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Communication

Climate Change and Inequality: Evidence from the United States

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Abstract: This paper examines the effects of climate change on income inequality in the United States. Computing impulse response functions (IRFs) from the local projections' method, we empirically show that there is an immediate temporary positive response in income inequality from rising temperatures within the first year. We also observe differences in the effects of temperature growth on inequality across different classifications, mainly states with high inequality and low temperature growth are more susceptible to changes in temperature growth than states with already high temperature growth and high inequality growth. States with low inequality growth exhibit similar positive effects on income inequality across low- and high-temperature-growth classifications. We find that the initial positive effect on income inequality is not permanent. However, if the effects of rising temperatures are unabated in the earlier periods, income inequality starts to rise in the later periods. Our results highlight an important pathway, that climate change can negatively affect sustainable development through increased income inequality.

Keywords: temperatures; climate change; income inequality; United States

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1. Introduction

Climate change has become a significant global topic of discussion today due to its long-term impacts on economic growth and development. Unfortunately, economically vulnerable groups carry the burden of adverse climate-change risks, particularly pertaining to their livelihoods. Evidence suggests that climate change is likely to have permanent economic impacts through destruction of the ecosystems, reduced agricultural yields, deaths from weather extremes and social disruption [1–4].

While the theoretical and empirical literature on climate change and economic growth is well-established [5–8], there is emerging literature on climate-change impacts on society's welfare, such as poverty, conflict and income inequality [9–11]. The existing literature on climate change and income inequality tends to position the adverse effects as being worse for developing countries, for example, [7] finds that higher temperatures reduce income per capita but only in poor countries. However, more evidence is becoming apparent that even developed countries, with their climate change strategies in place, are just as susceptible to climate change [12]. In addition, previous studies have concentrated on climate change impacts between countries, such as [13], which finds that income differences between Africa and the world's rich industrial regions can be explained by geographic variables, such as temperature. However, studies are increasingly highlighting that the impact is not limited to between countries only but also on the differences in inequality within countries [10]. For example, [14] finds that temperature changes can be a key driver of within-country inequality. Similarly, studies by [15] and [11] provide evidence that climate change can widen inequality within countries due to a lack of resources for the low-income groups to cope with the climate risk. We contribute to this emerging literature by investigating the effects of temperature growth on income inequality in the United States. According to [16], extreme heat is the cause of more deaths relative to other natural disasters today in the United States. At the same time, inequality has been on the rise in the United States since 1980, rating higher than other advanced economies at 0.434 in 2017, while other Group of Seven (G7)countries ranged between 0.32 and 0.39 [17]. Table 1 indicates that the average inequality across the states is 0.5 for the period 1980–2015, highlighting the widening income gap between populations relative to the period 1940–1979. In addition, we observe variation in average temperature growth between the two periods across the states, with some states moving from negative to positive temperature growth and vice versa, suggesting that various states are undergoing dramatic changes in temperatures.

Using local-projections impulse response functions (LP-IRFs), we find short- and long-run positive effects between temperature growth and income inequality. The findings highlight that climate change can have adverse effects on poverty reduction and economic opportunity. As such, understanding the impacts of climate change on societal welfare is important for designing and implementing climate mitigation and adaptation measures. Our findings may therefore inform the older debate on climate change and economic development and provide updated evidence that may highlight pathways to deal with this challenging issue.

Related Literature

Our study straddles two strands of the literature: the environment–economic-growth nexus and the determinants of inequality. The foundation of the environment–economic-growth nexus is based on the environmental Kuznets curve (EKC), which postulates that environmental degradation first worsens and then improves over the course of economic growth [19,20]. In the initial phases of economic growth, countries are rapidly developing and industrialising, thus utilising more natural resources and emitting high pollution. For example, according to [21], greenhouse gas emissions are one of the leading causes of climate change that followed the Industrial Revolution in 1750. However, over time and with increased wealth from development, countries started to transition from dirty energy to clean energy, resulting in less environmental degradation [22].

