The Distributional Incidence of Wildfire Hazard in the Western United States*

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Increases in wildfire activity in the western United States in recent years have led to significant property loss in wildland-urban interface areas, raising difficult questions for policymakers regarding who should bear these costs. Yet the distributional incidence of wildfire hazard is not well understood, despite its relevance for current policy debates related to wildfire and increased attention to how environmental and climate-related risks are distributed across socioeconomic groups. This paper fills this gap by combining property-level data on locations and values of residential properties, demographics, wildfire hazard, and historical wildfire perimeters. We find that while there is substantial heterogeneity within high wildfire hazard areas, wildfire risk to properties is disproportionately borne by high-income, white, and older residents, and owners of high-value properties. Properties whose value is the highest ten percent among properties in the same county are on average seventy percent more likely to be in high wildfire hazard areas than median value properties. Twenty percent of properties within 2011-2018 fire perimeters were in the top decile for property value among homes in the same county.

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1 Introduction

Wildfire activity in the western US has increased dramatically in recent years (see for e.g. Westerling, 2016; Abatzoglou & Williams, 2016), resulting in increasing losses to lives and property, among other impacts. Between 2005 and 2020, wildfires destroyed nearly ninety thousand homes in the US. Over sixty percent of these were lost in 2017, 2018, and 2020 alone (Headwaters Economics, 2020). The rapid escalation of risk has generated a series of policy challenges related to liability in utility-sparked wildfires (Kousky et al., 2018), affordability and availability of insurance in high wildfire hazard areas (Cignarele et al., 2018), and increasing costs of wildfire management for state and federal agencies (Calkin et al., 2005; Calkin, Thompson, & Finney, 2015). At issue in addressing these challenges is who should bear costs associated with rising risk; should increasing costs of wildfire risk be borne primarily by those living in high wildfire hazard areas or should they be distributed more broadly? For many, the answer to this question will hinge on fairness concerns. Yet despite its relevance to a variety of wildfire-related policy questions, relatively little is known is about the distributional incidence of wildfire risk.

To help fill this gap, we combine property-level data on residential property values within the western US[1] with Census economic and demographic data and spatial wildfire hazard data, and we contrast the distributions of property values and various Census demographic variables across high and low wildfire hazard areas in the western US.

This analysis contributes to a large literature documenting differences in exposure to environmental hazards and amenities across socioeconomic groups. While the literature documenting differences in exposure to anthropogenic hazards such as pollution and waste facilities spans decades (for reviews, see Ringquist, 2005; Mohai, Pellow, & Roberts, 2009; Banzhaf, Ma, & Timmins, 2019), the literature describing differences in exposure to natural disasters has emerged more recently (e.g. Walker & Burningham, 2011; Montgomery & Chakraborty, 2015; Grineski et al., 2015; Bakkensen & Ma, 2020). A broad finding of this emerging literature is that exposure to flood risk can differ among racial/ethnic groups and by economic status, but the relationship is confounded by the correlation between flood risk and valued coastal amenities, which often make coastal areas desirable in spite of attendant risks. As in flood risk areas, correlation between wildfire hazard and associated natural amenities

[1] Data provided by Zillow through the Zillow Transaction and Assessment Dataset (ZTRAX). More information on accessing the data can be found at `http://www.zillow.com/ztrax`. The results and opinions are those of the author(s) and do not reflect the position of Zillow Group.

complicates expectations regarding the distributional incidence of wildfire risk (Stetler, Venn, & Calkin, 2010). However, compared to flooding, few studies have explored the distribution of wildfire hazard. Existing studies document the relationship between social vulnerability and wildfire risk at national scales using Census data (e.g. Wigtil et al., 2016), or they have very limited study areas (e.g. Paveglio et al., 2016; Palaiologou et al., 2019).

We add to this existing body of research in several ways. First, we use assessors' data to investigate the relationship between wildfire hazard and property value across a broad study area. Property values are of interest because in the US homes often comprise a large portion of household wealth; for households in the middle three wealth quintiles, homes constitute approximately 60 percent of total wealth (Wolff, 2016). Therefore property values provide a reasonable proxy for household socioeconomic status (though we also supplement our property-level data set with Census variables measured at the Census block-group level). Moreover, precise property locations provided by the assessors' data allow us to more accurately measure wildfire hazard at the locations of properties,[2] as well as to locate properties relative to historic wildfire perimeters. Second, we analyze the distribution of wildfire hazard across the population at both regional and sub-regional scales. This feature of the analysis is important because distributions of property and demographic characteristics can vary substantially, and comparisons between property and demographic characteristics of high wildfire hazard areas to the national distributions of those variables may not be relevant. This is especially true for property values, which can vary dramatically over space due to differences in housing markets. Finally, property data include years when housing units in our sample were built, allowing us to consider how the relative value of properties built in high wildfire hazard areas has changed over time.

Comparing the property values within high wildfire hazard areas to other properties in the same county, state, or in the western US generally, we find areas most affected by wildfire risk are disproportionately made up of high value properties and higher income residents. Homes whose value is in the highest ten percent among homes in their same county are, on average, seventy percent more likely to be in high hazard areas than median value homes, and these homes were more likely to have been within areas burned in recent fires. Across much of the western US, high

[2] Figure A.5 (Supplementary Materials) illustrates wildfire hazard (Wildfire Hazard Potential) overlaid by the location of property locations for two example block groups from counties in Arizona and California. Wildfire hazard at the locations of properties may be systematically different from the spatial average of wildfire hazard in their block group.

wildfire hazard areas are, on average, whiter, higher income, and older. However, we also find that high fire hazard areas are highly heterogeneous, and properties whose value is among the lowest ten percent of homes across the western US, or among homes in the same state, are slightly over-represented in high fire hazard areas. Moreover, in a finding that has implications for the distribution of fire management—a local public good—we find that high property value areas constitute a relatively small portion of the total *area* facing wildfire risk in the western US, since high fire hazard areas with high property values tend to be denser than high fire hazard areas with low property values. Finally, in the Supplementary Materials, we find that the fraction of properties that are built in high fire hazard areas has been increasing over time, but that the fraction of high value homes built in high risk areas has dropped in recent years.

2 Results

2.1 Property values and demographic characteristics within high wildfire hazard areas

To investigate how wildfire hazard is distributed across households in the western US[3] we merge spatial data describing wildfire hazard with block group and tract-level American Community Survey demographic data[4] and property-level data county assessors' data. Wildfire hazard is measured using the US Forest Service Wildfire Hazard Potential (WHP) data set, which provides a continuous spatial index of the relative potential for difficult-to-contain wildfires within 270-m pixels across the US (Dillon, 2015). Property-level county assessors' data are from the Zillow ZTRAX data set, which compiles county assessors from across the US (Zillow, 2019). We restrict our attention to single family residential properties[5] because they are more likely to be owner-occupied and their property values are more likely to be a reasonable proxy for household wealth. In total, our data set comprises approximately 16.7 million properties across the western US. Using reported property coordinates, the WHP data set, and Census block group boundaries, we identify wildfire hazard and community demographic characteristics for each property in the data set.

[3]Our definition of the western US comprises the eleven western states in the contiguous US: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

[4]All demographic variables are measured at the block group level except percent below the poverty line, which is measured at the tract level.

[5]We include all properties ZTRAX categorizes as single-family homes, condominiums, mobile homes, and prefabricated homes.

