Economics 134 L16. Natural Disasters

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Natural resources

Economics of natural resources:

- oil (L13)
- conservation (L14)
- water (L15)
- forests, wildfires (today)

Nature and civilization

Myriad interactions between the **environment** and where people **live**:

- tastes for natural beauty, wilderness
- risks associated with the wilderness

Today: empirical example of how we can use economic analysis to study

- how the environment shapes where people choose to live and their quality of life
- how these choices interact with economic policy

Location choice

- Two places: **outside** and **inside** of a wildfire risk zone.
- N households, indexed by i, choose which place to live.
- Each household i's relative willingness-to-pay to live in the wildfire zone is

$$\theta_i,$$

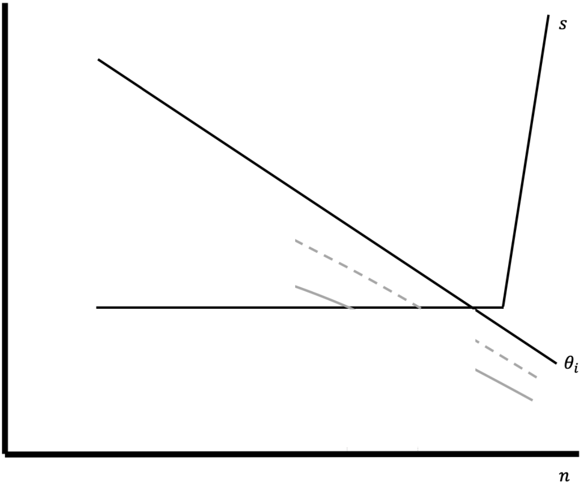
  which is decreasing in i, i.e., $\theta_1 > \theta_2 > \dots$.
- The marginal cost of building the n^{th} house in the risky zone given by some nondecreasing function, $s(n)$.
- Then, without any wildfires, the number of households who live in the wildfire risk zone, n^*, will satisfy

$$\theta_{n^*} = s(n^*),$$

  i.e., demand equals supply!

Equilibrium housing

Figure 1: The Market for Housing in a Risky Place



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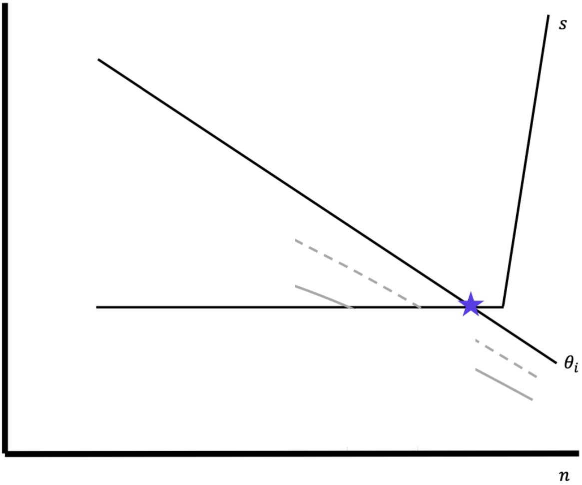

Wildfires

Now let's introduce wildfires.

In the wildfire risk zone, a fire occurs with probability p. (Outside the zone, a fire never occurs.)

- If a disaster occurs, the government can spend $f \geq 0$ to defend against it. The eventual **property damage** of the fire per household is given by

$$H(f)$$

  which is decreasing in f (more firefighting, less damage).

- Someone has to pay the firefighters. Suppose **defensive spending** f is split equally across households in the risky zone, so that each pay f/n.

Wildfires, cont'd

The total (expected) value of living in a wildfire zone for household i, when there are n houses, is now

$$\theta_i - p\left[\frac{f}{n} + H(f)\right].$$

Equilibrium housing in the zone, n^0, will be

$$\theta_{n^0} = s(n^0) + \underbrace{p\left[\frac{f}{n^0} + H(f)\right]}_{\text{defense + damage}},$$

and, clearly, $n^0 < n^*$.

