The Effect of Wildfire Proximity on Property Values in the Western United States

Sheldon Birkett

University of British Columbia

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Research Question

What is the effect of wildfire proximity on property values?

What is the environmental dis-amenity effect of wildfire proximity on property values?

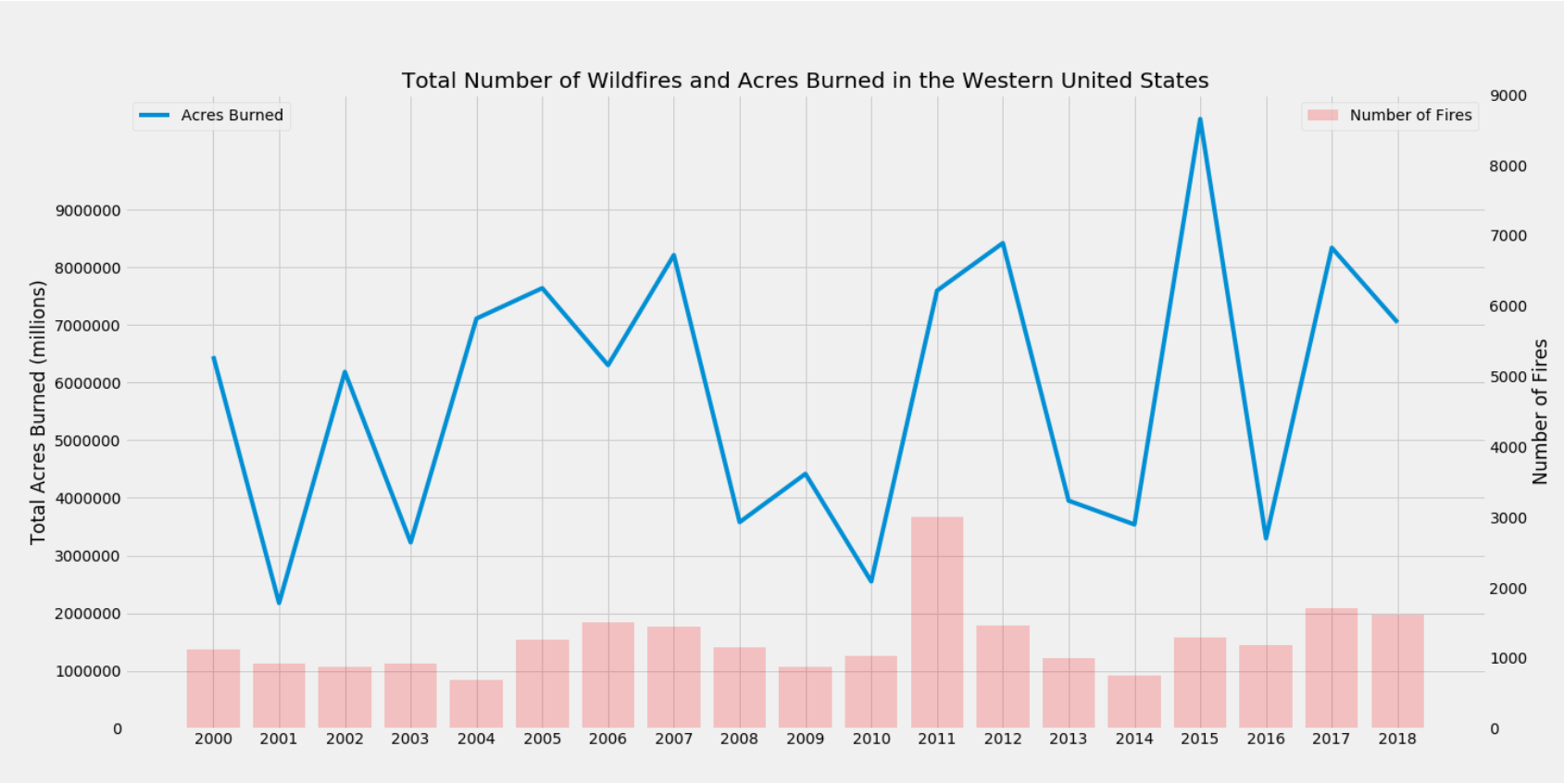
Hypothesis

Environmental destruction caused by wildfires reduces property values [1].

Unknown of the magnitude

[1] Controlling for wildfire risk, housing characteristics, demographic characteristics, and unobservable time-invariant factors

Motivation


Total Number of Wildfires and Acres Burned in the Western United States
Acres Burned
Number of Fires
Total Acres Burned (millions)
Number of Fires
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

Literature

- 9% to 16% drop in house prices in year following a wildfire (see Loomis, 2004; Mueller et al., 2009; McCoy and Walsh, 2018; Stetler, 2008).
- Homeowners underestimate wildfire risk (McCoy and Walsh, 2018; Patricia A. Champ and Barth, 2013).
- Homeowners risk salience from wildfires is relatively short-lived (McCoy and Walsh, 2018).
- Gap: Price drop due to perceived risk versus change in amenity values?
  - Explicitly control for wildfire risk?
- Gap: All literature on wildfires and property values only study localized effects.

Economic Model [2]

- Consumer derives utility U from housing and other goods.
- $(N_1 \ldots N_n)$ non-environmental neighbourhood characteristics.
- $(S_1 \ldots S_m)$ housing characteristics.
- $(Z_1 \ldots Z_i)$ environmental amenities.
- $(R_1 \ldots R_k)$ location specific wildfire risk.
- Where, $U_S > 0, U_N > 0, U_Z > 0, U_R < 0$.
- Competitive real estate market.
- P_h property value.

Hedonic Price Function:

$$P_h = f(N_1 \ldots N_n; S_1 \ldots S_m; Z_1 \ldots Z_i; R_1 \ldots R_k)$$

[2] (from Loomis, 2004; Rosen, 1974)

Estimation Strategy: First Difference

$$\Delta \ln(\text{Median Value}_{it}) = \beta_1 \text{4km 2015 Ring}_{it} + \beta_2 \Delta \text{race}_{it} + \beta_3 \Delta \text{travel}_{it} + \beta_4 \Delta \text{educ}_{it} + \beta_5 \Delta \text{yearbuilt}_{it} + \beta_6 \Delta \text{bedrooms}_{it} + \beta_7 \Delta \text{mortgagestatus}_{it} + \Delta \lambda_t + \Delta \nu_{it} \quad (1)$$

- Parameter of interest β_1, which is the % increase or decrease in median property value for being within 4km from a 2015 wildfire perimeter [3].
- Properties near a wildfire perimeter on average are more expensive.
- Controlling for time variant housing, demographic, and unobservable time-invariant variables only time varying change left is the wildfire treatment effect.
- No time-varying factors within a block-group that are correlated with both property values and being within 4km away from a wildfire perimeter.

