Mandatory versus Voluntary Adaptation to Natural Disasters: The Case of Wildfires in the United States

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Adapting to natural disasters: voluntary action vs. mandated resilience

- Large-scale disasters are becoming more frequent due to climate change and other factors.
- Losses can be reduced through adaptive investments, but takeup may be complicated by risk misperception, spatial spillovers, and emphasis on post-disaster aid.
- Growing federal and state initiatives to require or subsidize takeup of mitigation investments.

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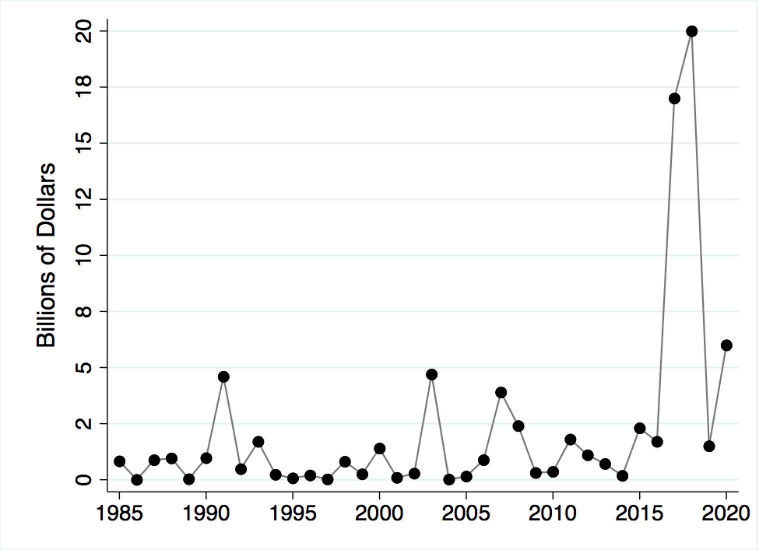
- Growing federal and state initiatives to require or subsidize takeup of mitigation investments.
- Limited evidence about the degree to which these programs increase resilience relative to a counterfactual of voluntary adoption.

We consider wildfire building codes in California

- Wildfires have caused $40+ billion of property damage in the United States in the past 5 years, mostly in California.



Patterns of structure loss

Tubbs Fire, Santa Rosa, CA. Aerial imagery from NearMap.

We evaluate the effect of building codes on survival of own- and neighboring structures.

- Assemble parcel-level damage data representing almost all U.S. homes destroyed by wildfire since 2003.
- Merge to the universe of assessor data for destroyed and surviving homes inside fire perimeters.
- Use differences in code requirements to measure the effects of building codes on structure survival.
- Measure spillover benefits of mitigation for neighboring properties due to reduced structure-to-structure spread.

This study advances our understanding of disaster mitigation in four ways.

1. We estimate policy effects.
   - Previous literature measures technology effects (e.g., Gibbons et al, 2012; Syphard et al 2012; Syphard et al 2017).
2. First estimates of spatial externalities from mitigation.
3. Scale: Our estimates are based on data for almost all U.S. homes experiencing wildfires since 2007.
   - This new dataset is useful beyond this study.
4. We deploy an explicit empirical design.
   - Previous literature is descriptive or relies on regression adjustment.

Spatial externalities and myopia may limit investment

Los Angeles Times

CLIMATE & ENVIRONMENT

Want to fireproof your home? It takes a village

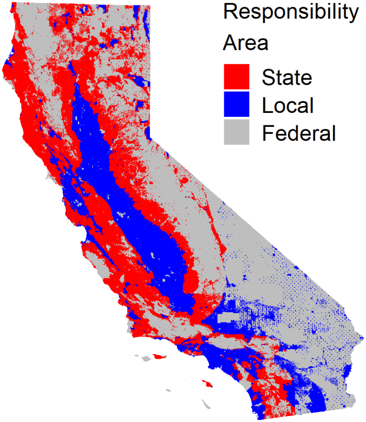
Local governments may also face split incentives

