Applying Program Evaluation Methods to Natural Resource Policy: Are Current Wildfire Mitigation Programs Effective?

David T. Butry[1], Subhrendu K. Pattanayak[2], Erin O. Sills[3], and D. Evan Mercer[4]

[1]Economist, NIST; [2]Fellow, RTI International and Research Associate Professor, North Carolina State University; [3]Associate Professor, North Carolina State University; [4]Research Economist, USDA Forest Service

Talk Outline

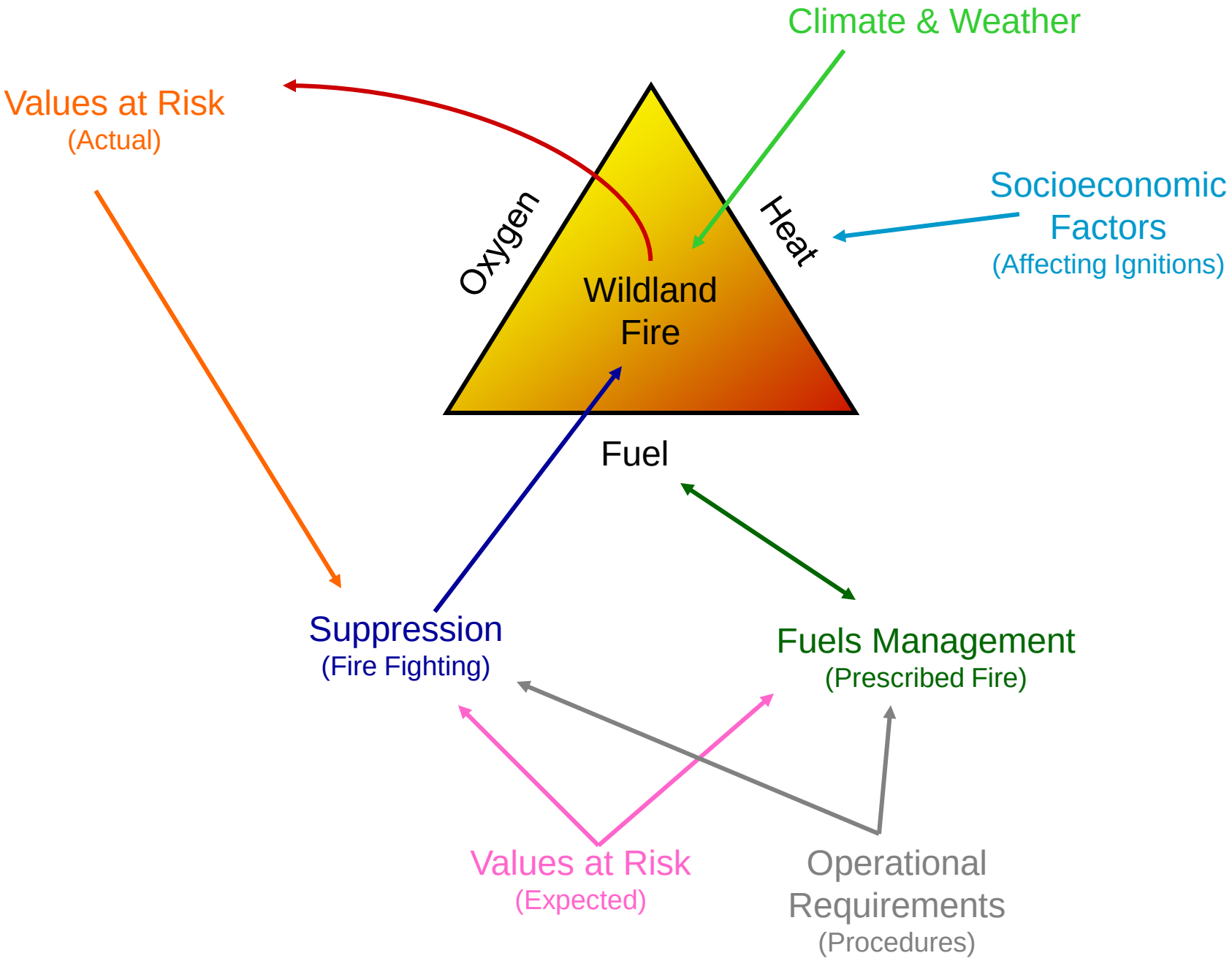
- Introduction
  - Wildfire in the US
- Program Evaluation Econometrics
  - Issues of Endogeneity
  - Lack of natural resource applications
- Case Study: NE Florida
  - Rapid response and prescribed burning
  - Propensity score matching model
- Conclusions and Discussion

Wildfire

- Between 1994-2004, over $830 million annually in wildfire suppression (Federal)
- Over 1.4 million acres are prescribed burned per year (1995-2000 yearly average) (Federal)
- Still wildfire burn more than 5.2 million acres a year (1994-2004)
- Is wildfire management doing enough?
  - Little research quantifies the returns to fire fighting and fuels management

Wildfire Economics

- Understanding tradeoffs
  - Optimal amount of wildfire
  - Optimal mix of wildfire mitigation strategies
- Economic framework
  - Minimize fire damage plus mitigation cost
  - Maximize fire damage averted given mitigation cost
  - Wildfire production function??


