Mortgage Markets with Climate-Change Risk: Evidence from Wildfires in California

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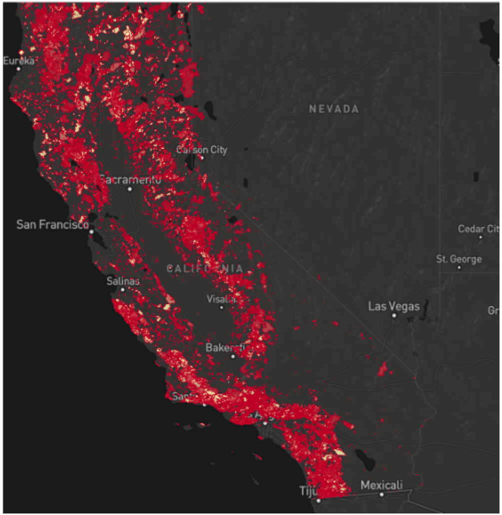
California Fire Statistics



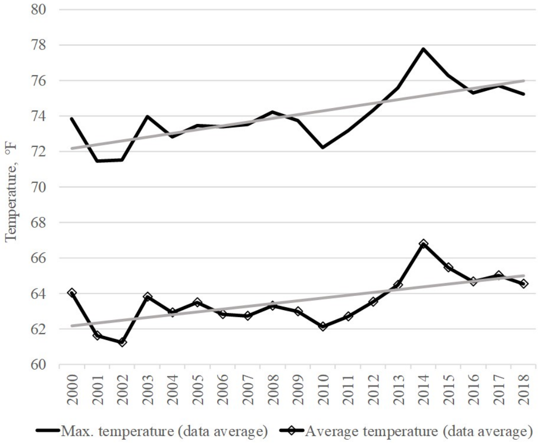
- Since 1972, the area burned each year in California has increased 5-fold.

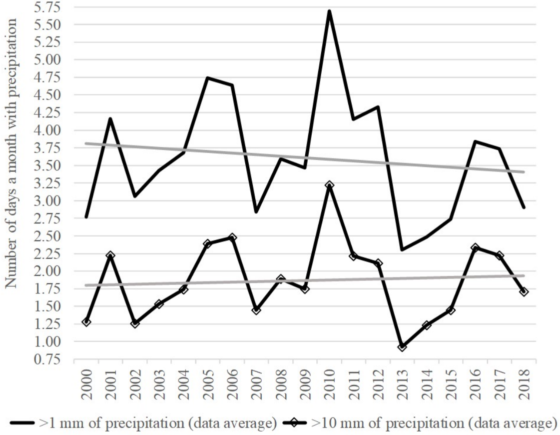
- In 2018, 1.8M acres burned in wildland and wildland-urban-interface (WUI): over $16B estimated losses and more than any other state in U.S., 85 deaths.

- In 2019, two wildfire events in Southern CA caused damage estimated at over $25 B.

- In 2020, 9,279 fire events, 4.2M acres burned, 32 deaths.

CA Counties: Temperature and Precipitation (2000–2018)





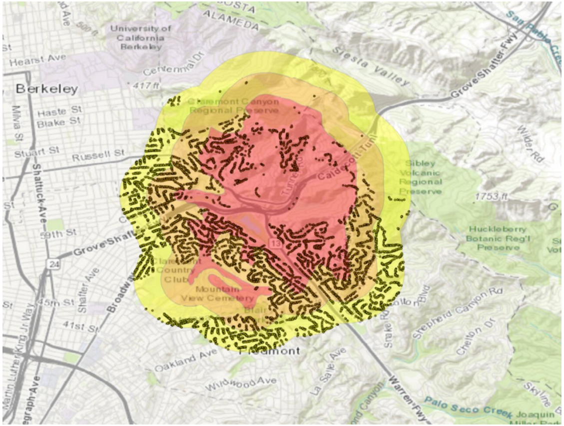
Purpose of this Study

- Empirical investigation of link between fire events, house price and size dynamics, mortgage default, and address-specific demographics to determine long and short run effects on:
  - Characteristics of the housing stock in treatment and control areas.
  - Housing returns in treatment and control areas.
  - Mortgage default risk in treatment and control areas.
  - Degree of gentrification in treatment and control areas.

- Focus on geospatial panel data and fire prediction: fire incidence and magnitude, house values and characteristics, mortgage performance, weather dynamics.
  - How predictable are CA fire events?
  - Are these characteristics dynamic?