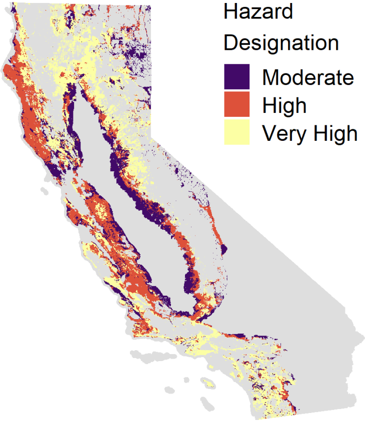
- Hazard designations are unpopular with incumbent homeowners
- Local governments internalize a small share of mitigation benefits (Baylis and Boomhower, 2019).
- Incomplete adoption of local govt FHSZ maps (Troy, 1998; Miller et. al., 2020)

- *Sacramento Bee* on rebuilding Santa Rosa after 2017:

Burned-out California town ignores stricter building codes, even with wildfire threat

California’s WUI code requirements depend on jurisdiction and mapped fire hazard





Mandatory codes in all state-managed areas, with opt-in adoption in local government areas (hundreds of municipalities and counties).

The 1991 Oakland Firestorm catalyzed important changes

- Mid-1990's building code reforms
    - A.B. 337, 1992 ("Bates Bill")
    - A.B. 3819, 1995 (Class A/B roofs required in high-hazard zones)
    - A.B. 423, 1999 (outlaws untreated wood shingles on all homes)
- Strengthened via "Chapter 7A" requirements in 2008
- Standards have been mandatory in SRA, and opt-in in LRA

Introduction

Background

Data

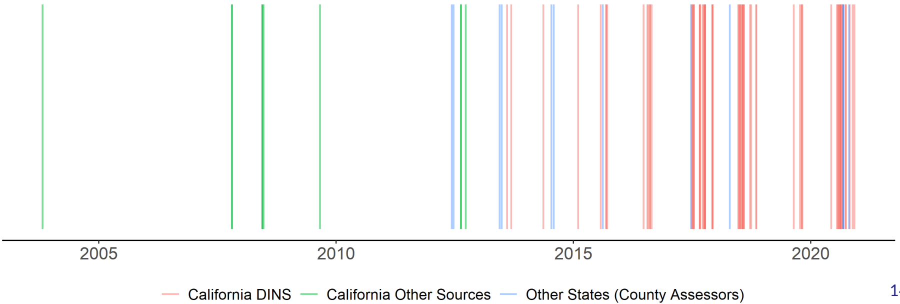
Spatial analysis

Empirical Strategy & Results

Discussion

We compile near-comprehensive data on U.S. homes destroyed by wildfire over two decades.

- Censuses of damaged homes for 112 wildfires, 2003–2020.
- APN, street address, extent of damage.
- Sources
  - Recent California fires: CAL FIRE DINS
  - Older California fires: Counties, CAL FIRE archives
  - Other states: County assessors



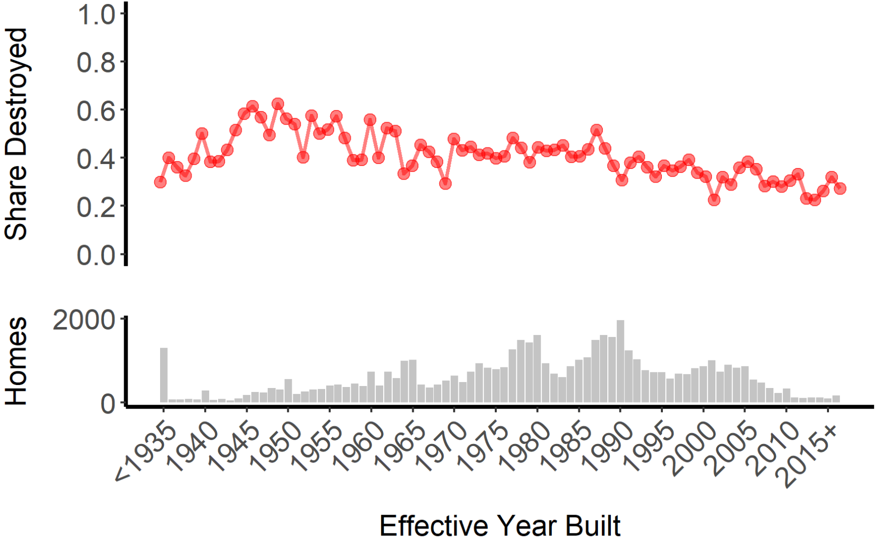
We merge to the universe of properties inside wildfire perimeters and leverage additional spatial data.

