A Cost-Effectiveness Analysis of Alternative Ozone Control Strategies: Flexible Nitrogen Oxide (NOx) Abatement from Power Plants in the Eastern United States

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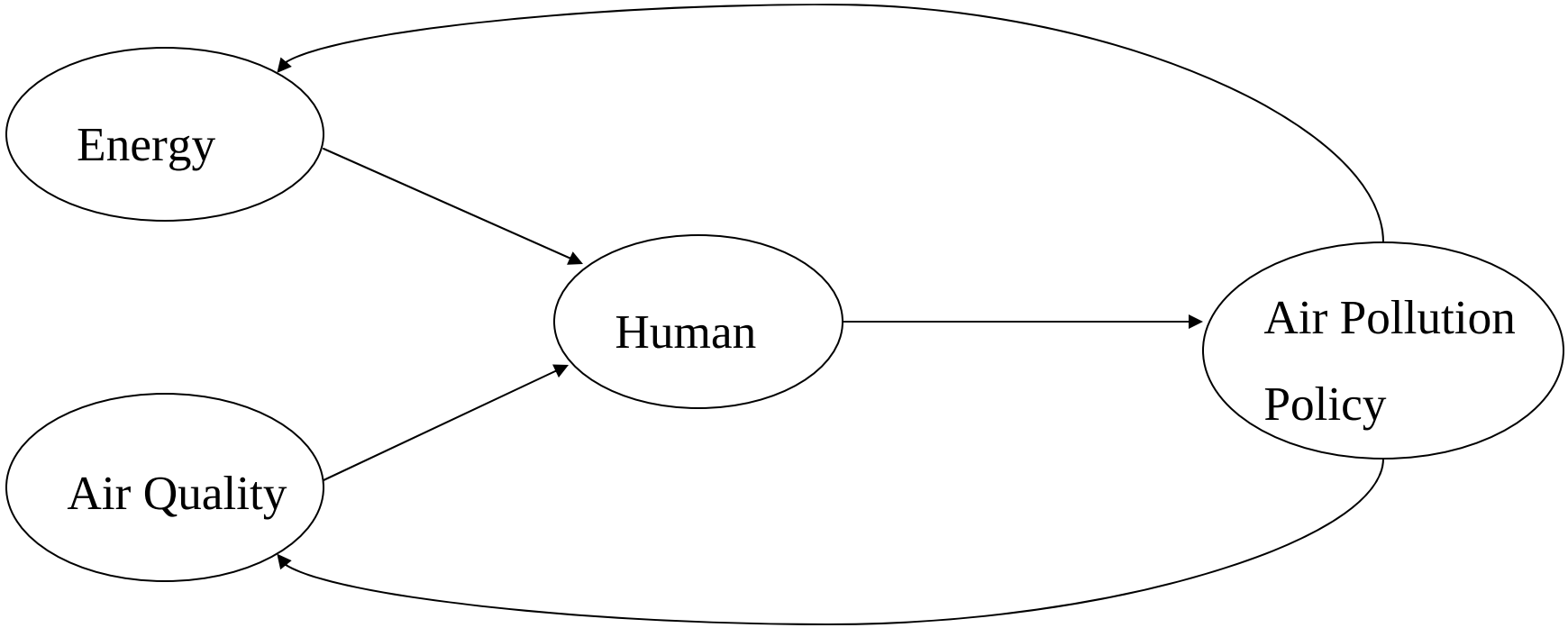
Outline

- Motivation
- Study Design
- Results
- Conclusions & Future Work

Engineering Systems ?



Ozone: Good Up High, Bad Nearby

- Stratosphere ozone: protect us from UV
- Ground level ozone: Harm respiratory systems; damage ecosystems; main ingredient of urban smog
- Forms when NOx and VOCs or CO mix in the presence of sunlight.
  - NOx + VOC + CO+  = Ozone
- Driven by sunlight intensity, absolute and relative concentrations of VOC and NOx, “reactivity” of VOC, temperature, and humidity.

Ozone Control Policies

- 1970: Federal Clean Air Act:
  - Requires the EPA to establish health-based standards called National Ambient Air Quality Standards (NAAQS)

- Eight-Hour Ozone Standard:
  - 1997 standard: 80 ppb; 2008 standard: 75 ppb.

- Technology-based Command-and-Control approach:
  - SCR (Selective Catalytic Reduction)
  - SNCR (Selective Non-Catalytic Reduction)
  - Competitive NOx reducing retrofit technologies

- NOx cap-and-trade program for stationary sources:
  - East Coast's NOx Budget Program since 1999

Motivation: Ozone Non-attainment

- Persistent ozone non-compliance

- Common problem for all the urban areas in US

- Non-attainment areas will expand under a NAAQS of 0.075 ppm for ozone concentrations averaged over 8-hours.

- ***Why is this so hard?***

blue=non-attainment counties in 2008

Source: EPA Office of Air and Radiation, AQS Database 2008

Why is this so Hard?

