The Unequal Burden of Climate Change in California

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June 16, 2023

Extended Abstract

The recent economics literature quantifying the impacts of anthropogenic climate change has largely focused on improving the modeling of aggregate global damages in order to inform the Social Cost of Carbon (EPA, 2022). However, while climate change is a global and gradual process, its impacts manifest locally in the form of community-level heat, drought, flood, and natural disaster events. These impacts are likely to vary substantially across populations, due to differences both in exposure and vulnerability, raising urgent and differentiated adaptation needs. Accurately quantifying these local economic impacts of climate change is key to four dimensions of decision making: private adaptation (e.g., migration), public adaptation (e.g., targeting of adaptation funds), equity weighted benefit cost analysis (e.g., Errickson et al., (2021)), and the quantification of the distributional impacts of climate change across income and ethnic/racial subpopulations. While substantial progress has been made on empirically grounding global climate damage estimates, communities, companies, and governments often lack local-level information about the magnitude and nature of specific climate risks, making it difficult to form evidence-based resiliency investments and near impossible for regulators to make equitable public adaptation investment decisions.

In this paper, we develop and execute an approach to quantify the community-level impacts of climate change, identify key inequities in damages, and decompose climate inequalities into their core drivers. We apply this approach across California at the census tract scale for four key categories of climate damages (labor supply, energy use, mortality, and flood-related property damages), providing the first community-level climate change assessment in the state, and, to our knowledge, the nation. We account for differential vulnerability based on socioeconomic and climatological conditions and show how such inequities in adaptive capacity shape measures of climate inequality across the state. Both prior research and earlier policy tools fail to account for local-level differences in adaptive capacity; this approach and our findings pave the way for future analysis of equity implications in other regions of the country and globe. Moreover, they demonstrate that ignoring heterogeneity in climate sensitivity across diverse local populations leads to dramatic mischaracterizations of climate inequality, even at the scale of a single U.S. state.

Economic impacts of climate change require two main ingredients: projections of future climate, and "dose-response functions", which translate future weather realizations into social and/or economic damages. There are hence three main sources of heterogeneity that can lead to unequal impacts across heterogeneous populations. The first is variation in projected physical impacts of climate change; for example, rates of warming are higher in California's mountainous regions than in the Central Valley (Figure 2). The second is differential vulnerability to a given weather or climate event; for example, lower income populations face far higher mortality risk from extreme heat than do high income populations (Carleton et al., 2022). The third is the distribution of different subpopulations across space; for example, temperate northern California is far less populated than the flood-prone Sacramento Valley. Most prior literature quantifying climate change impacts accounts only for the first, and sometimes the third, dimension of inequality, assuming a uniform dose-response function and therefore homogeneous adaptive capacity to adverse climate events. Therefore, any recovered estimates of distributional climate change impacts depend only on the spatial variation in climate change, weather variability, and population at risk. In this paper, we combine hyperlocal projections of climate change from downscaled CMIP6 climate models with

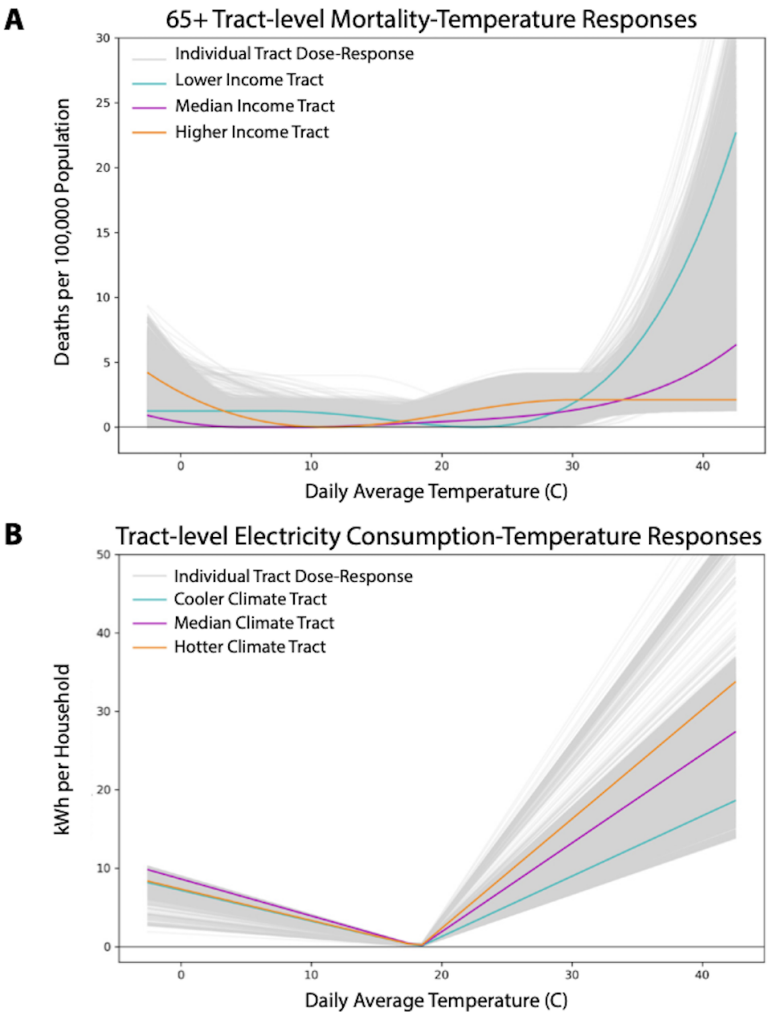
hyperlocal damage functions for four sectors (energy, mortality, property damage and labor supply), where damages are estimated from high resolution micro-data and take into account empirically calibrated adaptation behavior (Carleton et al., 2022; Auffhammer, 2022). We then break these impacts down by exposed populations and quantify the magnitude and drivers of inequality across the state. We believe this is the first paper to do such a decomposition at scale.