- Property tax assessment data (ZTRAX)
  - Universe of U.S. properties
    - Year built, effective year built, assessed value by year, etc.
    - Limit to single family homes inside wildfire perimeters.
  - Merge to damage data based on assessor parcel number.

- Additional spatial datasets
  - Parcel boundaries (county assessors).
  - High-res aerial imagery to validate locations & damage reports.
  - Building footprints

Summary of the final merged dataset (all states)

- 51,530 homes exposed to wildfires in CA, OR, WA, AZ.
- 41% destroyed.



Assigning rooftop locations

Redding, CA before the Carr Fire (2018)

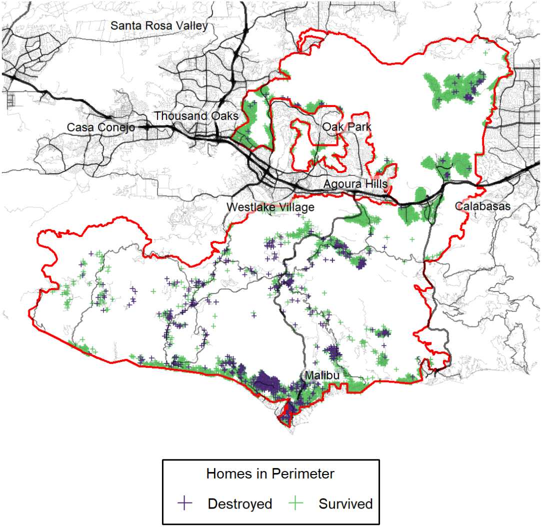
Validating damage reports.

Redding, CA after the Carr Fire (2018)

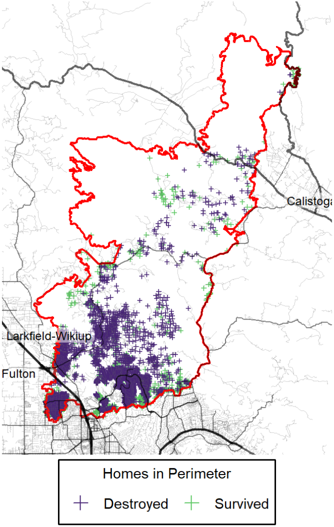
Calculating distances between structures

Homes before the Thomas Fire (2017)

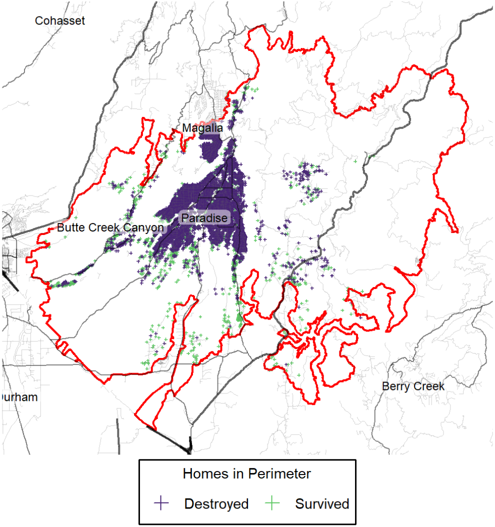
Woolsey Fire (2018)



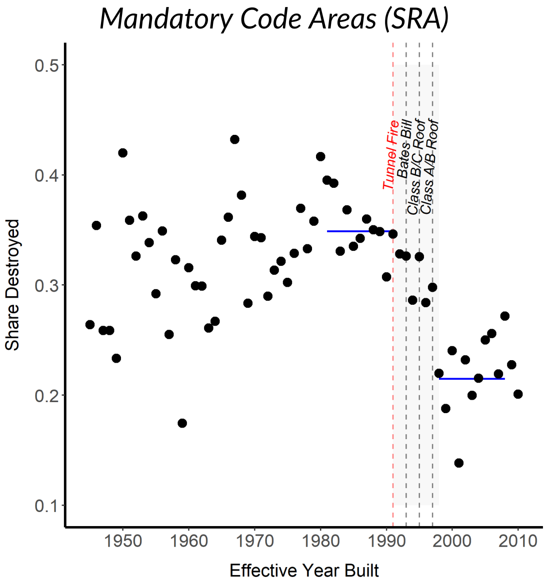
Tubbs Fire (2018)



