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Burning down the house: the cost of wildfires in heavily urbanized areas

S. Tanner;

Michigan State University, , United States of America

Corresponding author email: tannerso@msu.edu

Abstract:

The frequency and severity of wildfires in the United States has increased dramatically over the past few decades, with both climatic conditions and development into wildland areas fueling this trend. We explore how high-intensity wildfires impact communities living in areas of significant wildland fire risk near national forests in Southern California. The study area contains several megacities that are directly adjacent to four of the most heavily trafficked national forests. Home prices in communities near the forests are valued for their scenery, abundant recreational opportunities, and respite from the cities. Directly after a wildfire, disamenities such as a less attractive view, loss of recreation sites, and increased perception of risk should be capitalized into home prices. We contribute to the literature on wildfire impacts by estimating the impact of a recent fire on property sales prices along two dimensions: properties close to the wildfire compared with properties farther away, and properties in designated areas of high fire risk. Our findings suggest significant heterogeneous impacts of wildfire depending on whether the property is located on high-risk land, as well as evidence that proximity to a national forest can alter the risk perceptions of potential home buyers.

Acknowledegment: I would like to thank the U.S. Forest Service for supporting this research, and for the guidance and support of Professors Cloe Garnache and Frank Lupi. A previous version of this paper was presented at the Agricultural & Applied Economics Association Meetings in Chicago, IL, August 2017.

JEL Codes: Q54, Q58

#2389

Burning Down the House: The Effect of Wildfires on Housing Prices

November 30, 2017

Abstract

The frequency and severity of wildfires in the United States has increased dramatically over the past few decades, with both climatic conditions and development into wildland areas fueling this trend. We explore how high-intensity wildfires impact communities living in areas of significant wildland fire risk near national forests in Southern California. The study area contains several megacities that are directly adjacent to four of the most heavily trafficked national forests. Home prices in communities near the forests are valued for their scenery, abundant recreational opportunities, and respite from the cities. Directly after a wildfire, disamenities such as a less attractive view, loss of recreation sites, and increased perception of risk should be capitalized into home prices. We contribute to the literature on wildfire impacts by estimating the impact of a recent fire on property sales prices along two dimensions: properties close to the wildfire compared with properties farther away, and properties in designated areas of high fire risk. Our findings suggest significant heterogeneous impacts of wildfire depending on whether the property is located on high-risk land, as well as evidence that proximity to a national forest can alter the risk perceptions of potential home buyers.

Introduction

Wildfires have increased dramatically in number, size, and destructive force over the past 30 years; especially hard hit is the American West, from forests of the Pacific Northwest through to dry shrub land that dominates at the U.S.-Mexico border. Two factors contribute to the increasing risk of wildfire. First, there are climatic or natural factors: warmer temperatures, earlier springs, insects and infestations affecting forests, and the associated buildup of available fuel, spark more frequent and intense wildfires (Westerling et al. 2006). Second, while climate change has encouraged conditions conducive to wildfires, development and expansion into the wildland-urban interface (WUI), land in transition between development and wildland, has put more people directly into their path. Syphard et al. (2007) find that population density and distance from WUI are important factors in determining fire frequency in California, suggesting human patterns of development also determine exposure to risk. The wildfire burned area in California may grow by as much as 74% by 2085, putting many more people at risk (Westerling et al. 2011).

Wildfires have significant economic impact: federal agencies respond to tens of thousands of wildfires on roughly 7 million acres of land, spending a combined total of $1-2 billion each year on fire suppression (National Interagency Fire Center 2016). The US Forest Service expects its annual cost of fire suppression will reach an estimated $1.8 billion by 2025 (USDA Forest Service 2015), and have growing concerns that other management efforts suffer when funds are re-directed towards fire suppression. In addition to the direct costs of wildfire suppression and damages, people living near wildfires, even if their house was not directly affected, experience indirect costs such as the aesthetic disamenity of the burn scar, loss of nearby recreation opportunities, and heightened perceived risk of wildfires.

The policy background is particularly relevant for Southern California. Its native shrubland, chaparral has a natural high-intensity fire regime, and so the existence large wildfires is not a recent phenomenon as it is in the Pacific Northwest or the Rocky Mountains. In addition, the Bates Bill, passed in response to a severe 1991 fire, mandates the state fire-fighting agency CAL FIRE to develop maps of high wildfire hazard in wildland areas, where the state takes financial responsibility for fire containment costs, and in urban areas, where local governments have primary responsibility (California Govt. Code 51175-89). As part of this legislation, homeowners are also required to disclose the status of their property – whether it is on an area of significant wildfire hazard or not – at the time of sale. These two features may mean that, unique to other places, California residents are saturated with fire risk information. The question, then, is whether the event of a wildfire causes any significant change in risk perceptions.

This paper estimates the cost of wildfires to residents of southern California using a hedonic approach. Our study area is unique for a number of reasons: Southern California faces high levels of human development, with suburbs of Los Angeles and San Diego running straight into four fire-prone national forests. The ecosystems in these national forests are characterized by chaparral, a dense shrubland unique to this region with a natural high-intensity fire regime. The regulatory environment also sets California apart; the state is besieged by so many natural disasters that it is required by law to disclose potential risks to home buyers at the time of purchase. We employ difference-in-differences to identify the effects of proximity to a past wildfire and risk perceptions associated with wildfires. We ask the following two questions: 1) How are the effects of a wildfire capitalized into nearby housing prices? And 2) Can we attribute the impact to increased perception of risk as opposed to decreased aesthetic value?

Wildfire and natural disaster risk literature

This paper contributes to the literature on capitalization of risk perception into housing prices in response to natural disasters, which developed around discounts for properties located in flood plains following a major flood or storm (Atreya, Ferreira, and Kriesel 2013; Bin and Landry 2013).

In the past decade as wildfires have grown in the public consciousness, the literature on effects of wildfires has also developed. The broad direction of this research attempts to disentangle the aesthetic disamenity caused by a large wildfire from the effects of increased risk perception among potential buyers in addition to measuring the impact. In one of the earliest efforts, Loomis (2004) estimated the change in property values in a town near, but not directly affected by, a major wildfire in Colorado. He found that housing prices dropped 10-15% in the unburned town after the fire and that the effects were still present five years later. Following studies have innovated by incorporating more current econometric techniques such as controlling for spatial lag and autocorrelation (Donovan, Champ, and Butry 2007; J. M. Mueller and Loomis 2008); Donovan, Champ, and Butry (2007) in a study on impacts of housing prices after wildfire risk ratings are made publicly available, find that both spatial lag and spatial error dependence are statistically significant. However, Mueller and Loomis (2008) find that there is little economic significance between estimates using spatial dependence and those that do not. Mueller, Loomis, and González-Cabán (2009) estimate the effects of repeated wildfires in a small part of Los Angeles county. Concentrating on homes close to two successive fires that occurred within either 2 years or 4 years, the authors find a much steeper decrease in price after the second fire (23% as opposed to the first fire's 10%).