- ~60% of NOx emissions in U.S. come from mobile sources
- Only 22% of NOx emissions come from stationary sources (mainly power plants and industrial facilities)
- Expensive and politically difficult to reduce NOx emissions from mobile sources
- Easier and less expensive emissions reductions have already been made; additional permanent or annual reductions have even higher marginal costs

An Alternative:
Time-Differentiated Regulation for Stationary Sources (Smart Trading)!

Key Ideas behind the Time-differentiated NOx regulation (Smart Trading)

• *Smart Trading*: Target ozone episodes by reducing NOx emissions prior to forecasted episodes.

- Reduce NOx emissions *only* on high ozone days--potentially more cost-effective
- Electricity re-dispatch: High NOx rate→Low NOx rate
- Might become true real soon!
  - Feasibility study funded by the EPA Clean Air Division
  - Austin, Texas is considering this policy

Technical Barrier

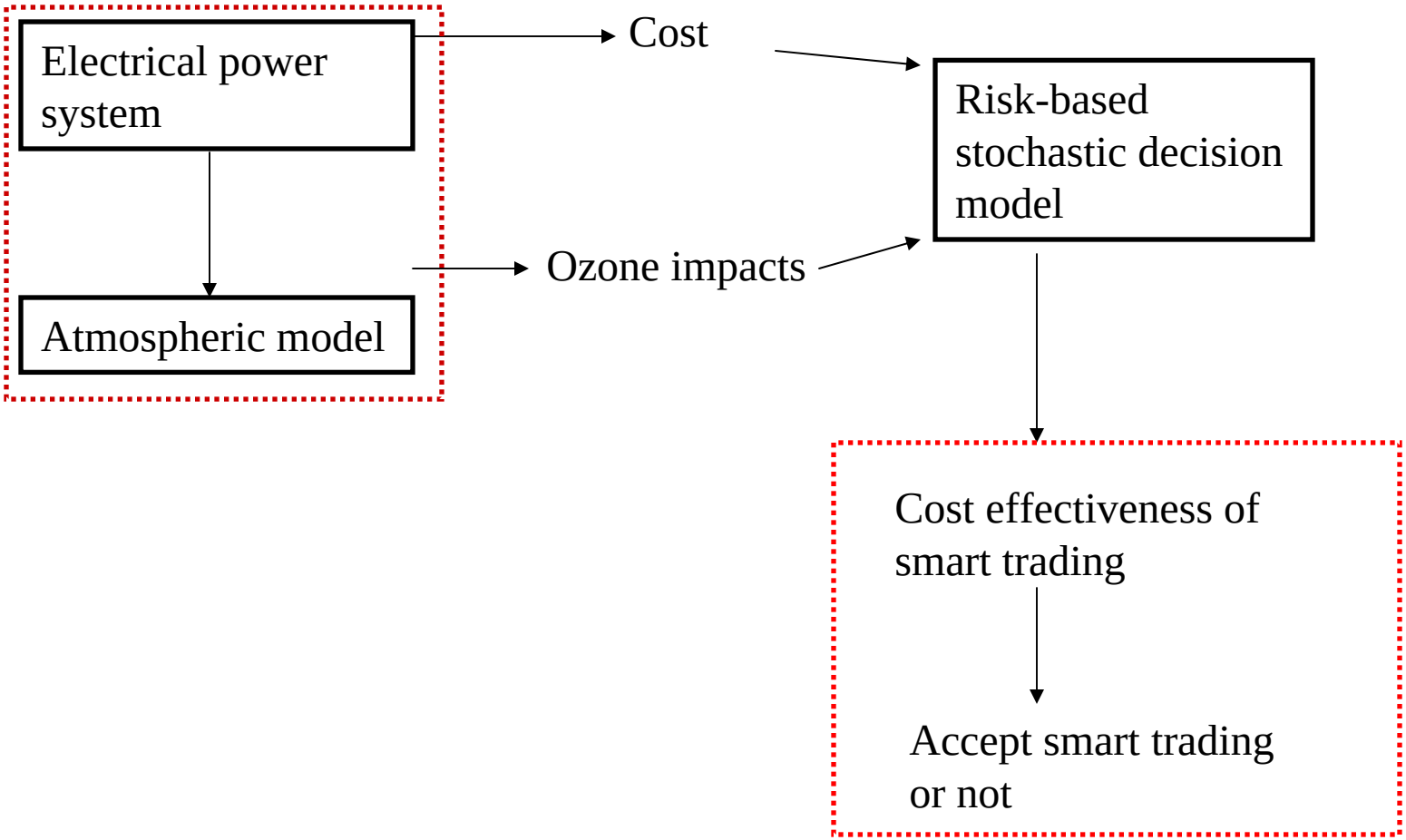
• The necessary reliance on weather and atmospheric chemistry forecasting, which is generally perceived to have large uncertainty

• Possible costs of not knowing
  – Type I error, unnecessary cost
  – Type II error, continued non-compliance

