Statistical evidence of fire prevention efficacy from Florida

Jeff Prestemon, USFS-SRS

David T. Butry, NIST

Karen Abt, USFS-SRS

Ronda Sutphen, Florida Division of Forestry

Acknowledgements

- Florida Division of Forestry
  - Special thanks to Ronda Sutphen for:
    - The fire data
    - The prevention data
- National Institute of Standards and Technology
- Forest Service-National Fire Plan

Context

- Wildfire management is
  - Proactive
    - Fuels management
    - Fire prevention
    - Defensible space
  - Reactive
    - Suppression
    - Rehab and Recovery
- Most fires are stopped within hours of starting
  - But how many are prevented?
  - What are effective ways to prevent them?
  - Preventing fires in times and places where expected damages would be highest would be preferred.
  - How does prevention fit within the broader context of fire management?

Theory of Fire Management

- Cost Plus Loss Model

$$\min W = \mathbf{w}'\mathbf{x}(\mathbf{z}) + \mathbf{p}'\mathbf{v}(\mathbf{z}, \mathbf{x}, \mathbf{y})$$

- Where:
- $\mathbf{w}$ = input prices
- $\mathbf{x}$ = input quantities (prevention, fuels management, suppression, rehab)
- $\mathbf{z}$ = non-management variables affecting fire output,
- $\mathbf{p}$ = prices of values at risk
- $\mathbf{v}$ = quantities of values lost
- $\mathbf{y}$ = non-fire variables affecting the quantity of values at risk

Theory of Fire Management

- Cost + Loss can be applied to
  - A single fire
  - All fires in a landscape in a fire season (or shorter)
  - All fires in a landscape in the long-run
- Fire input variables operate at differing spatial and temporal scales, and there are feed-backs
  - Prevention for a landscape for a time (more on this later)
  - Fuels management for a landscape in multiple years
  - Suppression for a fire or set of fires
  - Rehabilitation for a fire or a set of fires

Theory of Fire Prevention

- Definition: A reduction in fire starts through positive steps taken by people
- May or may not include arson (depends)
- Occurs through:
  - Education
    - Media, public meetings, school programs
  - Burn bans
    - e.g., announcements of red-flag warnings
  - Technology development
    - e.g., spark arrestors on trains, powerline equipment improvements
  - Law enforcement or other patrols, maybe

Theory of Fire Prevention

- Prevention:
  - Reduces the number of fire ignitions in the current period (hence, reducing suppression, rehabilitation)
  - May only prevent certain kinds of fires from occurring in the current period
  - May affect future fire ignitions (hence resources devoted to suppression and rehab)
  - Operates at uncertain or variable temporal and spatial scales

Fire Types

Type of Fire	Affected by Education?	Type of Fire	Affected by Education?
Incendiary (Arson)		Fire Use (Debris, Trash, Slash, Grass, etc.)	X
Prescribed fire escapes		Campfires	X
Equipment (Vehicles, Powerlines, etc.)		Children	X
Railroad		Smoking	X
Lightning		Others	X

Theory of Fire Prevention

- Effectiveness of Prevention Depends on:
  - Biophysical variables
    - Fuels
    - Weather
  - Societal variables
    - Size of population
    - Economic activity
    - Demographics
  - Fire prevention efforts
    - Decay rates of awareness and learning

Relative Effectiveness 4.0

A nationwide survey (1995) was conducted to determine the relative effectiveness of fire prevention activities. The following table shows the results of the survey. The table indicates the relative effectiveness of prevention activities when applied to a specific fire cause.

H = Fire prevention activity highly effective
M = Fire prevention activity moderately effective
L = Fire prevention activity less effective

	Campfire	Children	Fire Use	Equipment Use	Incendiary	Misc	Railroad	Smoking
Education - Target Specific	H	H	H	M	M	M	M	M
Education - General	M	M	M	M	L	M	L	M
Patrol	H	M	M	M	M	M	M	M
Public Contact-Individual	H	H	H	H	M	M	M	M
Public Contact - Groups	H	H	M	M	M	M	M	M
Signs	M	M	M	M	L	M	L	M
Inspections - Dispersed	M	M	M	M	L	M	M	M
Inspections - Site Specific	H	L	H	H	L	M	H	L
Engineering	M	L	M	M	L	M	M	L
Enforcement	H	M	H	H	M	M	M	M
Administration	M	M	M	M	L	L	M	L

Source: National Wildfire Coordinating Group. 1998. *Wildfire Prevention Strategies*. USDA/DOI/NASF. Available at http://www.nwcg.gov/pms/docs/wfprevnttrat.pdf

Theory of Fire Prevention

- Econometric Specification

$$N_{c,i,t} = f(\mathbf{z}_{1i,t}, \mathbf{h}_{i,t-j}, \mathbf{e}_{i,t-k}, \mathbf{x}_{1i,t-m})$$

- Where
  - $N_{c,i,t}$ = Number of fires of cause c in location i in period t
  - $\mathbf{z} = (\mathbf{h},\mathbf{z}_1)$ from before
  - $\mathbf{z}_{1i,t}$ = biophysical variables affecting ignition rates in location i in period t
  - $\mathbf{h}_{i,t\text{-}j}$ = societal variables affecting ignition rates in location i in periods t to $(t - j)$
  - $\mathbf{x} = (\mathbf{e},\mathbf{x}_1)$
  - $\mathbf{e}_{i,t\text{-}k}$ = fire prevention efforts in location i in periods t to $(t - k)$
  - $\mathbf{x}_{1i,t\text{-}m}$ = other fire management inputs in location i in periods t to $(t - m)$

Policy Questions: Prevention

- By preventing one kind of fire, are we affecting the expected damages from other kinds of fires in the future?
- How does prevention spending trade off with other fire management inputs?
- If a fire is prevented, does it matter?
  - Prevent only small fires?
  - Prevent only fires not likely to create large damages?