Table 1 contrasts Census demographic variables across high and low wildfire hazard block groups. Throughout the paper, we define high wildfire hazard properties to be properties where WHP is above 394, which corresponds to the ninety-fifth percentile of WHP among all properties in our data set (a kernel density plot is provided in the Supplementary Materials).[6] We define high wildfire hazard block groups to be those block groups in which more than twenty percent of properties are high wildfire hazard properties, and compare average demographics across high and low (non-high) wildfire hazard block groups. We find that on average, high wildfire hazard block groups have higher income than low wildfire hazard block groups, and a lower percentage of their population is below the poverty line. High wildfire hazard block groups also have a higher percentage of white non-Hispanic, Native American, and elderly residents, and a lower percentage of black and Hispanic residents. For each demographic variable, differences between high and low wildfire hazard areas across the western US are highly statistically significant. In the Supplementary Materials (Table A.1), we explore within-state differences in average demographic characteristics across high and low wildfire hazard areas.

Panel A of Figure 1 shows kernel density plots for the overall distribution of property values within high and low wildfire hazard areas in the western US. Property values in high fire hazard areas appear to have a higher variance than property values in low hazard areas, and they are higher on average. Figure A.1 repeats this figure separately for each state. The relative distributions of property values vary substantially by state, and the overall distribution appears to be driven primarily by California, which has the largest number of observations and the most similar distributions of property value across low and high fire hazard areas.

Panel B of Figure 1 shows the relative frequency of residences by property value decile, and WHP decile. Across the western US, properties in the eighth decile of wildfire hazard and above are more likely than properties in the lowest seven deciles to be in one of the highest property value deciles. However, properties in the highest wildfire hazard deciles are also more likely than low wildfire hazard properties to be in the lowest property value deciles. This pattern is repeated in most western states, as indicated by the bright cells in the upper right corner of most state panels in Figure A.2. This finding mirrors the finding of Wigtil et al. (2016), who found that high wildfire hazard areas on average had relatively low social vulnerability, but approximately 10 percent of high wildfire hazard areas had high social vulnerability.

[6] Our value of 394 is similar to the value of 401 used by Dillon (2015) to define the class break between high and very high wildfire hazard.

In Figure 2, we explore the relationship between property value and wildfire hazard in greater detail. The figure displays regression coefficients from a series of property-level regressions estimating differences in the share of high wildfire hazard properties across deciles of property value, as in equation 1. Coefficients are interpreted as the average difference between the share of high wildfire properties in a given property value decile and the share of high wildfire hazard properties in the fifth property value decile, which is the omitted category.
We estimate three sets of regression coefficients, using property value deciles calculated by comparing properties to properties from the entire US West (circles), and from each property's respective state (triangles) or county (squares). Regardless of geography we use to produce property value distributions, we find that high value properties are more likely to be in high wildfire hazard areas than low value properties. The differences are substantial. Within the fifth decile of property value, approximately 4 percent of homes are in high wildfire hazard areas, therefore we find that homes with value in the tenth decile for properties in their same county are more than 70 percent more likely to be in high hazard areas than homes in the fifth decile. Whether low value homes are more or less likely to be in high hazard areas depends on the geography of comparison property value distributions. When properties are compared other homes in their same county, low value homes appear no more likely to be in high hazard areas. Similarly, we find in Figure A.6 that when within-county comparisons are used, properties in areas where per capita income is relatively low or where a relatively high percentage of residents are below the poverty line are less likely to be in high wildfire hazard areas.

2.2 Home value and historical wildfire occurrences

To assess how historical wildfire occurrences have been distributed across western properties, we compare the overall distribution of 2010 assessed property values in each western state to the distribution of assessed property values among homes within a historical wildfire perimeter from years 2011-2018. Figure 4 shows the fraction of properties that intersected historical wildfires across deciles of the within region, state, and county property value distributions. If wildfire occurrences were randomly distributed with respect to property values, we would expect to observe ten percent of the properties inside a wildfire perimeter to come from each decile. Across the western US as a whole, we find that historical wildfires disproportionately affected homes in the highest property value deciles (deciles 9 and 10) between 2011-2018. Properties in the lowest ten percent of property values in the western US in each property's respective state also slightly over-represented within burn perimeters. When we compare properties only to other properties within the same county (brown bars), properties in the lowest property value decile are somewhat under-represented. This may be in part because wildfires occurred more frequently in counties where property values were low overall.

These results reinforce findings from the previous section that higher value homes face disproportionate wildfire risk; however, two qualifications should be noted. First, these results are highly influenced by a small number of fires. Between 2011-2018, the perimeters of 314 wildfires burned to encompass 38,662 properties within our sample. The fire that intersected the greatest number of properties, the 2018 Camp Fire, intersected a total of 14,367 properties in our sample, while more than sixty percent of affected properties were intersected by the top three fires. Second, we measure property location relative to the fire perimeter, not whether the property was damaged or destroyed. While it is likely that not all of the properties we identify as having been inside a fire perimeter were damaged or destroyed by fire, and some properties outside the the fire perimeter may have been damaged or destroyed due to airborne embers (Cohen, 2000), presence inside the fire perimeter nevertheless indicates increased risk of damage.

2.3 Geographic variation in the distributional incidence of wildfire hazard

Figure 3 illustrates how property values are distributed geographically within high wildfire hazard areas within the western US. The figure plots an approximately 140-sq. km hexagonal grid across the western US, where grid cells are colored according to the decile of the median property value among high wildfire hazard properties in the cell. We calculate deciles using the distribution of property values across the entire region so that colors are directly comparable. Colors corresponding to each decile are shown on the inset pyramid plot. Grid cells are omitted from the map if there are no high wildfire hazard properties within grid cell. Grid cells are displayed as more transparent when there are fewer high wildfire hazard properties within the grid cell; more vivid grid cells contain a greater density of high fire hazard properties. As expected, the coast of California is dominated by high property value high wildfire risk areas. Across the rest of the western US, high property value high wildfire risk areas occur around urban areas such as Salt Lake City and the Colorado Front Range.

The inset pyramid plot within Figure 4 shows how the number of grid cells and the number of properties per pixel varies across property value deciles. The left panel shows that a large portion of high wildfire hazard areas in the western US consists mainly of relatively low value homes, while a much smaller portion is made of mostly high value homes.

To reconcile this result with our previous result—that high wildfire hazard areas disproportionately comprise high value homes—the right panel illustrates how the the average number of high wildfire hazard properties within grid cells varies with the median decile of properties within the grid cell. While high fire hazard areas consisting mainly of low value homes cover a much broader portion of the western US than those with higher value homes, these areas tend to contain fewer high fire hazard properties than do areas where high fire hazard properties are primarily higher value.

3 Discussion

This paper finds that those living high wildfire hazard areas and those living in recently burned areas are disproportionately likely to live in relatively value homes, have a high income, and to be white. As in high amenity yet high risk coastal areas, it is likely that spatially-correlated wildland amenities make properties in high wildfire hazard areas desirable for higher income households. It is important to note that this paper does not identify, nor does it set out to identify, the effect of wildfire hazard on home prices; rather, we are interested in using home prices as a proxy for household wealth in order to understand how wildfire hazard is distributed across the population. Since 60 percent of the average middle class household's wealth is in their home, property value is a reasonable proxy for household wealth; however, we also test the relationships between wildfire hazard and other demographic variables measured by the US Census. The broad message of our analysis remains the same whether we examine property values or Census demographics.

