach the same conclusions, although less significant, for the impact of annual precipitations. We find that an additional millimeter of rainfall experienced by a country is associated with an increase of 0.91 points in its income inequality. However, these estimates become negative when looking at the squared values. Indeed, we find that large increases in temperature and precipitations (e.g., heatwaves and floods) are associated with negative growth in the GINI index. Figure 7 offers a visual interpretation of the linear and quadratic relationship between annual variations in temperature levels and income inequality.

In column 2, we also control for the quadratic term of the GDP of country c at time t represented by GDP_{ct}^2. The point estimate for the effect of temperature remains virtually unchanged at 0.45 points of GINI index per degree Celsius. The U-shape relationship between temperature and income inequality also remains unchanged. In column 3, we limit the sample to the 84 most unequal countries in the world. We define those countries as those reporting a GINI index > 0.5 points. In this case, although the point estimate for the effect of temperature remains positive and increases in magnitude, the standard errors increase substantially, and the results are no longer statistically significant (e.g., column 3 shows that an increase in 1 degree Celsius is associated with an increment of about 0.6 points of the GINI index with a standard error of 0.43). In column 4, we limit the sample to the 79 countries reporting a GINI index < 0.5 points. In this case, the point estimate for the effect of temperature remains positive and increases in magnitude. We show that each additional 1 degree Celsius is associated with an increment of 0.56 points of the GINI index with a standard error of 0.26. Columns between 5 and 10 show the estimates of the relationship between climate and income inequality relative to six different regions of the world.

5. Conclusions

Recent economic literature has addressed the impacts of climate change on economic development, focusing mainly on standard economic variables such as GDP per capita. This paper investigates the effects of historical variations in temperature on two different measures of income inequality for the whole world. Using annual historical data available for 165 countries, our results indicate that, while increases in temperature levels are generally associated with higher income inequality between and within countries, poor countries do not appear to be more affected than more advanced economies. Our conclusions shed light on the real economic impacts of climate variations.