Key Question for this Project

- How could a time-differentiated system operate prospectively?
  - Over a larger range of seasonal conditions, how do the ozone impacts under such a system compare to a conventional strategy of installing control technology?
  - What level of accuracy of ozone forecasting is required for such a system to be worth considering?
  - *Based on the current weather and air quality forecasting capability, are we ready for the flexible NOx regulation, or are we better off with the technology-based regulation?*

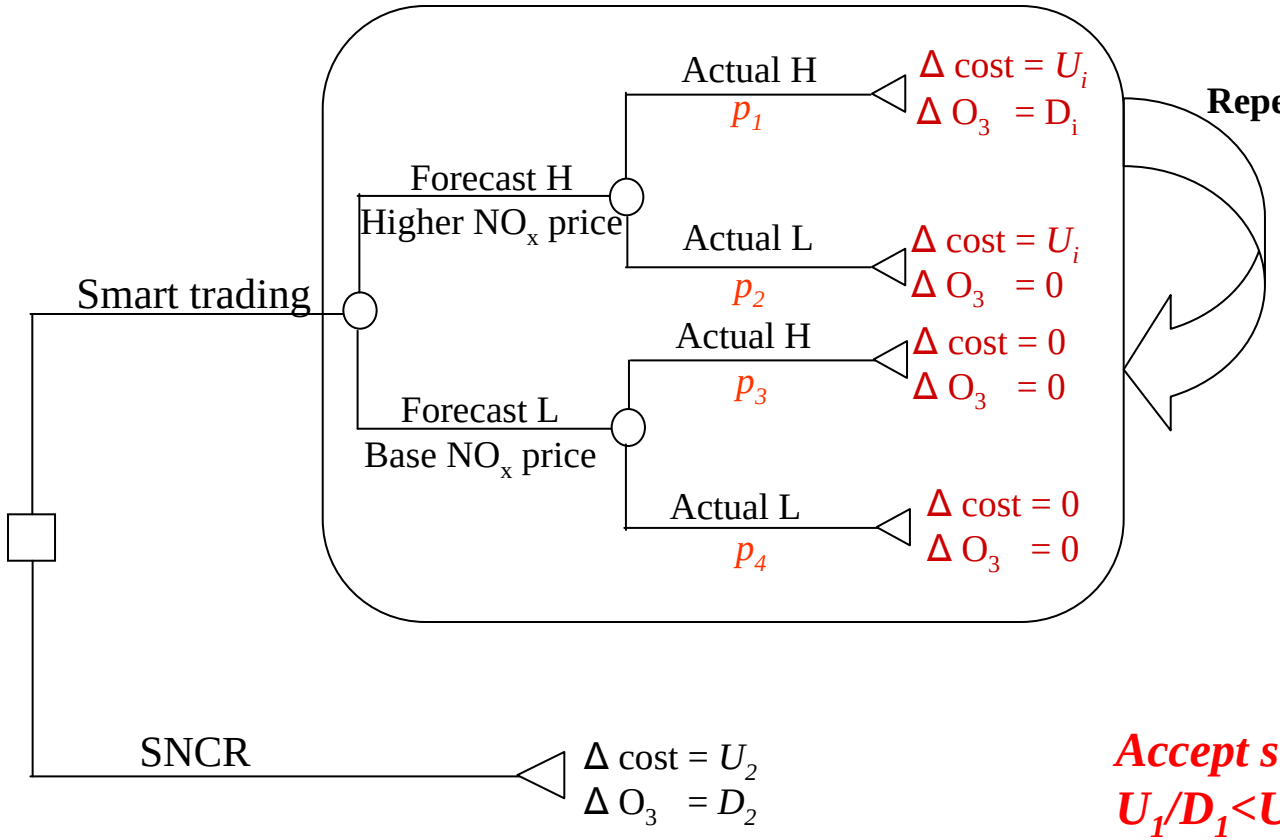
Components of the System



Study Design

- Sample episodes: summer 2002 (6/1~8/31)
- Electricity Generators in the “Classic PJM”
  - Electricity Redispatching Only
- Scenarios
  - Base Case: no additional controls; $2k/ton NOx
  - Trading Cases: higher NOx prices to all PJM units:
    - $30K, $50K, $100K
  - SNCR Case: coal plants within PJM get SNCR installed
    - Assume 40% cut of NOx emission rates