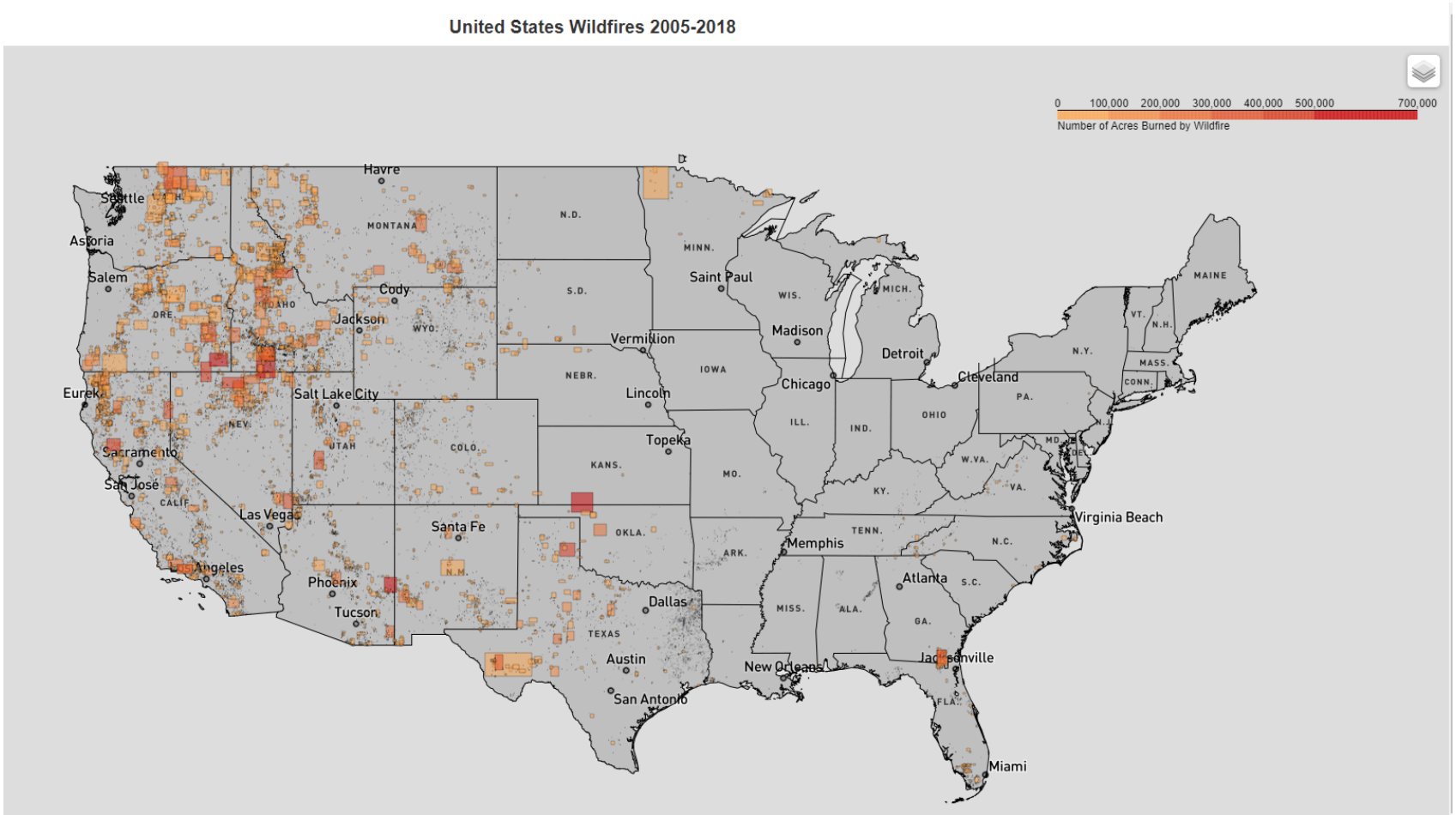
[3] Note 4km 2015 Ring_{it} includes fires in the pre-period

Data & Descriptive Statistics

- American Community Survey (ACS) 5-year estimates for 2005-2009, 2010-2014, and 2015-2019 (Manson et al., 2020).
  - Census Block Groups
- National Interagency Fire Center (NIFC) historical wildfire perimeter data 2000-2018 (NIFC, 2020).
  - Wildfire Perimeters
- Wildfire Hazard Potential Index 2020 at the census block group level (Dillon and Gilbertson-Day, 2020).
- Geography Covered: Arizona, California, Colorado, Idaho, Nebraska, New Mexico, Oklahoma, Oregon, South Dakota, Texas, Kansas, Wyoming, Montana, North Dakota, Utah, Nevada, and Washington + neighbouring state wildfires Minnesota, Iowa, Missouri, Arkansas, Louisiana.

Data & Descriptive Statistics

Location of Wildfires



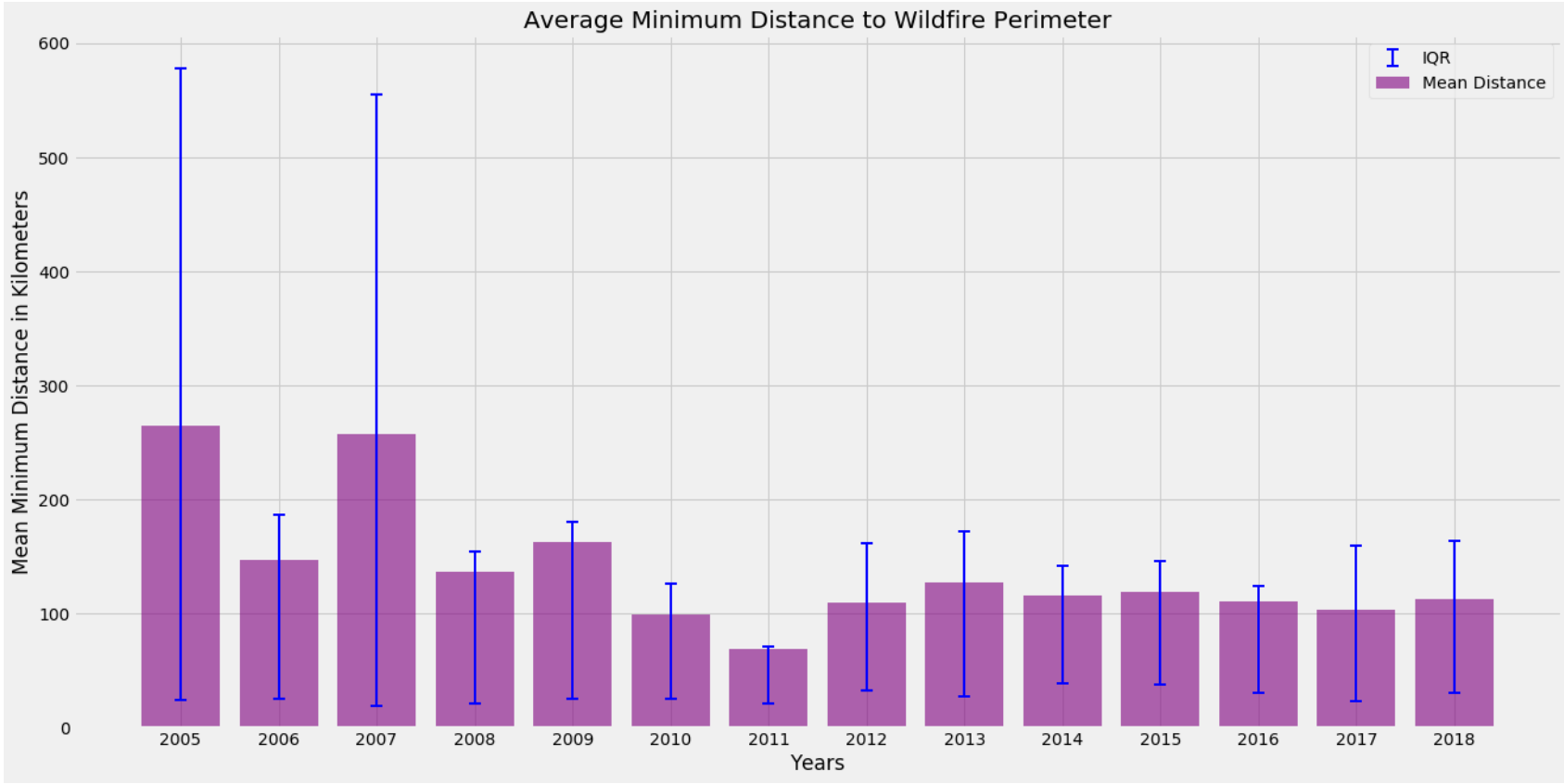
Data & Descriptive Statistics

Table: 1 Summary Statistics Property Value and Block Group Housing Characteristics