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Figures and Tables

Figure 1: Western Europe and Offshoots

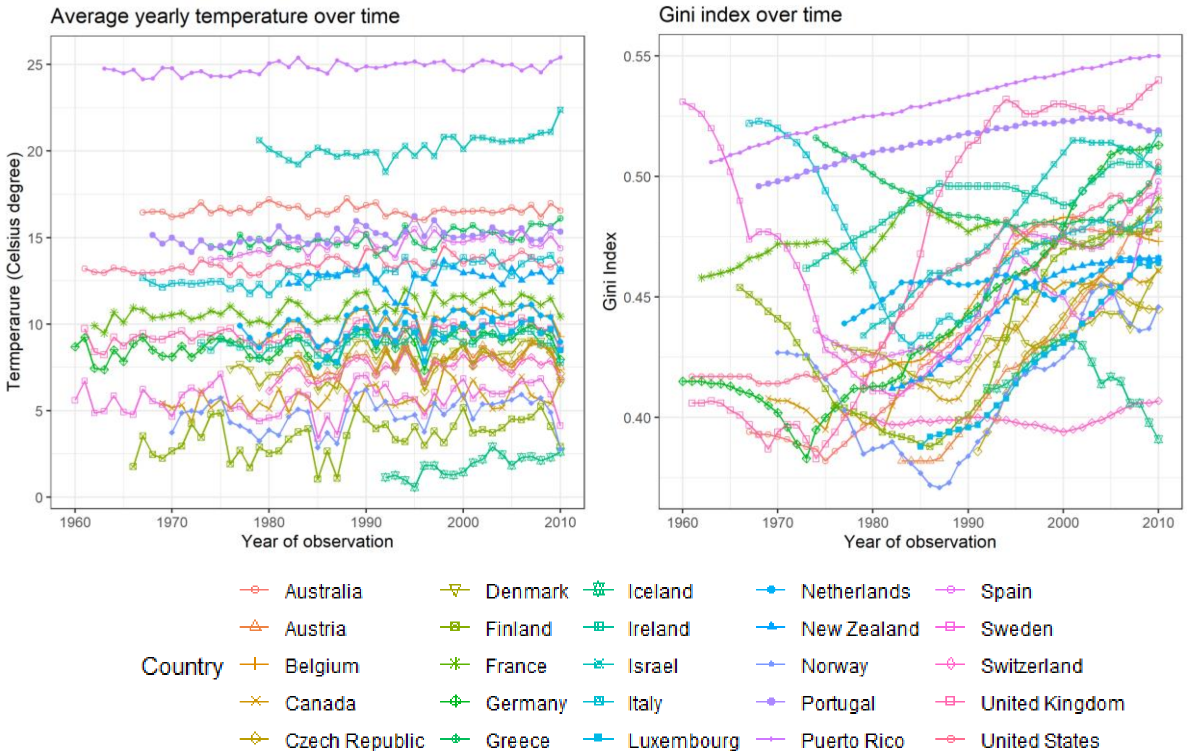
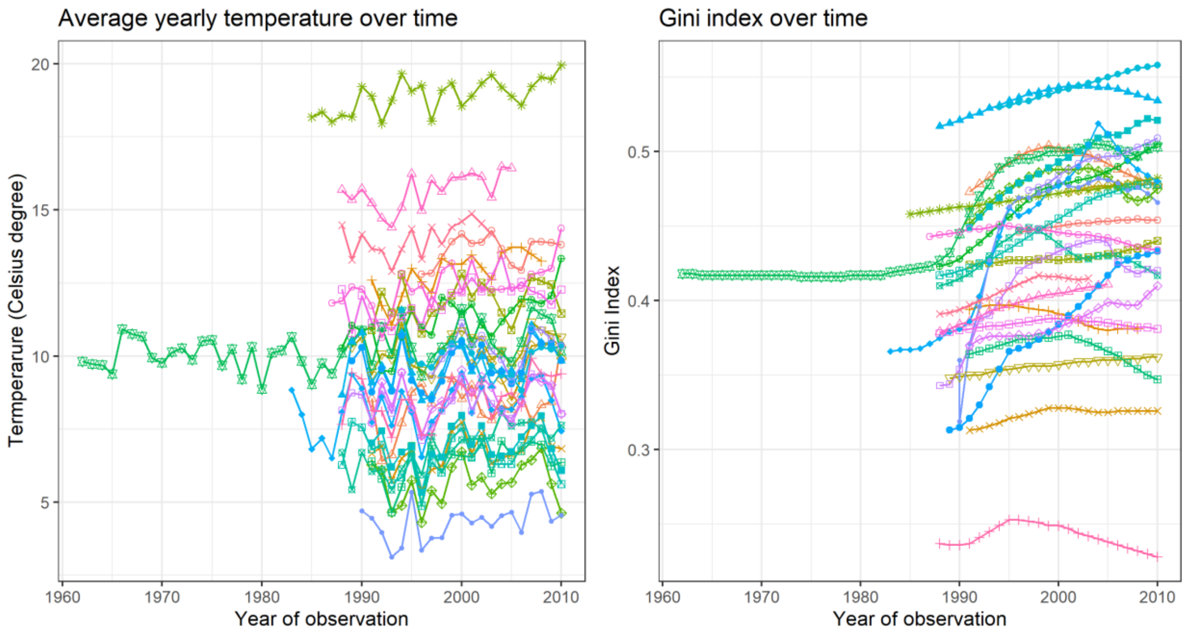