Evidence from [1] and [23] shows the adverse effects of temperature on the level of gross domestic product (GDP) using a dynamic stochastic general equilibrium (DSGE) framework, while [2] finds that a temperature shock in the United States results in higher welfare costs through negative impacts on total factor productivity (TFP), output and labour productivity. Furthermore, [6] finds that projected temperatures have a significantly negative impact on the economic growth in the United States and the European Union, highlighting the need for a more proactive climate policy in the present day. These findings are confirmed by [5], who estimates that not only are higher summer temperatures associated with lower annual growth in the United States but that projected increases in seasonal temperatures could potentially reduce economic growth by up to one-third over the next century.

More recent literature has started to focus on the impacts of climate change on income inequality, but the empirical evidence is still scant. The authors of [10] propose a framework for understanding the association between climate change and inequality. They identify three main channels through which climate change can increase inequality, particularly for disadvantaged groups. First, an increase in exposure to climate change due to location can increase within country inequalities. For example, [24] notes that a combination of economic and racial factors led to the concentration of low-income African American people in the low-lying districts of New Orleans that were severely affected by Hurricane Katrina. Second, an increase in the susceptibility to damage caused by climate change is relatively worse for the poor than the rich because of the lack of finances or asset diversification [25]. The third climate-change–inequality channel is a lowered ability to cope and recover from the damage of climate change, which compounds the initial income inequality of disadvantaged groups.

Table 1. Inequality and temperature growth by state.

	Gini 1940–1979	Gini 1980–2015	Temperature Growth % 1940–1979	Temperature Growth % 1980–2015
Alabama	0.442	0.561	0.008	0.144
Alaska	0.459	0.588	0.569	0.236
Arizona	0.443	0.568	−0.087	0.135
Arkansas	0.462	0.573	−0.027	0.159
California	0.438	0.604	−0.051	0.145
Colorado	0.455	0.571	−0.113	0.241
Connecticut	0.443	0.600	0.167	0.057
Delaware	0.507	0.536	0.102	0.133
Florida	0.479	0.616	0.060	0.136
Georgia	0.455	0.576	0.031	0.132
Idaho	0.435	0.581	−0.150	0.251
Illinois	0.437	0.575	−0.058	0.190
Indiana	0.417	0.543	−0.040	0.168
Iowa	0.440	0.543	−0.083	0.243
Kansas	0.450	0.562	−0.057	0.205
Kentucky	0.442	0.557	−0.026	0.159
Louisiana	0.449	0.589	0.006	0.149
Maine	0.438	0.536	0.180	−0.041
Maryland	0.439	0.541	0.071	0.121
Massachusetts	0.439	0.571	0.174	0.034
Michigan	0.419	0.554	−0.002	0.172
Minnesota	0.446	0.551	−0.127	0.390
Mississippi	0.464	0.580	0.001	0.161
Missouri	0.451	0.562	−0.042	0.195
Montana	0.448	0.598	−0.135	0.307
Nebraska	0.460	0.570	−0.111	0.245
Nevada	0.445	0.599	−0.091	0.177
New Hampshire	0.429	0.543	0.179	0.009
New Jersey	0.429	0.571	0.140	0.118
New York	0.458	0.612	0.143	0.067
North Carolina	0.448	0.552	0.021	0.136
North Dakota	0.456	0.569	−0.210	0.425
Ohio	0.417	0.534	0.009	0.151
Oklahoma	0.455	0.580	−0.049	0.162
Oregon	0.435	0.556	−0.082	0.196
Pennsylvania	0.424	0.556	0.080	0.114
Rhode Island	0.435	0.547	0.186	0.040
South Carolina	0.435	0.552	0.028	0.134
South Dakota	0.465	0.599	−0.131	0.306
Tennessee	0.453	0.570	0.006	0.154
Texas	0.466	0.605	−0.026	0.126
Utah	0.422	0.558	−0.157	0.234
Vermont	0.441	0.548	0.197	0.014
Virginia	0.444	0.545	0.037	0.136
Washington	0.415	0.552	−0.094	0.208
West Virginia	0.417	0.533	0.005	0.159
Wisconsin	0.429	0.540	−0.063	0.288
Wyoming	0.444	0.600	−0.157	0.275

Source: Authors' calculations using data from [18], National Oceanic and Atmospheric Administration.