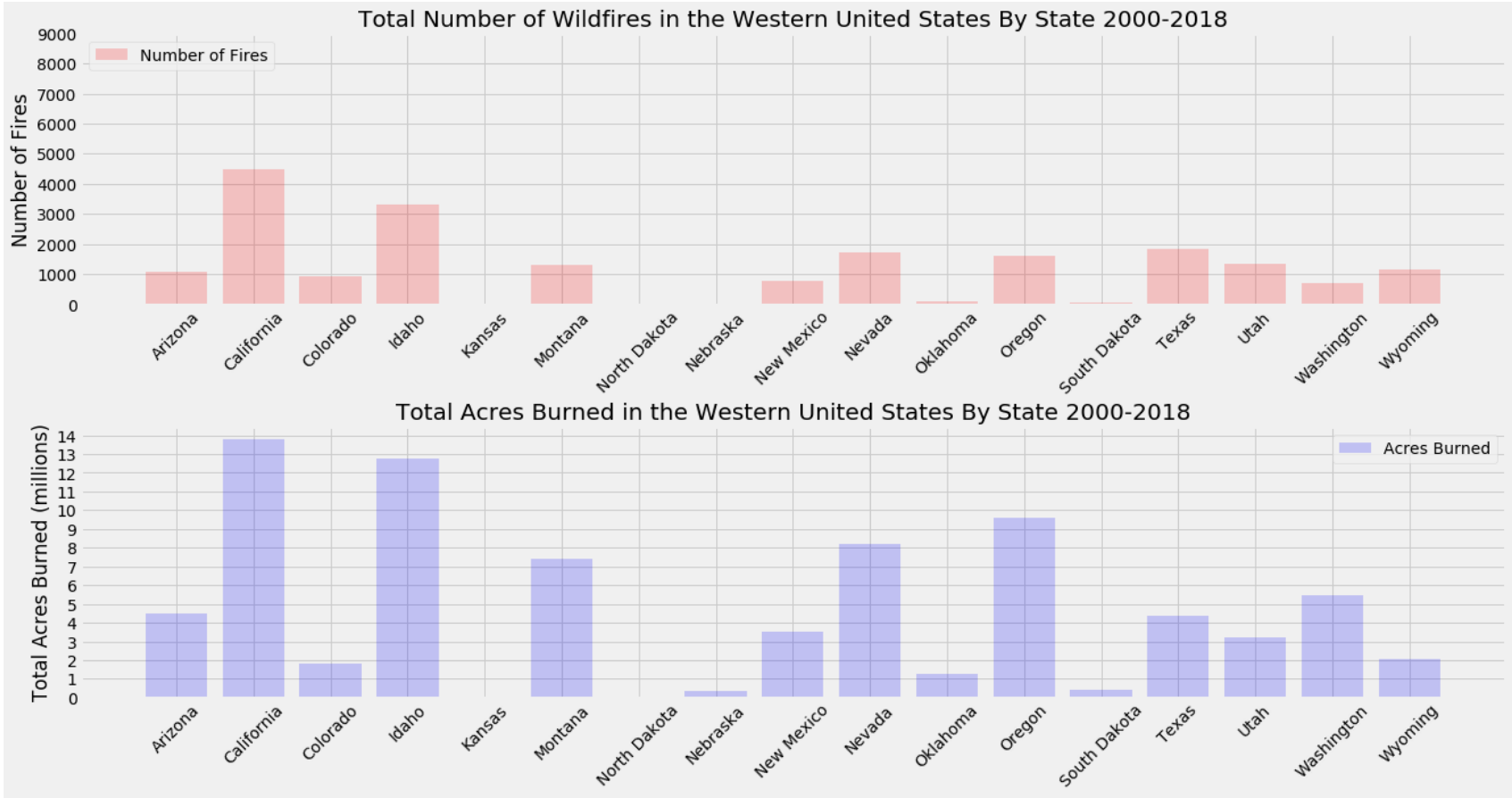
	Mean	Standard Deviation	Min	Max
Median Property Value	311203	250820	6450	2000001
Natural Log Median Property Value	12.34	0.81	8.77	14.51
Difference in Median Property Value	830	126561	-1034938	1513566
Natural Log Difference in Median Property Value	0.00	0.39	-3.87	3.97
Median WHP 2020	0.48	0.99	0.00	5.00
Average Minimum Distance to a Wildfire Perimeter	138.23	145.12	4.34	600.55
Built 2000 or later	0.22	0.30	0.00	29.33
Built 1990 to 1999	0.11	0.13	0.00	1.00
Built 1980 to 1989	0.14	0.15	0.00	1.00
Built 1970 to 1979	0.19	0.17	0.00	1.00
Built 1960 to 1969	0.14	0.14	0.00	1.00
Built 1950 to 1959	0.15	0.18	0.00	1.00
Built 1940 to 1949	0.07	0.10	0.00	0.97
Built 1939 or earlier	0.11	0.17	0.00	1.00
1 bedroom	0.10	0.12	0.00	0.87
2 bedrooms	0.27	0.17	0.00	1.00
3 bedrooms	0.41	0.18	0.00	1.00
4 bedrooms	0.16	0.14	0.00	0.96
5 or more bedrooms	0.04	0.06	0.00	0.85
Housing units with a mortgage contract to purchase or similar debt	0.64	0.19	0.00	1.00
Housing units without a mortgage	0.36	0.19	0.00	1.00
Observations	129746			

*All variables below 'Average Minimum Distance to a Wildfire Perimeter'are in proportion terms of the block group (e.g. 1 bedroom is proportion of homes in the block group with one bedroom)