An implication of this finding is that many households affected by escalating wildfire risk may be capable of bearing increased costs associated with living in these high amenity locations. In California and increasingly in other parts of the western US as well, policymakers are weighing options for how to distribute the costs of wildfire risk across electric utilities, insurance companies, state and federal agencies, and households in both low and high hazard areas. For example, a short-lived California policy—in place between 2011 and 2017— required households living in high hazard areas to pay an annual fee for wildfire prevention services. More recently, electricity customers around the state—even in low hazard areas—are being charged a per-kilowatt hour surcharge to help fund the California Wildfire Fund, which can be used to cover liabilities owed by utilities in the case of utility-sparked wildfires (see for e.g. Luna, 2019). The results of this paper indicate that, on average, policies of the latter type, which shift resources from low hazard areas to high hazard areas, provide subsidies to wealthier households.

A secondary finding of this paper, however, is that high wildfire hazard areas are highly heterogeneous. Average property values in high wildfire hazard areas are higher than those in low wildfire hazard areas, though the there is significant overlap in the distribution of property values across the two types of areas (Figure 1). As well, properties with very low values—compared to other properties in the western US or compared to properties in the same state—are somewhat over-represented in high wildfire hazard areas (Figure 2). Therefore, in some areas, the ability of households to bear increasing costs associated with wildfire risk will be a significant concern. Moreover, while most high wildfire hazard *properties* have relatively high values, most high wildfire hazard *areas* across the western US comprise relatively low value properties (Figure 3). Since wildfire management is a local public good that benefits all households in a given area (Wibbenmeyer, Anderson, & Plantinga, 2019; Baylis & Boomhower, 2019), investments in wildfire management may be more efficient and more substantial in wealthier and more densely populated areas. Wildfire Hazard Potential does not take into account geographic differences in wildfire management activities; therefore, additional research is needed to identify the extent to which different communities benefit from these actions.

Though exposure to wildfire hazard falls disproportionately on higher income households with higher property values, vulnerability to wildfire hazard may be distributed differently. Previous studies (e.g. Wigtil et al., 2016; Paveglio et al., 2016; Palaiologou et al., 2019) of the distribution of wildfire hazard have considered how exposure to wildfire hazard varies by social vulnerability, where social vulnerability is defined as the product of the probability of a hazard event, and an affected populations' ability to mitigate, adapt to, and recover from it (Cutter, 1996). We find that wildfire hazard is borne disproportionately by high income, high property value households; however, these populations may be more capable of adapting to and recovering from wildfire events than lower income populations.

Finally, this paper has focused on the incidence of wildfire property damage risk. A growing body of evidence suggests that a substantial portion of the economic damages associated with wildfire arise due to wildfire smoke (Wang et al., 2020; Burke et al., 2021). Health consequences of wildfire smoke may be distributed differently than wildfire risk to property. Moreover, factors that determine vulnerability to wildfire smoke—for example, age—may be different than those that determine vulnerability to property damage. Further research is needed to understand equity implications of increasing wildfire smoke.

4 Materials and Methods

4.1 Data

Our analysis merges two sources of socioeconomic data, data from Zillow ZTRAX and data from the US Census Bureau American Community Survey, with USDA Forest Service wildfire hazard data. We use wildfire hazard potential (WHP), a spatial index of the relative potential for wildfires that would be difficult to contain and therefore potentially damaging to valued assets such as homes (Dillon, 2015). WHP is the measure used by previous studies of the relationship between wildfire hazard and social vulnerability (Wigtil et al., 2016; Davies et al., 2018). WHP is produced by integrating outputs from FSIM, a simulation tool for estimating large fire probabilities, and the observed spatial distribution of small fires with a set of weights that describe the difficulty of implementing fire control strategies across the landscape. The result is a spatial dataset that ranks the potential for dangerous uncontrolled wildfires across the US using a continuous ordinal index that varies from 0 to approximately 100,000. The Supplementary Materials include a map of WHP across the western US and highlights the comparatively high fire risks in much of California and various regions in the Rocky Mountains (Figure A.3).

The Zillow ZTRAX database includes real estate transaction records and property tax assessment data for approximately 150 million properties across the US. An advantage of using property-level data is that they alllow us to measure wildfire hazard at the locations of properties, rather than averaging wildfire hazard within Census block or block group. Figure A.5 shows wildfire hazard and the locations of properties for example block groups in two western counties. Since locations of properties are not random with respect to wildfire hazard, using average wildfire hazard within a block group could bias wildfire hazard measurements. We restrict the property-level data set to single family residential properties and drop duplicates, yielding a total of 16.7 million observations across eleven western states. The Supplementary Materials provide additional details on the property-level data set and sample restrictions.

We merge our property-level ZTRAX data set with tract- and block group-level data from the 2018 US Census American Community Survey. Specifically, we collect data on various income (per capita income and percent above poverty line), demographic (percent above 65 years of age), and race and ethnicity (percent white non-Hispanic, percent American Indian, percent black, and percent Hispanic) variables.[7]

Finally, we merge the property-level data set with historical wildfire perimeter data from the USGS Monitoring Trends in Burn Severity (MTBS) data set (Eidenshink et al., 2007). Within the western US, the Monitoring Trends in Burn Severity data set defines burned area polygons for all fires larger than 1000 acres between 1984-2018. These fires constitute approximately 95 percent of total area burned in a typical year. To ensure that observed property values used in this analysis are not themselves influenced by wildfire occurrences, we use assessed property values from 2010 for this analysis, and we use wildfires from years 2011-2018.

4.2 Methods

Using the merged property and hazard data, we examine how the overall distributions of property values and demographic characteristics within each state vary from the distributions of these variables within high wildfire hazard areas.

To examine in greater detail differences in the share of high wildfire hazard properties across deciles of property value (and other variables), we estimate a series of binned regressions:

$$hwhp_i = \gamma_{d^s(i)} + \mu_{s(i)} + \varepsilon_i \tag{1}$$

where d indexes the property value decile of property i within geography s, $hwhp_i$ is an indicator variable denoting whether properties are in high wildfire hazard potential areas, and the fifth decile is in all cases the omitted category. In regressions in which s indexes counties, for example, deciles are calculated within individual counties. In this case, $\mu_{s(i)}$ represents the share of high wildfire hazard properties among those in the fifth property values decile within county s. Parameters $\gamma_{d^s(i)}$ indicate how the share of high wildfire hazard properties from $\mu_{s(i)}$, on average, in other deciles. This specification allows us to consider how relative wildfire risk varies across the distribution of property values, where the relevant property value distribution can vary depending on the geography of interest.

In the Supplementary Materials, we examine how shares of the population living in high wildfire hazard areas differs across the distribution other demographic Census demographic variables. When estimating binned regressions for Census variables, we weight properties according to the number of people each represents when calculating property value deciles, since our unit of

[7] All variables are measured at the block group-level, except percent above poverty line, which is available only at the tract-level.

analysis is a property but our Census variables describe characteristics of individuals. The number of people each property represents is calculated as the number of people per property in a given Census block group.

