Wildfires, Externalities, and Spatial Heterogeneity: An Economic Analysis of California

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Question

Across the globe, wildfires are occurring with increased intensity and severity as climate change has lengthened wildfire seasons and made droughts more pronounced. Smoke from wildfires has serious health ramifications, even for people that are not directly in the line of fire. In order to study how the California state government should allocate wildfire prevention funds to maximize the health benefit, we need to answer the following two questions:

1. What are the impacts of wildfires on respiratory health?
2. What is the impact of wildfire prevention spending on wildfires?

For the purpose of this class, I will focus on addressing the first of these two questions. However, I hope to address the broader question of the optimal funding allocation as part of my field paper this summer.

Motivation

The two largest wildfires California has experienced in recent memory were the August Complex fire in August 2020 and the Dixie fire in July 2021, which each burned approximately 1,000,000 acres[1]. In fact, 9 out of the 20 largest fires since 1932 were in the last 2 years [1]. The increased frequency and severity of fires in California is largely attributed to climate change. Summer wildfire seasons are 40-80 days longer on average than they were 30 years ago, and droughts are more pronounced throughout California, making potential wildfire fuels (e.g. dead leaves and shrubs) more flammable [2]. Common wildfire prevention includes vegetation management, brush clearance, and prescribed fire. As climate change has lengthened the wildfire seasons and made droughts more pronounced, the cost of wildfire prevention has increased dramatically as well. During the fire season, tens of thousands and firefighters and many millions of dollars' worth of equipment are dispatched throughout California [3].

In addition to the environmental and financial impacts of wildfires, exposure to wildfire smoke is associated with many respiratory health complications: decreased lung function, asthma, chronic obstructive pulmonary disease, and respiratory infections. Currently, an estimated 26% of organic

[1] This is equivalent to burning an area that is approximately 16 times the size of the city of Madison.

aerosols in the western United States come from wildfires, and this fraction is expected to increase as wildfires become more prevalent. Fine particulate matter (PM2.5), a component of wildfire smoke, is especially damaging to health. In the US, the daily average National Ambient Air Quality Standard for PM2.5 is 35 μg/m3. However, ambient concentrations of PM2.5 in the vicinity of a wildfire can be extremely high. Hourly concentrations of 6,106 μg/m3 and daily concentrations of 394 μg/m3 have been documented. Finer particles, such as those produced from wildfires, have been shown to be more toxic for respiratory health than particulate matter produced from other sources [4].

Further, wildfire risk is not contained by private borders, so decentralized fire prevention generates a large negative externality. For private property owners, there is heterogeneity in individual risk tolerances with respect to wildfires, so the willingness to pay for wildfire prevention varies within the same fire risk region. However, wildfires can easily spread across private borders, and poorly managed private property increases the fire risk for bordering areas as well. Depending on wind patterns, smoke from wildfires can also migrate to neighboring areas, triggering respiratory complications outside of the direct fire path. Wildfire prevention such as vegetation management, brush clearance, and prescribed fire need to be coordinated efforts across high risk regions in order to be effective, and due to the varying risk tolerances of private property owners, the private market fails. As such, wildfire prevention becomes the responsibility of the government.

There is also considerable spatial heterogeneity of risk for both wildfires and respiratory complications. General respiratory health risk is concentrated in urban areas, where people have exposure to higher concentrations of pollution caused by automobile traffic or industrial emissions. Conversely, wildfires are primarily fueled by grasses, shrubs, and dead leaves, so fires are more common in forested areas. This mismatch in the spatial heterogeneity of wildfire risk and respiratory risk is illustrated in Figures 1-4 in Appendix A.

Research Design

In order to address the health impact of wildfires, I plan to use publicly accessible data on health and wildfires from the following sources:

1. California Health and Human Services Hospital Annual Utilization Database
2. California Department of Forestry and Fire Protection Incident Data

Note, I will merge this data with demographic characteristics and weather data. Because there is potential endogeneity between the population density and the number and severity of wildfires in a given area, I will instrument for the wildfires using weather data.[2] Although the exact instruments are yet to be determined, one potential instrument is to look at drought levels, which would be highly correlated with wildfires but is exogenous from health outcomes. Note, I will need to include at least as many instruments as there are endogenous variables in order to have a well-identified system of equations. Using this instrumental variables regression, we will better understand the spatial dynamics at play between wildfires and respiratory health.