Data & Descriptive Statistics

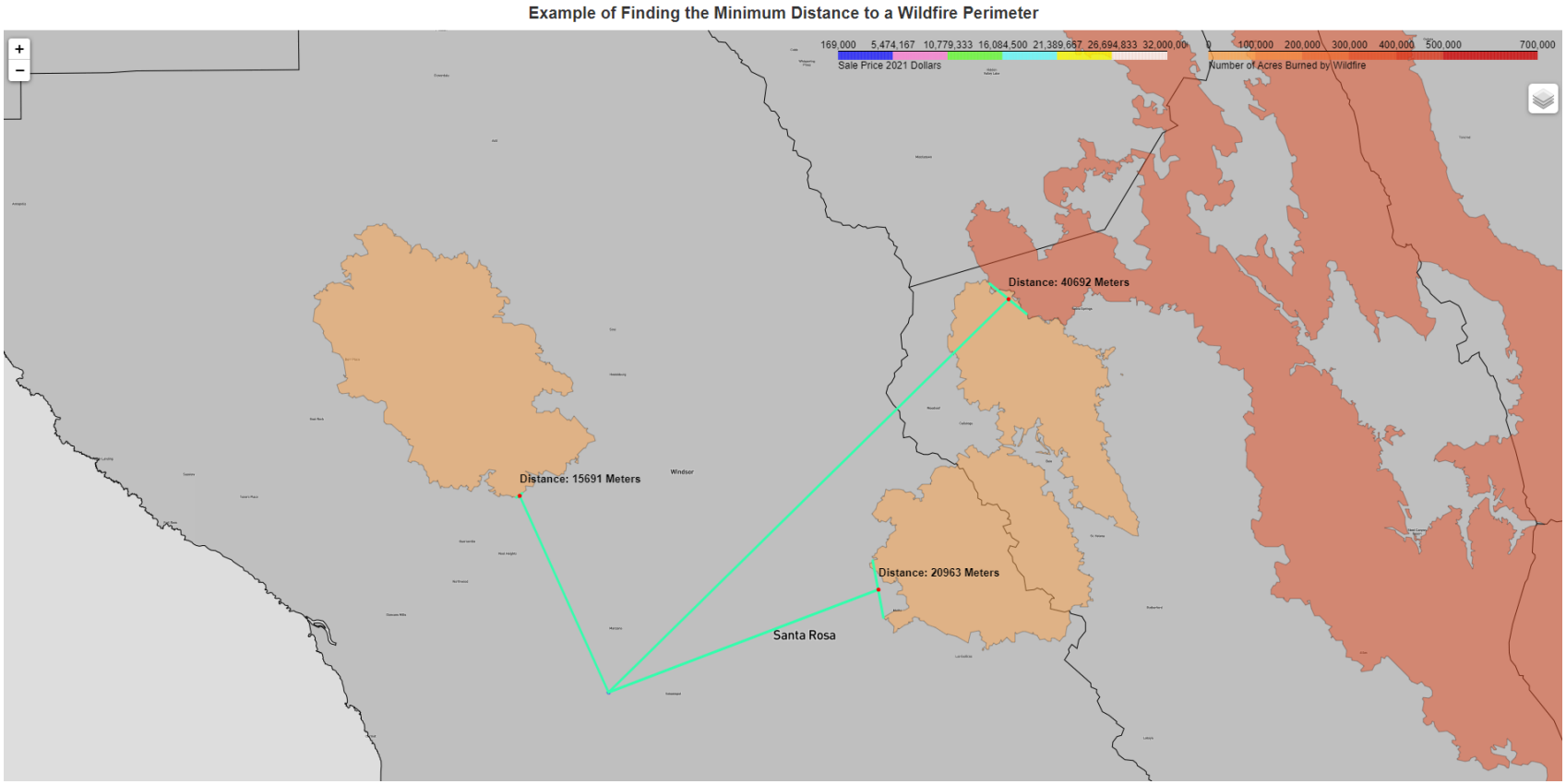


Data & Descriptive Statistics



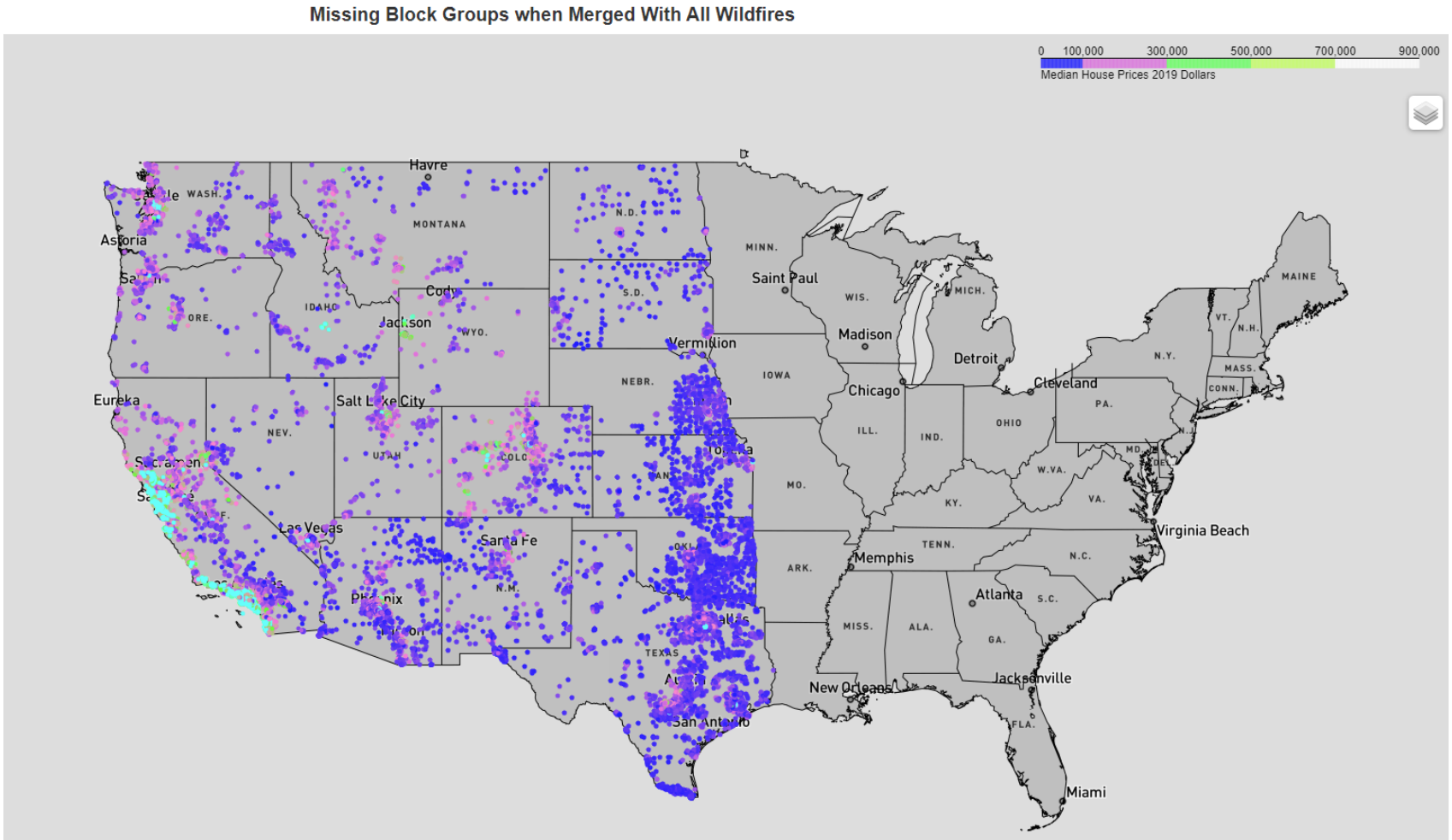
Data & Descriptive Statistics

Example of Finding the Minimum Distance to a Wildfire Perimeter



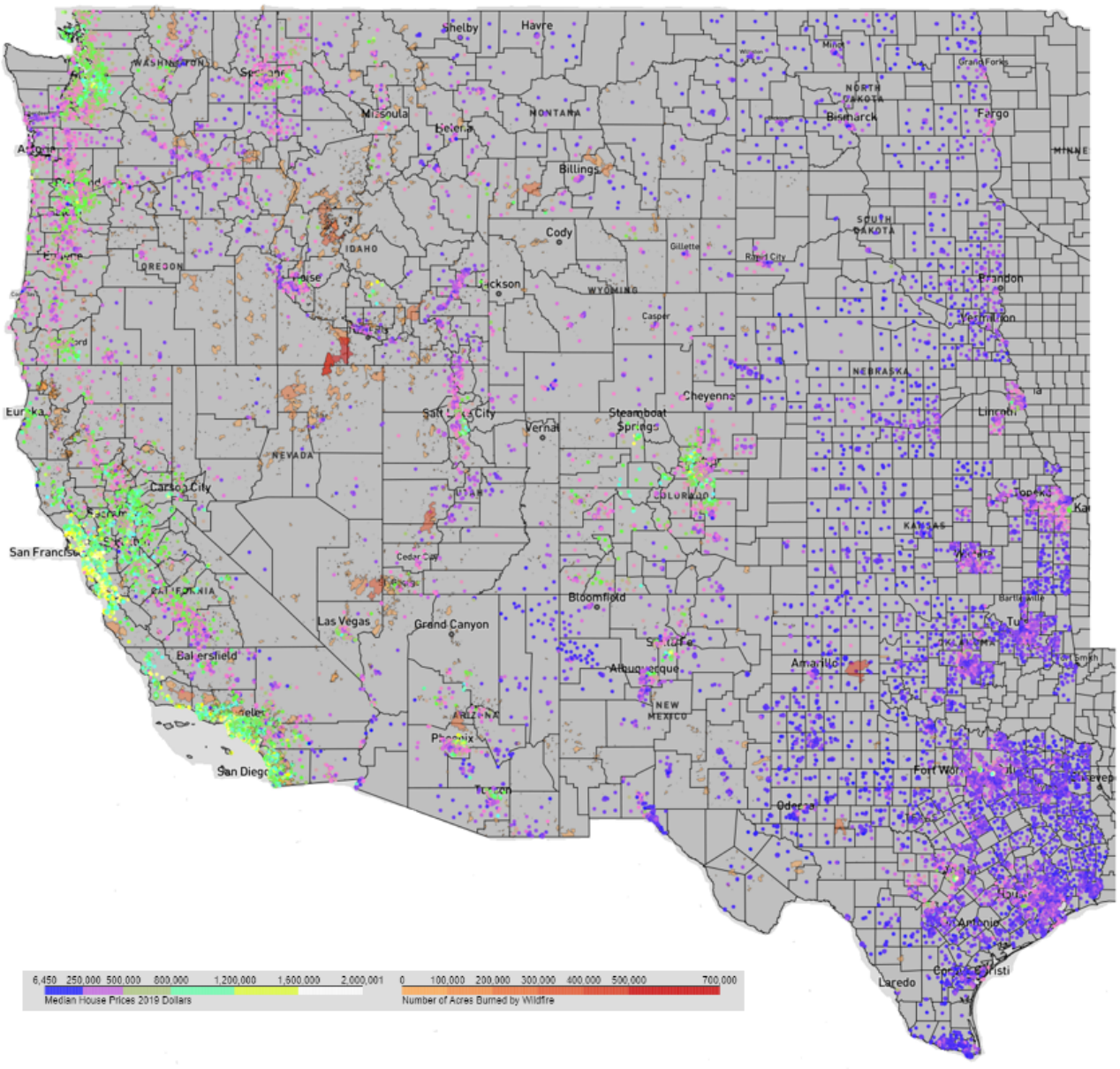
Data & Descriptive Statistics

Location of Missing Census Block Groups When Merged with Wildfire Perimeters



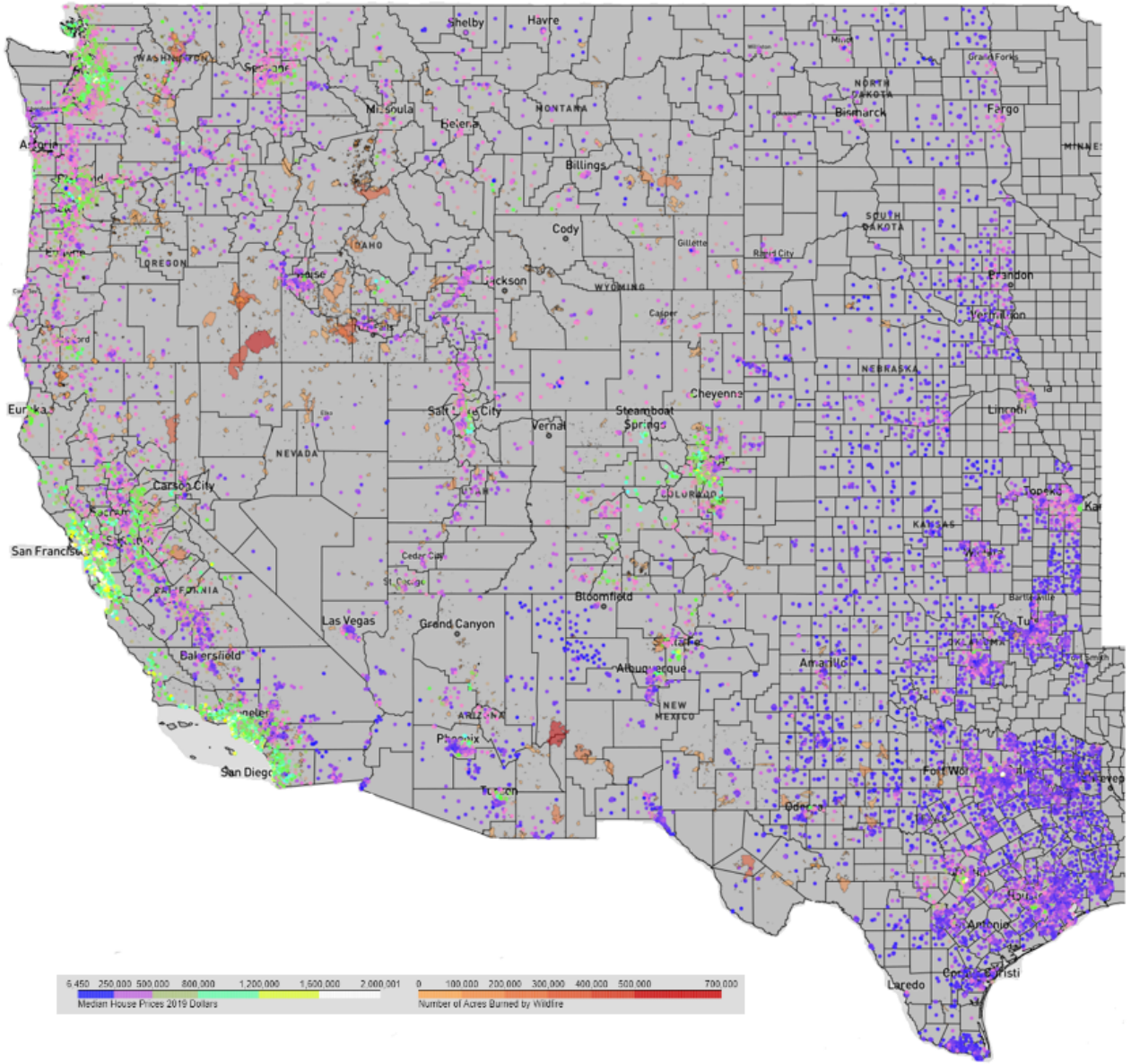
Data & Descriptive Statistics

2005-2009 Wildfire Perimeters and Median Property Values



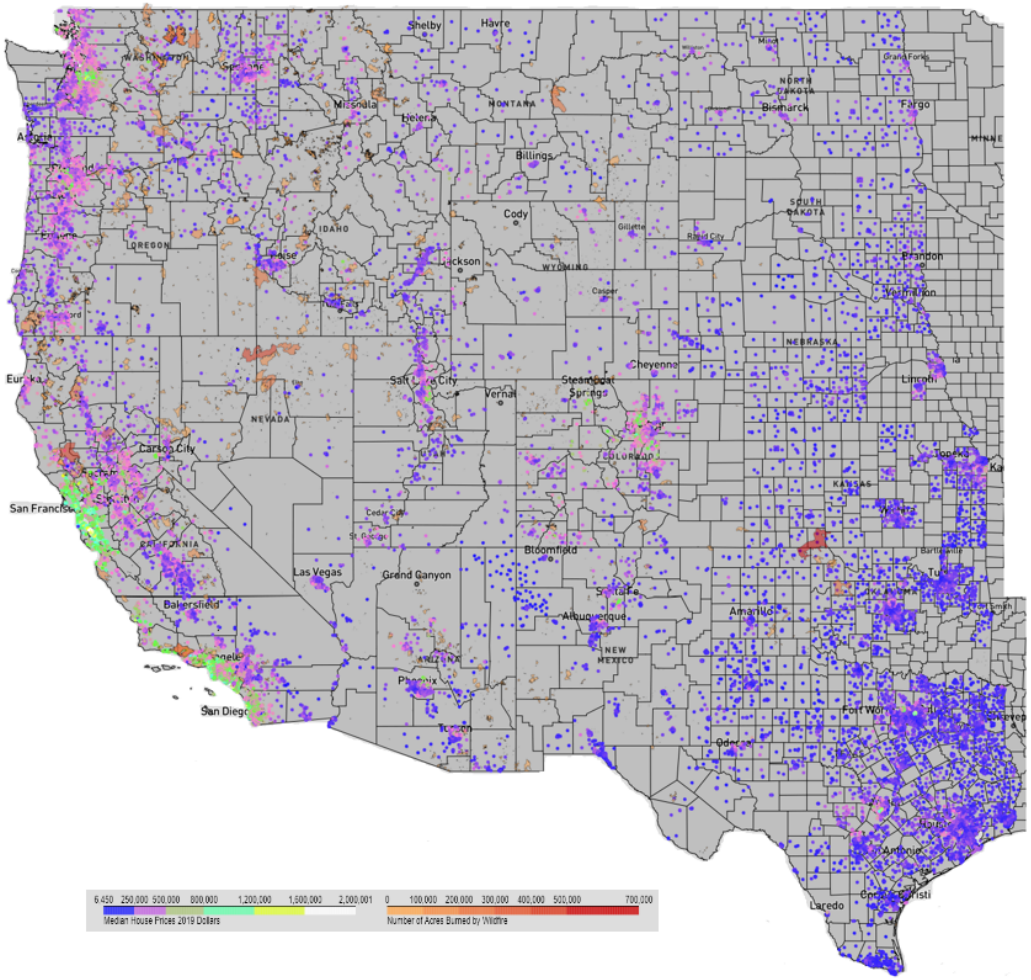
Data & Descriptive Statistics

2010-2014 Wildfire Perimeters and Median Property Values



Data & Descriptive Statistics

2015-2019 Wildfire Perimeters and Median Property Values



Data & Descriptive Statistics

Table: 2 Number of Block Groups Within Each Distance Category

		2010-2014			
		<=4km	4km<=20km	>20km	Total
2005-2009	<=4km	1475	4390	949	6814
	4km<=20km	2721	26076	16557	45354
	>20km	2536	18647	56395	77578
	Total	6732	49113	73901	129746
	Observations	129746			

Data & Descriptive Statistics

Table: 3 Number of Block Groups Within Each Distance Category