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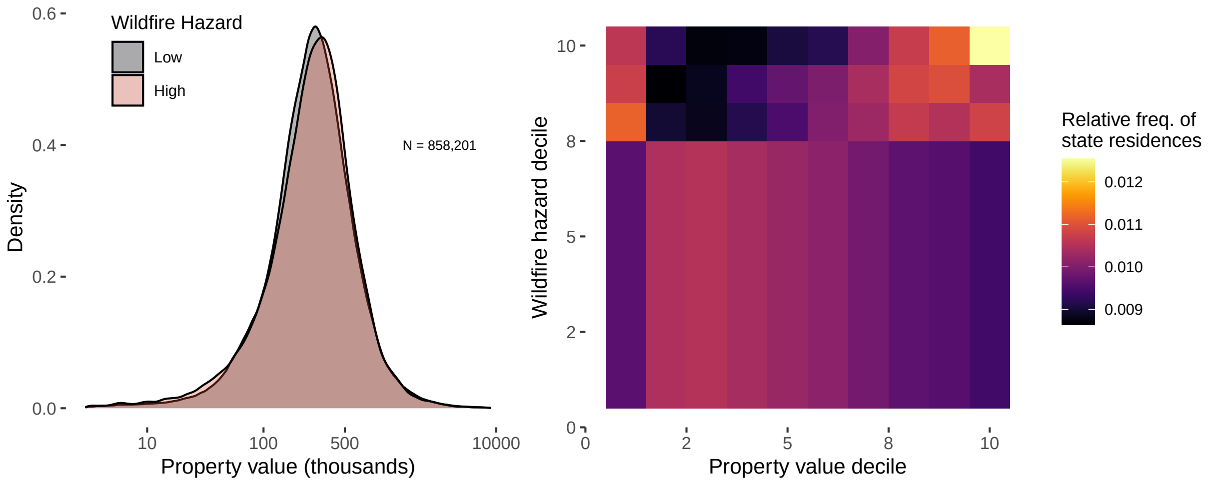
Figure 1: Plots of the distribution of property value by wildfire hazard. The left panel plots kernel density plots of the distributions of assessed property value within high (95th percentile and above) and low (below the 95th percentile) wildfire hazard areas. The right panel plots the relative frequency of properties within deciles of assessed property value and wildfire hazard. Average property values are higher within high wildfire hazard areas.



Note: Approximately 70 percent of properties are have WHP equal to zero; therefore, in the right panel, relative frequency in the seventh wildfire hazard decile and below represents the average frequency within a given property value decile.

Figure 2: Differences in the share of high wildfire hazard properties across property value deciles, by geography within which deciles are calculated.

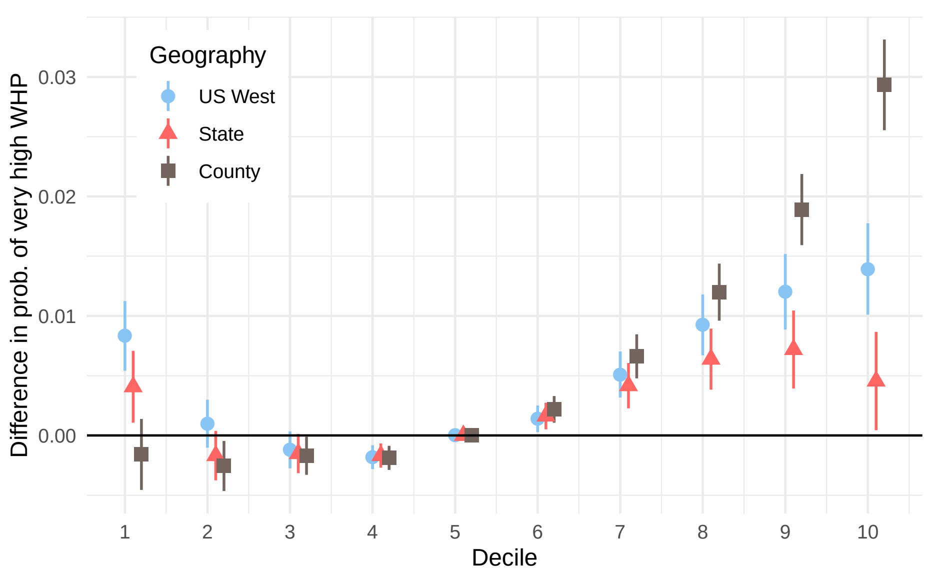


Figure 3: Property values within high wildfire hazard areas of the western US. Only grid cells containing at least one property in a high wildfire hazard area are shown. Grid cells are colored according to national decile that corresponds to the median property value among high fire hazard properties in the cell. Grid cells containing fewer high wildfire hazard properties are displayed as more transparent. The legend illustrates that areas in which high wildfire hazard properties are primarily high value are relatively rare relative to areas in which properties are primarily low value (left panel); however, areas where properties are primarily high value tend to be denser (right panel).

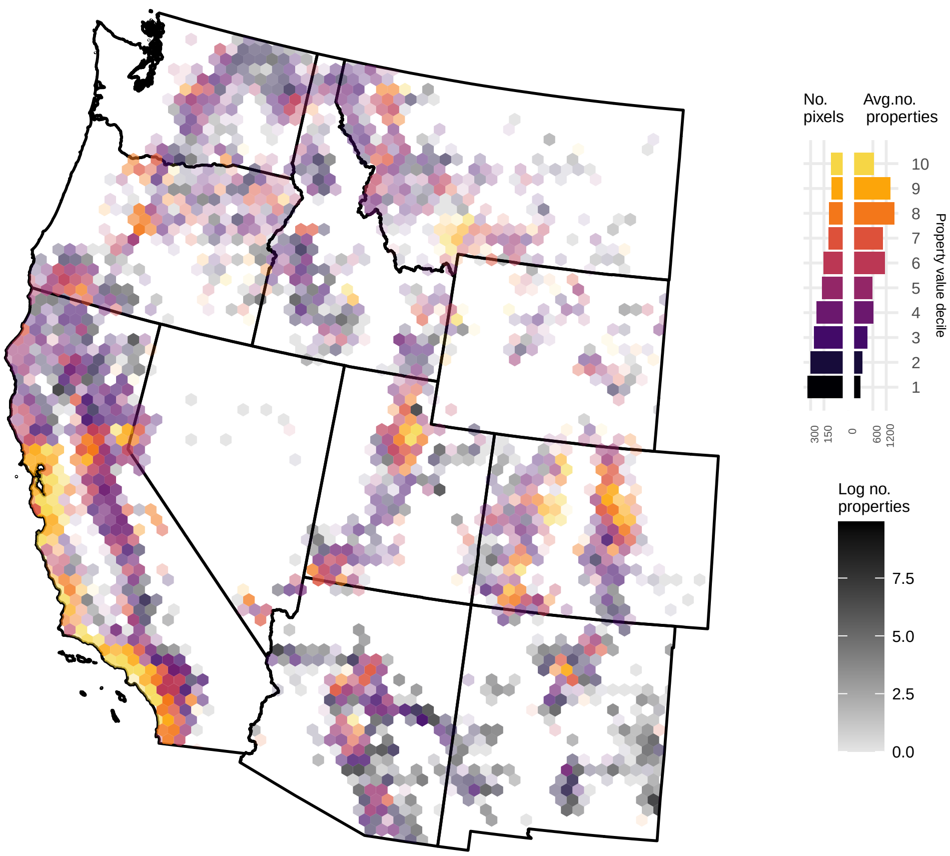


Figure 4: Fraction of properties in areas within burned areas (2011-2018) across deciles of the property value distribution. Fractions greater (lower) than 0.10 indicate disproportionately high (low) fire hazard within a given decile. Property value deciles are defined within various geographies (western US, state, and county) based on 2010 assessed property values. The number of properties in each decile are reported on each bar.