Policy Questions: Prevention Education

- What is the target population for education?
- How do media of different kinds differ in their contact rates with the target population?
- Given contact rates, how do different media affect behavior?
- What is the decay process in education?
- Does fire prevention education affect rates of preventable fires differently by fire cause?
- What is the spatial diffusion effect of media and prevention education?

Empirical Study: Florida

- Context
  - Florida has a high population, lots of fire, great data on fire prevention
    - Most fire is human-caused
    - About 30 or 40% of fires are “preventable” types
  - We have studied fire before in Florida
  - Florida has a highly developed fire prevention structure
- Objectives
  - Detect the effect of prevention education efforts, by type of effort
  - Identify the decay rates of prevention efforts
  - Evaluate whether it trades off with other kinds of fire management
  - Note: today, we have to pull back from some of these objectives, due to data constraints and modeling framework (spatial scale, trade offs with other inputs)

Empirical Study: Florida

- Unit of observation:
  - Number of fires of preventable causes in District or Region (i) by month (t)
  - Districts are multi-county
- Temporal window (approximate):
  - 2001 (July) – 2006 (April)
- Model type:
  - Panel Poisson model, with cross-section fixed effects

Empirical Model

- Fire Prevention District or Region fixed effects (6 spatial units)
- Three-month lags of prevention efforts
- No Instrumenting
  - Would be required in the case of current period prevention variables with prevention endogeneity
  - Avoids having efforts occur after fires within a month
  - There is a complicated nonparametric method, but not reported here
- Control variables included in the model
  - Weather variables (current, lagged)
    - Relative humidity, modified fire weather index, Keetch-Byram Drought Index
  - Population
  - Time trend
  - Year dummies

Empirical Model Prevention Variables

- Three Lags of Per Capita:
  - **Radio** contacts
  - **TV** contacts
  - **Print** contacts
  - **Homes** visited
  - **Brochures** distributed
  - **Hazard assessments** done
  - **School presentations** given
  - **Billboards** in place (statewide, post-2004 hurricane season only)
  - **Movie theater PSA’s** (statewide, post-2004 hurricane season only)
- **Six and 12-Month Lags of Police Per Capita**

Preventable Fire Causes Modeled

- Use Fire
- Children
- Campfire
- Smoking
- All four combined

Modeling Challenges

- Endogeneity of prevention variables
  - Preliminary tests seem to not reject exogeneity
  - Ideally, estimate a I.V. Panel Poisson; but methods to estimate have limitations

- Lack of spatial specificity
  - Multi-county Districts
  - Multi-District Regions
  - Spatial overlap of prevention effects

- Lack of temporal specificity
  - Month unit is not perfect

- Lots of potential regressors
  - Could break up districts into counties and model at the county level
  - Need to decide what's important
  - Regressors are correlated but usually *not highly* correlated (TV & Print, Radio & Print are exceptions some places)
  - Could precede the analysis with principal components

Results

- All weather variables and other control variables generally highly significant
  - Weather is a primary driver of preventable fire types
- Prevention variables are broadly significant and negatively signed
  - Varies by lag, however
  - Some lags even positively signed

Control Variables

Control Variable	Sign if Significant	Short-Run* Net** Elasticity (2000-2005)
Relative Humidity	Neg.	-11.40
Modified Fire Weather Index	Variable	-1.80
Keetch-Byram Drought Index	Variable	0.86
Year dummies (2001-2004)	Neg.	
Trend	Neg.	-3.00
Population	n.s.	

* “Short-Run” because of long-run feedback in area burned

** “Net” means sum of current and all lagged effects.

Prevention Variables

Prevention Variable	Sign if Significant	Short-Run* Net** Elasticity at Means
Police	Neg.	-11.11
TV PSAs	Neg.	-0.01
Radio PSAs	Pos.	0.19
Print PSAs	Neg.	-0.15
Presentations	Neg.	-0.04
Billboards	Neg.	-0.01
Movie Theater PSAs	Neg.	-0.01
Homes visited	Neg.	-0.20
Hazard assessments	Neg.	-0.06
Brochures		Not significant

* “Short-Run” because of long-run feedback in area burned

** “Net” means sum of current and all lagged effects.

Sensitivity Analyses

Change in All Prevention Variables (Percent)	Change in Number of Fires*	Short-Run Change in Economic Losses** ($ Million)
+ 10	-33	-1.58
+ 50	-142	-6.86
+ 100	-240	-11.64
- 50	209	10.14
-100	2,545	123.30

* Total Number of Non-Federal Preventable Fires/Year, 2000 to 2005: 1,247

* Total Number of Non-Federal Wildfires/Year, 2000 to 2005: 22,169

** Based on an average fire size: 38 acres, average loss per acre (Mercer et al. 2007): $1,012 (1994), $1,267 (2005)

*** Long-run impacts might be about one-third these levels…

Discussion

- Prevention appears to work
  - Elasticities are small
  - Benefits in losses averted are very high
- Rough economic calculations shows scale of benefits
  - Some methods appear more effective
  - Face-to-face contacts appear to be most effective
  - We still are ignoring other accidental fire types
- State B/C Ratio:
  - State spent about $0.6 million/year, 2000-2005
  - Losses averted are $123m/year in the short-run and $45m/year long run
  - Long-run B/C Ratio = 45/0.6 = 75

Discussion

- Models suffer from many complications
  - County-level analyses may resolve some problems from spatial specificity
  - Explicit spatial modeling could help
- Improved models could arise by
  - Including other fuel management efforts
  - Comprehending how aggregate economic activities affect accidental fires
- Needs further development to quantify the long-run impacts