Similar to other environmental risks such as hazardous waste sites, nuclear plants, and pipelines, the impact of a wildfire does not have a clearly demarcated boundary – things within a fire perimeter suffer damage, but people near the perimeter may also experience a loss of recreational opportunities, poorer view, or greater awareness of their own fire risk. A remaining question in the literature is how far away from a past fire's footprint should be included in the study area. Some studies impose an artificial boundary, outside of which they assume the wildfire has no impact (Loomis 2004; J. Mueller, Loomis, and González-Cabán 2009; J. M. Mueller and Loomis 2014). Mueller, Loomis, and Gonzalez-Caban in their Los Angeles study look at the impact of fires on properties within a 1.75-mile radius. They motivate this by appealing to Superfund studies (e.g. Gayer, Hamilton, and Viscusi 2000) which consider impacts on property values within a very short distance of a site, usually around one mile.

Others estimate the impact of fires allowing for a distance decay, with wildly different findings. In a study on an area of northwest Montana, Stetler et al. (2010) estimated several hedonic price models with a suite of environmental controls, including distances to many amenities – lakes, wilderness, and recreation areas –, canopy cover, location on wildland-urban interface, and view of the burned area. Their results suggest great importance of environmental amenities, and that there are significant differences for homes with a view of the burned area as opposed to without. They also found large and lasting effects of wildfires – home prices suffered at distances up to 10 km away from the nearest wildfire compared to homes at least 20km from a fire, and they did not find any significant attenuation in the effect for seven years after a wildfire.

McCoy and Walsh (2014) construct the problem as a quasi-experiment, looking at how a wildfire affects three distinct treatment groups: houses in close *proximity* to the burn perimeter, houses with a *view* of the burn scar, and those located in an area of *high latent wildfire risk* using data from properties in the Colorado Front Range. High latent risk areas are defined by geographic characteristics such as slope, vegetation, and housing density that make some communities more susceptible to fire than others. To test the sensitivity of their proximity treatment to the cutoff, they start with a treatment group of 1 km from a fire and increase the treatment group size in 250 m increments. In contrast to Stetler et al. they find no significant effect of a wildfire more than 2 km from the property. Within 2 km of the burn perimeter, housing prices decrease by 8.7% in the first year after a fire, 7.7% the second year, and 6.7% the third year after a fire.

In the vein of McCoy and Walsh we use a quasi-experimental approach to examine impacts of fire on nearby houses, as well as impacts of fire on areas of latent risk, but adapt the model to the southern California context; other California studies have used a cross-sectional hedonic function. While McCoy and Walsh allow their treatment groups to overlap, with properties in their proximity potentially on areas of high latent risk, we use exclusive treatment groups. Finally, most of the literature looking at location-specific risk uses discrete distance treatments or cutoffs, so we expand on this by also using continuous treatments.

Conceptual Model

The basic hedonic model developed by Rosen (1974) treats houses as differentiated products, where price is a function attributes such as structural properties of the house, characteristics of the neighborhood, and environmental amenities, such as those provided by the national forests. In addition, the housing value will capture subjective perceptions of wildfire risk. Consider the effect of a wildfire: it will cause a change both in the forest amenities and in the household's subjective assessment of risk. The average effect a wildfire has on property prices will include both these effects. A wildfire will tend to decrease forest amenities by decreasing the quality of the scenery or closing recreation areas. If the fire heightens home buyers' risk salience, we expect to find a significant decrease in property values nearby. However, in some areas years of fire suppression have caused an overgrowth of brush and fuel; after one fire occurs, the probability of a second fire decreases. In this case the overall impact will depend on how prospective buyers' priors are affected, and the magnitude of the amenity impacts.

More formally, we lay out a model of subjective risk in the housing market following Beron et al. (1997) and Huggett (2004). Let the hedonic price function be written:

(1) $$P = P\left(Z, D, Q, \rho^f, \rho^d(\rho^f)\right)$$

Where **Z** is a set of structural characteristics, neighborhood and geographic characteristics that influence housing price; D is the distance to the forest Q is the quality of the forest amenities received by the buyer (Q would tend to be greater for properties near the forest, and for forests that are old growth as opposed to young, but not always); ρ^f is the household's subjective probability of a fire occurring; and ρ^d the household's subjective probability of property damage. The partial derivatives $\partial P / \partial \rho^f$ and $\partial P / \partial \rho^d$ define the marginal willingness to pay to reduce the probability of fire and the probability of damage, respectively.

First consider the risk of a fire occurring. The probability of a fire occurring is a function of local averting behavior such as stand removal or prescribed fires, the environmental and geographic characteristics of the neighborhood, including forest quality, and elevation, and information about fires received by the buyer.

(2) $$\rho^f = \rho^f(L, D, Q, \boldsymbol{W}, I)$$

In equation 2:

- L is local averting behavior
- D is distance to the forest
- Q is forest quality, which captures both vegetation and stand maturity
- **W** is a vector of other characteristics that influence risk of fire
- I is the household's information about fire risk

An increase in local averting behavior should decrease the subjective assessment of wildfire risk:

(3) $$\frac{\partial \rho^f}{\partial L} \leq 0$$

Similarly, an increase in distance to the forest boundary, which is accompanied by less natural vegetation and more densely built structures, decreases subjective fire risk:

(4) $$\frac{\partial \rho^f}{\partial D} \leq 0$$

We also assume that an increase in forest quality increases subjective fire risk:

(5) $$\frac{\partial \rho^f}{\partial Q} \geq 0$$

Note that we cannot sign the final term $\partial \rho^f / \partial I$, as risk assessment could be increasing or decreasing in the level of information a buyer receives.