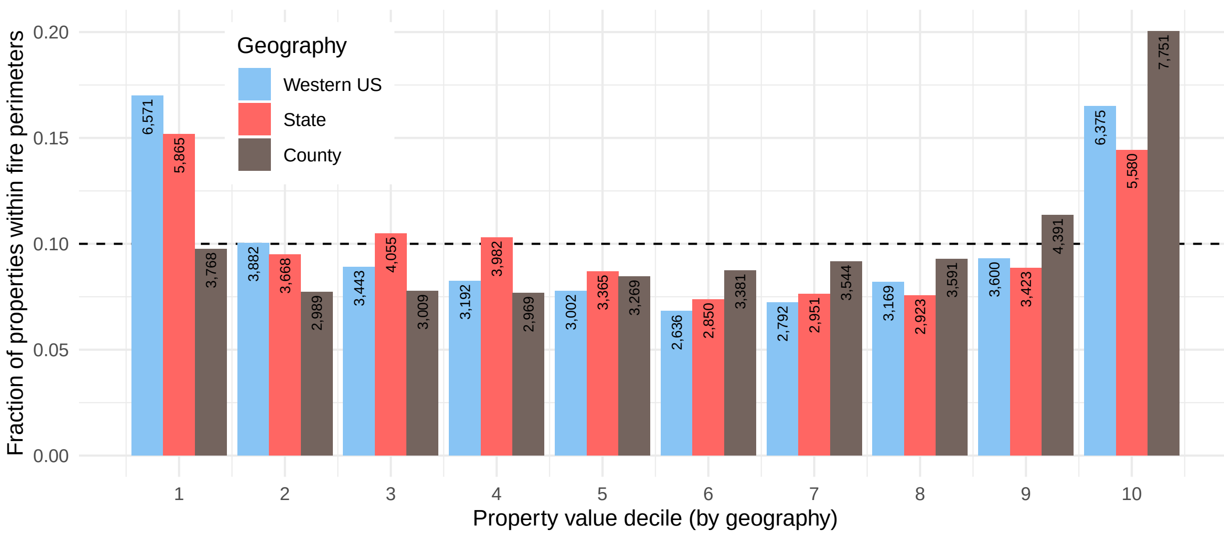


Table 1: Differences in demographics across high and low wildfire hazard block groups

	Low Hazard	High Hazard	t-stat
Per capita income	32,227	35,106	7.65
Percent below poverty line	14.4	11.7	-13.1
Percent white (non-Hispanic)	66.8	80.9	32.8
Percent black	4.5	2.1	-15.9
Percent Hispanic	27.8	16.3	-22.7
Percent Native American	1.3	2.1	8.2
Percent over 65	11.6	15.1	20.3

Note: High hazard block groups block groups within which 20 percent or more of the properties are in areas where WHP is above the 95th percentile among all homes in our data set. All other block groups are considered low WHP. The report t-statistic is the t-statistic on the difference between mean demographics in high and low WHP areas.

A Supplementary Materials

A.1 Details on property-level data

We use the current assessment data provided by Zillow ZTRAX, which collects the most recent available assessment for US properties (as of 2019). We restrict our property-level sample in two ways. First, we focus on single family residential properties[8] because these properties are more likely to be owner-occupied and their property values are more likely to be a reasonable proxy for household wealth. A disadvantage to focusing on single family residential property values is that we potentially overlook renters in multiple unit properties, whom we expect to have systematically lower income and household wealth than occupants of single-family residences. We partially mitigate this concern by integrating block-group level US Census data, which includes renters. In analyses of Census data, we weight property-level observations by the population per observed property in each Census block group. This procedure increases weight given to properties in block groups with high populations but relatively few single-family homes, while also maintaining some of the benefits of our property-level data set: rather than average wildfire hazard across entire block groups, we measure wildfire hazard at the locations of properties, providing a more accurate picture of wildfire hazard in the parts of block groups where people actually live. Second, we exclude properties without spatial coordinates, or with unreliable spatial coordinates. Nolte (2020) found that Zillow ZTRAX property assessment data contain some properties with duplicate coordinates, and that duplicates can result from county assessors' data assigning properties coordinates based on the centroid of their ZIP code. To avoid assigning incorrect wildfire hazard scores to properties based on unreliable spatial data, we drop all properties with duplicate coordinates. After these restrictions, our property-level data set contains a total of 16.7 million observations across eleven western states.

We use ZTRAX property tax assessment data because assessed values are provided for all properties, whereas transactions data are available for properties only in years they are sold. A disadvantage of assessment data is that property assessments may not reflect true property values as accurately as transaction data. However, because we are interested in the distribution of wildfire hazard across households, inaccuracies in the assessed value should affect our results only when they influence the rank ordering of properties with respect to assessed value. As well,

[8] We include all properties ZTRAX categorizes as single-family homes, condominiums, mobile homes, and prefabricated homes. We exclude apartments, commercial buildings, and vacation homes. Not all counties may report whether homes are vacation homes; therefore, our final data set may include some unreported vacation properties.

comparisons between results for assessed property value and related Census variables (such as per capita income) mitigate concerns over inaccuracies stemming from our use of assessors' data. California presents a special set of concerns with respect to differences between market and assessed values. There, Proposition 13—an amendment to the California constitution that passed in 1978—limits annual increases in assessed values to two percent, except when properties change ownership or new construction is completed.[9] Proposition 13 may influence both average assessed values for California properties and the rank ordering of California properties, which could be problematic, for example, if properties in high wildfire hazard areas were systematically transacted more or less frequently than properties in high wildfire hazard areas. Concern for the former issue is mitigated by comparing the distribution of high wildfire hazard property values to the distribution of property values within the same state in Figures 2 and 4. While the latter issue remains a concern, trends in California are similar to those of similar states, and the per capita income result for California in Figure 2 is qualitatively similar to the property value result. This gives us confidence that our results for California are not substantively affected by biases due to Proposition 13.

A.2 Binned regressions using Census variables

Figure A.6 presents estimates of differences in the share of properties in high wildfire hazard areas across Census variable deciles. Here, we estimate equation 1 with one minor deviation from the procedure described in the main text. First, since our unit of analysis is a property, but our Census variables describe characteristics of individuals, we weight properties according to the number of people each represents when calculating property value deciles. The number of people each property represents is calculated as the number of people per property in a given Census block group.

A.3 Changes in the incidence of wildfire hazard over time

To shed light on how the population of high fire hazard areas may be changing as wildland urban interface areas grow and new homes are built, Figure A.8 examines changes examines changes in the overall share of high and low value properties built in high wildfire hazard areas over time.

[9]For California properties, we explored using imputed property values based on use imputed property values based on reported assessed values, county-specific estimates of the annual rate of increase in property values, and the number of years since a property was sold. However, the year of most recent transaction was available for only a small subset of California properties in the assessors' data, and limiting the sample to properties for which we had transaction years appeared to affect results significantly more than using imputed property values in place of assessed values.

We define “high value” homes here as homes in the highest quintile of property values among homes built in a given county in the same five-year period; we call all other homes “low value.” Defining high value using the distribution of homes built in the same county at around the same time accounts for differences in home value due to differences in a home age, better allowing us to use property values assessed between 2017–2019 to provide evidence for how the distributional incidence of fire hazard has changed over time.

The left panel shows how the number of high and low value properties have changed over time relative to the total number of properties built in each five-year period. We find that overall, the share of US West properties built in high fire hazard areas has risen over time, though the share fell steeply in the most recent years of the study period. Figure A.7 (Supplementary Materials) reproduces the left panel of this figure individually for each state. Figure A.7 shows that California dominates Figure A.8 but that trends differ by state. For example, Utah has experienced a recent surge in construction within high fire hazard areas. In Colorado, approximately 35 percent of recent properties built in high fire hazard areas are high value. The right panel of Figure A.8 shows how the share of high value properties built within wildfire hazard areas has changed over time. While the share of high value properties built in high fire hazard areas rose in the final decades of the twentieth century, it has fallen recently, with especially steep declines in years 2015-2018.