		2015-2018			
		<=4km	4km<=20km	>20km	Total
2005-2009	<=4km	1320	4415	1079	6814
	4km<=20km	1745	25081	18528	45354
	>20km	361	6052	71165	77578
	Total	3426	35548	90772	129746
	Observations	129746			

Data & Descriptive Statistics

Table: 4 Number of Block Groups Within Each Distance Category

		2015-2018			
		<=4km	4km<=20km	>20km	Total
2010-2014	<=4km	772	2801	3159	6732
	4km<=20km	2286	22948	23879	49113
	>20km	368	9799	63734	73901
	Total	3426	35548	90772	129746
	Observations	129746			

Data & Descriptive Statistics

Table: 5 Average Median Property Values Within and Not Within 4 km Distance from Wildfire Perimeter

	Within 4km From a Wildfire Perimeter				
	No	Yes	*N* No	*N* Yes	p-Value
Median Property Value 2005-2009	321,676	408,280	39,062	4,662	0.00
Median Property Value 2010-2014	260,160	309,644	39,062	4,662	0.00
Median Property Value 2015-2019	332,680	383,864	37,784	4,514	0.00

N is the number of observations.

Estimation

$$\Delta \ln(\text{Median Value}_{it}) = \beta_1 \text{4km 2015 Ring}_{it} + \beta_2 \Delta \text{race}_{it} + \beta_3 \Delta \text{travel}_{it} + \beta_4 \Delta \text{educ}_{it} + \beta_5 \Delta \text{yearbuilt}_{it} + \beta_6 \Delta \text{bedrooms}_{it} + \beta_7 \Delta \text{mortgagestatus}_{it} + \Delta \lambda_t + \Delta \nu_{it} \quad (2)$$

- t= 2005-2009, 2010-2014, 2015-2019.
- Median Value$_{it}$ median property value for block group i in period t
  - $\Delta \ln(\text{Median Value}_{it}) \approx$ growth rate of median census block group property values.
- 4km 2015 Ring$_{it}$ dummy variable: Only within 4km from a 2015 Wildfire Perimeter OR within 4km from a 2015 wildfire perimeter and within 4km from at least one fire before 2015.
- λ_t Time fixed effects.
- Controls are in proportion terms of each block group.

Main Result Table

Table: 7 Within 4km from a 2015 Wildfire Perimeter on Block Group Median Property Values

	(1) Median Value	(2) Δ Median Value	(3) Δ ln(Median Value)	(4) Δ Median Value	(5) Δ ln(Median Value)
4km 2015 Ring	-15147.8	-26644.8***	-0.0760***	-22318.1***	-0.0603**
	(-1.52)	(-4.47)	(-3.85)	(-3.51)	(-2.92)
Observations	129741	86016	86016	6842	6842
R^2	0.664	0.328	0.301	0.459	0.386

t statistics in parentheses

Model (1) use state and time fixed effects, and robust standard errors.