(6) $$\frac{\partial \rho^f}{\partial I} \neq^{?} 0$$

Now, the subjective risk of probability of damage must be an increasing function of probability of fire. Risk can be decreased by private averting behavior such as defensible space and structural improvements to the house. Let subjective probability of damage be defined by the function

(7) $$\rho^d = \rho^d(A, \rho^f(L, D, Q, \boldsymbol{W}, I), I)$$

In equation (7), A is private averting behavior. An increase in averting behavior decreases subjective probability of damage:

(8) $$\frac{\partial \rho^d}{\partial A} \leq 0$$

And, clearly, probability of damage must be strictly increasing in probability of a fire occurrence:

(9) $$\frac{\partial \rho^d}{\partial \rho^f} \geq 0$$

Similar to equation (6), subjective risk assessment cannot be signed with respect to information:

(10) $$\frac{\partial \rho^d}{\partial I} \neq^{?} 0$$

In this framework, a wildfire acts as a shock to both information and forest quality. Much of the Southern California forests is in chaparral, a dense shrubland at maturity. Though it burns with high intensity, it also has a quick regrowth rate: sometimes burn scars are nearly invisible one to two years after a fire. In addition, if chaparral is not given time to recover before a successive fire, it may be replaced with non-native grasses, which are even quicker to burn (Barro and Conard 1991; Bell, Ditomaso, and Brooks 2009). In old growth forests, stand clearing fires have the effect of removing available fuel, making another fire less probable. Hence, the overall effect of the fire on subjective risk is indeterminable and depends on the features of the property.

A buyer on the market maximizes expected utility across three states of the world. In the first, a fire is not realized, and utility depends on housing characteristics and the level of forest amenities Q. In the second state of the world, which occurs with subjective probability ρ^f a fire occurs and affects the forest but does not damage the property, so Q changes to Q^f, where $Q^f<Q$ due to a loss in visual and recreational amenities. In the third, which occurs with probability ρ^d, property damage is sustained. In each state, the buyer faces a budget constraint that depends on a numeraire good X and the price of the home P.

(11) $$Y = X + P(\cdot)$$

Recall that equation (1) defined the hedonic price function below.

(1) $$P = P\left(Z, D, Q, \rho^f, \rho^d(\rho^f)\right)$$

Now we can show that

(12) $$\frac{\partial P}{\partial Q} = \frac{\partial P}{\partial Q} + \frac{\partial P}{\partial \rho^f} \cdot \frac{\partial \rho^f}{\partial Q} \rho^f + \frac{\partial P}{\partial \rho^d} \cdot \frac{\partial \rho^d}{\partial \rho^f} \cdot \frac{\partial \rho^f}{\partial Q} \rho^d \rho^f \neq^{?} 0$$

Since the sign of the term $\partial \rho^f / \partial Q$ is unknown.

The buyer's maximization problem over the three states is given by

(13) $$\max_{Z,D,A,Q} E[\![U]\!] = \rho^{f} \cdot v(X,Z,Q^{f}) + \rho^{d} \cdot v(X,Z,Q^{f}) + (1 - \rho^{f} - \rho^{d}) \cdot v(X,Z,Q)$$

In the model, a buyer maximizes utility from a home purchase by selecting characteristics Z, distance from the forest D, private averting behavior A, and forest quality Q.

Following from this conceptual model, we test two hypotheses: (1) buyers on the high risk FHSZ land will respond less to wildfires because of the upfront information about hazard when the home is purchased; (2) fires that affect areas with more chaparral than old growth forest will see significant reductions in price, whereas a fire might influence risk perception differently in an overgrown area, decreasing future subjective probability of fire, which would have a positive impact on price.

Econometric Model

The hedonic price method is commonly used to value environmental amenities, from the benefits of open space to air quality to risks such as nuclear waste (Anderson & West 2006; Kim, Phipps, & Anselin 2003; Gawande & Jenkins-Smith 2001). However, a concern in the estimation of hedonic price functions is that coefficients will be biased if unobserved variables that influence price are correlated with observed variables. To address this, we turn to a difference-in-differences approach commonly used in in the risk literature to identify the effects of wildfires on a group of treated properties (Hallstrom and Smith 2005; Gawande, Jenkins-Smith, and Yuan 2013; McCoy and Walsh 2014). A unique feature of using wildfires as treatments is that our events are scattered through time and space. As opposed to a single before and after time period for the study area, two properties selling in the same year far away from each other will be nearest to two different wildfire perimeters; one may have sold before its nearest wildfire, while the other may have sold after its nearest wildfire.

To implement this strategy, we first calculate the distance between each property and all wildfires within 15 km – because of the prevalence of wildfires in the area, many properties were within 15 km of multiple fires. We drop transactions that are close (within 7 km) to more than one wildfire occurring in the five years before that sale, in order to focus on transactions that could have been affected by one wildfire at most. If the property experienced two or more wildfires in the five years preceding the transaction, but all but one of those fires was 7-15 km away from the property, that observation remains in the sample. We then separately consider properties (1) near a wildfire, but not on a Fire Hazard Severity Zone (FHSZ), and (2) both near a wildfire and on FHSZ, for two mutually exclusive treatment groups. For each group, the model takes this form:

(14) $$lnP_{it} = \beta_0 + \beta_{near}\, near_i + \beta_{post}\, postfire_{it} + \beta_{nearpost}\, (near \times post)_{it} + \boldsymbol{\beta}_{house}\boldsymbol{X}_{it} + \boldsymbol{\beta}_{geo}\boldsymbol{G}_i + \boldsymbol{\beta}_{neighbor}\boldsymbol{N}_{it} + \boldsymbol{\beta}_{county}\boldsymbol{C}_i + \boldsymbol{\beta}_{time}\boldsymbol{T}_{it} + \varepsilon_{it}$$

where $\ln P_{it}$ is the natural log of the sale price for house *i* selling in year *t*. $Near_i$=1 if the property is near a wildfire perimeter. Since the housing closing process takes 30-60 days, we define $Post_{it}$=1 if the property is sold between 60 days and five years after the nearest fire occurs. The coefficient of interest is $\beta_{nearpost}$, the difference-in-difference coefficient that measures the effect of selling after a fire for houses in each treatment group. The model also controls for housing characteristics X, geographic characteristics G, neighborhood demographics N, and includes county fixed effects C, and year by quarter dummies T. For unbiasedness in difference-in-difference estimates, three assumptions must be met: correct specification of the model, error terms satisfy $E(\varepsilon_i) = 0$, and there must be parallel trends between treatment and control groups. Kuminoff, Parmeter, and Pope recommend simple functional forms in case of omitted variables (2010), so we use a log-linear function common in the hedonic literature. In the future, other simple functional forms will be tested (linear, log-log, and linear Box-Cox).

