Housing and Mortgage Markets with Climate Risk: Evidence from California Wildfires

Paulo Issler* Richard Stanton* Carles Vergara† Nancy Wallace*

*Haas School of Business, U.C. Berkeley
†IESE Business School

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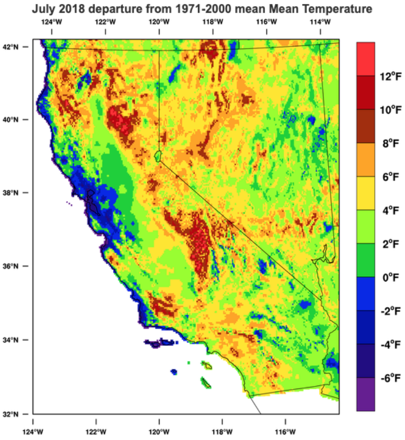
Wildfires in California

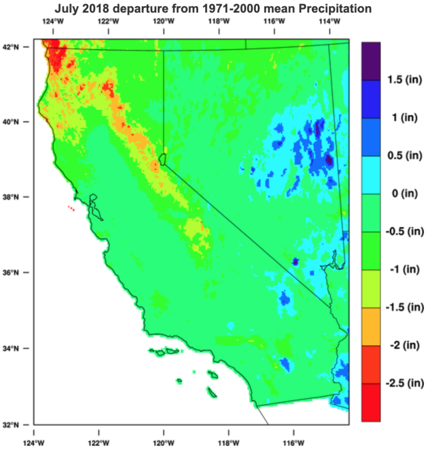
- Since 1972, the area burned each year in California has increased 5-fold.
- 2018: 1.8 M acres burned (over $16 B estimated losses and 85 deaths); more than any other U.S. state.
- 2019: 4 wildfires caused losses $>$ $25 B.
- 2020: 9,279 fire events, 4.2 M acres burned, 32 deaths. August Complex, largest ever wildfire in California, burned $>$ 1 million acres.
- 2021: Second largest wildfire in CA history, Dixie fire: 960,335 acres burned (as of Sept. 12).

California Temperature and Precipitation

July 2018 vs. 1971–2000 average



(a) Temperature



(b) Precipitation

Purpose of the Study

- To investigate of the effect of wildfire events on:
  - Residential house-price and size dynamics,
  - Household income and wealth,
  - Mortgage default,
  - Property-insurance risk.

- Our focus:

  1. Carry out empirical analysis based on high-frequency geospatial data:
     - To estimate the wildfire exposure of residential single-family homes and mortgages.
     - To determine the long- and short-term effects of wildfires on insured properties.

  2. Exploit a quasi-experimental design identified by fire “treatment” and “control” areas.
     - Burn-area boundaries are determined by CalFire scientists.

  3. Inform policy debate concerning residential fire-insurance regulation in California.

Empirical Analysis I: Estimate the Probability of California Wildfires

- **Geographic Area** — Geoprocess all of California into 1.5 by 1.5 kilometer grids (urban areas) and 4.5 by 4.5 kilometer grids (rural areas).

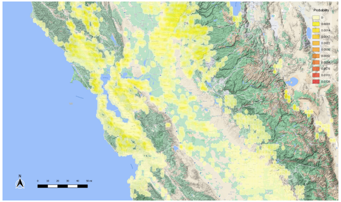
- **Data collection for each grid point (June through October)**:
  1. **USGS**: slope and elevation.
  2. **SILVIS Labs Data**: Wildland Urban Interface (vegetation and urban coverage).
  3. **Meterological NARR data are simulated with WRF/UCM models and verified with NOAA station measurements (Vahmani, Jones, and Patricola, 2019)**: daily averages for wind direction, wind speed, max. temperature, relative humidity.
  4. **ATTOM Data Solutions**: grid location of single-family residential homes (prices/characteristics) and mortgages (contract/performance).

- **Estimation strategy:** Logistic regression.

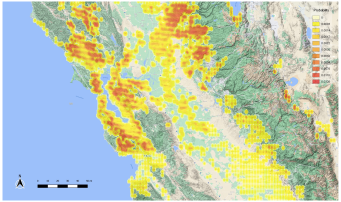
Probability of wildfires: Logistic regression

	coefficient	std. err.
Constant	-10.7559***	0.039
Wind Speed	0.3976***	0.005
Maximum Temperature	0.4854***	0.018
Relative Humidity	-0.2549***	0.016
Slope	0.4003***	0.011
Elevation	0.2821***	0.011
Percentage of Urban Site Coverage	-0.0429*	0.021
Percentage of Vegetative Site Coverage	0.0677***	0.018
Northeasterly Wind	0.3743***	0.031
Southeasterly Wind	0.3921***	0.032
September	1.9573***	0.042
October	3.2897***	0.043
Observations	28,978,800	
Pseudo R-squared	0.16	

