Economic Impacts of Fire and Fire Management

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How do Wildfires Impact Society?

- Cause human deaths, injuries
- Damage and destroy structures
  - Buildings
  - Roads
  - Power lines
- Disrupt local economies
  - E.g., evacuations which reduce economic activity
- Burn up valuable resources (e.g., timber)
- Negatively affect things not traded in markets

Large Fires Do Most Of The Damage

- The Forest Service keeps about 98% of wildfires in the “small” category
- Remaining fires can be hugely damaging, average thousands of acres
- Here are some examples…

Examples

- Oakland Hills Fire of 1991
  - 3,354 homes, 437 apartment units
  - 25 deaths, 150 injuries
  - $1.6 billion in damages

- Florida Wildfires complex of 1998:
  - $0.6 billion in damages
  - hundreds of homes burned,
  - 207,000 hectares

- Bitterroot Fires of 2000
  - 127,000 hectares
  - $8 million in timber losses
  - Large scale evacuations

- Biscuit Fire of 2002
  - 206,000 hectares
  - $80 million in timber losses

Examples (Continued)

- Hayman Fire of 2002
  - 57,000 hectares
  - Over $40 million in economic losses

- Cedar Fire of 2003
  - 107,000 hectares
  - 2,232 houses destroyed
  - 15 deaths

- Old + Padua + Grand Prix Fire Complex of 2003
  - 310,000 hectares
  - 7 deaths (Old Fire), 32 injuries (Grand Prix Fire)

- Station Fire of 2009
  - 89 houses destroyed
  - 65,000 hectares
  - 2 deaths

Society Responds to Wildfires

- Put them out
  - Spend over $1 billion in actively suppressing them each year on public lands
  - $1 billion/yr on national forests from 2000-2009
- Develop an infrastructure of wildfire suppression
- Reduce flammable vegetation
- Encourage people to do things that reduce vulnerabilities (e.g., create defensible space)
- Teach people how to not accidentally start fires
- Go after and deter people who intentionally start wildfires
- “Clean up” after fires (post-fire activities)

An Economic Approach

- Some Definitions:
  - Losses: The economic value of the damages
  - Benefits: Possibly the economic value of the “good things” deriving from wildfire
  - Net Value Change = Losses – Benefits
  - Costs: Expenses of doing things to limit wildfire losses or net value change
- Since at least Headley (1916), fire managers have often sought to balance costs and losses.

Optimal Wildfire Management

- In economic optimization:
  - Minimize Costs + Losses, or…
  - Minimize Costs + Net Value Change, or…
  - Other objectives?

- This calculus can operate on:
  - A single fire
  - A group of fires in a limited time frame (e.g., over a fire season, across a national forest)
  - All fires in a spatial unit over the long-run

- Questions of the scope of managerial responsibility and equity emerge:
  - Whose resources and property and lives?
  - Whose fire management actions and expenditures?