[2]For my field paper, I hope to use incident-level expenditure data from the California Department of Forestry and Fire Protection as an instrument for wildfires as well. I have submitted the Public Records Request for this data, but I have not yet heard back.

References

[1] California Department of Forestry and Fire Protection. Top 20 largest california wildfires, 2021.

[2] Michael Goss, Daniel L Swain, John T Abatzoglou, Ali Sarhadi, Crystal A Kolden, A Park Williams, and Noah S Diffenbaugh. Climate change is increasing the likelihood of extreme autumn wildfire conditions across california. *Environmental Research Letters*, 15(9):094016, 2020.

[3] Patrick Baylis and Judson Boomhower. Moral hazard, wildfires, and the economic incidence of natural disasters. Technical report, National Bureau of Economic Research, 2019.

[4] Colleen E Reid and Melissa May Maestas. Wildfire smoke exposure under climate change: impact on respiratory health of affected communities. *Current opinion in pulmonary medicine*, 25(2):179, 2019.

[5] Conservation Biology Institute. California fire perimeters (1898 - 2019), 2021.

[6] California Department of Forestry and Fire Protection. Fire hazard severity zone viewer, 2021.

[7] California Office of Environmental Health Hazard Assessment. Calenviroscreen 4.0 indicator maps: Pm 2.5, 2021.

[8] California Office of Environmental Health Hazard Assessment. Calenviroscreen 4.0, 2021.

Appendix A

In Figure 1, we can see the areas in California that were impacted by wildfires through 2019. Recall, 9 of the 20 largest wildfires documented are from the last 2 years, so they are not included in this map.

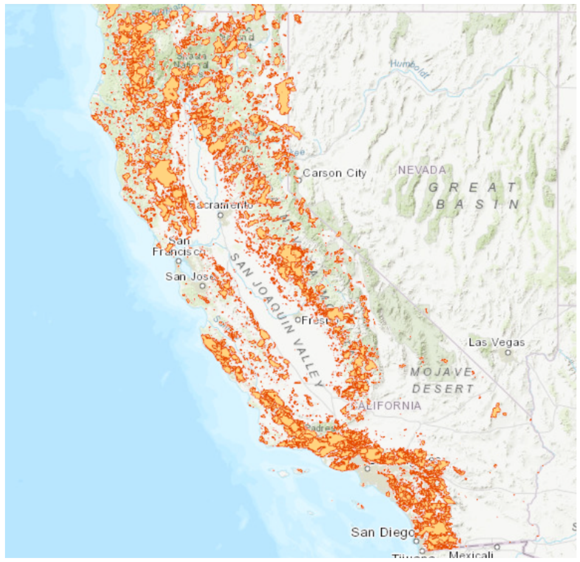

Figure 1. Wildfires Through 2019 [5]. The dark orange shows the perimeter of each fire, and the light orange shows the area impacted by each fire.

In Figure 2, we can see the fire hazard severity zones as determined by the California Department of Forestry and Fire Protection. This map is largely consistent with the location of the fires in Figure 1; much of the higher fire risk in Figure 2 is concentrated on the perimeter of the San Joaquin Valley, or near Los Angeles or San Diego.