Figure 2: Eastern Europe and Central Asia



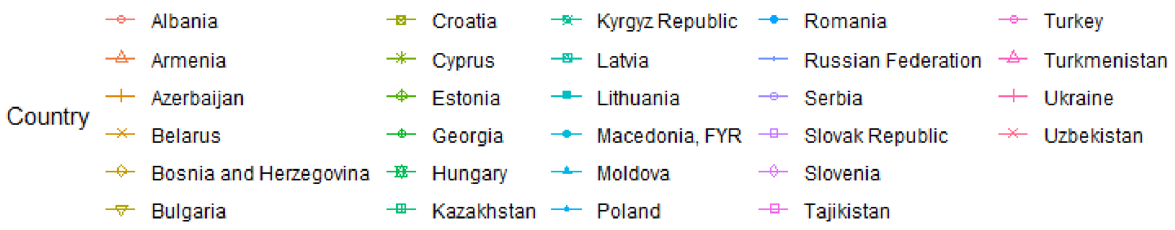


Figure 3: Latin America and the Caribbean

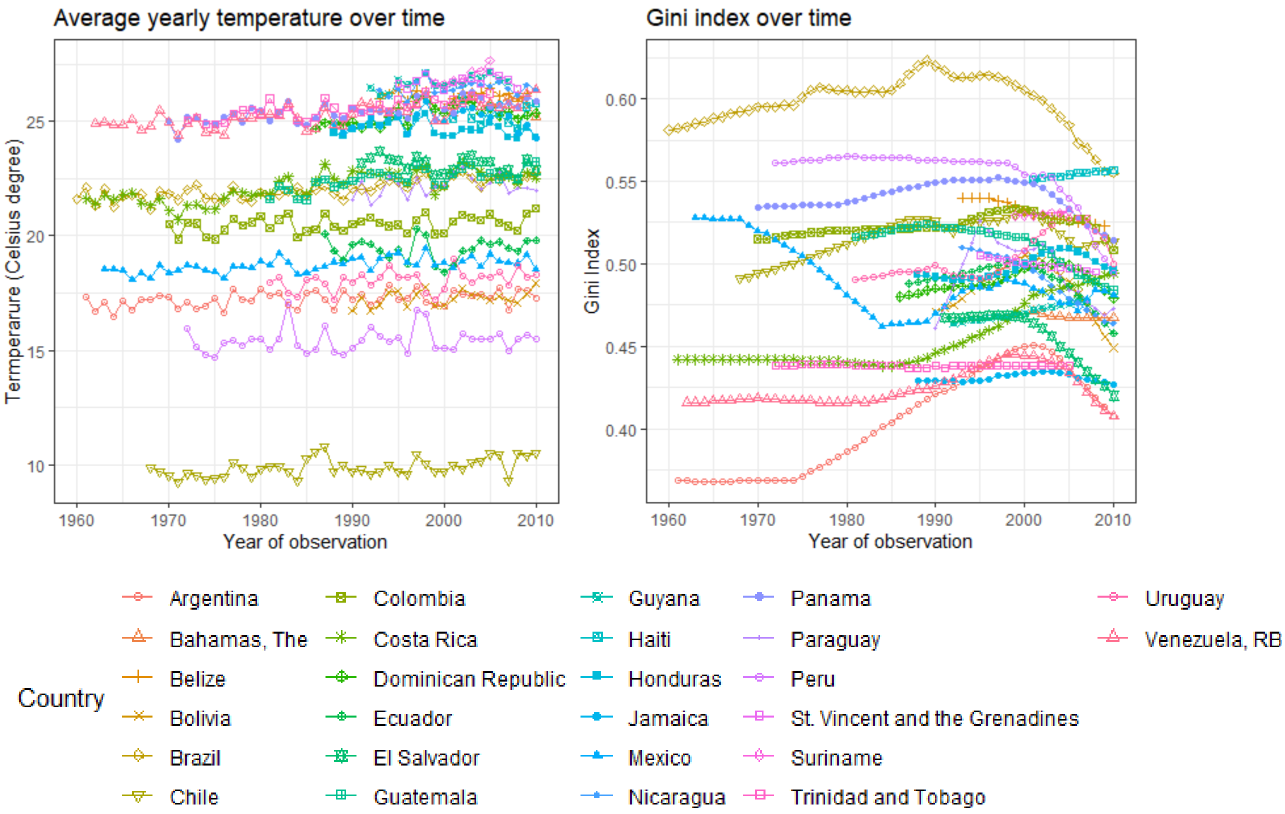


Figure 4: South-East Asia and Pacific Islands

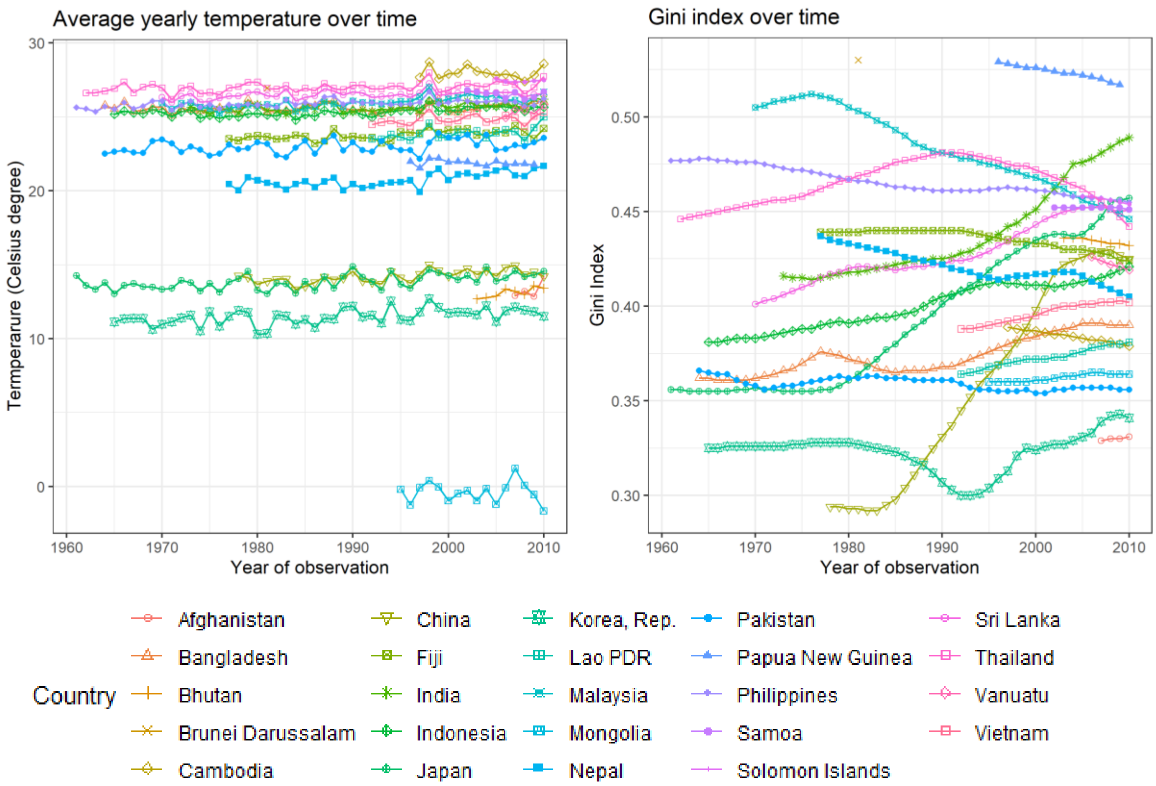


Figure 5: Sub-Saharan Africa

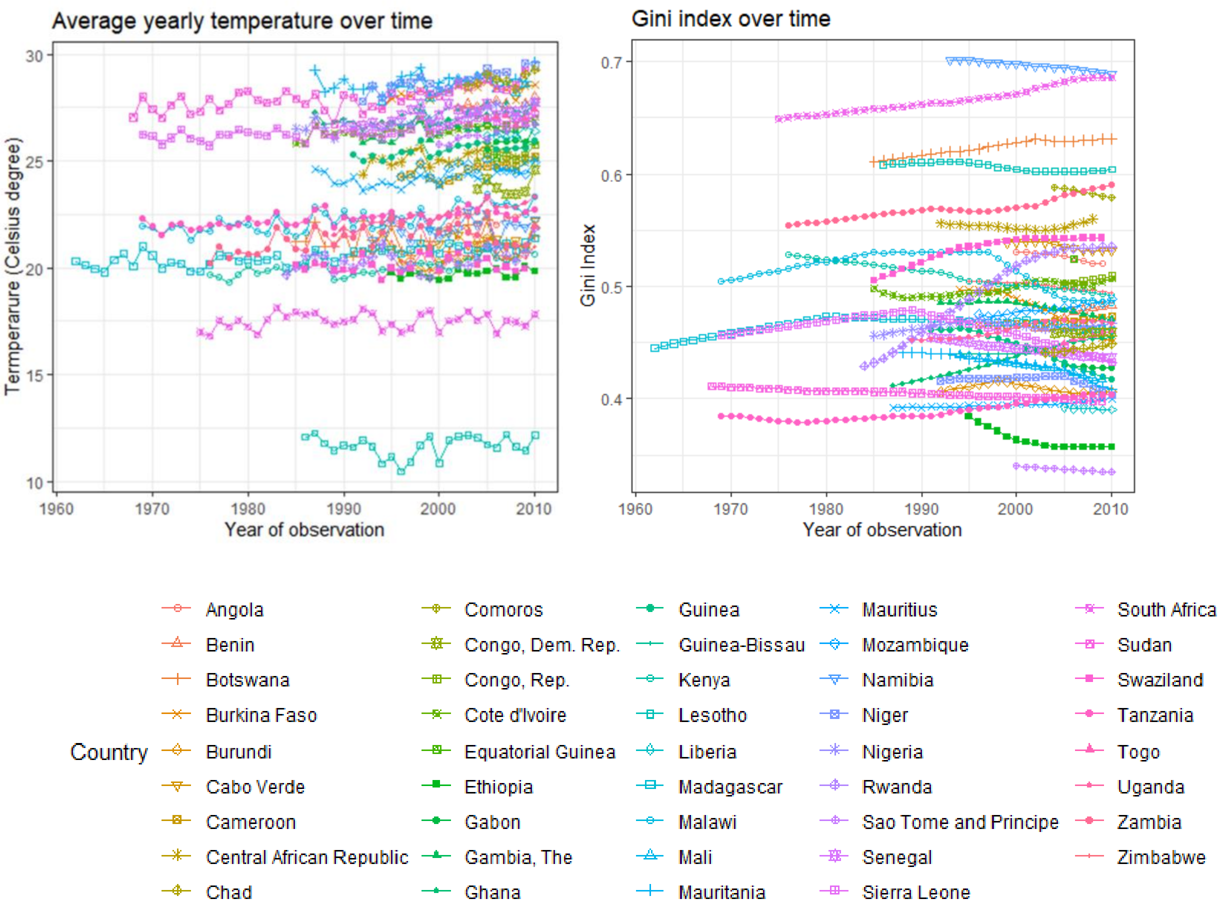


Figure 6: Middle-East and North Africa