The Math

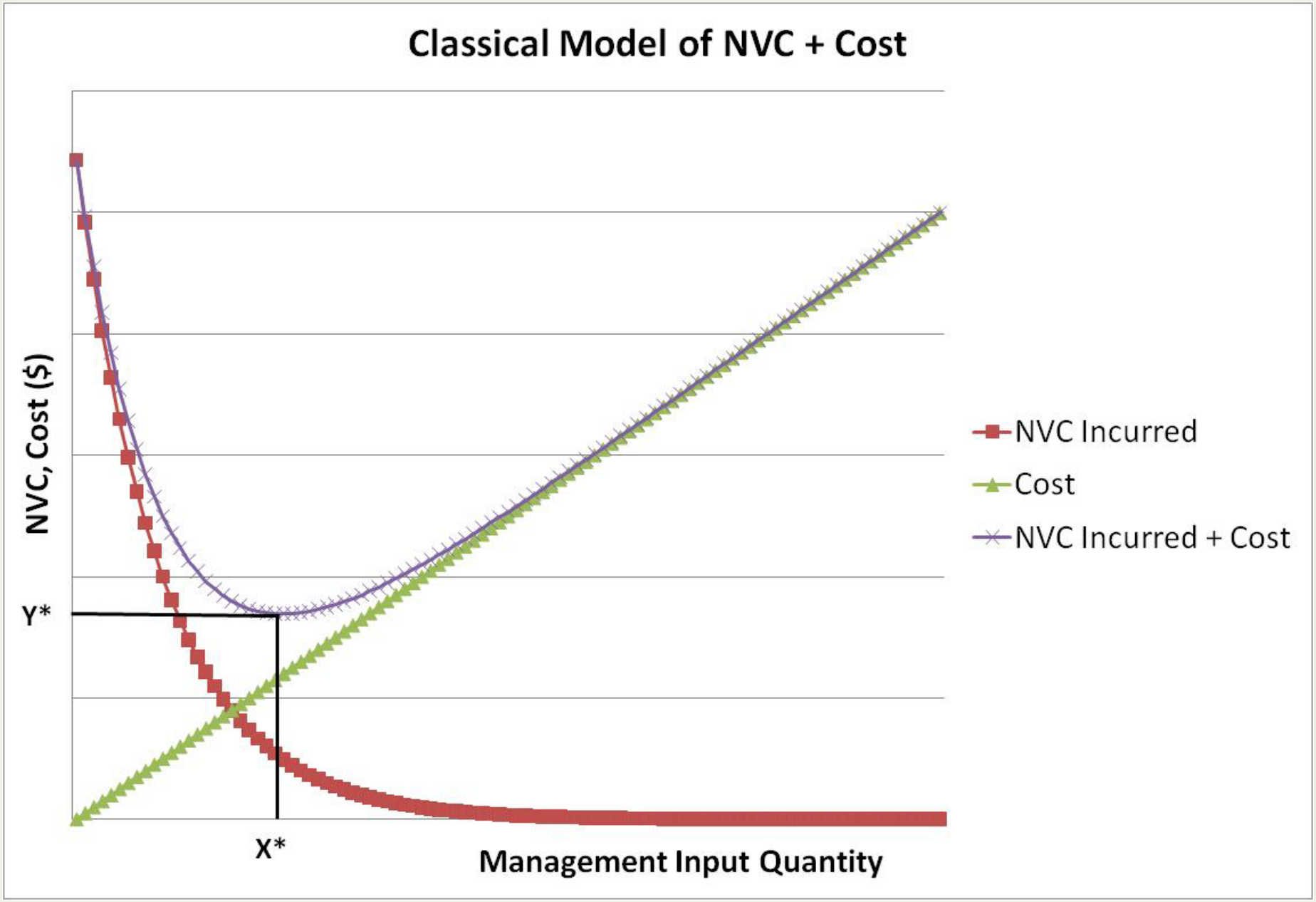
$$\min_{\mathbf{x}(T)} E(V) = \sum_{i=1}^{I} \sum_{t=0}^{T} e^{-rt} [\, p_t y_{i,t}(\mathbf{x}_{i,t-j}) + \mathbf{w}_t^{'} \mathbf{x}_{i,t} + \varepsilon_{it} \,]$$

This minimizes the expected value of NVC + Costs in the long run [from year *t*= 0 to *t*=*T*, over all spatial units (*i*=1 to *i*=I)].

p is the net value change per unit of wildfire
y is the quantity units of wildfire
w is the price per unit of fire management inputs
x is the quantity units of fire management inputs
e is the exponential operator
r is the discount rate
ε is a prediction error

Take Home From Math

- The optimal quantity of fire management input:
  - The quantity that minimizes the sum of their costs plus net value change from wildfire
- There is a “dual” to this problem:
  - Maximize the sum of net value change averted minus management costs (get the same answer)
- The true optimization is multidimensional:
  - Many possible inputs, and it may vary over time


Classical Model of NVC + Cost
NVC, Cost ($)
Y*
X*
Management Input Quantity
NVC Incurred
Cost
NVC Incurred + Cost

Wildfire Fuel Treatment

- Wildfire consumes fuel, which affects fire in the future and in other places
  - Considered one of the benefits of wildfire (Donovan and Brown 2005)
  - Could be quantified mathematically using statistics (ignoring location indicator, *i*):

$$y_t = f(\mathbf{Y}_{t-K}, \mathbf{X}_{t-J}, \mathbf{Z}_{t-M}) + \nu_t$$

Statistical Analysis

- Related wildfire area burned on national forests in year *t* to lags of wildfire area burned (*t-1* to *t-k*)
- Other variables:
  - PDSI
  - Ocean temperature and pressure indices
  - Time trend
  - Suppression *spending* on national forests in each region, nationally (endogenous variable, controlled for in the analysis)
  - No fuel treatment information (limited activity historically in the West)
- Methods:
  - Fixed effects time series cross-sectional panel (fixed effects are forests), instrumental variables to account for suppression spending
  - One panel for each of six western Regions of the Forest Service (Regions 1-6), and one with all Regions included in one panel.
- Data from 1972-2002
  - Data provided by Karen Abt
  - Updated data still in process