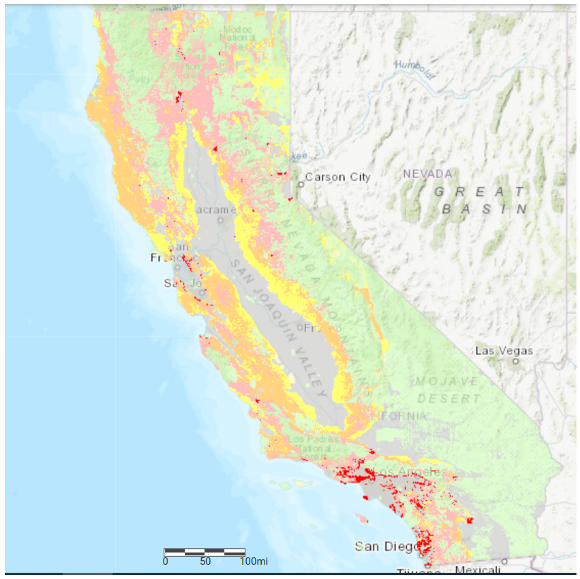

Figure 2. Wildfire Hazard Severity Zones [6]. The light green shows federally managed lands, and the grey shows Local Responsibility Areas (LRA). Of the state lands, yellow designates moderate fire risk, orange designates high fire risk, and light red designates very high fire risk. The dark red shows high fire risk within LRAs.

In Figure 3, we can see air quality in California as measured by PM2.5 levels. We can see higher concentrations of PM2.5 near urban areas, such as Fresno and Los Angeles, which is likely due to more vehicular traffic and industrial pollution. Note, there are very high levels of PM2.5 in the San Joaquin Valley, an area that is surrounded by high wildfire severity zones, despite not having many fires in the Valley itself.

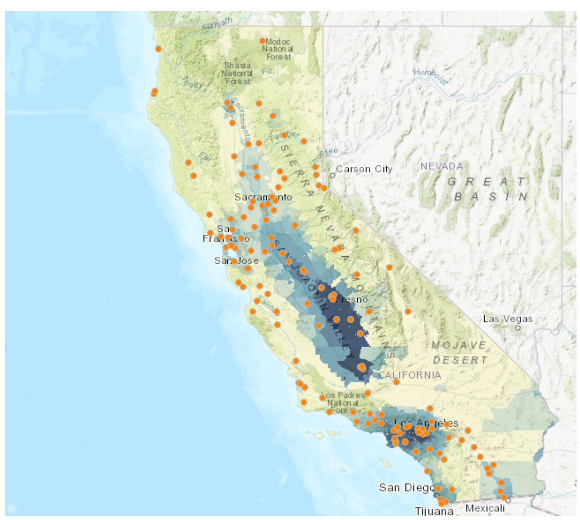

Figure 3. PM2.5 Concentrations [7]. The orange dots represent PM2.5 monitoring stations, and the darker blue indicates higher concentrations of PM2.5

In Figure 4, we can see which regions are disproportionately burdened by, and vulnerable to, multiple sources of pollution as determined by the California Office of Environmental Health Hazard Assessment. As expected, the regions with the most disadvantaged communities largely correspond to the areas with higher concentrations of PM2.5 that we observed in Figure 3.

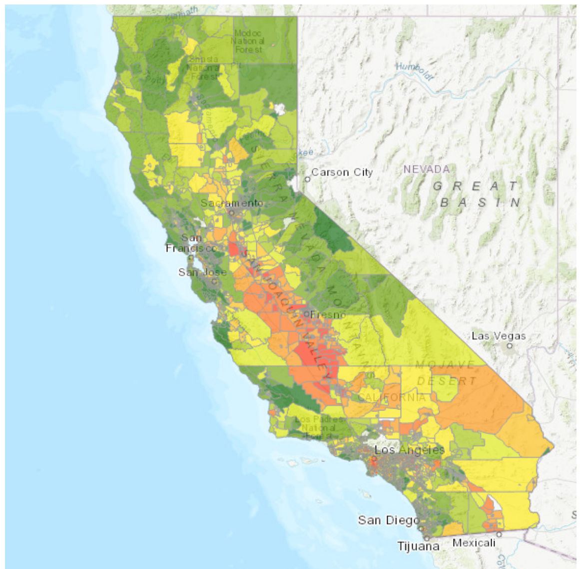

Figure 4. Communities at Risk for Respiratory Complications [8]. The more orange and red regions indicate census tracks that are disproportionately burdened by and vulnerable to multiple sources of pollution.

As we can see in Figures 1-4, there is a spatial mismatch between where the wildfires occur and where the most vulnerable populations for respiratory complications live, which causes ambiguity about where wildfire prevention funds should be focused. Using the structural model and estimation proposed in the following sections, we can solve this constrained optimization problem to determine the optimal policy.