Logistic Regression: Wildfire Probability Heat Maps

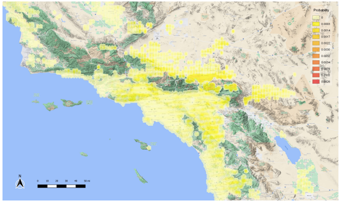


i. June

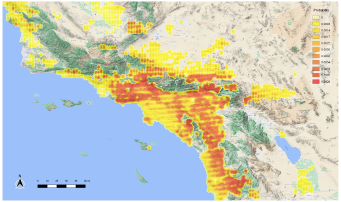


ii. October

(a) Northern California



i. June



ii. October

(b) Southern California

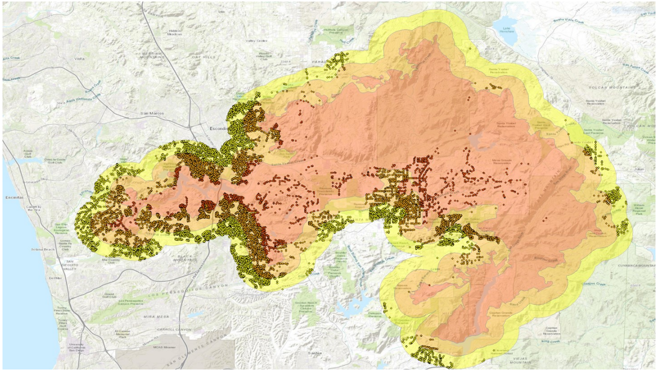
Analysis II: Difference-in-Differences Estimation

- Burn-area boundaries define a quasi-experimental design:

  1. **Random treatment effect:** Weather, ignition event, and fire boundary.
  2. Test for long-run post-fire differentials between treatment and control areas:
     - Quality of the housing stock,
     - House price dynamics,
     - Gentrification,
     - Mortgage default.
  3. Also use panel spatial autoregressive (SA) model to allow for spatial autocorrelation.

Analysis II: DID Identification Strategy

San Diego Witch Fire Example



- 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

Data Sources (2000–2018)

- **CalFire:** treatment areas, control 1 and control 2, and size of fires.

- Administrative data:
  - **ATTOM Data Solutions – Transaction data** house price transaction data, mortgage performance data.
  - **ATTOM Data Solutions – Annual house specific snapshot of characteristics (e.g. square footage, number of rooms etc).**
  - **Zillow – zip code house price indices.**

- **McDash Black Knight:** Mortgage characteristics and performance.

- **Data Axle:** Household demographics, income, wealth.

Gentrification: Effect on House Size after 5 Years

Approach:	DID	DID	Panel SA	Panel SA
Treatment group:	Fire	Fire	Fire	Fire
Control group:	Control1	Control1	Control1	Control1
Dep. variable:	$\log(size)$	$\log(size)$	$\Delta \log(size)$	$\Delta \log(size)$
	[1]	[2]	[3]	[4]
Fire × Afterfire	0.0103**	0.0114***		
	(0.00516)	(0.00353)		
Fire	0.0552***	0.0536***	0.0138***	0.0146***
	(0.00398)	(0.00354)	(0.00367)	(0.00481)
Afterfire	-0.0098***	0.0117		
	(0.00125)	(0.00860)		
$\log(size_{t_0})$			-0.0647***	-0.0763***
			(0.00251)	(0.00375)
Controls	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	No	Yes
Observations	152,765	152,765	20,483	20,483

Gentrification: Effect on House Prices after 5 Years

Approach:	DID	DID	Panel SA	Panel SA	Panel SA	Panel SA	Panel SA
Treatment group:	Fire	Fire	Fire	Fire	Fire	Fire	Fire
Control group:	Control1	Control1	Control1	Control1	Control1	Control1to2	Control1to2
Dep. variable:	$\log(price)$	$\log(price)$	$\Delta\log(price)$	$\Delta\log(price)$	$\Delta\log(price)$	$\Delta\log(price)$	$\Delta\log(price)$
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Fire $\times$ Afterfire	0.0536***	0.0580**					
	(0.01253)	(0.02562)					
Fire	-0.0085	-0.0038	0.0498***	0.0418***	0.0344***	0.0567***	0.0492***
	(0.00973)	(0.02172)	(0.00970)	(0.00982)	(0.00961)	(0.00960)	(0.00927)
Afterfire	0.0413***	-0.0263					
	(0.00307)	(0.07985)					
$\log(price_{t_0})$			-0.1883***	-0.1910***	-0.1820***	-0.1699***	-0.1565***
			(0.00478)	(0.00477)	(0.00552)	(0.00276)	(0.00313)
$\Delta\log(size_{t_0,t_0+5})$			0.2620***	0.2632***	0.2580***	0.2644***	0.2663***
			(0.0173)	(0.0172)	(0.0166)	(0.0102)	(0.0098)
Control1						0.0228***	0.0179***
						(0.00381)	(0.00370)
Controls	Yes	Yes	No	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	No	No	Yes	No	Yes
Observations	118,582	118,582	13,359	13,359	13,359	41,802	41,802