A caveat to using difference-in-difference is that it alters the parameters of Rosen's original hedonic price function. Instead of measuring willingness to pay for an attribute, the parameters measure a capitalization effect which may understate willingness to pay (Kuminoff and Pope 2014). When using a narrow time window around the change in the level of the public good, one can reasonably assume that the hedonic price gradient did not shift in the interval. We do not expect disamenities from wildfire to last more than a few years; however, given the chance the price gradient does change over this time, the estimate of willingness to pay could be understated.

Data and Study Area

Housing Data

We obtained property transactions data for homes sold between January 2000 and December 2015 in the area surrounded by the Los Padres, Angeles, San Bernardino, and Cleveland National Forests, spanning seven counties: Santa Barbara, Ventura, Los Angeles, San Bernardino, Riverside, Orange, and San Diego counties. We selected Zip Code Tabulation Areas (ZCTA) within 30km of the National Forests on the coastal side to define the study area. Figure 1 shows the study area with selected ZCTA and four National Forests. Housing data was purchased from CoreLogic, a company that provides real estate data obtained from public records to financial and research institutions. Transactions are limited to owner-occupied residential houses, duplexes, and condominiums. To identify arms-length transactions as opposed to transfers between family members or built-to-order homes, we excluded properties built in the same year as they were sold, that sold twice in 12 months, properties transferred using quit claim or other unusual deeds, and those marked with a partial sale code.

We drop houses in the top and bottom 1% by sale price, in the top 1% of bedrooms, bathrooms, and total rooms, and the top 1% of square feet, to remove extreme values from the sample[1]. After doing so, we have 1,413,238 transactions; some properties sold twice between 2000-2015, and information from each sale is used. To reduce the likelihood that the hedonic gradient shifts over time, models are limited to transactions which occur in the five years before or after the nearest wildfire, and properties within 15 km of the nearest wildfire footprint.

Wildfire and Geographic Data

Using wildfire perimeter data available from California's Fire Resource and Assessment Program (FRAP), we select wildfires that occur between 1995-2015, and only fires at least 500 acres in size, assuming fires older than five years or smaller than 500 acres have a negligible effect on sales. The FRAP data set includes all footprints of fires 10 acres or greater. After matching each property with all fire perimeters within 15 km, there are 1116 individual footprints 10 acres or more. The 25th percentile in size is 40 acres, the 50th is 131, and the 75th percentile in fire size is 521 acres. Thus, limiting to fire perimeters 500 acres or more allowed us to concentrate on a subset of significantly large fires. A total of 288 wildfires are within 15 km of a property in the data set and 500 acres or more. Figure 1 shows the selected study area and spatial distribution of wildfires in the area.

Conditional on being more than 500 acres, on average, these fires burned 10,900 acres and lasted roughly a week. The study period spans some of California's worst wildfire incidents, including the "California Fire Sieges" of 2003, in which 14 fires blazed through southern California

[1] Muehlenbachs Spiller and Timmins (2015) and McCoy and Walsh (2014) use similar methods

over the course of two weeks, and 2007, which charred nearly one million acres between Santa Barbara and the US-Mexico border (Blackwell and Tuttle 2003; CAL FIRE, USFS, and OES).

Addresses were geocoded with Texas A&M Geoservices, after which geographic data for properties was obtained, including distance to the nearest wildfire perimeter, distance to the closest National Forest boundary, and distances to other amenities for each individual property. Distance to major roads and highways is calculated using road data from the US Census Bureau, distance to city centers was calculated using metropolitan boundaries from the San Diego Association of Governments and the city of Los Angeles, and distance to nearest park or open space used data from the California Protected Area Database.

Fire Hazard Data

Previous research has suggested that risk of wildfire is generally not salient to potential home buyers except shortly after an information shock such as publicly available risk ratings, or an actual fire (Champ, Donovan, & Butry 2009). We therefore identify effects of wildfires along two main dimensions: the effect of being close to a recent fire for properties located on and off areas of high risk.

California Department of Forestry and Fire Protection (CAL FIRE) produces statewide maps of areas with significant fire hazards, called Fire Hazard Severity Zones (FHSZ), for land where the state has financial responsibility for wildland fire protection. Hazard zones are developed using information about the physical attributes of the area and fire history, including fuel availability, topography, typical weather, and models of ember production and movement. It does not take into consideration private actions to reduce fire risk on a given property, such as fuel reduction and defensible space. There have been efforts to map "state responsibility areas" (SRA), which are at greater risk of wildland fire, since the 1980s, with FHSZ mapping efforts in the early 2000s. Current FHSZ maps for SRA were proposed in 2007 and adopted by January 2008. Hazard Severity is rated moderate, high, or very high for SRAs. Hazard zones for local responsibility areas (LRA) were adopted by local jurisdictions by July 1, 2008, and only map areas of very high hazard. All models use the 2008 FHSZ zones.

FHSZ may be used in the development of building standards and defensible space requirements, but more importantly since 1998 California's Civil Code has required natural hazard disclosures at the time of property sale, including both location on areas of wildland fire risk (any SRA rating) and whether the property is in a "Very High" wildfire hazard zone (anywhere with a "very high" hazard rating). Location of FHSZ is shown in Figure 2.