The agricultural sector is one of the most climate vulnerable sectors in North America and accounts for up to 40% of the global SCC (EPA, 2022). While there is a significant literature on the impacts of climate change on yields, this project currently focuses on the mortality and labor impacts on California's agricultural communities. The sector is significantly more labor intensive in the state of California compared to other agricultural regions, as high value specialty crops require a more significant exposure to weather outside as well as in processing facilities indoors. In addition to studying effects across the income distribution and across ethnic groups, we will also examine whether agricultural regions of California face larger impacts of climate change by 2050 under a moderate emissions scenario compared to less agricultural regions. In ongoing work, we aim to include agricultural outcomes, such as farm profit and agricultural wages, directly in our analysis.

In this paper, we show how measures of climate damage inequality depend critically on both climate *and* dose response function differences across the state. Figure 1 suggests the latter is likely to be important. Two example sets of dose-response functions are shown, one for mortality (panel A), and the other for electricity consumption (panel B). The large range of responses across the 8,057 grey lines, each of which represents a response function for one census tract, highlights the substantial heterogeneity in responses to weather across the California localities. Estimates of unequal burdens of climate change that ignore such heterogeneity are likely to be substantially biased.

We combine the heterogeneous dose-response functions shown in Figure 1 with local projections of warming under RCP4.5 in the year 2050 (shown in Figure 2) to generate sector-specific and aggregate estimates of census tract level damages from climate change. These results are shown for aggregate damages in Figure 4, where each sector's physical damages are monetized using stan-

Figure 1: Differential vulnerability to temperature across California's 8,057 census tracts