These results are subject to two important qualifications. First, wildfire hazard may change over time, in part due to new development. As residential development expands away from an urban core and into previously vacant lands, wildfire risk in the interior may decline. Thus for earlier years, the fraction of properties of total properties currently in high fire hazard areas may be lower than the fraction of properties in high fire hazard areas at the time they were built. Second, while measuring property value deciles among properties built in the same five year span within the same county accounts for differences in home value due to home age, it does not account for differences in home appreciation or depreciation that may be correlated with wildfire hazard.

Figure A.1: Distributions of assessed property value within high and low wildfire hazard areas, by state. Across all western states, assessed property values are slightly higher in high wildfire hazard areas; however, there are sharper differences between high and low wildfire hazard areas within some individual states.

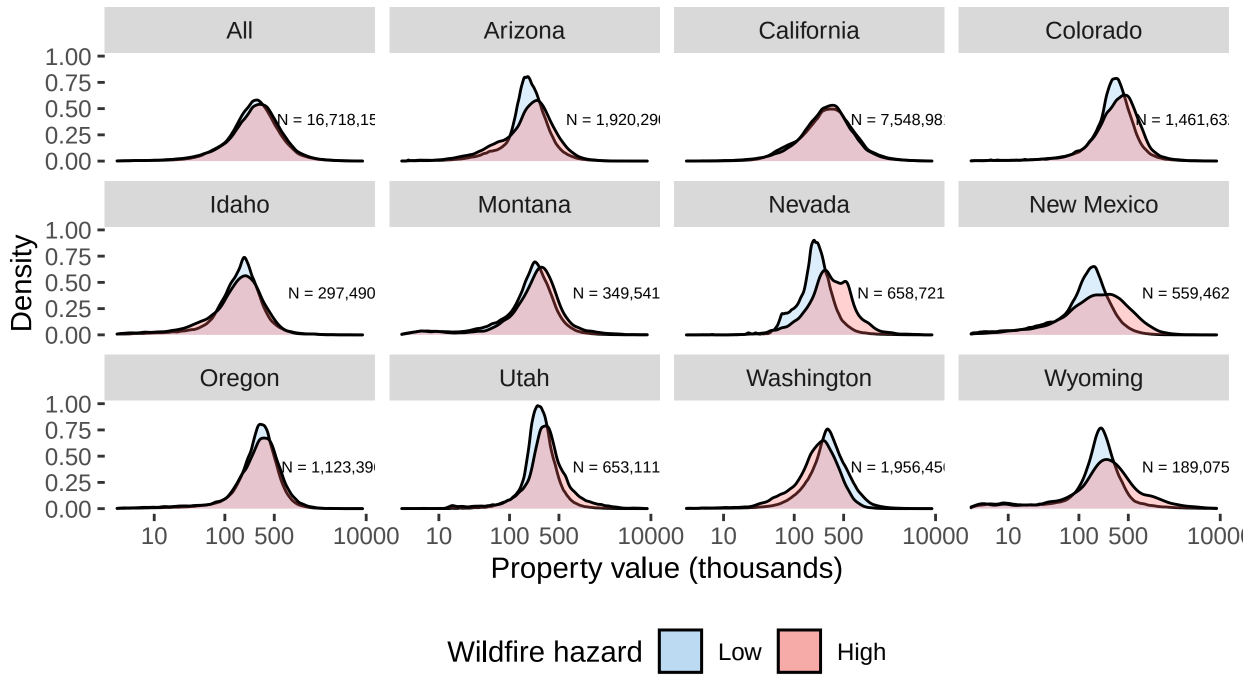


Figure A.2: Heat maps of the relative frequency of residences within state deciles of wildfire hazard and property value, by state. In most western states, high wildfire hazard properties come disproportionately from the highest property value deciles. In some states, there are are also a disproportionate number of very low value properties in high wildfire hazard areas.

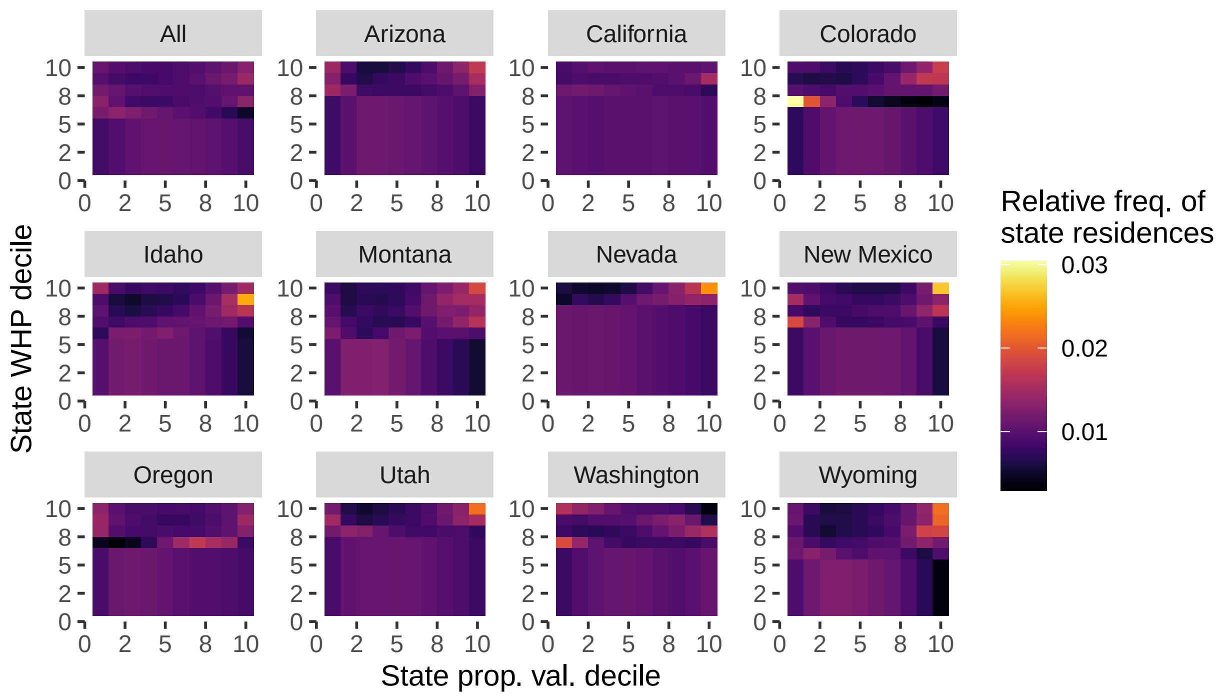


Figure A.3: Wildfire hazard potential (WHP) in the western United States.