- Implications of results for residential fire-insurance pricing policies and mortgage lending.

Case Study: 1991 Oakland Tunnel Fire



Densely populated WUI in Berkeley and Oakland, CA:

- 25 people died, 150 seriously injured.
- 1,540 acres burned.
- 3,354 single-family homes destroyed.
- 437 apartment units destroyed.
- 2,000 vehicles destroyed.
- Overall replacement cost $3 Billion (1991 dollars).

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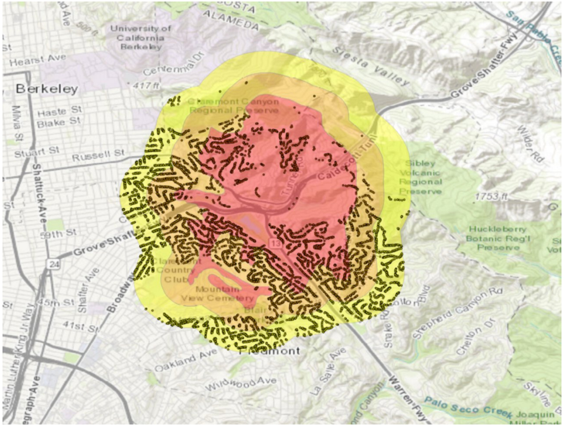


Physical elements:

- Terrain, slope aspect, temperature, and wind — all elevate probabilities of fire.
- Temperature 90 degrees Fahrenheit.
- Wind: strong, dry, downslope winds.

Tunnel Fire: Four Facts

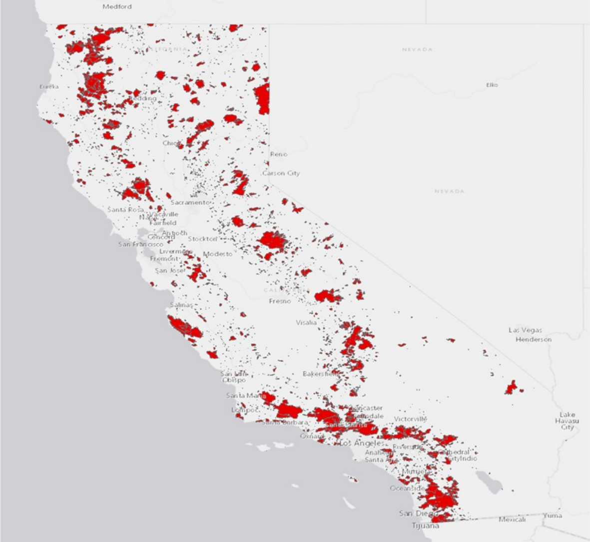
- Rebuilding: More than 95% of properties were rebuilt and newly reconstructed homes in fire area were more valuable.

- Relatively low mortgage-default rates for mortgage borrowers in the devastated area.

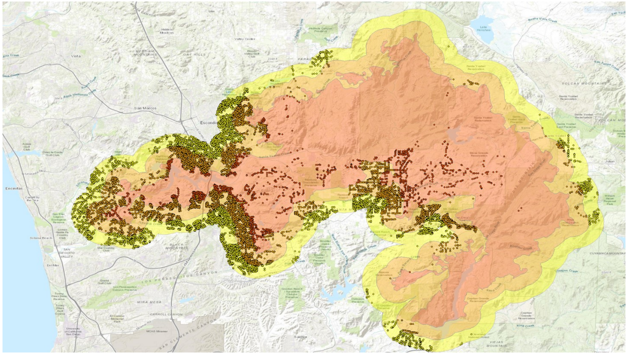
- Long-term effects: The disincentives for mortgage default lasted a long time.

- Coordination externalities: Large tracts of homes were replaced with modernized structures (due to build-to-code requirements). Related to fire insurance:
    - Fire insurance is required for all residential mortgages in the U.S.
    - Rebuilt homes must be built-to-code (priced in coverage).
    - Fire insurance is “priced” by deterministic fire-risk maps (CA Dept. of Insurance allows no probabilistic pricing and no pricing of re-insurance costs).