According to [9], global warming has contributed to increased global economic inequality. They attribute this finding to historical disparities in energy consumption between poor and wealthy countries, with the poor countries exposed to higher temperatures arising from the wealthy countries' fossil-fuel use. The authors further estimate that the ratio between the top and bottom income deciles is likely to be 25% larger today than it would have been in the absence of global warming. A recent study by [11] finds that climate change is one of the main drivers of inequality, especially when the damage delays the economic convergence between poor and rich countries. In addition, the same study also highlights the trade-off faced by policymakers between climate-change hazards that fall more heavily on poor countries, slowing down their growth, and the costs of mitigating climate change by reducing emissions, which could potentially also slow down the economic catch-up of poor countries.

As highlighted above, several discussions have been focussed around climate change and economic growth outcomes. While the interlinkages between climate change and income inequality are starting to receive some attention, there is still scope for more evidence-based studies. This study addresses the gap by contributing empirical evidence to this underexplored theme.

2. Data and Methods

We investigate the impact of rising temperatures on income inequality for 50 U.S. states between 1940 and 2015 using the following local-projections specification:

$$y_{i,t+s} = \alpha_{i,s} + \sum_{j=1}^{k} \beta_{i,j,s} y_{i,t-j} + \gamma_s tempgrowth_t + \sum_{j=0}^{k} \delta_{i,j,s} X_{i,t-j} + \epsilon_{i,t+s} \forall s = 0, 1, 2, ..., H \quad (1)$$

where y_i is the Gini coefficient obtained from the U.S. State-Level Income Inequality Data [18] (https://www.shsu.edu/eco_mwf/inequality.html, accessed on 31 January 2022). See also [18], pp. 66, Appendix A, for detailed construction of the Gini measure. The Gini coefficient measures the income distribution across a population, that is, the average distance between all pairs of proportional income (e.g., 90-10, 80-20, etc.) in the population. The coefficient is also known for being sensitive to transfers in the middle of the income distribution, which makes it an attractive measure to use in analysing inequality, as any reallocation of income will be associated with a change in overall inequality. The coefficient is scaled from zero to one, with higher values indicating more inequality. $tempgrowth_t$ is the main explanatory variable for temperatures. The U.S temperature, in degrees Fahrenheit, is obtained from the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information. We aggregate the monthly temperatures to annual time periods. For both the Gini coefficients and temperature values, we calculate the percentage growth rates for ease of interpretation in the model. We test for unit roots in the panel specification using the Im–Peasarn–Shin and the Fisher-type (i.e., Augmented Dickey–Fuller and Phillips–Perron) stationarity tests. We reject the null hypothesis that all panels contain unit roots. We also consider the fixed effects in a panel specification. The fixed effects as captured by the $\alpha_{i,s}$ are included in the model to control for unobserved differences in characteristics across states. γ_s captures the responses of state-level inequality at time $t + s$ to an identified temperature change at time t. The $X_{i,t-j}$ is a vector of contemporaneous and lagged effects of the control variables which includes per capita personal income, education and population. The per capita personal income and population are obtained from the Bureau of Economic Analysis and logged, while education is the ratio of the total number of college graduates divided by the total state population, taken from the U.S. Annual State-Level Human Capital Measures [18]. We choose individuals with a bachelor's or first professional degree instead of individuals with a high school diploma because this measure gives us a good indication of the quality of human capital in the United States. Evidence suggests that education can play a role in reducing income inequality. For example, [26] finds that education reduces the income share of top earners and increases the share of the bottom earners, while [27] observes that income gaps are mainly due to the difference in education investment. The variables' definitions can be found in Table A1 in the Appendix.