Equilibrium housing with damages

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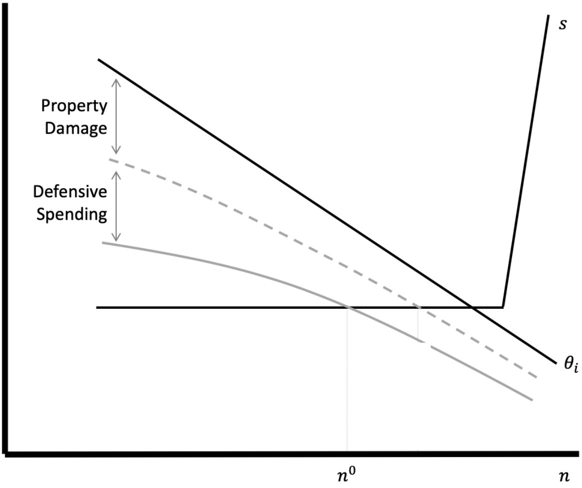

Moral hazard

A practical concern is the following:

If **someone else** (e.g., the state or federal government) pays the firefighters, then the expected value of living in the zone for a household becomes

$$\theta_i - pH(f),$$

which will lead to greater development in riskier places, from n^0 to n'.

This is an example of what is as known as "**moral hazard**."

- inefficiency that arises if households—while they bear the ultimate risk of fires, H—do not internalize the full cost of the risk (the firefighting expenses) when they choose where to live
- not about "morality": it's just another kind of externality, here arising from incomplete contracts

Moral hazard

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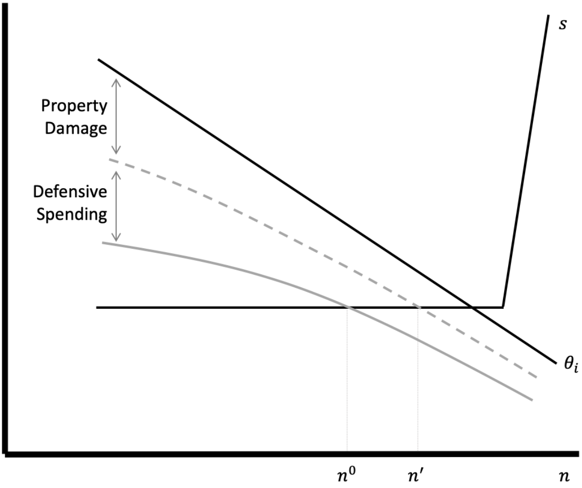


Moral hazard, cont'd

A related concern is somewhat subtler.

For a fixed n, the optimal firefighting expenditure is

$$\min_f \left[f + nH(f) \right].$$

More households increase protection, which lowers H (and further incentivizes development).

This is an additional form of moral hazard.

Discussion

From a measurement perspective, to assess moral hazard, we want

1. the average cost of firefighting in the risky zone, pf/n
2. the rate at which defense spending increases with more development, $f'(n)$

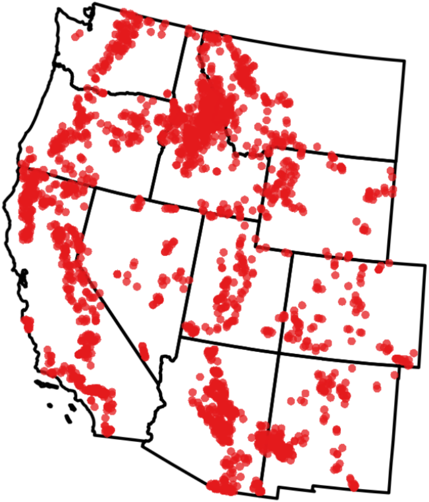
This is precisely the approach taken in a nice recent paper:

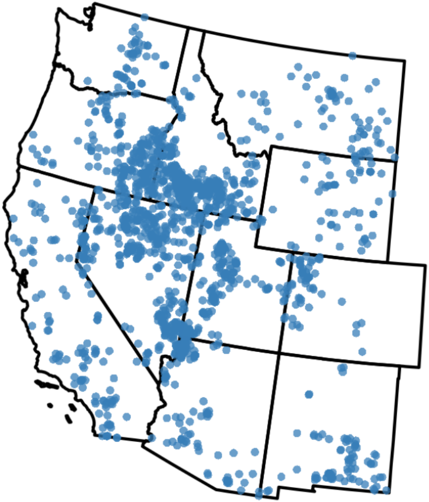
- Boomhower, Judson, and Baylis, Patrick (2023). "The economic incidence of wildfire suppression in the United States." American Economic Journal: Applied Economics, **15**(1), January.