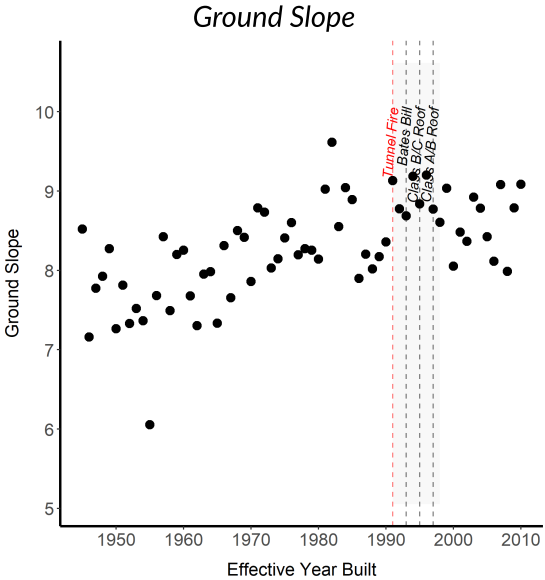
Camp Fire (2018)



Homes built after 1995 in mandatory code areas are more likely to survive.



Other home characteristics do not change in 1995.



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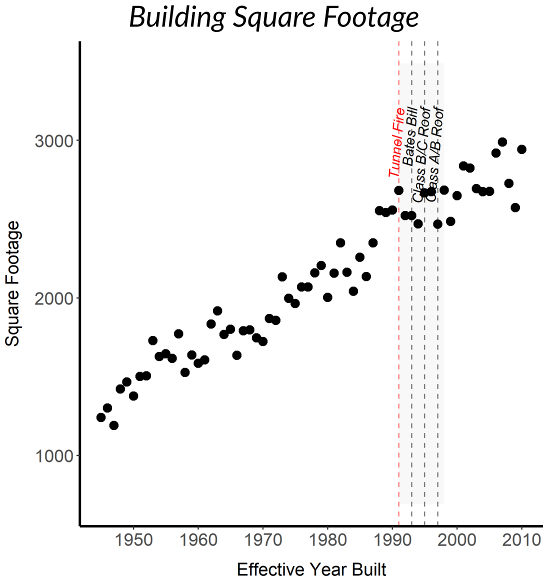


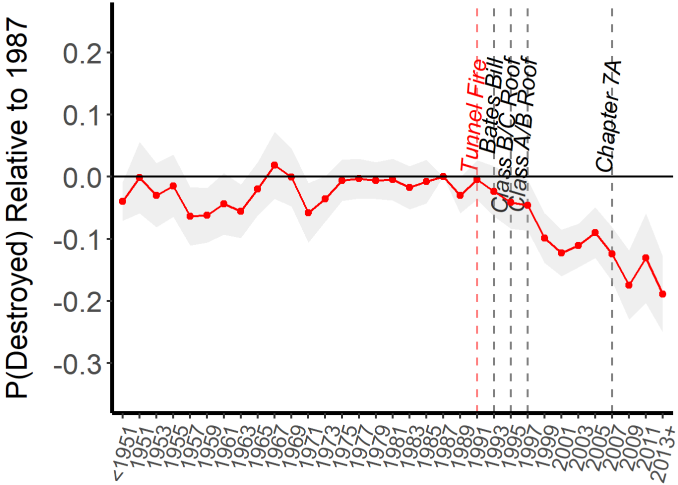
The empirical strategy compares survival for homes on the same street built in different years.

$$1[Destroyed]_{isf} = \sum_{v=v_0}^{v=V} \beta_v D_i^v + \gamma_{sf} + X_i \alpha + \epsilon_i \tag{1}$$