Climate & Weather
Values at Risk
(Actual)
Socioeconomic
Factors
(Affecting Ignitions)
Oxygen
Heat
Wildland
Fire
Fuel
Suppression
(Fire Fighting)
Fuels Management
(Prescribed Fire)
Values at Risk
(Expected)
Operational
Requirements
(Procedures)

Wildfire Management

- Suppression
  - Rapid response
- Prescribed Fire
  - Intentionally set, low intensity fires administered under ideal weather conditions by trained specialists
- Intended effect of management
  - To limit fire spread and intensity

Potential Endogeneity of Wildfire Management

- Fuels Management—*selection*
  - Factors that influence wildfire behavior also influence placement and intensity of fuels management
  - Some of these factors may be unobserved
- Suppression—*simultaneity (and selection)*
  - Fire fighting response and effort influenced by wildfire behavior,
  - Wildfire behavior influenced by fire fighting

Program Evaluation Econometrics

- Focuses on establishing causality for endogenous treatment
- Program evaluation isolates the causal effect of a program/treatment
  - Natural experiments
  - Instrumental variables (IV) and control functions
  - Matching (e.g. with propensity scores, or PSM)
- Most commonly applied to social policies
- Little or no application to resource policies

Program Evaluation & Natural Resource Applications

- Edmonds 2002 - IV and matching – community organizations on fuelwood extraction in Nepal
- Pattanayak 2004 – PSM - disturbance on forest amenities
- Ferraro et al. 2005 – PSM – ESA on species recovery
- Somanathan et al. 2005 – PSM – decentralized management on forest cover

Program Evaluation Econometric Methods

- Instrumental Variables
  - Proxy endogenous program/treatment variable with exogenous instrument(s)
- Control Functions
  - Controls for endogeneity by modeling treatment (selection) as a function of observable data
- Propensity Score Matching
  - Matches treated observations with "like" untreated observations, identified by equivalent propensity scores
  - Propensity score estimated as the probability of treatment using all variables that directly influence treatment *and* treatment outcome

Propensity Score Matching

- Estimate propensity score
  - Propensity score is the estimated probability of a wildfire receiving management
  - Function of variables that directly affect management and also directly affect wildfire production
- Match wildfires based on their propensity score
  - Matched wildfires have similar probability of being managed
  - Thus, matched wildfires have no underlying differences, except management status
- The difference between matched wildfires is the management effect
  - The average effect (over all managed wildfires) is consistent

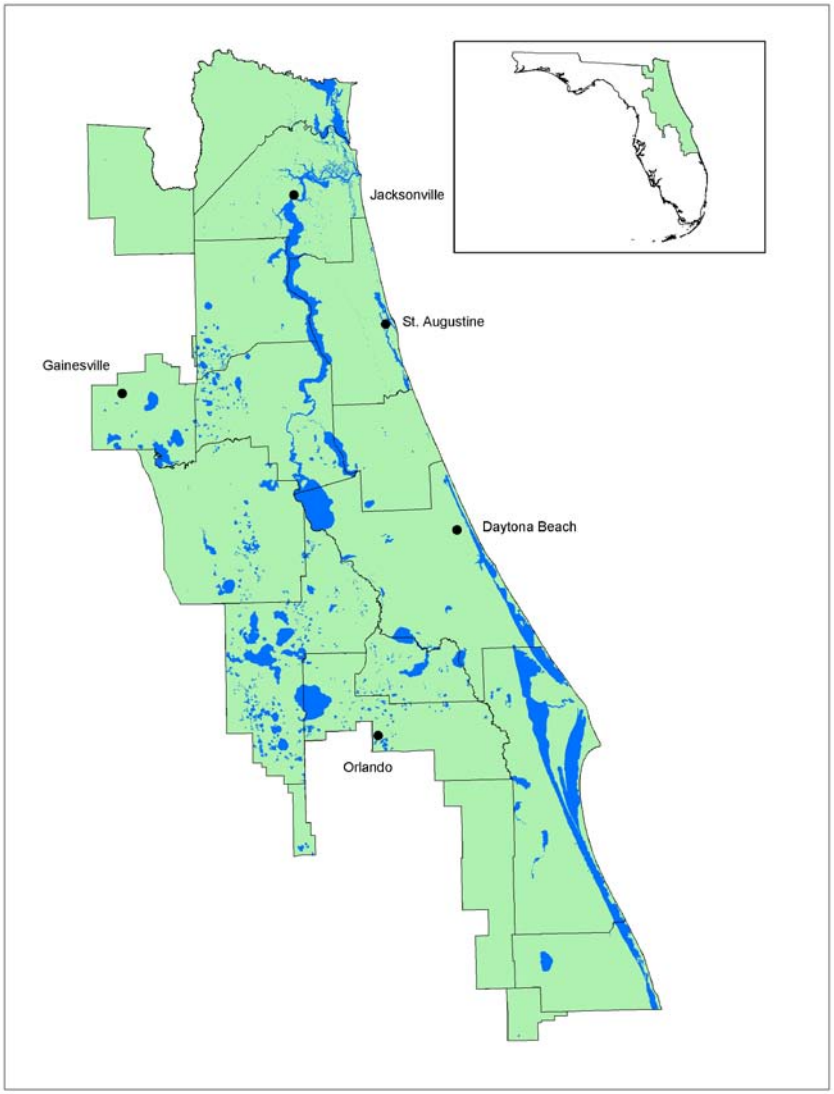
Case Study—St. Johns River Water Management District (SJRWMD), Florida