Wildfires

- Total property damages of **$51 billion** from 1985–2017
  - increased human development, climate change, forest management
- Total federal firefighting costs, **$43 billion**
  - firefighting on national forest land, US Forest Service (USFS)
  - FEMA also reimburses 75% of state and local expenses for large fires
  - 50–95% of costs come from efforts to protect homes
- Firefighting data from 2,419 fires on USFS land, from 1990–2016
- Parcel data from 8.6 million at-risk homes

Fires in the Western US, 1995–2016





Estimating equation

Goal is to determine how housing development patterns affect firefighting costs.

Consider fire i in national forest f and month t. Suppose that observed firefighting costs are

$$\ln \mathtt{Cost}_{ift} = g(\mathtt{Homes}_{it}) + \beta' X_{ift} + \varepsilon_{ift}$$

where $\mathtt{Homes}_{it}$ is the distance from the ignition point to the nearest home, and the controls X_{ift} include

- permanent fixed effect for the forest f
- state-by-time fixed effects
- terrain slope, aspect; weather conditions,

and ε_{ift} is the unobserved determinant of firefighting costs.

We can obtain a causal estimate of g with this regression if the error ε_{ift} is uncorrelated with the housing locations, $\mathtt{Homes}_{it}$, conditional on the controls X_{ift}.

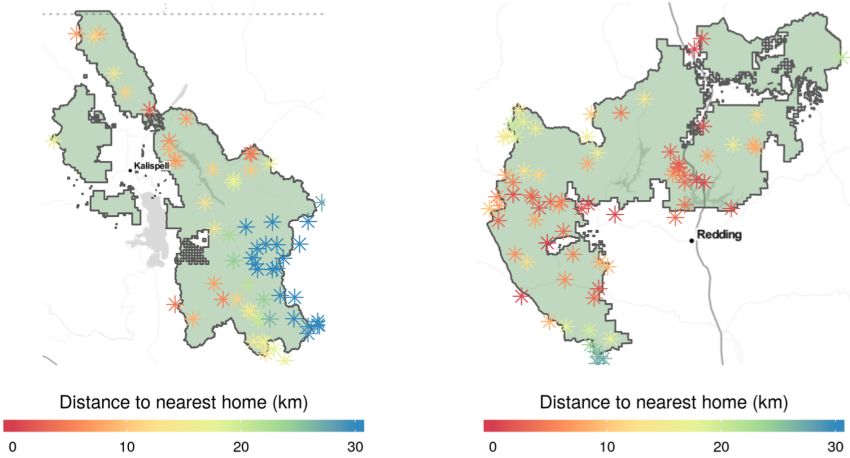
Source of identifying variation

Basic idea to identify the prior regression:

- many fires occur within the same forest and general time period
- some occur in locations close to houses, and some don't

focus on this narrower comparison $\hookrightarrow$

Ignition locations



Notes: Each panel shows a single national forest area in green. Stars show individual wildfires colored by distance from ignition point to nearest home (top-coded at 30 km). Left map is Flathead National Forest (Montana); right map is Shasta Trinity National Forest (California).