Table 2 indicates the descriptive statistics. The statistics show heterogeneity in the variables across our sample of states, with the lowest temperature recorded at 22.3 degrees Fahrenheit and the highest at 73.4 degrees Fahrenheit. The statistics also indicate that some states have low inequality, with the lowest Gini coefficient at 0.3, while others are characterised with high inequality, even reaching a Gini coefficient of 0.7. Overall, the mean Gini coefficient is 0.5, suggesting large income gaps in the population. This income distribution inequality makes our sample an interesting testing ground for our hypothesis that rising temperatures contribute to higher inequality. Moreover, the variations in temperature allow us to split the sample of states by inequality and test whether the effects of climate change on income inequality are contingent on the status of temperature growth in each U.S. state.

Table 2. Descriptive statistics.

Variable	Number of Observations	Mean	Standard Deviation	Minimum	Maximum
Gini	3629	0.503	0.074	0.322	0.711
tempgrowth	3629	51.354	8.464	22.275	73.358
pperincome	3629	14,423	14,743	212	67761
population	3629	4,605,257	5,105,866	113,000	38,900,000
college	3629	0.101	0.065	0.013	0.306

Source: Authors' calculations using data from [18], Bureau of Economic Analysis, National Oceanic and Atmospheric Administration.

Equation (1) can be respecified into a regime-dependent model following the method of [28]. A switching variable that distinguishes states with high temperature growth from those with low temperature growth can be incorporated into a nonlinear model defined as follows:

$$y_{i,t+s} = (1-D)\left[\alpha_{i,s}^{high} + \sum_{j=1}^{k} \beta_{i,j,s}^{high} y_{i,t-j} + \gamma_s^{high} tempgrowth_t + \sum_{j=0}^{k} \delta_{i,j,s}^{high} X_{i,t-j}\right] + D\left[\alpha_{i,s}^{low} + \sum_{j=1}^{k} \beta_{i,j,s}^{low} y_{i,t-j} + \gamma_s^{low} tempgrowth_t + \sum_{j=0}^{k} \delta_{i,j,s}^{low} X_{i,t-j}\right] + \epsilon_{i,t+s}, \quad \forall s = 0,1,2,\ldots H \tag{2}$$

where D is a switching variable that takes a value of 1 if state i has low temperature growth and 0 otherwise. We define the temperature growth as low (high) when $tempgrowth_t$ is below (above) the mean average temperature growth over the sample period. Superscripts high and low denote high- and low-temperature-growth states, respectively.

Our analysis involves computing the impulse response functions (IRFs) of inequality to temperature growth, based on the local-projections (LPs) method introduced by [29] and used by other empirical studies, such as [30] and [31]. In our specification, the LP-IRFs are calculated as a series of γ_s which are estimated separately at each horizon s. According to [29], the method consists of estimating local projections at each period of interest rather than extrapolating into increasingly distant horizons from a given model, as done with conventional vector autoregressions (VAR), which can compound misspecification errors. As such, local projections produce impulse responses that are more robust to lag length misspecification and highly persistent data. In addition, local projections can be estimated by simple least squares; they provide simple joint or individual analytic inference, and they easily accommodate estimations with highly nonlinear specifications that may be impractical in a multivariate context. See [29] for further information on local projections. We also use the ordinary least squares (OLS) regression method to examine the effects of the independent variable (i.e., temperature growth) on the dependent variable (i.e., inequality), as well as consider both unit fixed effects and time fixed effects in estimation while using the LP-IRFs method. The results and patterns are qualitatively similar. These results are available upon on request.

3. Results

Figure 1 shows the linear IRF of inequality to a percentage change in temperature growth using 95% confidence intervals. Overall, we find that rising temperatures have a positive impact on income inequality in the short and long run. The evidence suggests that there is a positive and statistically significant immediate impact on inequality growth a year after the temperature change. However, the effect is not permanent, as inequality starts to decline back and continues to decline quite sharply in the third to fourth year. This declining trend is, however, reversed as income inequality starts to increase again and remains above zero in the fifth to sixth year.