FIGURE 1: STUDY AREA WITH NATIONAL FORESTS AND WILDFIRES WITHIN 15KM OF PROPERTIES IN THE SAMPLE

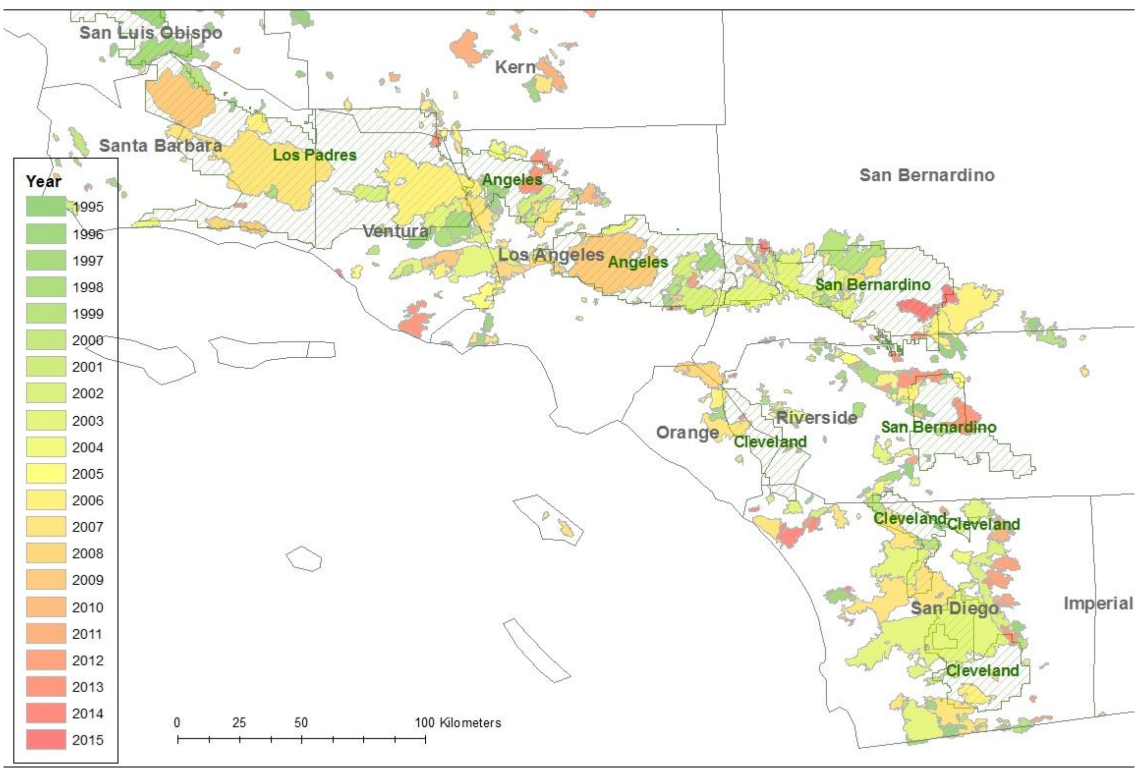


FIGURE 2: FIRE HAZARD SEVERITY ZONE (FHSZ) MAPS ADOPTED IN 2008: BOTH SRA AND LRA

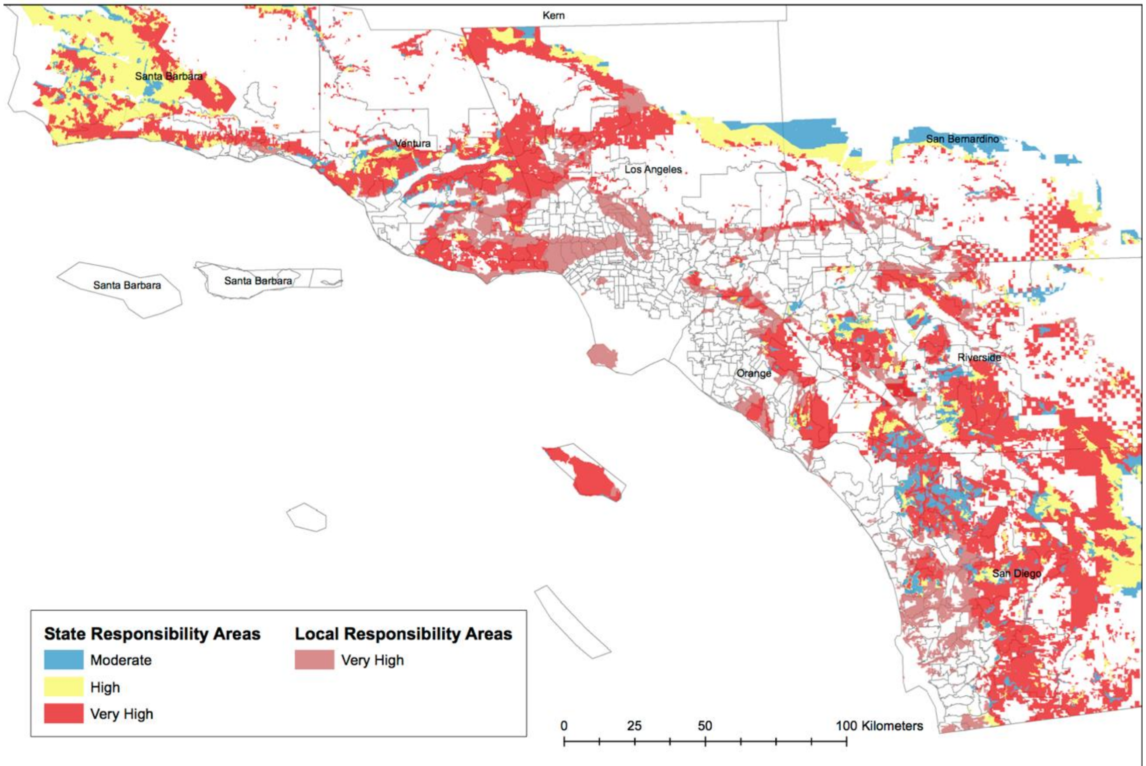


TABLE 1: DESCRIPTIVE STATISTICS FOR WILDFIRES > 500 AC AND WITHIN 15 KM OF A PROPERTY BY YEAR

Year	Number of Fires	Smallest (Acres)	Median (Acres)	Largest (Acres)
1995	23	531	1,680	21,444
1996	24	502	1,084	19,861
1997	19	522	1,326	24,797
1998	11	580	2,056	28,136
1999	16	502	3,298	63,508
2000	4	798	1,199	11,734
2001	8	531	1,599	10,438
2002	20	555	3,432	61,691
2003	21	806	8,474	270,686
2004	17	513	3,693	16,447
2005	12	618	1,630	23,396
2006	12	500	6,549	161,816
2007	27	602	3,839	240,359
2008	8	500	7,059	30,305
2009	8	839	4,824	160,833
2010	7	522	717	12,582
2011	5	508	1,027	2,134
2012	9	519	2,637	11,667
2013	14	510	2,505	30,268
2014	7	959	1,952	15,186
2015	5	1,049	1,462	31,284