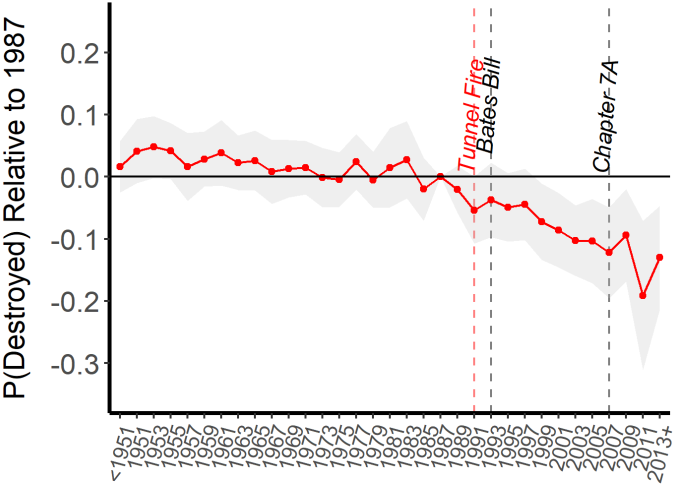
- D_i^v: indicator for V vintage bins
- γ_{sf}: street-by-fire fixed effects
- X_i: ground slope, vegetation, building square footage, and number of bedrooms.

1. Estimate Equation 1 separately by jurisdiction.
2. DiD specification that interacts vintage bins with jurisdiction.

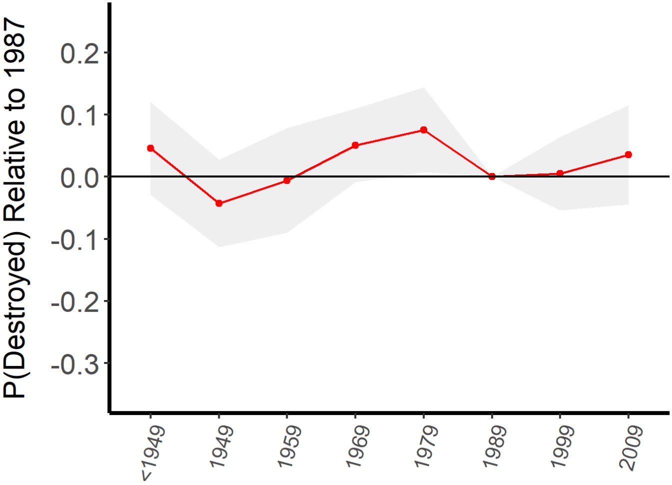
Vintage effects in mandatory code areas (SRA)



Vintage effects in opt-in code areas (LRA-VHFHSZ)



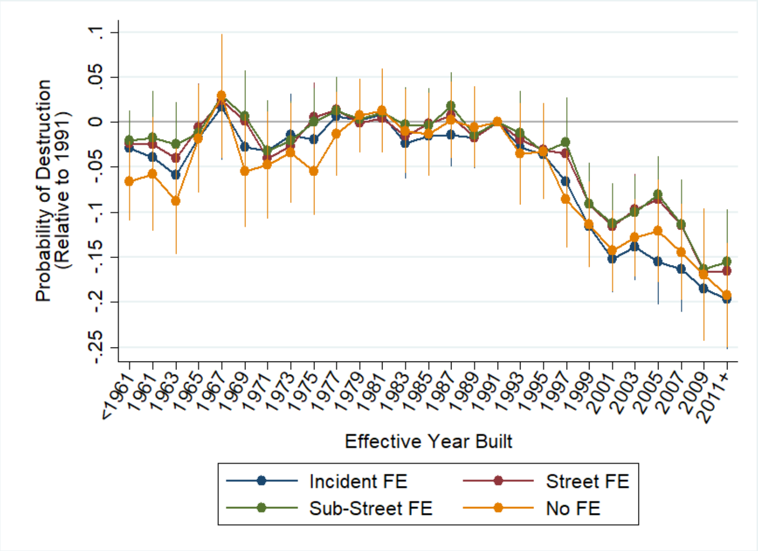
Vintage effects for other CA areas plus OR, WA, AZ