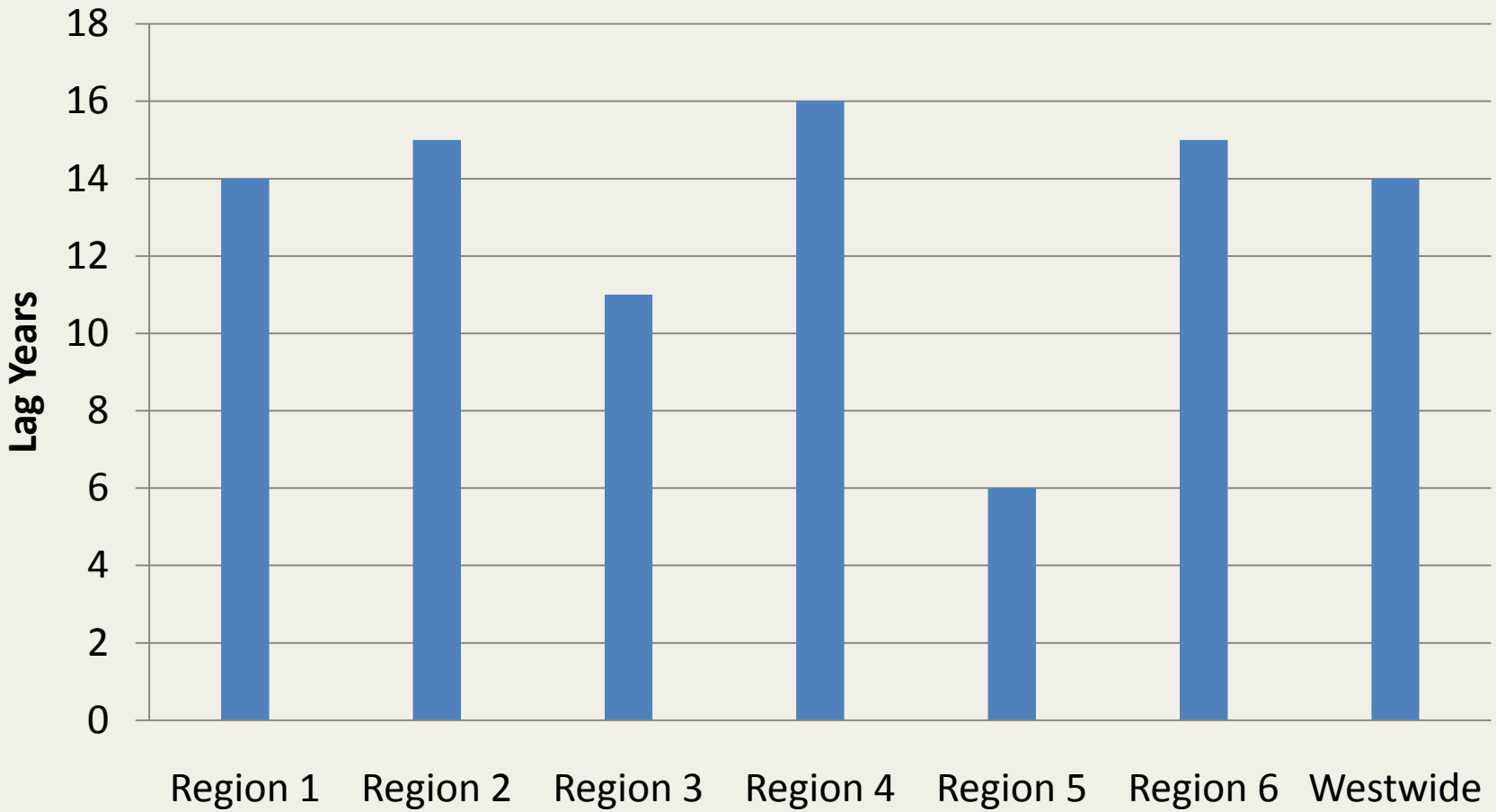
Forest Service Regions

Source: John Pye (2007)

Results of the Statistical Models

- All-regions national forest panel: 14 years of lagged wildfires significant, negative
  - A negative coefficient implies that past wildfire reduces current wildfire
  - Translation: Wildfire suppresses previous wildfire for 14 years, on average, so wildfire has a long-lasting fuel treatment benefit
- Varying lagged effects by region…

Fuel Treatment Effects of Wildfires



Notes: Region 2 may last 21 years, Region 3 has much uncertainty

Results of the Statistical Models (Continued)

- Suppression spending: not significant
  - Translation: lack of good instruments, no good information on suppression resources used at the national forest level
  - Reported results drop suppression spending as an imperfect measure, therefore assume constant effort per unit of wildfire
- Other findings
  - ENSO, PDO, NAO, Drought indices are drivers
  - May or may not be a time trend, depending on functional form, region
  - Population not significantly related, but it varied (+/-), collinear with a time trend in some cases