Specifying distance

Baseline specification for g is a step function that takes on a different value for each of five distance bins:

- 0–10 km
- 10–20 km
- 20–30 km
- 30–40 km
- 40+ km

In the next slide, we will see results that give the value of g relative to the 0–10 km case $\hookrightarrow$

Proximity and firefighting costs

Table 1: The Effect of Proximity to Homes on Firefighting Costs

	(1)	(2)	(3)	(4)	(5)
Distance to Homes (km)					
10–20	-0.34	-0.34	-0.42	-0.38	-0.46
	(0.15)	(0.15)	(0.19)	(0.21)	(0.32)
20–30	-0.97	-0.90	-1.00	-0.97	-1.52
	(0.28)	(0.27)	(0.37)	(0.34)	(0.57)
30–40	-1.73	-1.66	-1.67	-1.72	-2.50
	(0.46)	(0.45)	(0.51)	(0.50)	(0.73)
40+	-2.09	-2.03	-1.93	-2.11	-2.21
	(0.41)	(0.38)	(0.46)	(0.45)	(0.91)
Controls for Weather, Topography, and Vegetation		X	X	X	X
National Forest FE	X	X	X	X	X
Year by State FE	X	X		X	X
Month-of-Year by State FE	X	X		X	X
Month-of-Sample by State FE			X		
Lightning fires only				X	
Timber Fuels only					X
Fires	2,089	2,089	2,089	1,470	772
R^2	0.42	0.43	0.54	0.45	0.58

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Robust to different controls

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Robust to source of fire

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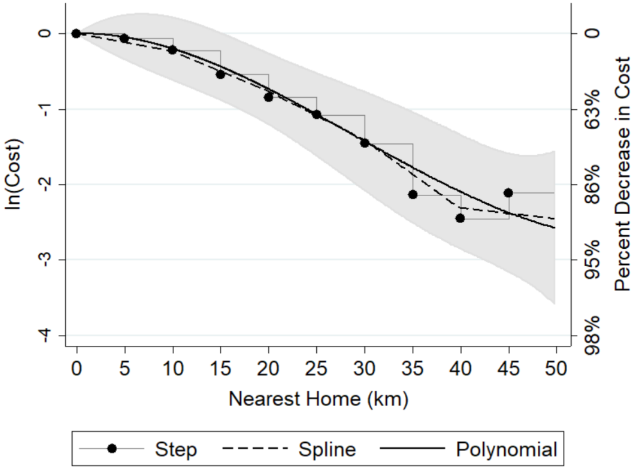
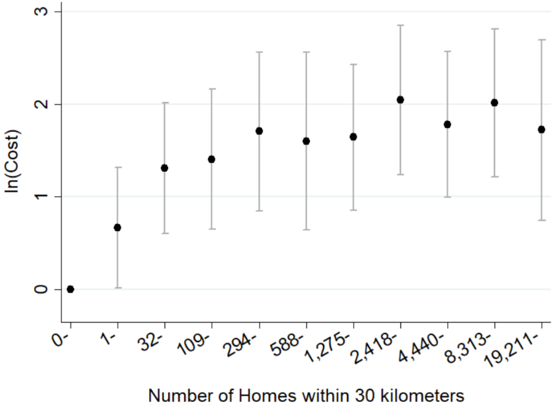
Robust to more flexible function g

Figure 3: The Effect of Homes on Firefighting Costs



Costs also depend on the number of homes

Figure 4: Non-linear Effects of the Number of Nearby Homes



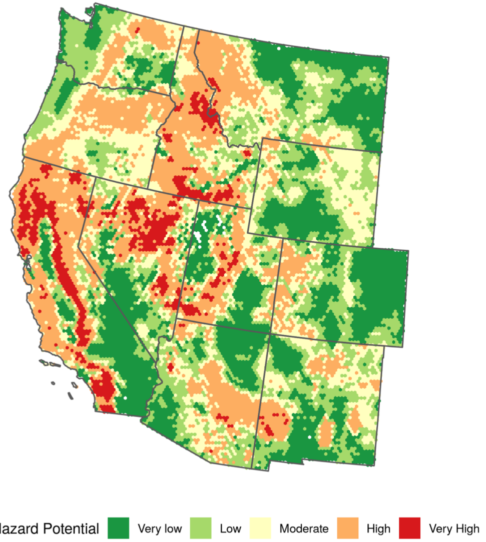
Notes: Figure shows point estimates and 95% confidence intervals from a regression of log firefighting cost on deciles of home counts within 30 kilometers of the fire's ignition point. The regression includes national forest fixed effects, state by month-of-year fixed effects, and state by year fixed effects. Standard errors are clustered by national forest.