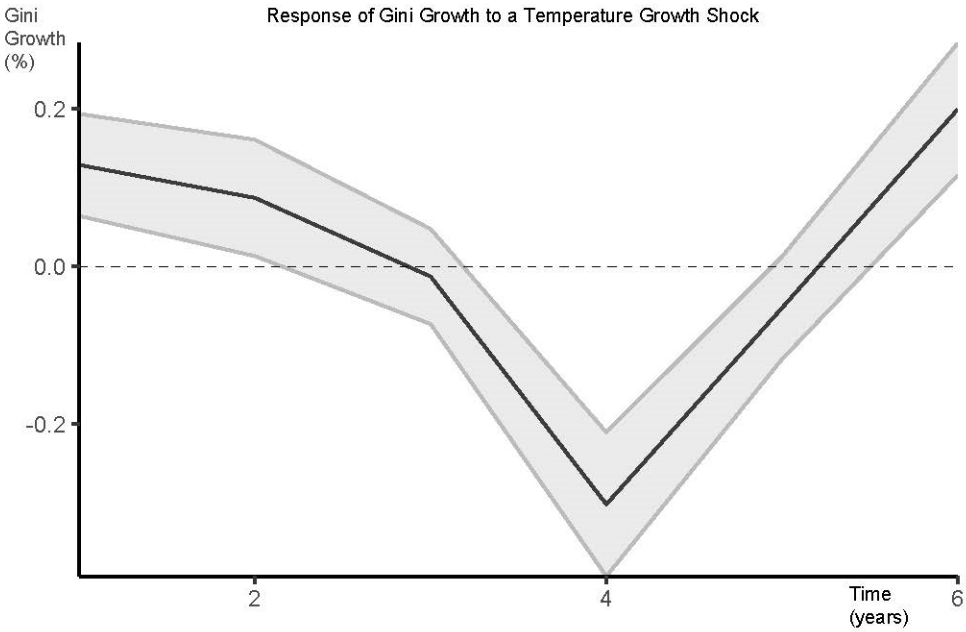

Figure 1. Temperature growth and inequality. Note: This IRF shows the effects of temperature growth on income inequality growth. The solid black line is the estimated response. The grey shading is the 95% confidence bands. The values reported are in percentages.

As additional analysis, we split the sample of states by inequality and temperature classifications, that is, high-inequality–high-temperature, high-inequality–low-temperature, low-inequality–high-temperature and low-inequality–low-temperature. We observe interesting differences across these splits in Figure 2, which shows the nonlinear responses of income inequality to a temperature growth effect.

While the IRFs depict positive effects of temperature growth on income inequality in the longer term (i.e., in the fifth to sixth year) across all classifications, we do observe different short-run effects a year after the change. For states with high inequality growth and high temperature growth, we find that temperature growth has a negative impact on inequality growth in the short term, whereas the states with high inequality growth but low temperature growth exhibit an immediate increase in inequality in the first year. These findings suggest that states with low temperature growth and high inequality growth appear to be more sensitive to changes in temperatures. In essence, the impact of a percentage increase in temperature will be significantly larger on inequality in the short run for states with initially low temperature growth and high inequality growth relative to states with already high temperature growth and high inequality growth.

For states with low inequality growth, we observe a relatively similar trend irrespective of high vs. low temperature growth. In the short term, both classifications exhibit a positive response to a temperature change, which decreases in the third to fourth year. The effects are significant for states with low inequality growth and low temperature growth.