Lagged Wildfire Effect

- Long run effect of any management action on wildfire output is calculated as:

$$b_{j,LR} = \frac{b_j}{(1 - \sum_{k=1}^{K} a_k)}$$

Where:

$$y_t = a_0 + \sum_{k=1}^{K} a_k y_{t-k} + \sum_{j=1}^{J} b_j x_{j,t} + \sum_{m=1}^{M} c_m z_m$$

Long-run Feedback Effect

- Long-run feedback effect (*E*) of averting fire summarized by

$$E = 1 - [1/(1 - \sum_{k=1}^{K} a_k)]$$

- Statistical analysis shows an average feedback effect of:

$$E = 1 - [1/(1 - \sum_{k=1}^{14} a_k)] = 0.67$$

- Translation: 1 hectare of wildfire avoided through suppression or other management today will lead to 0.67 hectare of new wildfire in the future

Simulation of Suppression Net Benefits

- Research shows that economic losses from wildfire are highly variable
  - Butry et al. (2001): $1,000 per hectare timber, $1,300 per hectare non-timber in Florida = $2,300 per hectare total
  - Westwide national forest timberland (work in progress: $4,200 per hectare--ignores low-timber productivity forest, which is one-third)
    - $2,800 if we assume productive reserve has similar value, $1,400 if it does not
  - My Assumption in this research: $2,000 per hectare

- Research shows that suppression costs vary with fire size
  - "Small fires": $16,900 per hectare (1.8 ha)
  - "Large fires": $1,930 per hectare (2,340 ha) [Donovan et al. forthcoming)]
  - Large fires are 96% of area burned on national forests of the West

Simulation Set-Up (Continued)

- Sensitivity analysis on size of averted fires
  - Assume that all fires stopped in initial attack would have been some percent of the size of large wildfires:
    - 100% of size of those not stopped in initial attack (max)
    - 75%
    - 50%
    - 25%
    - 10% (min)
  - Lenihan et al. (2008) say we would have 8 times as much wildfire if we did not suppress them, consistent with 45% in the above range

- Varied the discount rate in losses and costs:
    - 2%
    - 4%
    - 7%

Benefits and Costs

- Benefits are the long-run losses averted, accounting for the feedback-effect, deflated to the present, using the discount rate
- Costs are the suppression costs from putting out wildfires, as observed
- B/C = The ratio of Total Benefits (NVC averted) to the Total Suppression Costs
- Short-run B/C (SR) = $C_t^{-1} B_t$
- Long-run B/C (LR) = $C_t^{-1} \sum_{t=t0}^{t0+K} B_t e^{-rt}$

Results of the Simulation

Size of Averted EA Fires	Short-run Benefits/Costs	Long-run Benefits/Costs, 2% Discount Rate	Long-run Benefits/Costs, 4% Discount Rate	Long-run Benefits/Costs, 7% Discount Rate
100%	38.0	15.1	17.4	20.3
75%	28.5	11.4	13.1	15.2
50%	19.0	7.6	8.7	10.1
25%	9.5	3.8	4.3	5.1
10%	3.8	1.5	1.7	2.0

- It appears that the long-run net benefits of suppression range from about 2 to about 20 on national forests of the western US

- Long-run B/C ratios are greater with higher discount rates because future losses are discounted more heavily

Summary of Findings

- Suppression spending is rising over time
- Higher spending might be partly connected to suppression effectiveness of the 1970's and 1980's
- Wildfires fuel treatment effects last an *average* of 14 years across western national forests, ranging from 6 to 16 years
- Wildfire fuel treatment effect means that fire management inputs have smaller long-run effects than short-run effects
- Accounting for wildfire fuel treatment effect, suppression still apparently pays off

Cautions and Caveats

- Not every hectare is worth “saving”
  - Great variability on landscapes for values at risk
  - Some places yield tremendous benefits from suppression, others do not
- Much uncertainty about the average value at risk (losses from wildfires)
- Could refine the analysis to smaller scales
  - E.g., by region

Implications

- Taking advantage of fuel treatment effects of wildfires is difficult
  - Human infrastructure depends on suppression
  - Public demands action on active forest fires
    - Evacuations
    - Smoke impacts
    - Fear
    - Esthetics/Place attachment impacts
- Other forms of management could help
  - Fire prevention education
    - Especially in places where human-caused fires predominate
    - Some ecosystems may have “too much” fire because of human starts
  - Fuels management, targeted
  - Human caused wildfire surveillance and prediction