SJRWMD 1996-2001

Wildfire
7490 ignitions

502,754 acres burned

Prescribed Fire
73,099 for hazard reduction



Estimation Objectives

- Quantify the effectiveness of management (treatment) on wildfire behavior (outcome)

  Treatment

  - Rapid Suppression Response

    A rapid response is when fire report time to fire crew arrival is an hour or less

  - Prescribed Fire

    If the landscape had been treated with prescribed fire within the last three years prior to the wildfire

  Outcome

  - Wildfire behavior

    Measured as intensity-weighted acres burned

- Compare OLS estimates to propensity score matching methods

Data Sources

- FL Dept. of Forestry
  - Wildfire
  - Management
- NOAA & NCDC
  - Climate and Weather
- Census TIGER/Line & NLCD
  - Landscape Characteristics

Data

Wildfire Management (**X**Management): rapid suppression response indicator, previous prescribed fire indicator.

Fire Characteristics ($\mathbf{X}_{\text{Fire Characteristics}}$): ignition cause, fire year, fire month, use fire indicator, and report time.

Climate and Weather ($\mathbf{X}_{\text{Climate and Weather}}$): measures of the Niño3 sea-surface Pacific ocean temperature, Keetch-Byram Drought Index, humidity, spread index, wind speed, and wind direction indicators.

Landscape Characteristics ($\mathbf{X}_{\text{Landscape}}$): forest density, proportion of landscape in upland forest, vegetation build-up, elevation, slope, fuel type indicators, latitude, longitude, wildfire history, fire district indicator, and county indicators.

Socioeconomic Factors ($\mathbf{Z}_{\text{Socioeconomic}}$): population, percent of landscape in residential, distance to nearest school, hospital, and fire department, and population living in a nursing home.

Ordinary Least Square Model

$$\ln(\mathbf{w}) = f_w(\mathbf{X}_{\text{Management}}, \mathbf{X}_{\text{Fire Characteristics}}, \mathbf{X}_{\text{Climate and Weather}}, \mathbf{X}_{\text{Landscape}}, \mathbf{X}_{\text{FireHistory}}, \boldsymbol{\varepsilon}_{\text{OLS}})$$

Propensity Score Estimators

Rapid Suppression Response Estimator (probit model)

$$\mathbf{s} = f_s^{psm}\left(\mathbf{X}_{\text{Fire Characteristics}}, \mathbf{X}_{\text{Climate and Weather}}, \mathbf{X}_{\text{Landscape}}, \boldsymbol{\varepsilon}_s^{psm}\right)$$

Prescribed Fire Estimator (probit model)

$$\mathbf{p} = f_p^{psm}\left(\mathbf{X}_{\text{Landscape}}, \mathbf{Z}_{\text{Socioeconomic}}, \mathbf{Z}^{p}_{\text{Management}}, \mathbf{Z}_{\text{Weather}}, \boldsymbol{\varepsilon}_p^{psm}\right)$$

A kernel matching was used to weight the best potential matches

Results—Ordinary Least Squares

- Model highly significant
- $R^2 = 0.13$
- N=7490, K=81
- Suppression parameter significant (5% level) and negative
- Prescribed fire parameter insignificant (5% level)

Results—Propensity Score Matching

- Both propensity score estimator models are highly significant
- "Good matches" exist
- Conditional mean impact negative for both suppression and prescribed fire
- Standard errors generated from bootstrapping the PSM kernel estimator shows significance at 1-5%

Average Effect of Wildfire Management on Wildfire Intensity-Acres (kW-acres/meters)

Wildfire Management	Treated	Control	Treatment Effect
Suppression			
Means	322	723	-401
OLS	337	546	-210
PSM	325	500	-175
Prescribed Fire			
Means	286	366	-80
OLS*	520	546	-26
PSM	286	367	-81

**insignificant*

Summary of Results

- Wildfire management has a significant impact on wildfire behavior
  - Rapid suppression response yields a 35% reduction in wildfire intensity-acres
  - Prescribed fire yields a 22% reduction in wildfire intensity-acres
    - For prescribe fire, OLS does not find statistical relationship impact
- OLS overestimates the effectiveness of suppression compared to PSM estimates

Discussion

- Estimated results suggest huge benefits
  - 1998 one of the worst fire years in SJRWMD
  - Damage approximately $325 million
  - Estimated reduction in wildfire intensity-acres suggests $140 million in damages were avoided
- OLS estimates would overvalue wildfire management's effectiveness