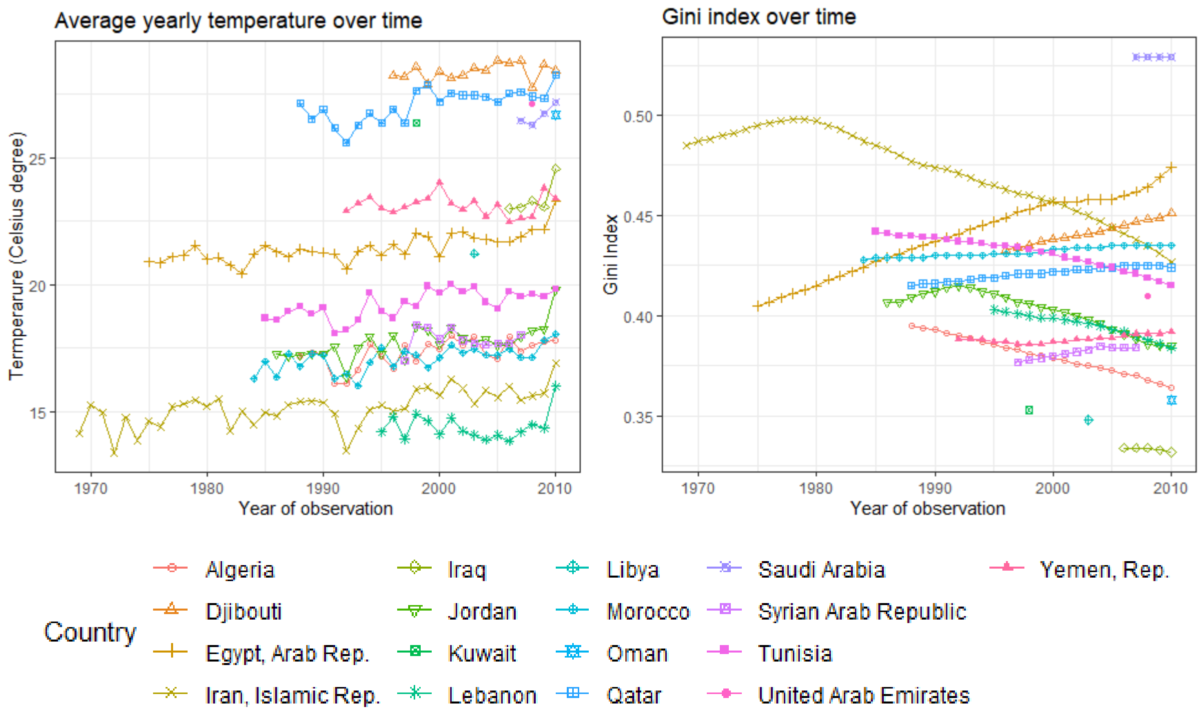


Figure 7: Relationship between annual average temperature on Gini Index

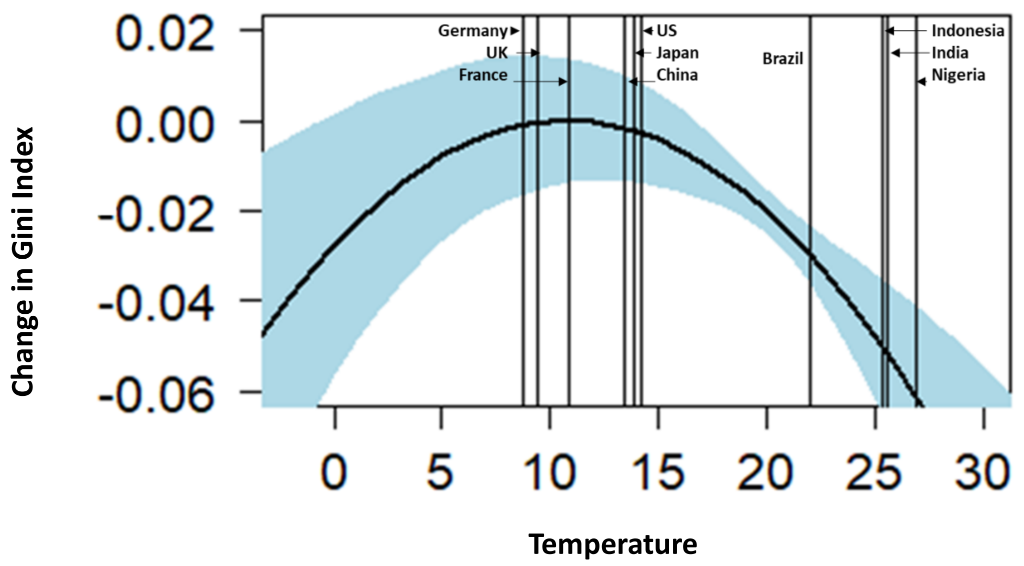


Figure 8: Effect of uniform 1 °C warming on country-level Gini Index

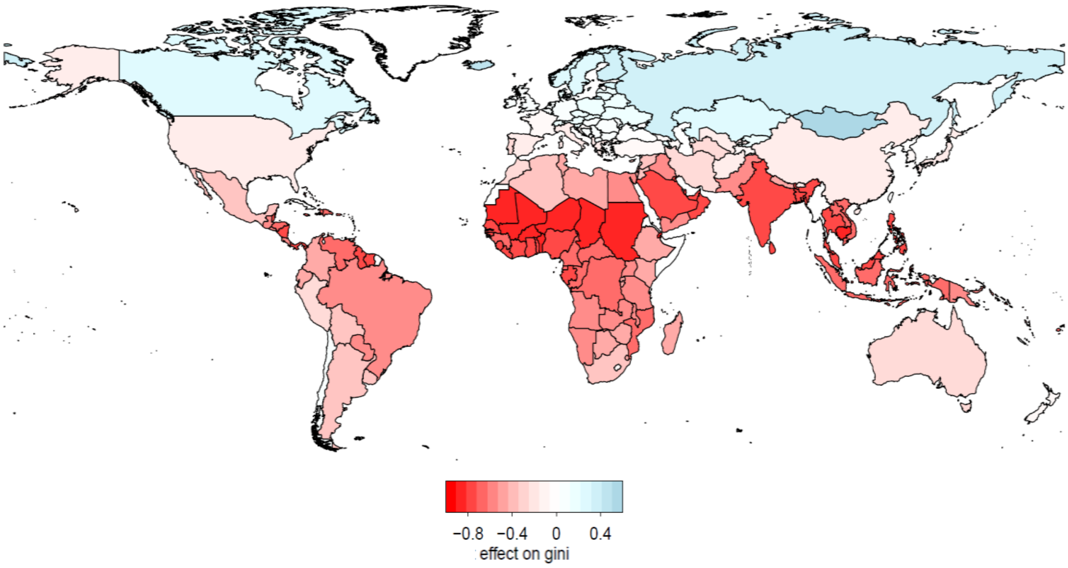


Table 1: Relationship between climate variables and GINI index