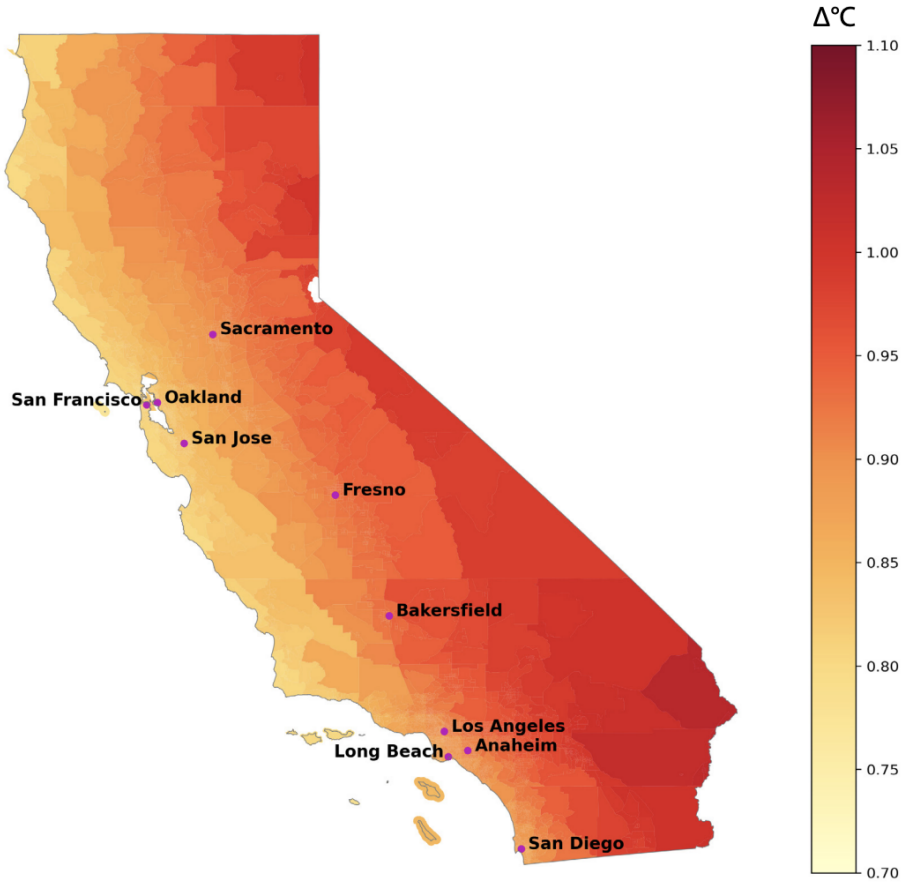


Notes: Each figure shows the relationship between a sector-specific outcome (e.g., deaths per 100,000) and daily average temperature for each of 8,057 census tracts across California. Example tract "response functions" are highlighted in color based on key determinants of vulnerability. Panel A shows results for mortality and panel B shows results for electricity consumption. Both empirical models estimate heterogeneity in tract-specific response functions by interacting weather conditions with long-run average income and climate. See Carleton et al. (2022) for details on panel A and Auffhammer (2022) for details on panel B.

dard tools such as the VSL and average energy prices. This figure reveals substantial inequality in the impacts of climate change across the state. For example, while mean damages across the state amount to ∼1% of GDP per capita, many northern regions gain under climate change due

to avoided deaths and lost working hours under extreme cold, while some southern regions suffer damages amounting to over 20% of local GDP per capita.

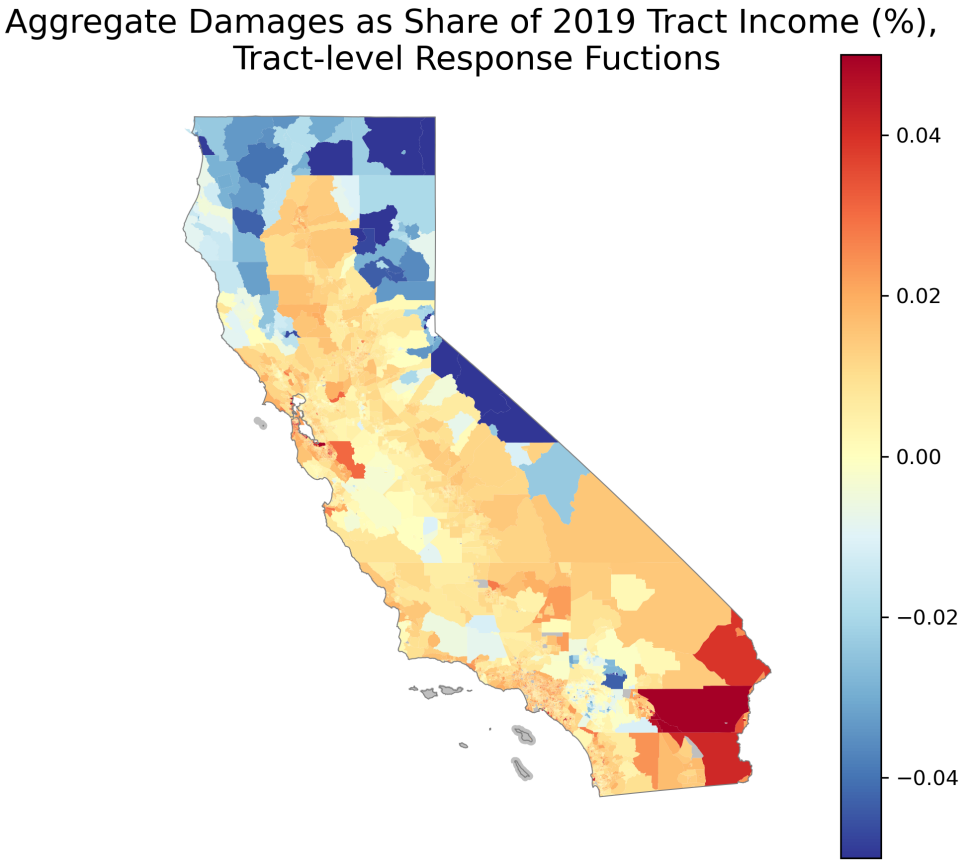
Figure 2: Change in annual average temperature from 2020 to 2050 under moderate emissions (RCP4.5, °C)



Notes: This figure displays downscaled climate model projections at the scale of census tracts across California using the CMIP6 climate model ensemble (weighted mean shown).