Stochastic Decision Analysis Framework



Repeat *N* times

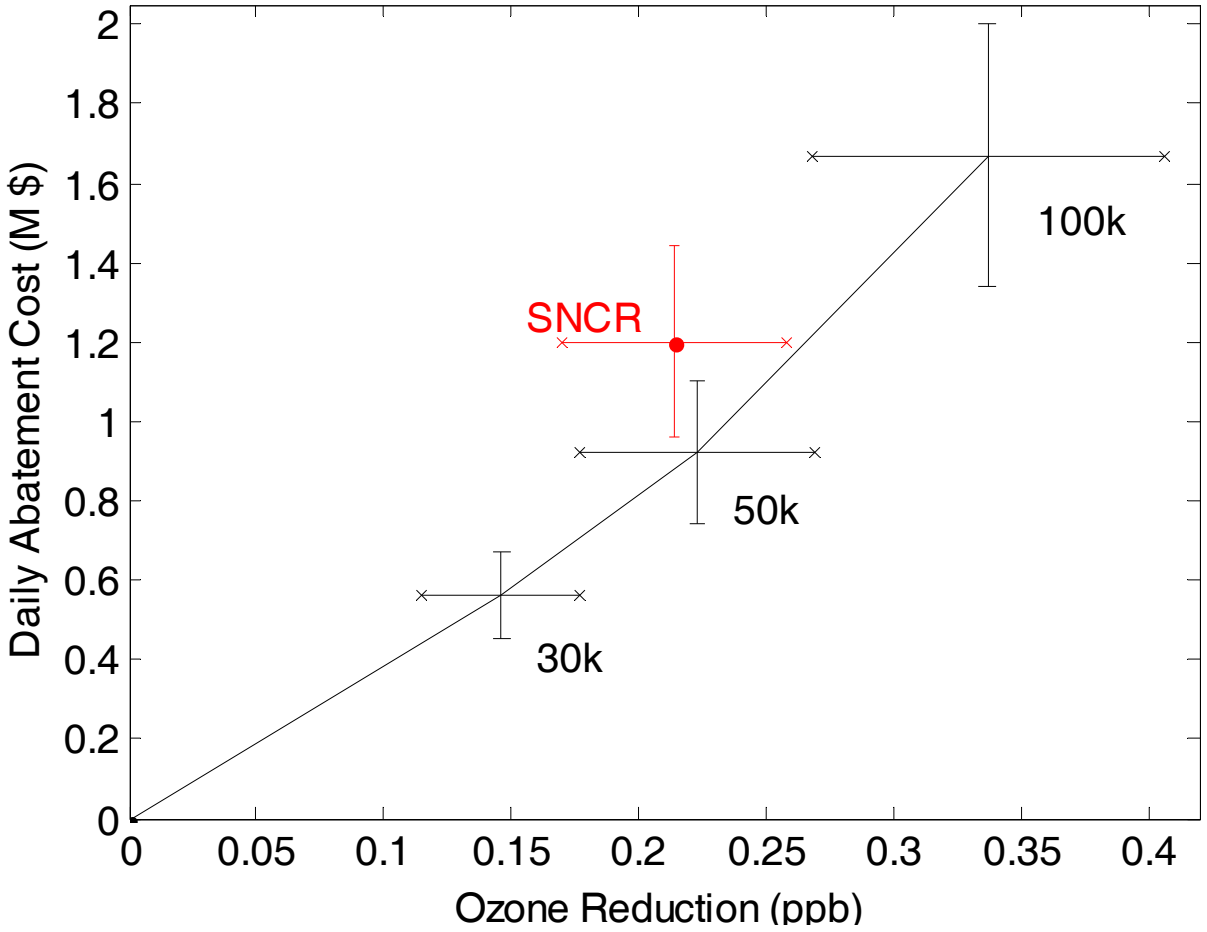
$$\Delta\text{cost} = \sum_{i=1}^{N} (\Delta\text{cost})_i \Big/ N = U_1$$