Overall California Fire Study: 2000–2018



Control group example: San Diego Witch Fire (2007)



- Treatment Group (orange):
  - 5,508 properties
  - 1,446 mortgages.
- Control Group 1 (pale orange): 0 to 1 mile:
  - 22,000 properties
  - 6,570 mortgages
- Control Group 2 (yellow): 1 to 2 miles
  - 22,000 properties
  - 7,289 mortgages

The Long-Run Effects on House Size (sq. feet). 5 and 10 years

	$ln(Size_{t+5})$	$ln(Size_{t+5})$	$ln(Size_{t+10})$	$ln(Size_{t+10})$
bigfire	0.00712 ***	0.00549 ***	0.00802 ***	0.00729 **
	0.00206	0.00204	0.00269	0.00268
fire		0.01149 ***		0.01142 *
		0.00393		0.00607
$ln(Size_t)$	0.86493 ***	0.86491 ***	0.81048 ***	0.81046
	0.00625	0.00625	0.01128	0.01128
Num. rooms	-0.00064 ***	-0.00064 ***	-0.00096 ***	-0.00096 ***
	0.00014	0.00014	0.00019	0.00019
Year FE	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes
Observations	34,545,997	34,545,997	6,805,306	6,805,306
R^2	0.85	0.85	0.84	0.81

The Long-Run Effects on House Prices. 5 and 10 years

	$ln(H_{t+5})$	$ln(H_{t+5})$	$ln(H_{t+5})$	$ln(H_{t+10})$	$ln(H_{t+10})$	$ln(H_{t+10})$
bigfire	0.0517 **	0.0527 **	0.0514 **	0.0566 **	0.0564 **	0.0546 *
	0.0223	0.0240	0.0238	0.0257	0.0269	0.0268
fire			0.0213			0.0283
			0.0154			0.0187
$ln(H_t)$	0.6905 ***	0.6840 ***	0.6840 ***	0.6360 ***	0.6381 ***	0.6381 ***
	0.0079	0.0081	0.0081	0.0162	0.0161	0.0161
$\Delta(ln(Size_t))$		0.1768 ***	0.1768 ***		0.2017 ***	0.2017 ***
		0.0040	0.0040		0.0072	0.0072
Num. rooms	0.0054 ***	0.0063 ***	0.0063 ***	0.0064 ***	0.0077 ***	0.0077 ***
	0.0006	0.0005	0.0005	0.0007	0.0006	0.0006
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
(Year)*(Census tract) FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	57,227,115	11,221,195	11,221,195	26,147,870	6,654,055	6,654,055
R^2	0.80	0.80	0.80	0.78	0.78	0.78

Hypothesis 1: The probability of mortgage default conditional on a wildfire in the treatment group is higher than the probability of default in the control group.

A reduced-form difference-in-differences (DID) analysis:

$$default_{i,f} = treatment_{i,f} * afterfire_{i,f} + afterfire_{i,f} + treatment_{i,f} + \bar{X}_{i,f} + \varepsilon_{i,f}, \tag{1}$$

where:

- $default_{i,f}$ = either delinquency or foreclosure of mortgage i during the 6-month period after the event of fire f;
- $treatment_{i,f}$ = one if mortgage i is within the fire f zone and zero otherwise;
- $afterfire_{i,f}$ = one after the fire f event zero before the fire f.
- $\bar{X}_{i,f}$ = mortgage controls,
- $\varepsilon_{i,f}$ = the error term.

A Stylized Model of Mortgages with Fire Risk

- Borrowers' options at each t: i) Keep making mortgage payments, ii) default, iii) prepay.
- If there is a fire... Borrowers' options at each t: i) rebuild or not, ii) keep making mortgage payments, iii) default, iv) prepay:
  - The rebuilding decision is made by borrowers given their insurance coverage and the requirements of local building codes.
  - Rebuilding presents large externalities – the larger the fire the greater the potential gentrification externalities.

Hypothesis 2: The probability of default conditional on a wildfire decreases with: i) the probability of rebuilding; ii) the house price conditional on rebuilding; iii) the house price conditional on non-rebuilding; iv) the size of the fire.

Builds upon the DID analysis in equation (1):

$$\begin{aligned} default_{i,f} = & treatment_{i,f} * bigfire_f * afterfire_{i,f} + treatment_{i,f} * afterfire_{i,f} + \\ & treatment_{i,f} * bigfire_f + bigfire_f * afterfire_{i,f} + \\ & afterfire_{i,f} + treatment_{i,f} + bigfire_f + \bar{X}_{i,f} + \varepsilon_{i,f}, \end{aligned} \tag{2}$$

Measurement challenge with Hypothesis 2

- Use "Big Fires" as a proxy for both the probability and the conditional distribution.
    1. With large fires, the probability of rebuilding is higher (most CA homeowners and all mortgage borrowers have casualty insurance);
    2. With large fires, future house prices are higher (benefits of positive coordination externalities and build-to-code requirements).