Interpreting the estimates

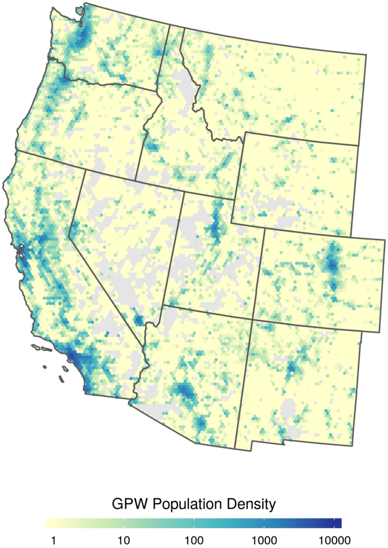
Next step: calculate implied subsidy $\hat{s} = pf/n$ for each home, using

- these estimated coefficients
- map of fire risk
- map of homes (8.6 million homes near wildland; 44% of all western US homes)

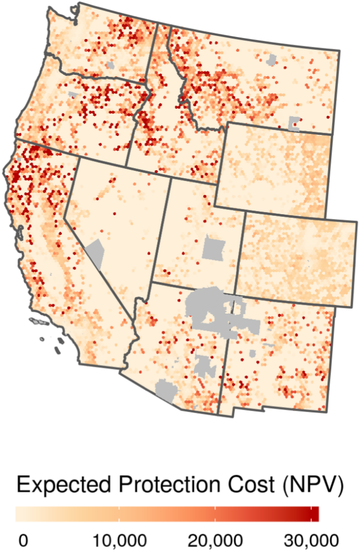
1. Fire risk


Wildfire Hazard Potential
Very low
Low
Moderate
High
Very High

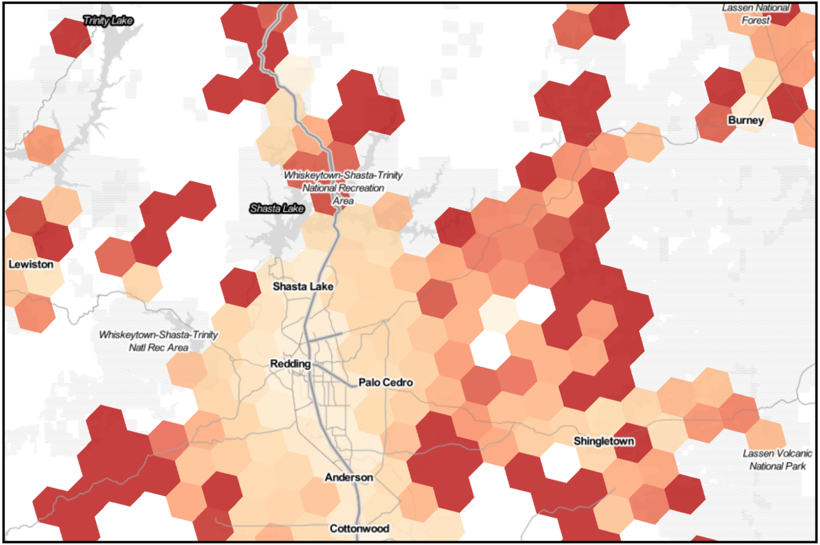
2. Population density



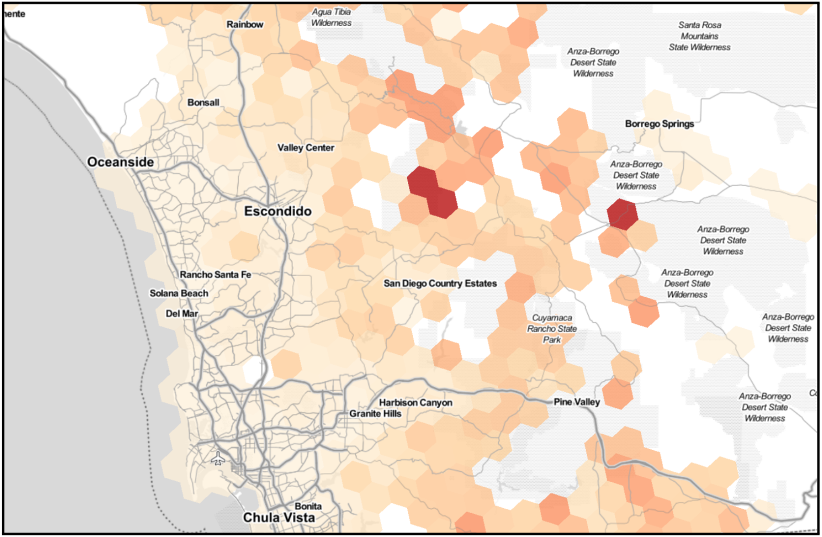
Expected protection costs



Local variation, Shasta County

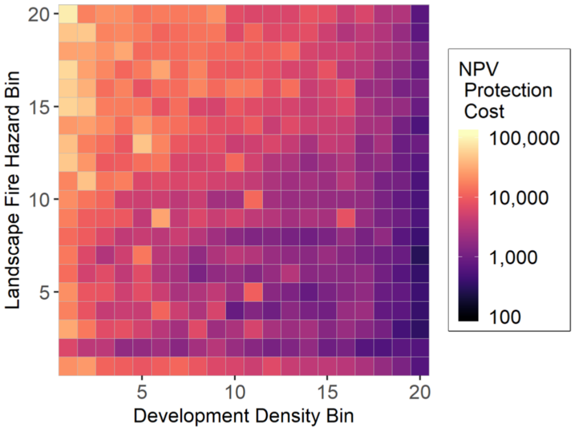


Local variation, San Diego County



Expected protection costs

Figure 5: Average Historical Protection Costs for 8.6 Million W.U.I. Homes



Notes: Figure shows average NPV of historical protection costs in each cell. The 20 horizontal-axis bins are defined by the grid cell-level distribution of population density. The 20 vertical-axis bins are defined by wildfire hazard potential (Dillon 2015).

Expected protection costs

Table 2: Expected Protection Costs for 8.6 Million Western Homes

	(1) **Federal Suppression Only ($)**	(2) **Suppression Plus ($)**	(3) **California Only ($)**	(4) **Share of Property Value (%)**
Mean	1,077	2,408	2,712	1.6
p50	500	1,200	1,300	0.6