Gentrification: Effect on Household Income after 5 Years

Approach:	DID	DID	Panel SA	Panel SA	Panel SA	Panel SA	Panel SA
Treatment group:	Fire	Fire	Fire	Fire	Fire	Fire	Fire
Control group:	Control1	Control1	Control1	Control1	Control1	Control1to2	Control1to2
Dep. variable:	$\log(i)$	$\log(i)$	$\Delta\log(i)$	$\Delta\log(i)$	$\Delta\log(i)$	$\Delta\log(i)$	$\Delta\log(i)$
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Fire $\times$ Afterfire	0.0404*	0.0550**					
	(0.02289)	(0.02335)					
Fire	-0.0468**	-0.0682***	0.1311***	0.1272***	0.0525**	0.2101***	0.1240***
	(0.01953)	(0.01988)	(0.02110)	(0.02091)	(0.02131)	(0.02082)	(0.02080)
Afterfire	0.3783***	0.4012***					
	(0.00651)	(0.00621)					
Control1						0.0749***	0.0696***
						(0.00779)	(0.00741)
Controls	Yes	Yes	No	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	No	No	Yes	No	Yes
Observations	36,610	36,610	10,818	10,818	10,818	24,108	24,108

Gentrification: Effect on Household Wealth after 5 Years

Approach:	DID	DID	Panel SA	Panel SA	Panel SA	Panel SA	Panel SA
Treatment group:	Fire	Fire	Fire	Fire	Fire	Fire	Fire
Control group:	Control1	Control1	Control1	Control1	Control1	Control1to2	Control1to2
Dep. variable:	$\log(w)$	$\log(w)$	$\Delta\log(w)$	$\Delta\log(w)$	$\Delta\log(w)$	$\Delta\log(w)$	$\Delta\log(w)$
	[1]	[2]	[3]	[4]	[5]	[6]	[7]
Fire$\times$ Afterfire	0.0754***	0.0565**					
	(0.01501)	(0.02721)					
Fire	-0.0111	-0.0155	0.0506***	0.0519***	0.0214*	0.0740***	0.0433***
	(0.01268)	(0.01999)	(0.01061)	(0.01071)	(0.01120)	(0.01072)	(0.01081)
Afterfire	-0.3176***	0.0182					
	(0.00331)	(0.01670)					
Control1						0.0216***	0.02370***
						(0.00395)	(0.00387)
Controls	Yes	Yes	No	Yes	Yes	Yes	Yes
Fixed effects	No	Yes	No	No	Yes	No	Yes
Observations	51,129	51,129	10,818	10,818	10,818	24,108	24,108

Wildfires and Mortgage

- Insured mortgages on houses that are burned in wildfires are more likely to become 90 day delinquent or to become foreclosed.

- However, insured mortgages in very large wildfires are less likely to become 90 day delinquent or to become foreclosed.

- Possible positive externalities due to CA fire-insurance codes.
    - Replacing “old” for “new built-to-code.”
    - Payout from personal property coverage is fungible.
    - Large scale gentrification due to incentives to rebuild in place.
    - Mis-pricing of fire casualty insurance coverage

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; topographical, vegetative, and meteorological data; house price and characteristic dynamics; and mortgage characteristics and performance.

- Establishes the actuarial risk of wildfire to the residential single family mortgage market.

- Evidence of gentrification in wildfire recovery areas:
  - Long-run elevated returns.
  - Long-run housing size growth.
  - long-run increases in household income and wealth.

Conclusions 2

- Insurance-related findings for mortgage performance
  1. 6-month delinquency/foreclosure rates about 60 bps higher in fire- than control areas.
  2. 6-month delinquency/foreclosure rates fall by 1.4% after large wildfires.
     - Positive externalities from coordinated re-building.

- Implications for losses from insured mortgages in California
  - **Back-of-the-envelope** expected peak-season daily risk exposure for the assessed value of California housing is $2.89 billion.
  - **A one standard deviation max temperature shock** increases the daily risk to $8.74 billion.

- Implications for regulation of fire insurance/bank supervision.
  - Need for probabilistic wildfire forecasting models.
  - Need for actuarial casualty-insurance pricing.
  - Need for bank stress-test monitoring of wildfire risk.