Empirical Model & Results

A Test of Distance Decay

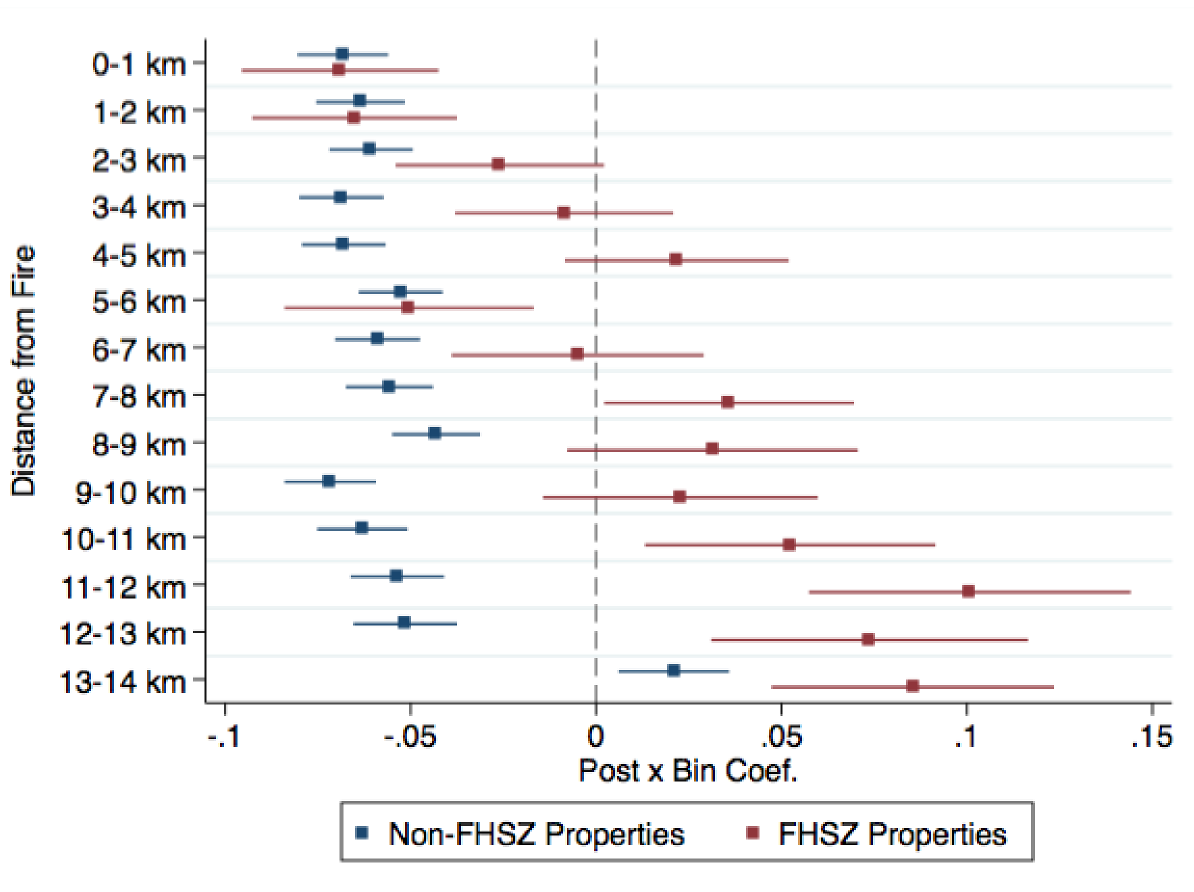
Prior studies testing the effect of wildfire proximity on housing prices have used a range of values from 2km (McCoy Walsh 2014) to roughly 3.2 km (Loomis 2004). In line with McCoy & Walsh as well as other work on shale gas development and other risks that spill over confined boundaries (Muehlenbachs, Spiller, and Timmins 2015; Boslett, Guilfoos, and Lang 2016; Gawande, Jenkins-Smith, and Yuan 2013) we attempt to identify a distance cutoff to use as a proximity treatment group. To explore the spatial extent over which a wildfire may affect housing price, we modify the model to include 1-km distance bins.

$$lnP_{it} = \beta_0 + \sum_{j=1}^{14} \delta_j bin_{ij} + \beta_{post} postfire_{it} + \sum_{j=1}^{14} \beta_{post \times binj} (bin_j \times post)_{it} + \beta_4 \boldsymbol{Z}_{it} + \beta_5 \boldsymbol{G}_i + \beta_6 \boldsymbol{N}_{it} + \boldsymbol{\beta}_{county} \boldsymbol{C}_i + \boldsymbol{\beta}_{time} \boldsymbol{T}_{it} + \varepsilon_{it} \quad (15)$$

$\mathbf{Z}_{it}$ are property characteristics, $\mathbf{N}_{it}$ a set of neighborhood controls, and $\mathbf{G}_i$ geographic controls, including slope, elevation, and distance from a national forest boundary. The variable $bin_{ij}=1$ if the property is between *j-1* and *j* km from the nearest wildfire perimeter, and 0 otherwise. Then $\beta_{post\ x\ bin\ j}$ is an estimate of the difference between effect of selling after a fire for houses *j-1* and *j* km from a fire and a house 14 – 15 km from a fire. If there is a distance decay, we expect $\beta_{post\ x\ bin\ j}$ to converge to 0 as j increases. Refer to Appendix A for summary statistics of characteristics, neighborhood controls, and geographic controls for properties used in the analysis.

Results for the treatment effects from these regressions are illustrated in Figure 3. FHSZ and Non-FHSZ models were estimated separately. For houses not located on FHSZ, we see a negative impact of a fire on housing price: prices decreased by about 5% in the five years following a wildfire. However, we find no evidence of a distance decay for those properties within 15 km from a fire. For houses on the FHSZ, there is a distinct spatial pattern to the results. For properties with 2 km of the nearest wildfire, selling after the fire decreases price by about 6% compared to properties farther away. Between 2 and 10 km of a fire, the difference-in-difference is insignificant or close to 0, with the exception of bin 5-6 km. For properties greater than 10 km from the nearest fire on FHSZ, prices increase by as much as 10% after a fire. This somewhat surprising result may indicate that properties located on FHSZ are desirable for many other reasons (good neighbors, attractive landscape, relief from the city), and demand shifts away from areas close to a recent fire to areas farther away.

FIGURE 3: EFFECTS OF A FIRE ON PROPERTY PRICES NEARBY USING A MODEL WITH 1-KM DISTANCE BINS



Effects by Forest Type

Among the four national forests in the study area, the Angeles, Los Padres, and San Bernardino National Forests are predominantly in chaparral on the southern regions, where our property sample lies. However, neighborhoods adjacent to the Cleveland National Forest may be in more forested areas. To examine the effect of different vegetation types, we split the sample along forest lines and compare results for the northern three forests with the Cleveland National Forest.