Difference in differences estimates

	(1)	(2)
Comparison Group $\times$ 1998–2007	-0.023	-0.009
	(0.026)	(0.026)
Comparison Group $\times$ 2008–2016	-0.003	0.019
	(0.033)	(0.038)
SRA $\times$ 1980–1997	-0.007	-0.046
	(0.033)	(0.041)
SRA $\times$ 1998–2007	-0.096***	-0.137***
	(0.034)	(0.042)
SRA $\times$ 2008–2016	-0.137***	-0.187***
	(0.036)	(0.043)
LRA VHFHSZ $\times$ 1980–1997	-0.024	-0.049
	(0.032)	(0.049)
LRA VHFHSZ $\times$ 1998–2007	-0.108***	-0.140***
	(0.033)	(0.048)
LRA VHFHSZ $\times$ 2008–2016	-0.144***	-0.176***
	(0.037)	(0.050)
Ground slope (deg)		0.005***
		(0.001)
Lot Size (Acres)		-0.000
		(0.000)
Building Square Feet		-0.000
		(0.000)
Bedrooms		-0.000
		(0.003)
Street FEs	Yes	Yes
Fuel Model FEs	No	Yes
Aspect FEs	No	Yes
Observations	48,213	38,386
R^2	0.62	0.63

Alternative fixed effects specifications

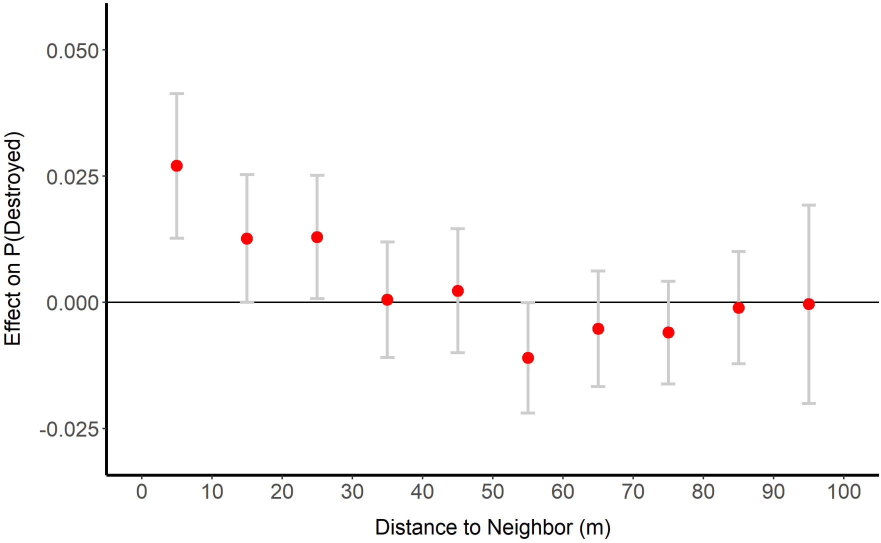


Structure to Structure Spread

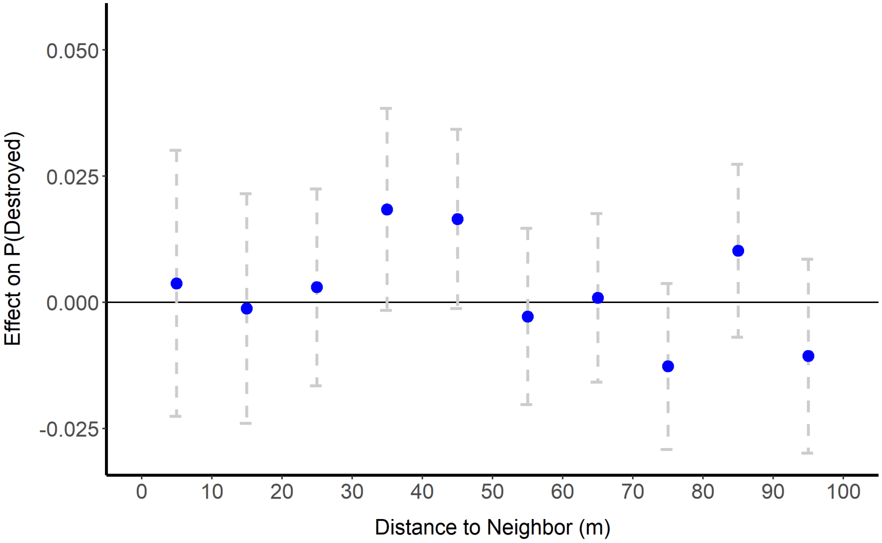
$$1[Destroyed]_{isf} = \sum_{j=1}^{J} \rho_j NoCode_j + \sum_{j=1}^{J} \phi_j Code_j + \sum_{v=v_0}^{V} \beta_v D_i^v + \gamma_{sf} + X_i \alpha + \epsilon_{isf}$$