The wide range of impacts shown in Figure 4 is due both to differential vulnerability of local populations and to differential exposure to extreme weather conditions. To elucidate the importance of the former in determining patterns of inequality,Figure 3 displays damages for the state of California assuming a common dose-response function across all census tracts for each sector. This map reveals a far more uniform distribution of damages, with the largest estimated impacts located in the hot, but sparsely populated Southeastern parts of the state, as well as some

Figure 3: Economic Damages From Climate Change - Hyperlocal Damage Functions

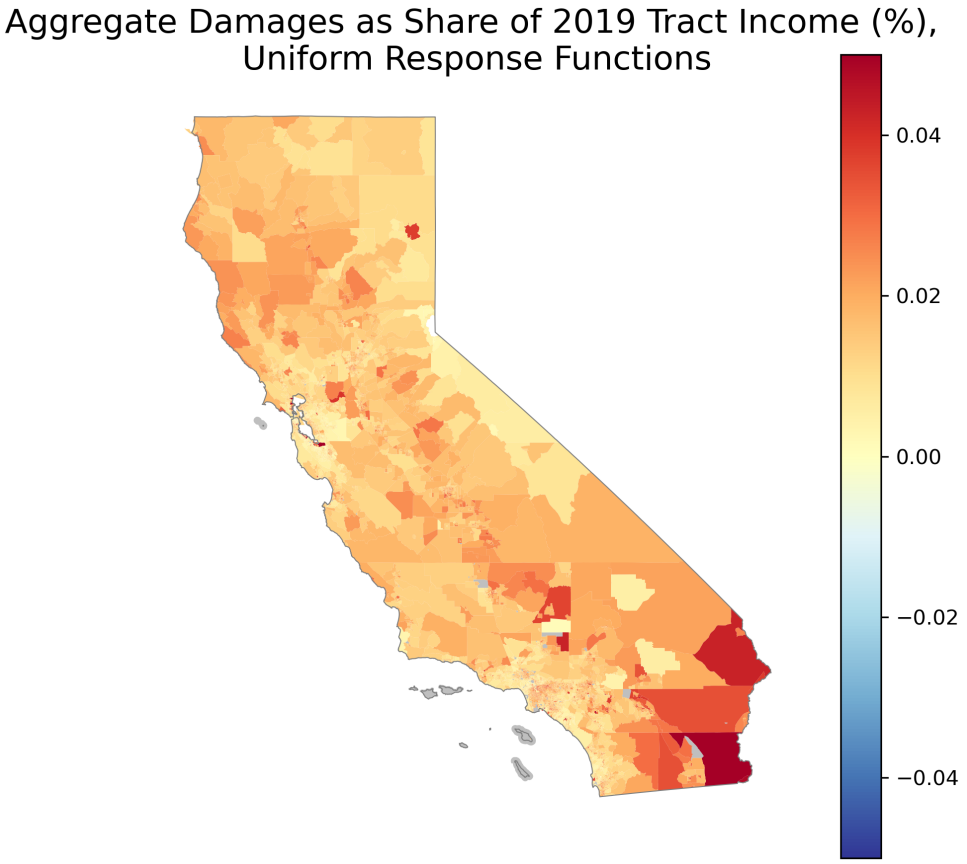


Notes: This figure displays the impact of a moderate emissions scenario of climate change in 2050 on labor supply in low and high risk sectors, mortality, property value damages from flooding, and energy consumption as a share of census tract income. The figure assumes econometrically estimated census tract specific dose-response functions.

communities in the agricultural heartland of California, the San Joaquin Central Valley. If we use our hyperlocal dose-response functions by sector, a completely different distribution of damages emerges, as Figure 4 indicates. These preliminary results reveal the critical importance of accounting for differential vulnerability when quantifying the unequal damages of climate change, and when constructing equity-focused adaptation planning.

In the paper we will characterize and examine the equity implications of this heterogeneity in far more detail. We will examine whether regions and sectors are affected differently across

Figure 4: Economic Damages From Climate Change - Uniform Damage Functions



Notes: This figure displays the impact of a moderate emissions scenario of climate change in 2050 on labor supply in low and high risk sectors, mortality, property value damages from flooding, and energy consumption as a share of census tract income. The figure assumes econometrically estimated uniform response functions for the entire state.

the state, underscoring the importance of sector and location specific analysis for adaptation planning. We stress that quantifying differential vulnerability is key to accurately predicting the equity implications of climate change. If we assume homogeneous adaptive capacity, as has prior work, indicators of inequality, such as the the 90-10 damage ratio, are expected to fall, indicating that differences in exposure are only a small component of differences in climate damages across the state of California. Throughout our work, we will separate out California's agriculture dependent communities and examine impacts separately for this important subset of the local economy. We

will also break down our results by the official "disadvantaged" community status. We expect to have a draft of the paper ready well before the conference and are proactively working on it.

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