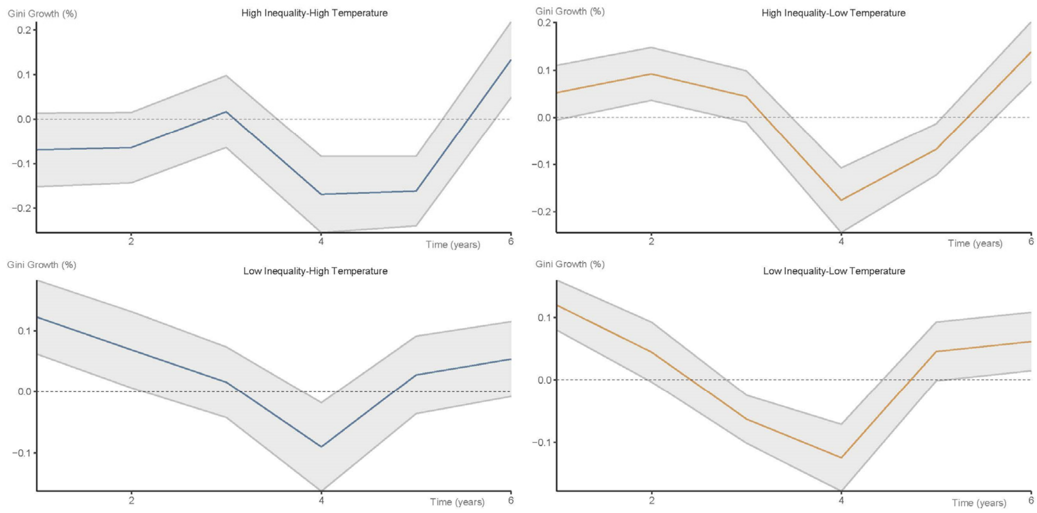

Figure 2. Temperature growth and inequality by inequality and temperature classifications. Note: This IRF shows the effects of temperature growth on income inequality growth across different income and temperature classifications. The solid lines within the grey shading are the estimated responses. The grey shading is the 95% confidence bands. The values reported are in percentages.

According to [7], without a climate adaptation strategy in place, the magnitude of short-run effects of temperature on economic activity can be large enough to explain income differences over a long period. In addition, several channels put forward in the literature can explain some of the differences we observe across the classifications. States with low temperature growth may be in the initial phases of adopting climate risk policies such that the effects of climate change may still contribute to the uneven distribution of resources among income groups [32]. Regions, such as the South, have three of the country's five large cities with intensifying heatwaves (Birmingham, New Orleans and Raleigh) [33]. Unfortunately, the same region also has the lowest per capita income of the U.S. regions [32]. As such, increases in temperature in these warmer areas are likely to lead to greater damage to productivity and health than they would in cooler areas, exacerbating existing inequalities. Moreover, low-income households are disproportionately affected because they have limited resources to adapt to climate change through less access to insurance and credit [11,32]. Climate change can also increase inequality by lowering productivity in certain economic sectors, such as agriculture. According to the Fourth National Climate Assessment, counties in the Southeast region will lose significant productivity relative to other counties because they predominantly rely on rural economic activity that is sensitive to temperature changes [33]. The authors of [32] also show that the most negative impact of climate change on agricultural yields is mainly in the low-income counties in the South region, which also has warmer temperatures. Loss in agricultural productivity can also affect food security through increased prices, especially since the low-income groups spend a significant portion of their budget on food [34].

4. Discussion

Our analysis exploits random fluctuations in temperature growth across years and provides evidence that temperature growth affects income inequality in the United States. Our findings show that, in general, temperature growth results in increased inequality growth in the long run. These findings are consistent for the full sample as well as across the different classifications.

While our findings are mostly in line with the strand of literature that finds a positive association between climate change and inequality [9,11], we do find evidence of delayed effects suggesting complex ways in which temperature increases can affect economic activities. We find that the effects of temperature growth on income inequality are not permanent. Initially inequality increases, then falls in the next period before increasing again in the later periods. These trends may be a result of possible long-term effects of temperature growth on other predictors of inequality.

For example, temperature growth can affect economic activities through reduced labour productivity [35], earnings, investments and health, which is likely to worsen the economic situations of vulnerable groups in society. Moreover, the temperature effects have been found to affect not only productivity in agricultural sectors as is expected but also productivity in non-agricultural sectors in both developing and developed countries [15,36]. For instance, rising temperatures can aggravate existing disparities in living standards, such as access to clean water and affordable food. In addition, extreme weather conditions can result in mass migration to more weather-conducive regions, putting undue resource pressure on these regions [32,37]. According to [37] and [32], climate change can result in large migration from the global South to the global North (including the U.S), and this inflow of populations that are relatively poorer will inevitably increase inequality within the receiving countries.

