Wildfire Hazards: An Analysis of Duration, Cost, and Size

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Motivation

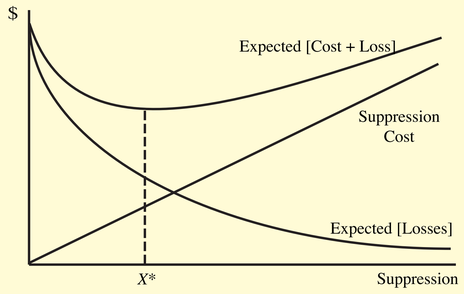
- Wildfire suppression expenditures have exceeded $2 billion per year over past decade
- Better understanding of suppression behavior over the course of a fire leads to more efficient wildfire management
- Wildfire often studied as a set of single outcomes (i.e., cost and size), neglecting the allocation decisions within a fire that drive those outcomes

Objectives of Study

- Develop a theory of wildfire suppression and to motivate the empirical hazard model
- Estimate joint hazard (frailty) model that accounts for correlation in three wildfire outcomes: duration, total cost, and final fire size

Theory of Wildfire Suppression

The wildfire management team chooses suppression effort to minimize suppression costs and losses to values at risk over the course of the fire.



Theory *cont.*

- Managers face tradeoff between two forms of suppression effort: 1) designed to mitigate overall fire growth and 2) protect values at risk
- Fires fought in a dynamic uncertain environment where managers accrue information and revise action plan
- Fire managers may divert suppression effort from overall containment to protecting specific assets at the expense of fire duration, total cost, and size.

Hazard Framework

- Focused on the time (accumulation of cost or area) until a wildfire is contained
- **Hazard rate** $h(t|\mathbf{x})$ is the probability that a fire is contained in the next interval of time (cost, or area) conditional on not yet having be contained
- **Survival function** $S(t|\mathbf{x})$ represents the proportion of fires expected to last longer than time t conditional on variables $\mathbf{x}$
- Unobservable differences between fires arise from variation in management and geography and are allowed to be correlated across fire outcomes duration, cost, size

Data

- Wildfire data from incident status reports filed by firefighters intermittently throughout the course of a fire. U.S. fires from 2001 to 2008.
- Housing data from 2010 U.S. Census

Results

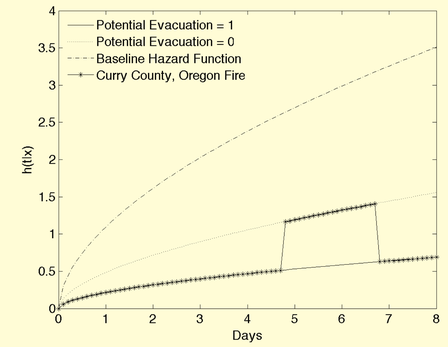
The percent effect of one unit change in covariate on the baseline hazard rate. Lower hazard implies larger expected outcome.[a]

Covariate (units/baseline)	Duration	Cost	Area
Threatened OutBuildings (1000s of Structures)	-36.80	-79.68*	-96.59***
Threatened Residential (1000s of Structures)	-58.42***	-87.14***	-89.49***
Potential Evacuation (No Evacuation)	-55.42***	-76.66***	-79.81***
Home Value <20 mi. ($ Billions)	-0.28**	-0.30*	-0.34***
Fatalities	-21.79***	-26.88***	-22.65**
Wind (100 mph)	-5.56	-16.82	-89.54***
Resource Scarcity (100,000 Acres)	0.00	-0.06**	-0.15***
Cause Lightning (Human)	-52.66***	-17.28***	-37.24***
Year (2001=0)	-4.09***	-2.70*	-2.07**
Washington & Oregon (Southern US)	15.90	-52.59***	-23.72*
California (Southern US)	99.84***	-55.42***	11.09

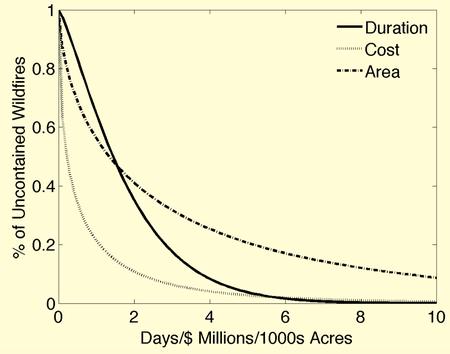
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$; 10,321 observations on 3,829 fires

[a] For example, when 1000 residential structures become threatened, the duration hazard of containment falls by 58% which implies a longer expected duration.

Duration Hazard Function



Survival Functions



- Increased values at risk (i.e., evacuation) reduce the hazard rate and imply longer, larger, and more costly expected fires consistent with theory.
- Resource Scarcity is aggregate fire activity in a region over the monthly average (instrument for opportunity cost). Higher resource scarcity implies larger and more expensive fires.
- California fires cost more despite shorter and smaller fires relative to those in the Southern U.S. Result likely due to high density of high value homes.
- Model may be integrated with tools currently used to predict wildfire spread to provide probabilistic information on economic outcomes

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