p90	2,100	5,200	6,600	3.6
p95	3,800	8,400	9,000	5.5
p99	12,700	22,700	18,200	19.6
N	8,633,554	8,633,554	3,483,715	8,633,554

Notes: This table describes the distribution of expected firefighting costs for homes in the western United States.

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Drawing things together

Suppose that p_h is the initial price of housing. We have an estimate,

$$\hat{s} = p\frac{f}{n},$$

of the expected protection cost.

Suppose the long-run price elasticity of demand for new housing is $\eta = -1$.

Then the counterfactual percentage increase in housing **without** the subsidy is

$$\underbrace{\frac{n' - n^0}{n^0}}_{\%\uparrow \text{ housing}} \approx \eta \cdot \underbrace{\frac{-\hat{s}}{p_h + \hat{s}}}_{\%\downarrow \text{ price}}.$$

Moral hazard

Table 3: Implied Changes in Housing Quantity

Wildfire Hazard Class	Density Group	Subsidy as % of Observed Price	Observed Number of of Homes	% Increase in Quantity Due to Subsidy
Panel A. Highest Risk Areas				
5	0	36.2	11,331	26.6
4	0	21.9	28,118	18.0
1–3	0	15.9	111,713	13.7
5	1	13.5	15,019	11.9
4	1	11.0	31,968	9.9
1–3	1	6.1	154,463	5.7
5	2	5.8	26,010	5.5
4	2	7.0	60,453	6.5
1–3	2	4.0	265,348	3.8

Next time

After Thanksgiving, we will discuss innovation, renewable energy, and electric vehicles.