VARIABLES	(1) Base	(2) GDP Squared	(3) Poor	(4) Rich	(5) Mid East & Nor Afr
$Temp$	0.451**	0.447**	0.616	0.557**	-5.013*
	(0.198)	(0.200)	(0.432)	(0.269)	(2.552)
$Temp^2$	-0.0203***	-0.0202***	-0.0138	-0.0319**	0.134*
	(0.00668)	(0.00676)	(0.00979)	(0.0124)	(0.0702)
$Precip$	0.914*	0.907*	0.114	1.250	-0.386
	(0.516)	(0.514)	(0.466)	(0.812)	(2.054)
$Precip^2$	-0.318**	-0.317**	-0.0366	-0.487**	-0.389
	(0.124)	(0.124)	(0.126)	(0.209)	(1.240)
$GDP\ pc$	0.000143***	0.000162	0.000717	0.000121**	1.12e-05
	(4.69e-05)	(9.86e-05)	(0.000772)	(5.44e-05)	(7.69e-05)
$GDP\ pc^2$		-2.52e-10			
		(8.51e-10)			
$Time$	0.0227	0.0195	0.0996**	-0.0368	0.0415
	(0.0539)	(0.0519)	(0.0475)	(0.0779)	(0.201)
$Time^2$	0.000403	0.000433	-0.00137*	0.00170	-0.00108
	(0.000828)	(0.000801)	(0.000792)	(0.00119)	(0.00211)
Constant	42.10***	42.08***	36.93***	42.13***	86.94***
	(1.782)	(1.792)	(5.652)	(1.847)	(19.00)
Observations	4,087	4,087	1,832	2,194	264
R-squared	0.232	0.232	0.064	0.301	0.215
Number of countries	165	165	84	79	17
Country FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1 continued: Relationship between climate variables and GINI index