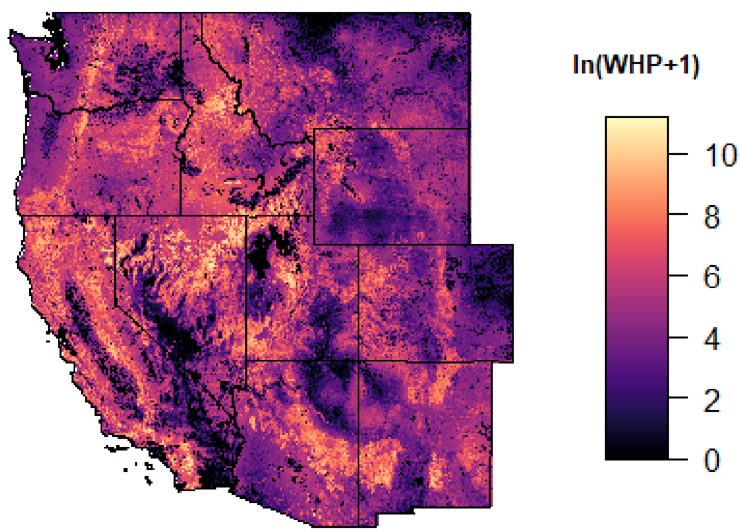


Figure A.4: Kernel density plot illustrating the distribution of wildfire hazard (WHP) across western properties. Selected percentiles of the distribution are labeled and illustrated using dashed lines. WHP equals zero for XX percent of western properties.

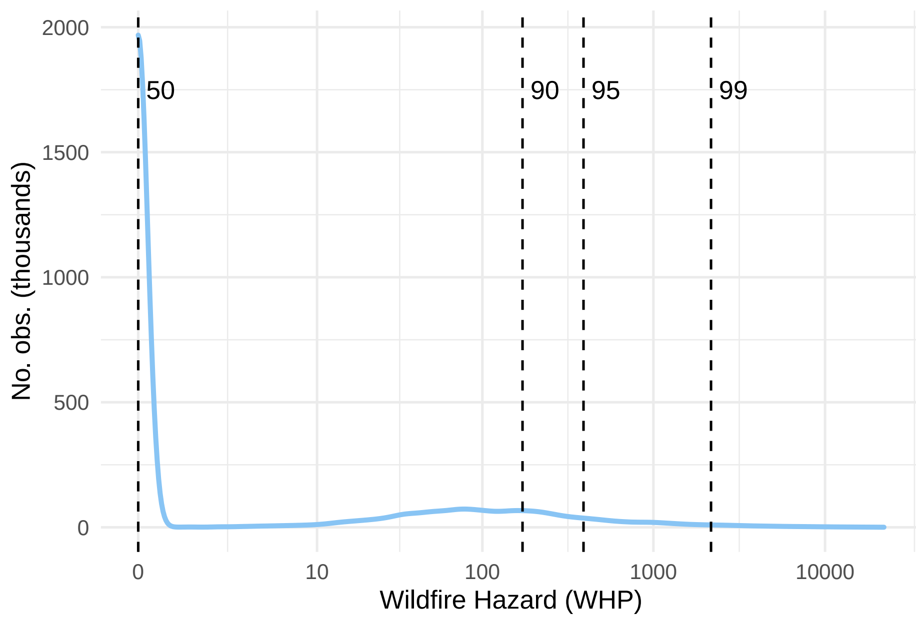
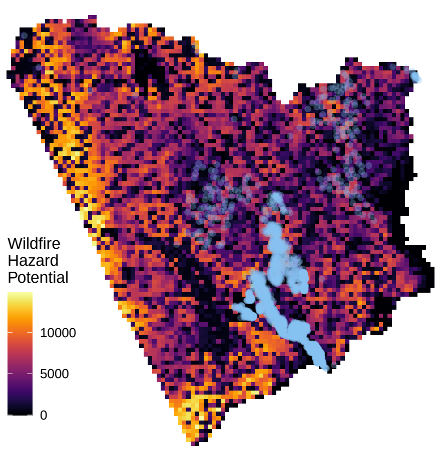
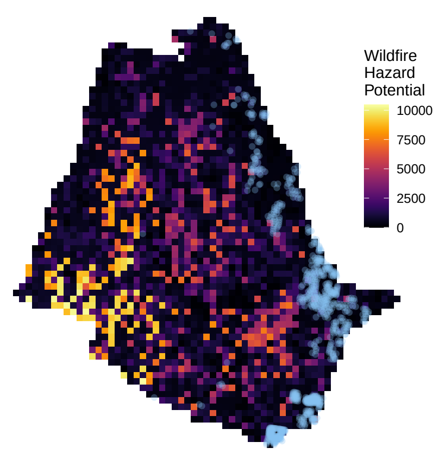


Figure A.5: Property locations (blue marker) plotted against wildfire hazard in block groups from selected western counties



(a) Yavapai County, California



(b) Calaveras County, California

Figure A.6: Differences in the share of high wildfire hazard properties across Census variable deciles, by geography within which deciles are calculated. REMAKE USING WHOLE DATA SET

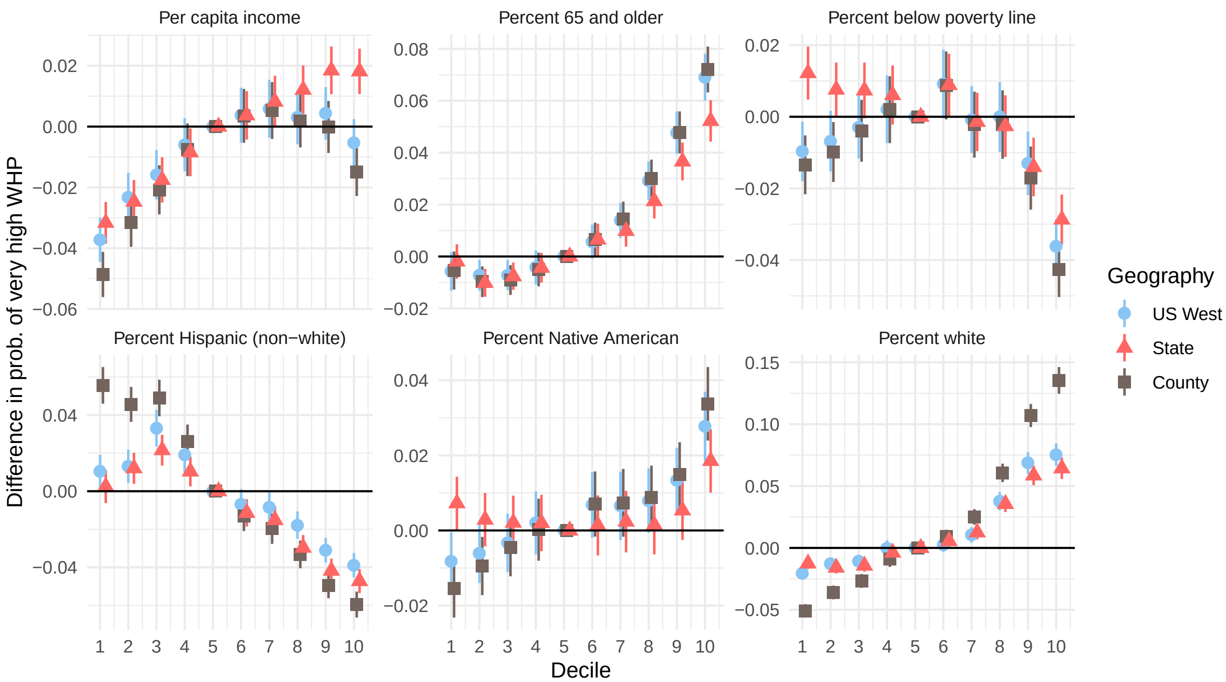


Figure A.7: Trends in the fraction of total properties in high wildfire hazard areas, by relative value and state. High value properties are properties whose assessed value is in the top quintile among properties in the same county that were built in the same five-year period.