Models (2)-(5) use time fixed effects and standard errors are clustered on block groups.

Models (4) and (5) exclude block groups greater than 20km from a wildfire perimeter.

Controls: Percent Race, Percent Educated, Percent Travel Time to Work, Percent Year Built, Percent Number of Bedrooms, Percent With Mortgage.

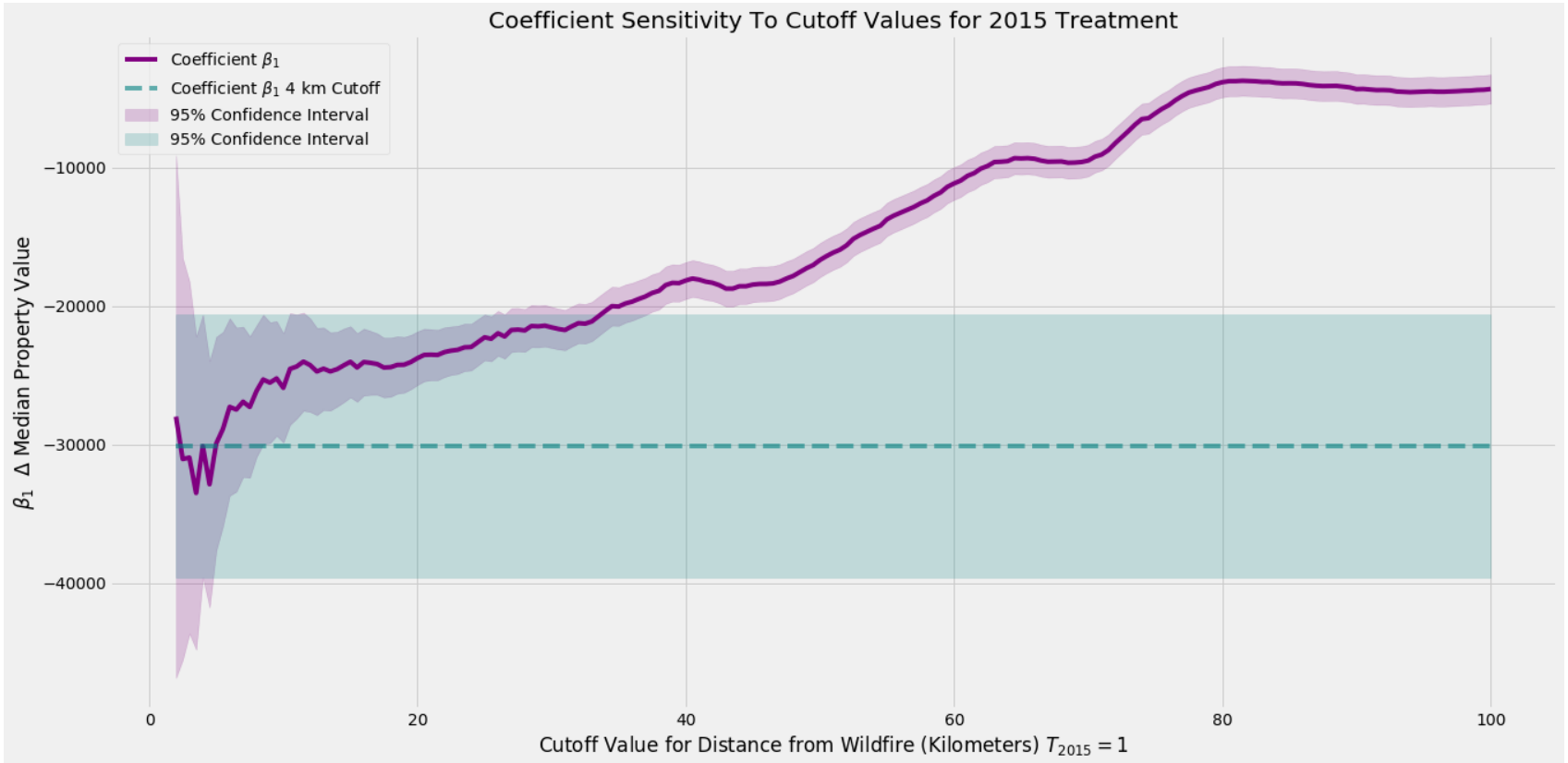
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Main Result

- 7.60% reduction in the median property value for being within 4km from a 2015 wildfire perimeter [4]
- Marginal Implicit Price $= \hat{\beta}\text{Median}\bar{\text{Value}}_{it} = -\$23,651.45$
- 6.03% reduction in the median property value for within 4km from a 2015 wildfire perimeter in comparison to homes between 4km-20km from a 2015 wildfire perimeter.
- Specification robust to pre-wildfire controls and inclusion non-overlapping distance cutoff categories.
  - 4km, 4km-10km, 10km-15km, and 15km-20km from a 2015 Wildfire Perimeter.
- No association beyond 10km from a 2015 wildfire perimeter.

[4] Note 4km 2015 Ring_{it} includes fires in the pre-period

Distance Cutoff Values 2km-100km by 500m



Main Result with Non-Overlapping Cutoff Values [5]

Table: 11 OLS & First Difference Within 4km, 4km-10km, 10km-15km, and 15km-20km from a 2015 Wildfire Perimeter on Block Group Median Property Values

	(1) Median Value	(2) Median Value	(3) Δ Median Value	(4) Δ Median Value	(5) Δ ln(Median Value)	(6) Δ ln(Median Value)
4km 2015 & 2015-2019	-17841.9	-17079.1	-27113.6***	-27187.2***	-0.0774***	-0.0776***
	(-1.78)	(-1.71)	(-4.55)	(-4.57)	(-3.93)	(-3.94)
4km-10km 2015 & 2015-2019	-11341.6	-10216.2	-16473.6***	-16610.0***	-0.0552***	-0.0555***
	(-1.91)	(-1.71)	(-4.94)	(-5.00)	(-5.28)	(-5.32)
10km-15km 2015 & 2015-2019	-27653.9***	-26268.2***	-6733.3*	-6860.4**	-0.00939	-0.00969
	(-7.27)	(-6.88)	(-2.56)	(-2.62)	(-1.13)	(-1.16)
15km-20km 2015 & 2015-2019	-32870.6***	-31162.1***	-688.7	-963.9	-0.00817	-0.00881
	(-9.04)	(-8.54)	(-0.33)	(-0.46)	(-1.21)	(-1.30)
Pre-Fire 4km 2005-2014				-14506.4***		-0.0197**
				(-7.78)		(-3.27)
Pre-Fire 4km-10km 2005-2014				-18388.9***		-0.0340***
				(-13.82)		(-7.74)
Pre-Fire 10km-15km 2005-2014				-29540.1***		-0.0659***
				(-22.67)		(-15.10)
Pre-Fire 15km-20km 2005-2014				-41842.6***		-0.104***
				(-34.70)		(-25.60)
Observations	129741	129741	86016	86016	86016	86016
R^2	0.664	0.669	0.328	0.362	0.301	0.320

t statistics in parentheses

Models (3)-(6) use time fixed effects, and standard errors clustered on block groups.

Models (1)-(2) use time and state fixed effects with robust standard errors.