- $NoCode_j$, $Code_j$: Counts of neighbors within wall distance j with and w/o WUI building codes in place

Pre-code neighbors



Post-code neighbors



Neighbor effects table

	C2C, All	C2C, HQ	W22, All	W2W, HQ
1 pre-code nearby homes	0.026***	0.027***	0.019***	0.025***
	(0.007)	(0.007)	(0.007)	(0.008)
2+ pre-code nearby homes	0.049***	0.050***	0.031***	0.039***
	(0.009)	(0.009)	(0.009)	(0.010)
1 post-code nearby home	0.009	0.002	0.001	0.006
	(0.012)	(0.012)	(0.013)	(0.014)
2+ post-code nearby homes	0.003	-0.006	-0.002	0.004
	(0.019)	(0.020)	(0.016)	(0.018)
Observations	44,923	28,073	38,226	21,349

Net social benefits of mandated mitigation

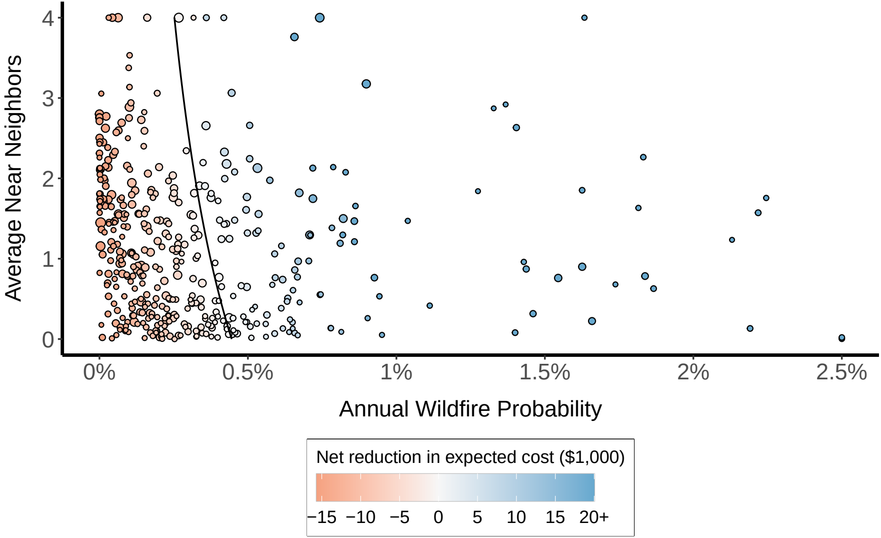
- We find a ~15-ppt decrease in own-structure loss and a ~2.5-ppt decrease for near neighbors.
- Given estimates of mitigation costs and values at risk, we can benchmark the net social benefits of universal mitigation.
- Thought experiment: “What is the minimum annual probability of wildfire exposure that makes WUI building codes cost effective?”

- A conservative measure: “Risk-neutral cost effectiveness’ ’

$$\sum_{i=1}^{N}[p^F p_i^D(L^I + L^U)] - \sum_{i=1}^{N}[p^F(p_i^D - \sum_{j=1}^{N}\tau_{ij})(L^I + L^U) + m] \tag{2}$$

- Why conservative?
  - Assumes no voluntary mitigation in non-code areas $\Rightarrow$ underestimates τ_{ii}
  - Accounting for risk aversion $\Rightarrow$ higher benefit (in paper)

Lower Bounds on Net Benefits



Conclusion

- We assembled data on nearly all homes exposed to wildfires in the United States during 2003–2020.
- We identify remarkable, non-linear vintage effects in survival for California homes.
- We show that these effects are due to state and local building code changes following the 1991 Oakland Firestorm.
- These preventive investments improve survival for neighboring homes.
- Calculations suggest the building code mandate was likely cost-effective.

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