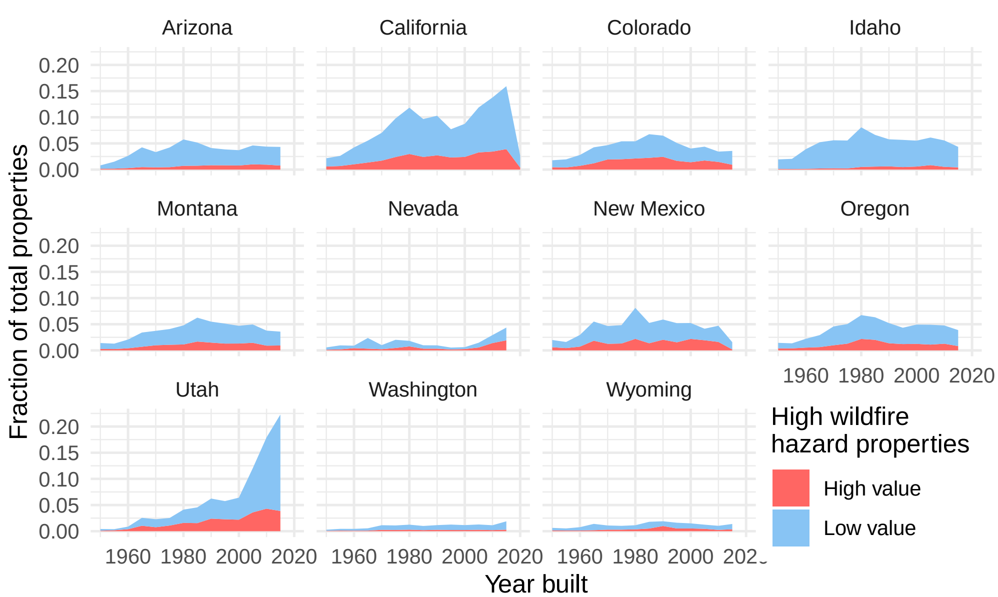


Figure A.8: Trends in the fraction of total properties in high wildfire hazard areas, by relative value. High value properties are properties whose assessed value is in the top quintile among properties in the same county that were built in the same five-year period.

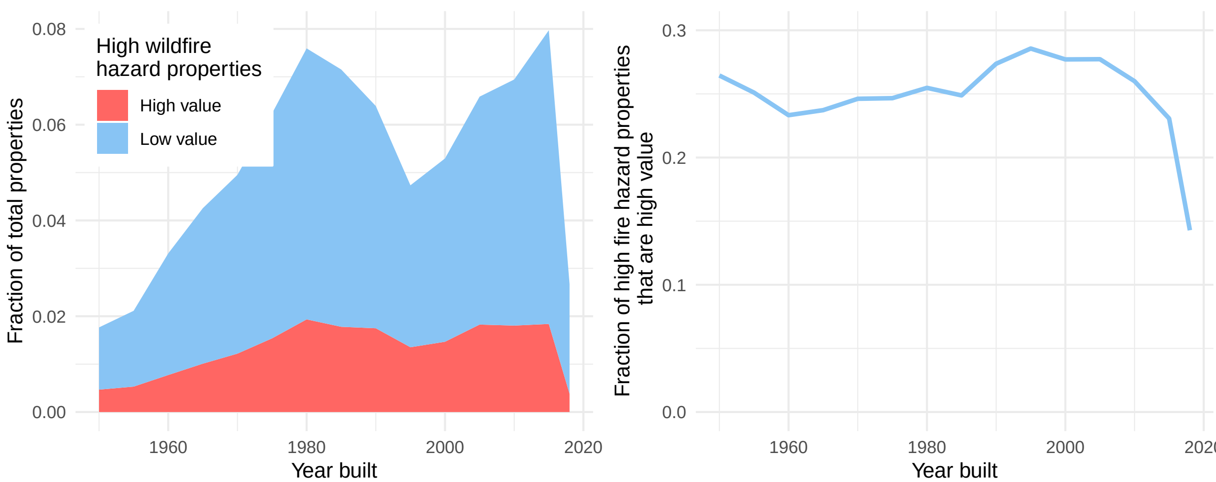


Table A.1: Differences in demographics across high and low WHP block groups, by state

	Per capita income	Percent below poverty line	Percent white (non-Hispanic)	Percent black	Percent Hispanic	Percent Native American	Percent over 65
Arizona							
Low WHP	28,957	16.3	74.5	3.7	27.6	2.2	13.5
High WHP	29,765	15.2	82.7	0.9	14.0	6.6	20.7
t-stat	0.67	-1.21	6.39	-9.13	-7.40	8.35	6.39
California							
Low WHP	33,306	14.9	56.2	5.9	36.6	0.9	11.1
High WHP	35,891	11.7	77.0	2.8	19.7	1.5	14.6
t-stat	4.82	-12.01	41.21	-13.45	-25.71	16.95	17.93
Colorado							
Low WHP	35,095	11.8	81.1	3.5	18.8	0.9	10.6
High WHP	43,823	7.8	92.5	0.5	6.2	1.8	14.0
t-stat	6.82	-5.56	10.80	-6.32	-9.58	6.68	6.13
Idaho							
Low WHP	24,846	15.0	90.4	0.4	9.0	1.4	12.7
High WHP	25,347	11.7	90.9	0.5	7.1	1.5	15.3
t-stat	0.42	-2.72	0.42	1.31	-1.45	0.20	3.21
Montana							
Low WHP	29,051	13.9	89.8	0.4	2.7	5.7	14.7
High WHP	31,519	12.7	95.6	0.2	1.8	1.1	17.0
t-stat	1.29	-0.75	1.86	-1.06	-2.46	-1.56	1.84
Nevada							
Low WHP	29,199	14.2	65.3	7.4	23.7	0.8	11.6
High WHP	41,643	8.5	83.2	6.2	10.8	3.0	13.9
t-stat	4.38	-3.19	5.67	-0.82	-3.64	4.15	1.24
New Mexico							
Low WHP	25,374	19.6	69.8	2.1	46.6	6.5	12.7
High WHP	34,908	14.3	78.6	0.6	31.5	6.9	20.2
t-stat	6.90	-4.34	4.71	-6.51	-5.73	0.26	10.12
Oregon							
Low WHP	30,656	14.7	83.2	1.7	11.0	1.2	13.6
High WHP	31,934	13.9	93.2	0.3	4.7	1.4	20.1
t-stat	1.04	-0.97	9.94	-4.92	-6.20	0.85	9.22
Utah							
Low WHP	26,832	11.1	86.0	1.0	11.8	0.9	8.8
High WHP	30,704	8.8	93.0	0.3	5.1	0.5	9.4
t-stat	4.02	-3.04	7.56	-6.53	-6.99	-1.85	1.16
Washington							
Low WHP	35,142	12.1	77.1	3.2	10.2	1.3	12.2
High WHP	28,886	12.6	88.2	0.4	5.3	4.8	14.9
t-stat	-3.11	0.47	5.55	-4.53	-3.01	6.79	3.18
Wyoming							
Low WHP	31,368	11.3	90.9	0.8	8.4	2.2	12.3
High WHP	40,456	6.1	97.5	0.0	3.1	0.4	18.4
t-stat	1.21	-1.02	0.87	-0.89	-1.01	-0.25	1.32

Note: High WHP block groups block groups within which 20 percent or more of the properties are in high WHP areas. All other block groups are considered low WHP. The report t-statistic is the t-statistic on the difference between mean demographics in high and low WHP areas.