FIGURE 4: EFFECT OF FIRE PROXIMITY FOR ANGELES, LOS PADRES, AND SAN BERNARDINO NF

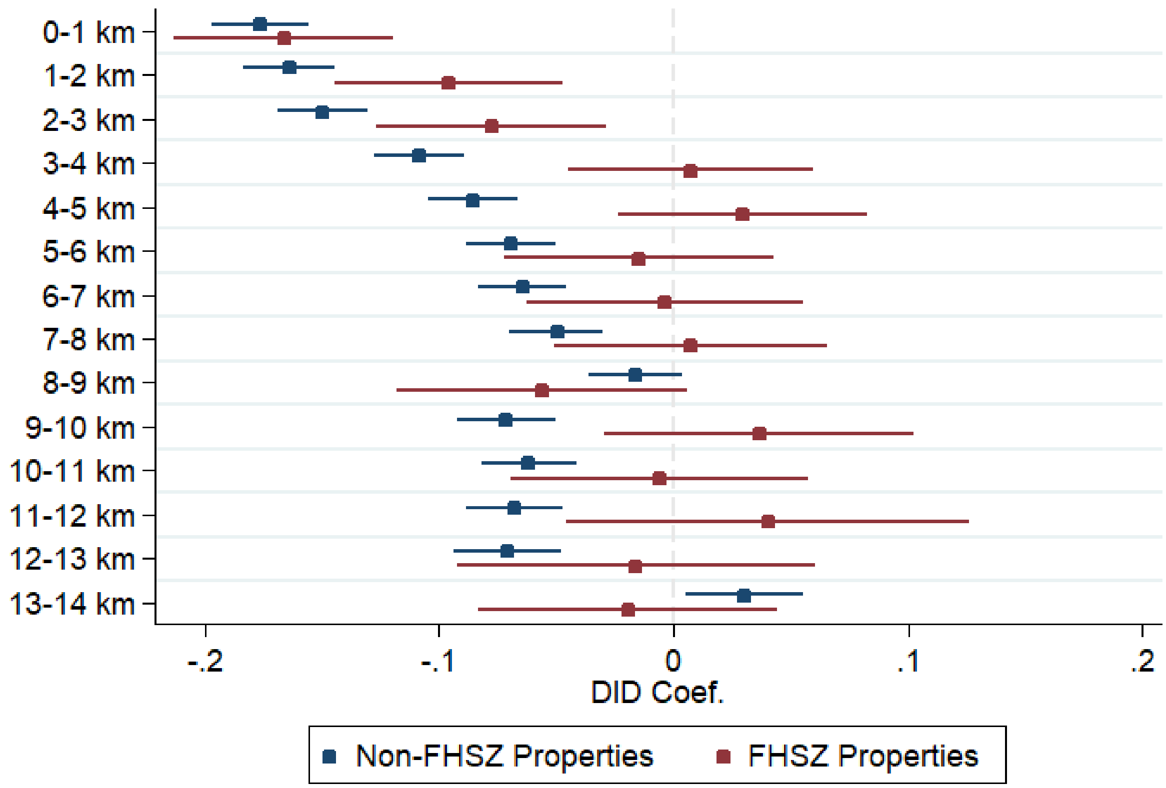
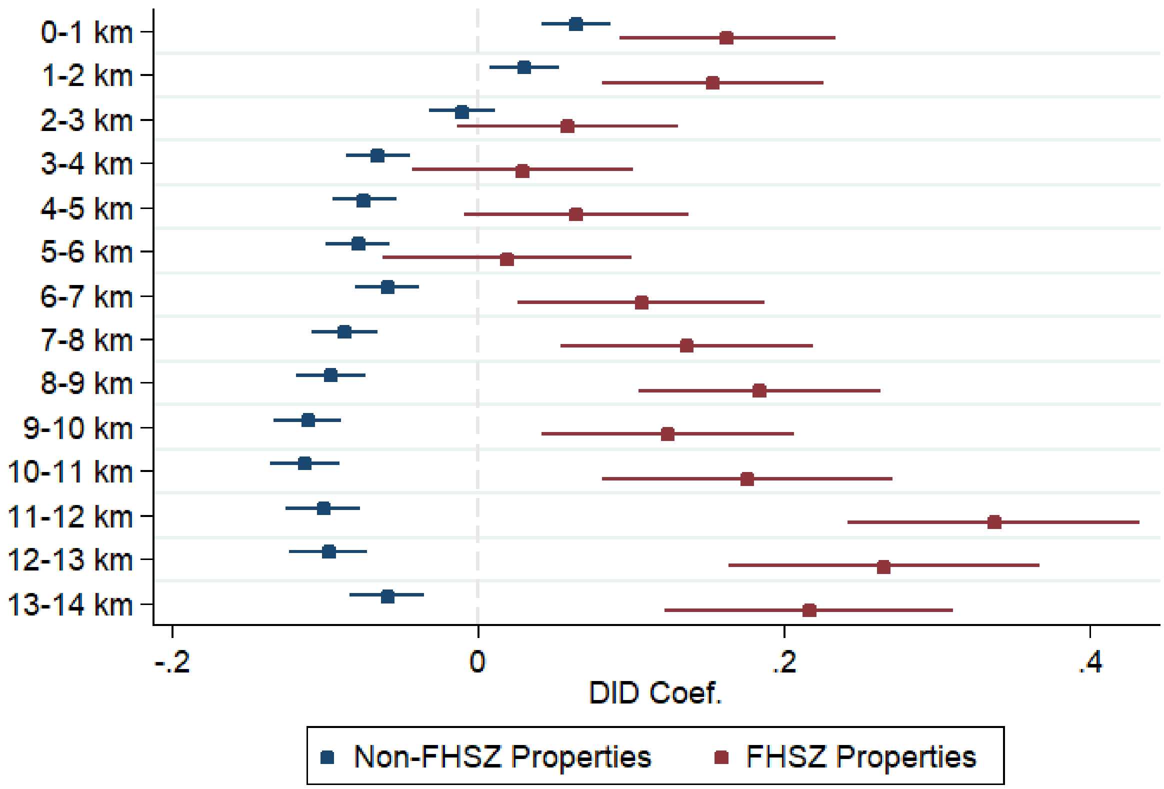


FIGURE 5: EFFECT OF FIRE PROXIMITY FOR CLEVELAND NF



These patterns suggest an effect predicted by the conceptual model. In chaparral areas where after a wildfire, risk of wildfire in the future remains the same, home buyers' perception of risk should increase. However, if a wildfire reduces the fuel load in a forested area, decreasing future probability of a fire occurring, wildfires should decrease risk perception, and push property prices in the opposite direction.