- Big-Fire dummy:
    - Equals 1 if the number of mortgages affected by the fire is at least one standard deviation above the mean number of mortgages affected by all CA fires;
    - Equals 0 otherwise.

Difference in Differences Result: Mortgage Foreclosures

Treatment group:	Fire	Fire	Fire	Ring 0–1	Ring 0–1
Control group:	Ring 0–1	Ring 0–1	Ring 0–1	Ring 1–2	Ring 1–2
	[1]	[2]	[3]	[4]	[5]
treatment*bigfire*afterfire			-0.00605***		
			(0.00198)		
treatment*afterfire	0.00105	0.00116	0.00463**	-0.00076***	-0.00052*
	(0.00081)	(0.00088)	(0.00184)	(0.00027)	(0.00030)
treatment*bigfire			-0.00079		
			(0.00064)		
bigfire*afterfire			-6.10e-05		
			(0.00047)		
afterfire	0.00270***	0.00279***	0.00280***	0.00345***	0.00331***
	(0.00019)	(0.00021)	(0.000258)	(0.00025)	(0.00021)
treatment	7.04e-05	-0.00021	0.00036	6.34e-05	0.00013
	(0.00027)	(0.00027)	(0.00062)	(9.00e-05)	(0.00010)
bigfire			-0.00041***		
			(0.00015)		
Mortgage controls	No	Yes	Yes	No	Yes
Observations	208,422	177,532	177,532	412,604	350,590
R-squared	0.001	0.007	0.007	0.001	0.008

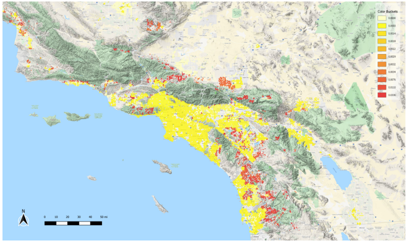
IV Panel Regression

- First stage: estimate the probability of a big-fire event for each house as a function of weather.
    - Maximum temperature by month at the property location (triangulated to nearest NOAA measurement stations).
    - First-stage results: Important seasonal and geographic dynamics of the estimated probabilities of big fire events compared to the deterministic California fire maps.
- Second stage: IV panel regression with month-by-month measurement of mortgage delinquency or foreclosure given estimated fire probabilities, loan-to-value ratio, loan coupon differential to 10Y Treasury, fixed effects.
    - Second-stage results: Identical to prior analysis for both delinquency and foreclosure.

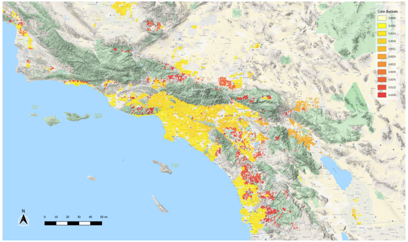
First-Stage Probability Estimates: Big Fire Event as a Function of Weather Data

	[1]	[2]	[3]	[4]
Max. temp.	5.93e-05***		7.99e-05***	7.95e-05***
	(7.01e-06)		(8.13e-06)	(7.95e-06)
haz_code		0.00797***	0.00822***	
		(8.92e-05)	(9.78e-05)	
D. hazard=1				0.00777***
				(0.000153)
D. hazard=2				0.00553***
				(5.37e-05)
D. hazard=3				0.0285***
				(0.000373)
Constant	-0.00234***	0.00119***	-0.00473***	-0.00465***
	(0.000521)	(9.56e-06)	(0.000608)	(0.000594)
Fixed effects:	Yes	Yes	Yes	Yes
Observations	184,958,421	194,499,073	184,958,210	184,958,421
R-squared	0.002	0.008	0.008	0.010

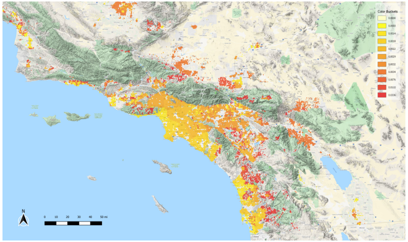
Southern California Probabilistic Fire Estimates 2017