Model (2),(4), and (6) controls for previous wildfires in the 2005-2009 and 2010-2014 periods within 4km, 4km-10km, 10km-15km, and 15km-20km from block group

Controls: Percent Race, Percent Educated, Percent Travel Time to Work, Percent Year Built, Percent Number of Bedrooms, Percent With Mortgage.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[5] Note treatment variables here do not include pre-fires as they are controlled for.

OLS Controlling for WHP

- What about wildfire risk? Recall both dis-amenity and risk effects influence property values in the HPM model.

Table: 6 Comparison of Wildfire Hazard Potential (WHP) 2020 Within 4 km Distance from Wildfire Perimeter

	Within 4km From a Wildfire Perimeter		
Within 4 km	No	Yes	Total
Mean 2005-2009	0.4486311	0.9628983	0.4756296
N	43724		
Mean 2010-2014	0.4375499	1.169604	0.4756296
N	43724		
Mean 2015-2019	0.4562906	1.306798	0.4788129
N	42298		

*WHP is not a forecast or outlook to any particular time or season.

I split it by periods so that this table can be compared with the above table.

OLS Controlling for WHP Complete Specification

$$\begin{aligned}
\text{Median Value}_{it} = {} & \beta_1 \text{4km 2015 \& 2015-2019}_{it} + \\
& \beta_2 \text{4km-10km 2015 \& 2015-2019}_{it} + \beta_3 \text{10km-15km 2015 \& 2015-2019}_{it} + \\
& \beta_4 \text{15km-20km 2015 \& 2015-2019}_{it} + \beta_5 \text{Pre-Fire 4km 2005-2009}_{it} + \\
& \beta_6 \text{Pre-Fire 4km 2010-2014}_{it} + \beta_7 \text{Pre-Fire 4km-10km 2005-2009}_{it} + \\
& \beta_8 \text{Pre-Fire 4km-10km 2010-2014}_{it} + \\
& \beta_9 \text{Pre-Fire 10km-15km 2005-2009}_{it} + \\
& \beta_{10} \text{Pre-Fire 10km-15km 2010-2014}_{it} + \\
& \beta_{11} \text{Pre-Fire 15km-20km 2005-2009}_{it} + \\
& \beta_{12} \text{Pre-Fire 15km-20km 2010-2014}_{it} + \\
& \beta_{13} \text{Median WHP 2020}_i + \cdots + \lambda_t + \delta_s + \epsilon_{it} \quad (3)
\end{aligned}$$

OLS Controlling for WHP

Table: 14 OLS Within 4km, 4km-10km, 10km-15km, and 15km-20km from a 2015 Wildfire Perimeter on Block Group Median Property Values With WHP Controls

	(1) Median Value	(2) Median Value	(3) Median Value	(4) Median Value	(5) Median Value	(6) Median Value
4km 2015 & 2015-2019	-22049.1*	-21532.1*	-25284.2*	-22534.4*	-25213.1*	-24557.1*
	(-2.22)	(-2.17)	(-2.55)	(-2.28)	(-2.54)	(-2.48)
4km-20km 2015 & 2015-2019			-28329.7***	-24856.1***		
			(-11.10)	(-9.65)		
4km-10km 2015 & 2015-2019					-14886.9*	-13865.9*
					(-2.52)	(-2.34)
10km-15km 2015 & 2015-2019					-29088.1***	-27823.7***
					(-7.66)	(-7.29)
15km-20km 2015 & 2015-2019					-34060.5***	-32488.5***
					(-9.47)	(-9.00)
Median WHP 2020=1	29835.6***	29863.9***	29746.8***	29704.8***	29730.1***	29386.3***
	(24.26)	(24.32)	(24.18)	(24.22)	(24.17)	(23.98)
Median WHP 2020=2	29911.8***	30041.1***	30164.7***	29775.1***	30154.7***	30460.4***
	(16.99)	(17.09)	(17.15)	(17.05)	(17.14)	(17.44)
Median WHP 2020=3	39091.3***	38932.3***	39926.5***	38928.0***	39815.2***	39771.5***
	(16.95)	(16.84)	(17.33)	(16.92)	(17.27)	(17.30)
Median WHP 2020=4	26726.9***	25475.5***	28137.5***	26189.2***	28047.2***	27357.8***
	(8.71)	(8.32)	(9.19)	(8.60)	(9.16)	(8.94)
Median WHP 2020=5	25242.8**	24614.0**	27408.3**	25375.8**	27250.5**	25845.7**
	(2.85)	(2.77)	(3.11)	(2.90)	(3.09)	(2.93)
Observations	129492	129492	129492	129492	129492	129492
R^2	0.666	0.666	0.666	0.670	0.666	0.671

t statistics in parentheses
Models (1)-(6) use state and time fixed effects with robust standard errors.
Model (2) controls for previous wilfires in 2005-2009 and 2010-2014 within 4km.
Model (4) controls for previous wilfires in 2005-2009 and 2010-2014 within 4km and 4km-20km.
Model (6) controls for previous wildfires in the 2005-2009 and 2010-2014 periods within 4km, 4km-10km, 10km-15km, and 15km-20km from block group.
Controls: Percent Race, Percent Educated, Percent Travel Time to Work, Percent Year Built, Percent Number of Bedrooms, Percent With Mortgage.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

OLS Controlling for WHP

- Model robust to controlling wildfire proximity before 2015.
- Effects from wildfire risk were putting upward pressure on property values between 10km-20km from a wildfire perimeter.
- Does not control for unobservable time-invariant variables (e.g. distance to water, elevation, etc.).

Additional Robustness Checks

- Two sample t-test on controls shows there are significant differences between block groups within/not within 4km from a 2015 wildfire (possibly driven by differences in amenity values).
- Random treatment, regressed 4km 2015 Ring_{it} on the controls, controls close to zero or not statistically significant.
- Regressed the growth rate of property values between 2005-2009 and 2010-2014 on the treatment (original FD specification) to test that there are no time-varying factors within a block-group that are correlated with both property values and wildfire perimeters.
  - No association between pre-period growth rate and being within 4km from a 2015 wildfire perimeter.

Limitations & Future Research

- Data: Comparison of five-year estimates is not exact, better to have property values for each year.
  - Block groups not constant, maybe helpful to use census tracts at the cost of less geographic detail.
- WHP is time-invariant measure of wildfire risk, better to process USGS raster data on the Large Fire Probability Index for every year.
- No post period to see how trend evolves would be corrected for with more detailed time period data.
- Cannot directly control for the compound effect of wildfires on property values in the 2015-2019 period.
  - Depends on the persistence of the 2015 wildfire effect.
- Ideal to have a richer set of geographic, vegetation, and neighbourhood amenity controls (e.g. distance to bodies of water, elevation, etc.).

Conclusion

- About a 7% reduction in median property values within 4km from a 2015 wildfire perimeter robust to pre-fire and wildfire risk controls.
  - The combined wildfire dis-amenity/risk effect dissipates after 10km from a wildfire perimeter.
- Wildfire dis-amenity effects on property values are significant over a larger geographic area than the combined dis-amenity/risk effect from wildfires.
- This suggests that wildfire risk effects are greater for properties further away from a 2015 wildfire perimeter.
- Future research should test specification against a series of wildfire risk indexes for controls with more detailed time and geographic data.

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