Continuous Treatment Effect

Since there is mixed evidence for a discrete distance after which a wildfire has no effect on housing price, we turn back to the standard model and instead estimate a continuous treatment effect of distance on price:

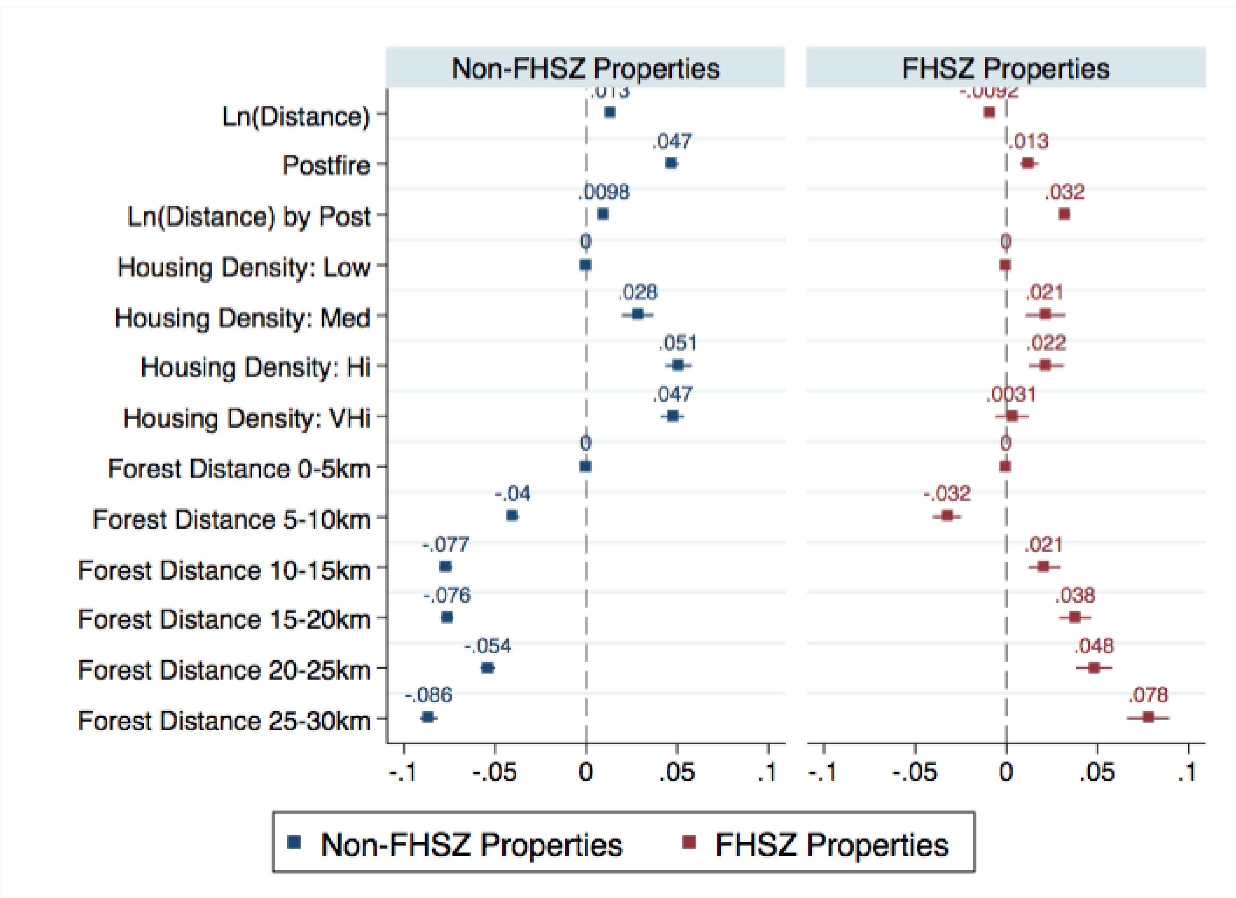
(16) $lnP_{it} =$

$$\beta_0 + \beta_{dist} \ln(distance)_i + \beta_{post}\, postfire_{it} +$$

$$\beta_{distpost}\,[\ln(distance) \times post]_{it} + \boldsymbol{\beta}_{house}\boldsymbol{X}_{it} + \boldsymbol{\beta}_{geo}\boldsymbol{G}_{i} + \boldsymbol{\beta}_{neighbor}\boldsymbol{N}_{it} + \boldsymbol{\beta}_{county}\boldsymbol{C}_i + \boldsymbol{\beta}_{time}\boldsymbol{T}_{it} + \varepsilon_{it}$$

Results of the continuous treatment model are displayed in Figure 4. The difference-in-difference estimate shows that increasing distance from a recent wildfire impacts the price of FHSZ properties more than those on non-FHSZ land. On a FHSZ, increasing distance from the nearest wildfire by 10% is associated with a 0.32% increase in housing price, compared to a 0.10% increase for properties not on FHSZ. The median sales price of properties in the sample is roughly \$475,000, so the increases correspond to \$1520 and \$475 respectively.

FIGURE 6: EFFECTS OF CONTINUOUS DISTANCE TREATMENT ON PROPERTY PRICE AFTER FIRE



Discussion and next steps

Our analysis suggests that there may be complicated interactions between a wildfire's effect on vegetation, and the ultimate impact on risk perceptions. If the event reinforces a belief that an area is wildfire-prone and likely to see more in the future, we see a drop in nearby housing prices. However, in areas with an excess of fuel, wildfires may actually decrease risk perception and cause an increase. On average, estimates from the continuous treatment model show a moderate economic impact: on a FHSZ, increasing distance from the nearest wildfire by 10% is associated with a 0.32% increase in housing price. On Non-FHSZ land, a 10% increase in distance is associated with a 0.10% increase in price.

The results above are somewhat unusual in that they do not show a clear diminishing effect of the wildfire as you move farther away from it. To explore the potential causes, future work will include a number of consistency checks, including looking at the effects of different fire sizes, attempting to find information on the amount of structural damage caused by wildfires in the dataset, and controlling for the amount of media coverage generated by a fire. In addition, there may be heterogeneous effects by market: we will expand on this general model by splitting properties by county.

We will also incorporate older FHSZ. Current maps replaced older and less thorough maps of SRA and LRA which had been in place since the 1990s. Preliminary results using a similar difference-in-difference framework to the one in this essay with FHSZ as a treatment and the coefficient for FHSZ x PostUpdate the coefficient of interest suggest that better mapping of the FHSZ increased housing prices for affected properties, which is counterintuitive. This holds both for areas that started with no information and received a rating of "Moderate" (increases in price around 8% depending on WUI status), as well as areas that started with no information and receved a rating of "Very High" (increases in price around 5% depending on WUI status).

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