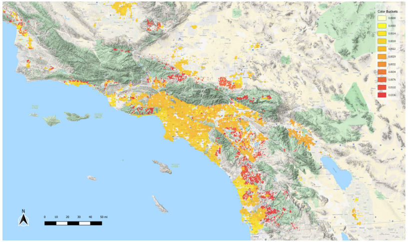
(a) January



(b) April

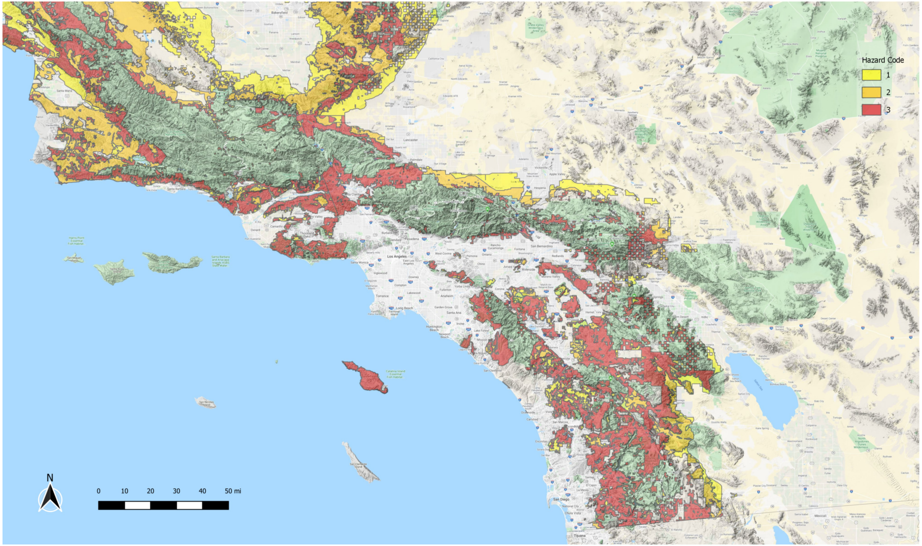


(c) July



(d) October

Southern California Deterministic Fire Codes



Panel Regression Result: Mortgage Foreclosures

	OLS Num. of mortgages per wildfire [1]	OLS Dummy [2]	IV Dummy [3]
Big fire	-1.31e-07**	-0.0104**	-0.033258**
	(5.17e-08)	(0.00415)	(0.01498)
LTV	8.14e-09	8.19e-09	-4.02e-08
	(1.39e-08)	(1.39e-08)	(2.03e-06)
coupon-interest rate diff.	-1.497	-1.498	-0.412
	(0.911)	(0.912)	(0.591)
Mortgage controls:	Yes	Yes	Yes
Fixed effects:	Yes	Yes	Yes
Observations	90,368,381	90,368,381	86,303,137
R-squared	0.072	0.072	—

Fire Insurance Exposure to the CA Mortgages

- **Expected Big-Fire Loss (EBFL)**

  1. Estimate the value of each property for each month.
  2. Estimate the probability of a big fire for each month from first stage IV.
  3. Compute EBFL per property as as the time-specific value of each property multiplied by the probability of a big fire for the property at that time (assuming that the value of each property is zero after a fire has occurred).

Expected Big-Fire Losses (EBFL): (Prob. of Big Fire) $\times$ (Property Value)

Variable	Hazard Code	Obs	Property-level Mean ($)	Property-level Std. Dev. ($)
EBFL	3	4,030,442	20,189	27,323
EBFL	2	2,132,588	4,722	5,916
EBFL	1	2,525,164	6,376	6,346
EBFL	0	173,594,311	669	897

Variable	Total Months	Obs	Total ($ Mil.)	Std. Dev. ($ Mil.)
EBFL Annual Total	12	194,499,425	14,982	4,647

Conclusions

- First study of the effect of California wildfires on long-run house price dynamics, long-run dynamics of the housing stock, and mortgage delinquencies and foreclosure.
  - Merging large geospatial datasets: fire incidence and magnitude; maximum temperatures; house prices; and mortgage characteristics and performance.

- Findings for house price dynamics:
  - Long-run elevated returns in “big-fire” areas.
  - Long-run housing size growth in “big-fire” areas.

- Findings for mortgage performance: Difference-in-differences and IV panel regressions:
  - A significant increase in mortgage delinquency and foreclosure after a fire event.
  - Default and foreclosure decrease in the size of the fire (probably due to coordination externalities from build-to-code requirements and casualty-insurance coverage).

- Important implications for the pricing regulation of fire casualty insurance as well as banking regulation and supervision