$$\Delta O_3 = \sum_{i=1}^{N} (\Delta O_3)_i \Big/ N = D_1$$

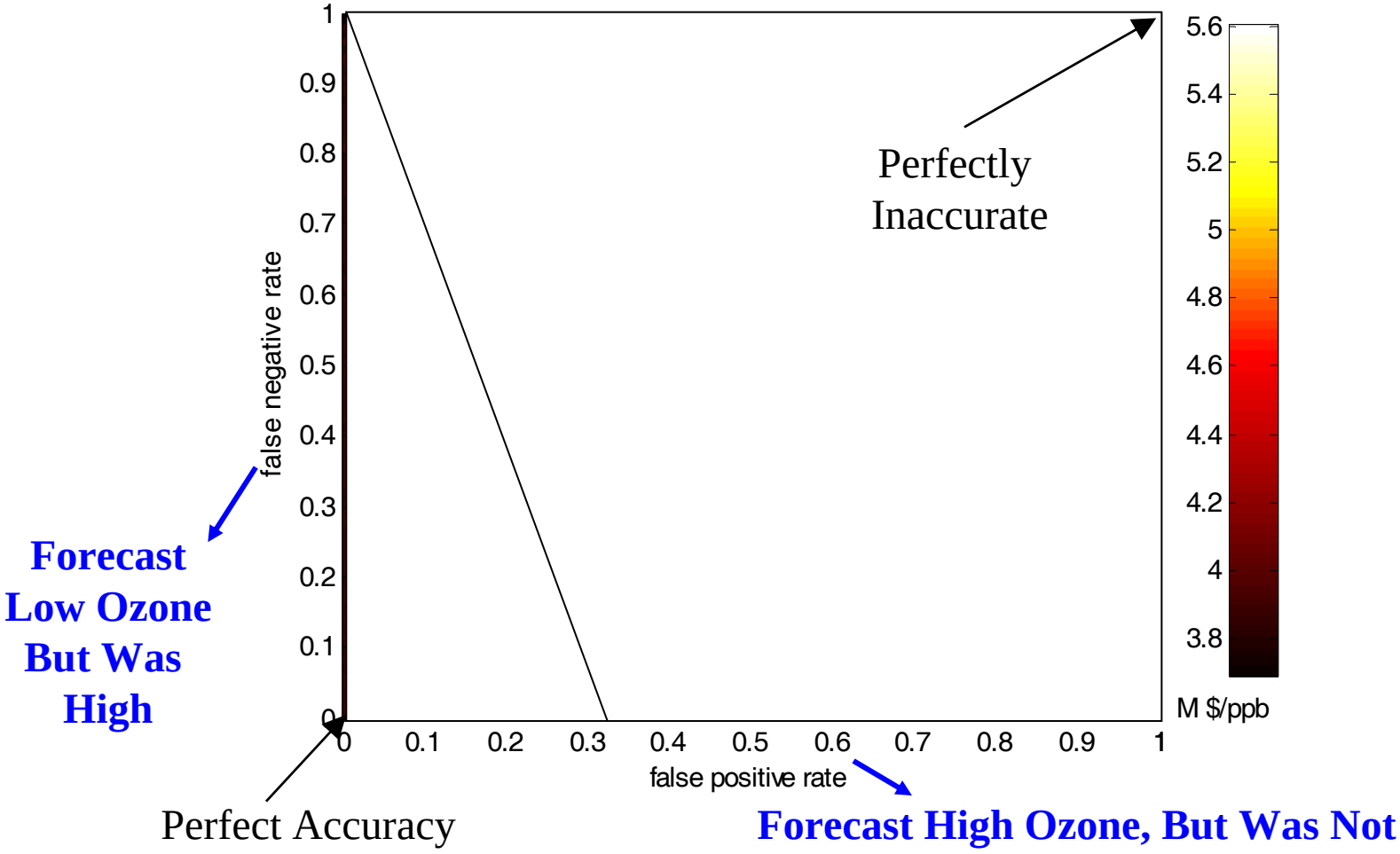
Accept smart trading if:
$U_1/D_1 < U_2/D_2$

Ozone Abatement vs. Costs

(Assuming 100% Accurate Forecast)



Sensitivity Analysis of Forecast Errors ($50k)



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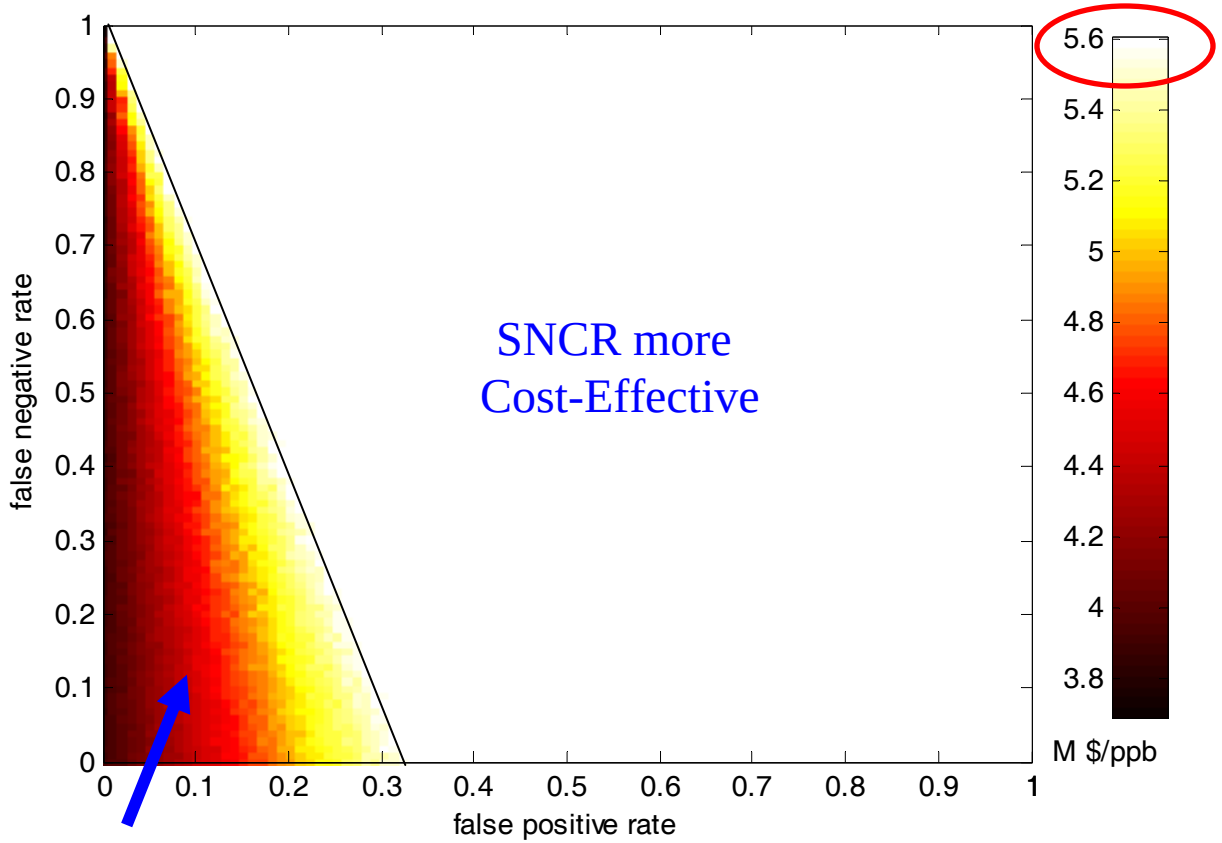