On the other hand, our findings indicate that the adverse effects on income inequality from temperature growth appear to lessen after approximately three to four years. This finding is not consistent with the evidence in the literature that persistently reports rising inequality because of global warming. However, we believe that this finding may highlight a gap that can be exploited for future research exploration. For example, temperature increases do not affect all regions or sectors homogeneously; therefore, disaggregating the data into regions or industry sectors may uncover more nuanced information on the impact of temperature growth on income inequality and provide us with an opportunity to identify where policy responses are needed most. This finding may also indicate a brief period of opportunity for recovery when income inequality is increasing at a decreasing rate due to temperature changes. Within this period, interventions targeted at improving the economic opportunities of the vulnerable groups can assist to secure their livelihoods against future climate risks.

Much of the emphasis in the previous literature is on the adverse effects of higher temperatures being larger in developing countries. However, our findings indicate that even in a developed region, temperature growth can also have not only immediate temporary adverse effects on income inequality but also long-run adverse effects, especially in a region with worsening income inequality, such as the United States. According to [35], temperature shocks tend to have stronger adverse economic effects among richer economies, while [38] finds that changes in temperature volatility can, in fact, affect not only poor countries but rich ones too.

Finally, our findings indicate that the adverse effects on income inequality from the temperature growth start to increase again after five years. The implication of this finding is that if we do not address the severity of the adverse effects of temperature changes on economic activities during the short-to-medium period, then we increase the long-run likelihood of becoming trapped in a vicious cycle of climate-induced poverty.

5. Conclusions

In this study, we examine the relationship between climate change and income inequality using local-projections IRFs for 50 U.S. states between 1940 and 2015. We document that temperature growth can temporarily increase income inequality in the first year, with the adverse effects on inequality lessening after three years. However, the declining inequality trend is reversed five years after the temperature change. These results remain consistent with different inequality- and temperature-growth classifications.

While our model may be subject to a few limitations, such as not accounting for technological progress or quality of institutions, which may counterbalance the adverse effects of temperature growth on income inequality, we maintain that our model allows us to address an important issue concerning climate change and inequality. Overall, our study provides some insights about the climate–inequality nexus in the U.S. First, the adverse effects of climate change are not limited to developing countries but can also contribute to inequality within a developed country, such as the U.S. Second, inequality in states with lower temperature growth may be disproportionately affected by increases in temperature, as they may not have adequate climate-risk strategies in place. Third, inequality in regions that rely on agriculture may be aggravated by changes in temperature. Last, an important insight from our findings, is that there is a window of opportunity that may buy policy action time to alleviate the climate impacts, particularly for vulnerable groups who struggle to adapt to climate risk.

There remains scope for future research on climate change so that we continuously update current policies to make them more effective in attenuating future climate risk. For example, more evidence is needed on the migratory patterns related to climate change, specifically in identifying avenues to adopt strategies within these affected areas to avoid people migrating en masse. More evidence on the differential effects of climate adaptation costs based on the type of climate change can also assist in designing changes in policies that can reduce disparities in exposures to various climate risks. Given that low-income households are the most vulnerable to climate-change exposure, understanding the effects of financial development on climate change may provide one channel that can be positively exploited to counter the inequality caused by climate change. It is necessary to slow down the adverse effects of climate change in the present if we hope to achieve sustainable development in the future.

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Appendix A

Table A1 shows the variable definitions and variable statistics.

Table A1. List of variables and definitions.

Variable	Description	Source
Gini	Gini coefficient converted to growth rates	U.S. State-Level Income Inequality Data [18])
tempgrowth	Mean temperature in degrees Fahrenheit converted to growth rates	National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information
pperincome	Per capita personal income	Bureau of Economic Analysis, U.S. Annual State-Level Human Capital
college	Total number of college graduates divided by the total state population	Measures [18])
population	Total population per state	Bureau of Economic Analysis

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