VARIABLES	(6) Sub Afr	(7) West Eu Offsho	(8) East Eu & Cent Asia	(9) Pacif & SE Asia	(10) Lat Amer & Carab
$Temp$	0.787	0.461	0.0220	1.110	0.698
	(1.061)	(0.314)	(0.336)	(1.406)	(0.848)
$Temp^2$	-0.0250	-0.0263	-0.00940	-0.0322	-0.0167
	(0.0237)	(0.0205)	(0.0189)	(0.0331)	(0.0253)
$Precip$	-1.842**	-0.690	6.287	1.515	1.116**
	(0.799)	(0.958)	(3.781)	(1.022)	(0.428)
$Precip^2$	0.636***	0.131	-3.132*	-0.507*	-0.346***
	(0.230)	(0.249)	(1.820)	(0.278)	(0.0697)
$GDP\ pc$	0.000399	7.23e-06	-0.000123	0.000192	-0.000215
	(0.000292)	(5.80e-05)	(0.000184)	(0.000132)	(0.000280)
$Time$	0.0938*	-0.0698	0.358***	-0.0625	0.183*
	(0.0550)	(0.153)	(0.0782)	(0.0646)	(0.0929)
$Time^2$	-0.00114	0.00356	-0.00210	0.00174	-0.00262*
	(0.00108)	(0.00229)	(0.00156)	(0.00135)	(0.00149)
Constant	43.25***	42.97***	31.37***	31.94**	39.90***
	(11.82)	(2.318)	(2.628)	(14.86)	(7.245)
Observations	887	946	589	668	733
R-squared	0.061	0.414	0.479	0.249	0.134
Number of countries	44	25	29	24	26
Country FE	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2: Relationship between annual mean temperature and share of income held by the bottom 50%, middle 40%, top 10%, top 1% of the population

VARIABLES	(1) Bottom 50%	(2) Middle 40%	(3) Top 10%	(4) Top 1%
Temp	-0.00460	-0.00487***	0.00943**	0.00788**
	(0.00303)	(0.00180)	(0.00382)	(0.00317)
Temp2	0.000263***	0.000280***	-0.000544***	-0.000435***
	(9.28e-05)	(8.68e-05)	(0.000147)	(0.000142)
Precip	-0.00439	0.0151*	-0.0113	-0.0111
	(0.0124)	(0.00907)	(0.0183)	(0.0133)
Precip2	-0.000372	-0.00289	0.00345	0.00255
	(0.00418)	(0.00344)	(0.00642)	(0.00470)
Time	-0.00106	-0.000323	0.00137	0.00127
	(0.00118)	(0.000755)	(0.00175)	(0.000926)
Time2	6.92e-06	1.29e-06	-8.02e-06	-1.68e-05
	(1.56e-05)	(1.05e-05)	(2.39e-05)	(1.42e-05)
GDP pc	-2.74e-07	-5.36e-07	8.11e-07	1.13e-06**
	(3.62e-07)	(3.66e-07)	(6.26e-07)	(5.24e-07)
Constant	0.204***	0.381***	0.416***	0.134***
	(0.0341)	(0.0167)	(0.0431)	(0.0260)
Observations	2,345	2,345	2,352	2,366
R-squared	0.083	0.048	0.074	0.053
Number of iso_id	104	104	105	105
Country FE	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix

A. The Climate Change Knowledge Portal (CCKP)

The CCKP is the result of the effort of a collaboration between different research institutions. The National Center for Atmospheric Research (NCAR) processed the climate data; The International Research Institute (University of Columbia) developed the spatially disaggregated maps; Finally, the European Space Agency (ESA) 's Earth Observation for Sustainable Development (EO4SD) and ERA5 Land Product of European Commission's Copernicus Climate Change service provided access to earth-observation datasets

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