Smart Trading more
Cost-Effective

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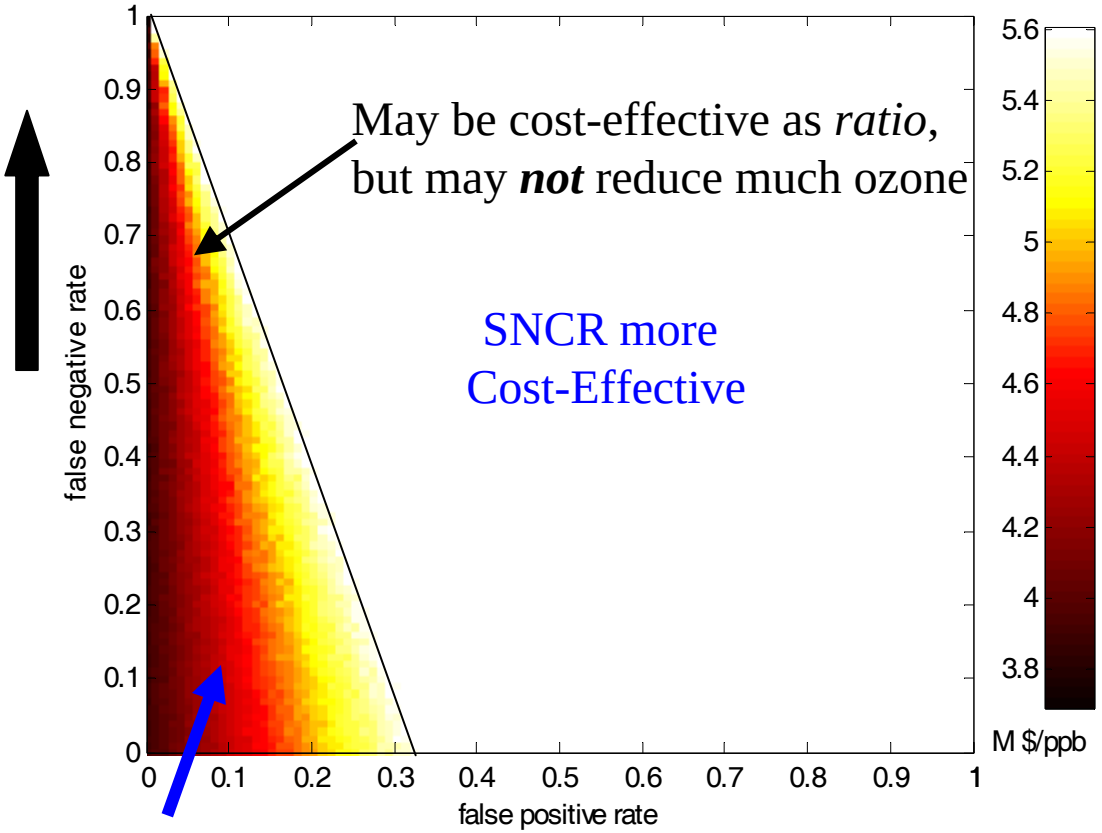

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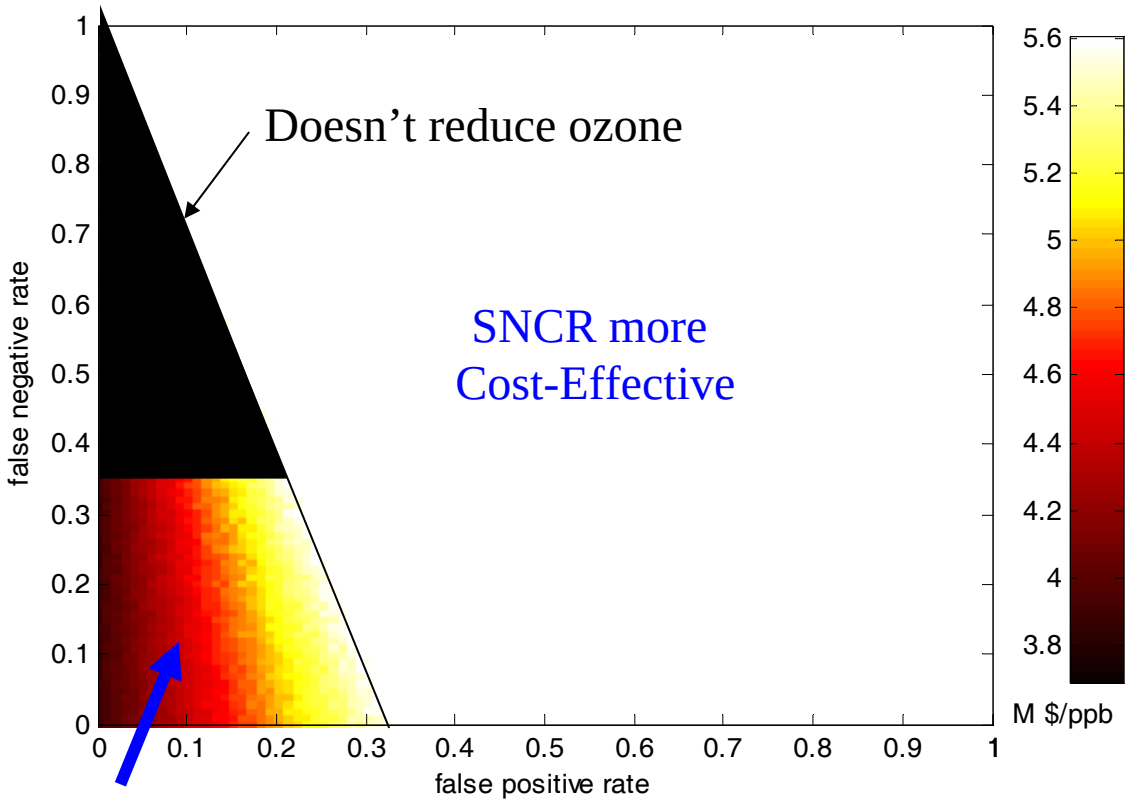

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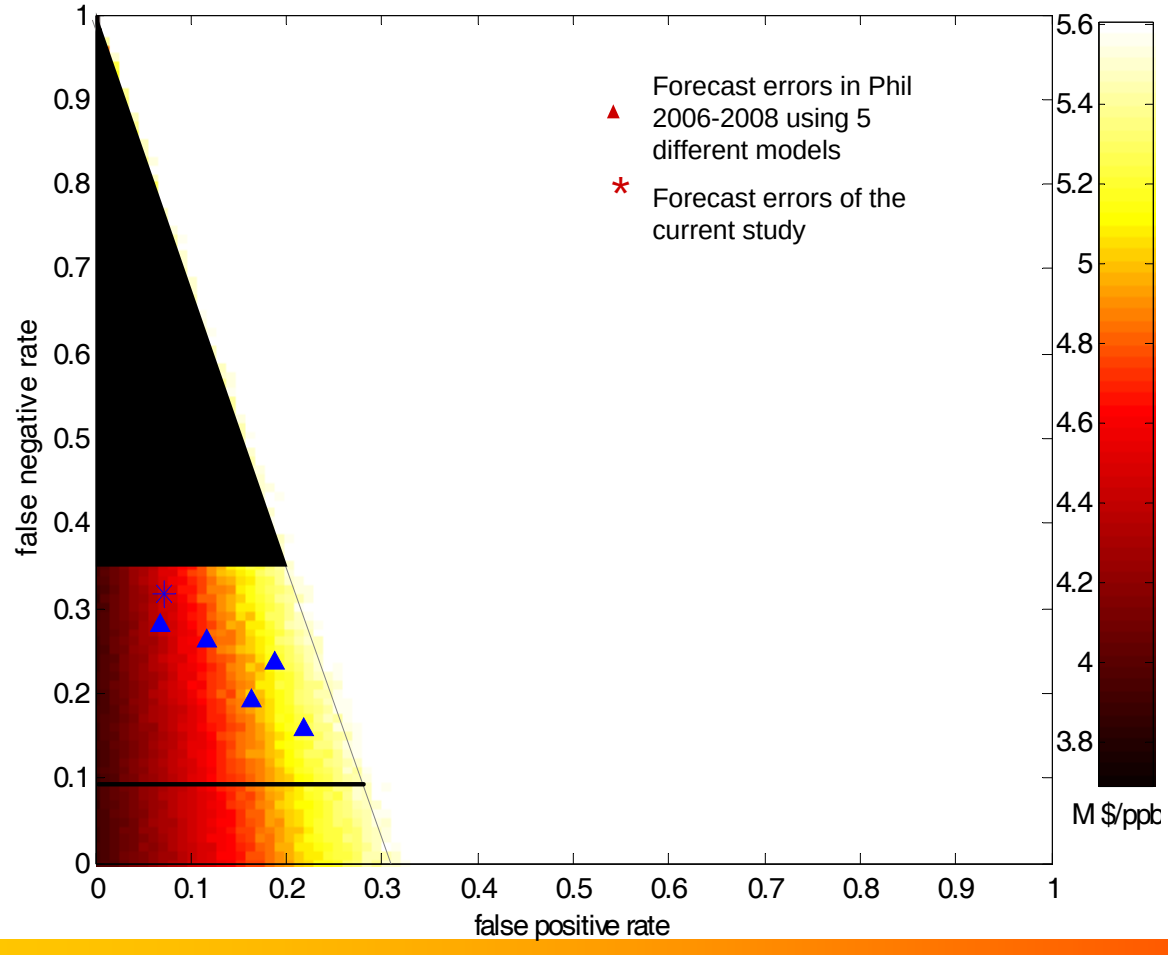
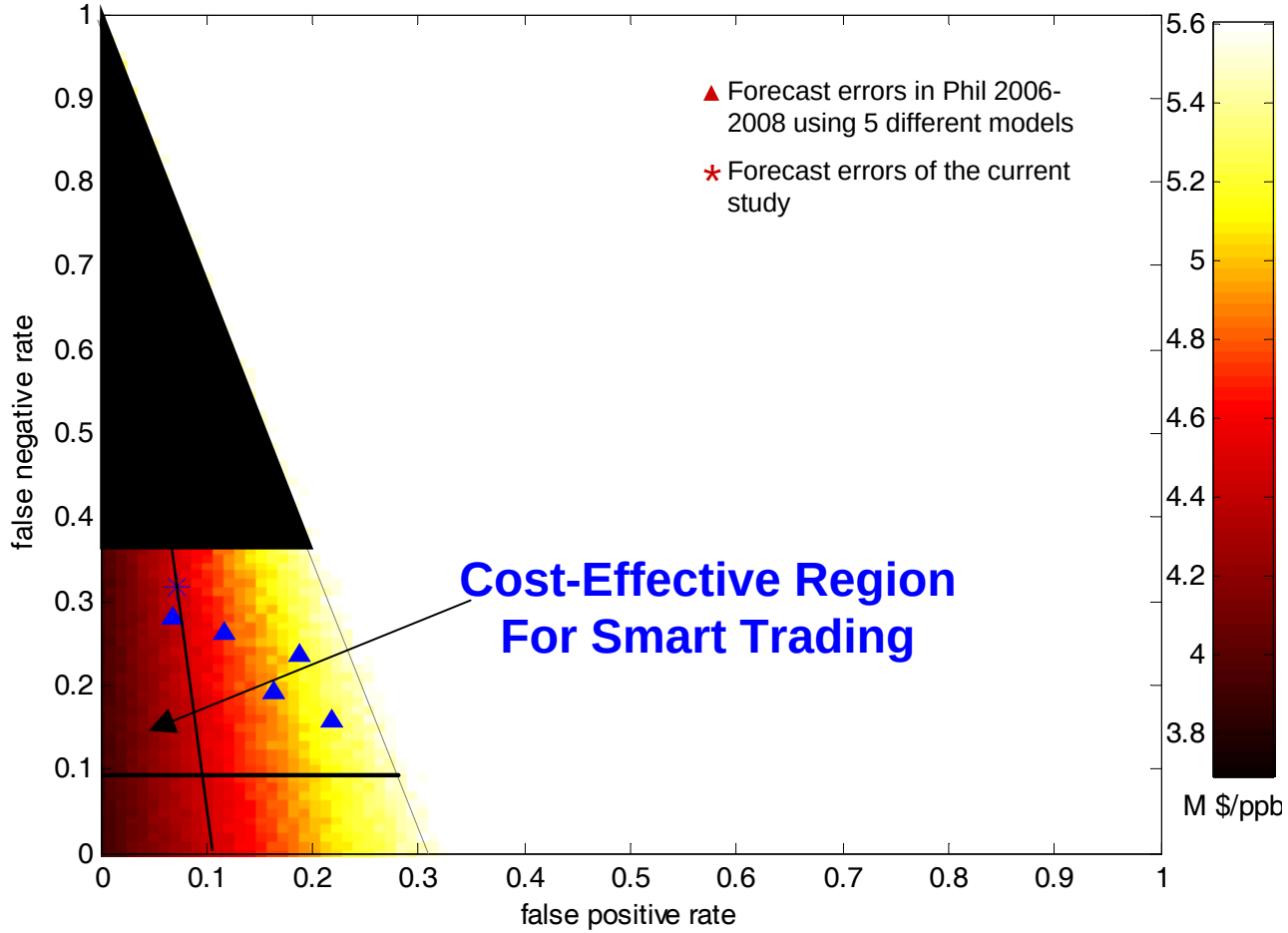


Sensitivity Analysis of SNCR cost

80% Reference Assumption



Conclusions

- Redispatching from stationary sources for high ozone episodes appears technically & economically feasible:
  - Lower NOx generation *is available* at peak hours
  - Not transmission constrained
  - Results in ozone *reductions*
  - Required accuracy of forecasting *may be attainable* now or in near future

Critical Caveats

- This analysis is for PJM region only, using 2002 ozone season as the population of samples
- We assumed the only possible response to higher NOx price / allowance redemption ratio is redispatching
  - More realistic response by facility also includes operational controls (combustion temperature, air mixing ratios), and decisions to install secondary controls)
- Results conditional on assumed technology control case (SNCR)
  - Additional secondary controls should be considered (SCRs), as well as which units are assumed to have controls installed.

Thank you for your attention!