Addressing Distributional Issues in Environmental Health Benefits Analysis

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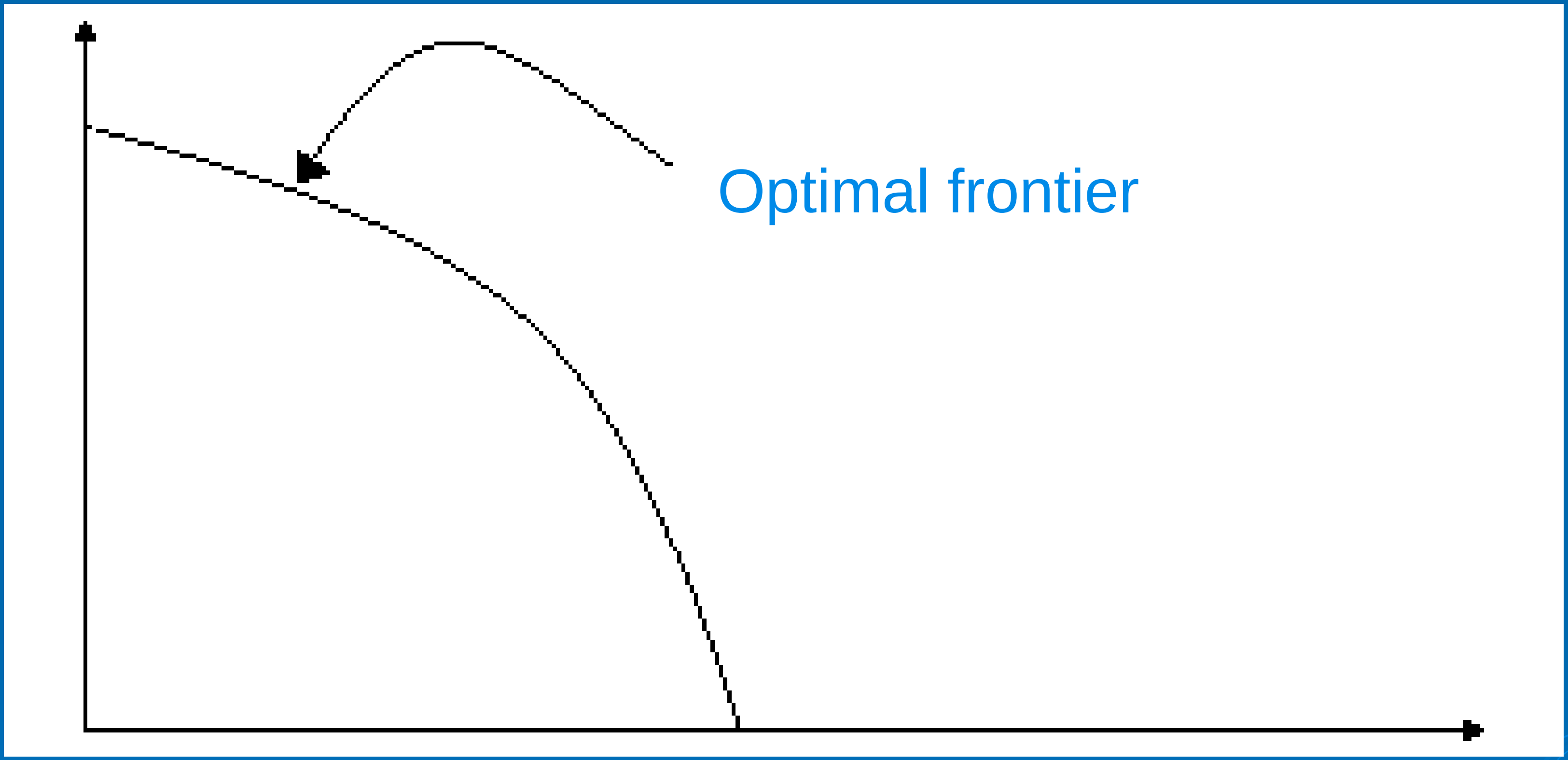
Quantifying inequality

- Analysts have developed simple, meaningful indicators that can capture the magnitude of the benefits of pollution control from a source or set of sources in a benefit-cost analysis context
  - Deaths, monetized benefits, QALYs, etc.
- Is there a simple, meaningful indicator that can capture the distribution of the benefits of pollution control from a source or set of sources?
  - Inequality of outcomes ≠ injustice of process and should not be interpreted as such

“Equality” = Distribution of Health Benefits



“Efficiency” =
Magnitude of Health Benefits
(or Benefits - Costs)

What does a meaningful inequality indicator look like?

- Numerous income inequality studies developed axiomatic approaches to select indicators
- We modified the standard list of axioms and proposed additional axioms relevant to health benefits analysis (Levy et al., 2006)

Highlights

- Many core axioms were similar for health and income, but not identical
  - Ex.: Anonymity desirable for income but not health, scale invariance means something different for health and income
- Selected "additional" axioms:
  - Analyst must not impose a value judgment about the relative importance of transfers at different percentiles of the risk distribution
  - The welfare measure must be as close to a measure of health risk as possible
  - The inequality indicator should not be applied without consideration of baseline risk distributions
  - The geographic scope and resolution should be identical for inequality and efficiency measures, with as fine resolution as possible given available data
  - The inequality indicator should be derived for multiple competing policy alternatives

Atkinson index

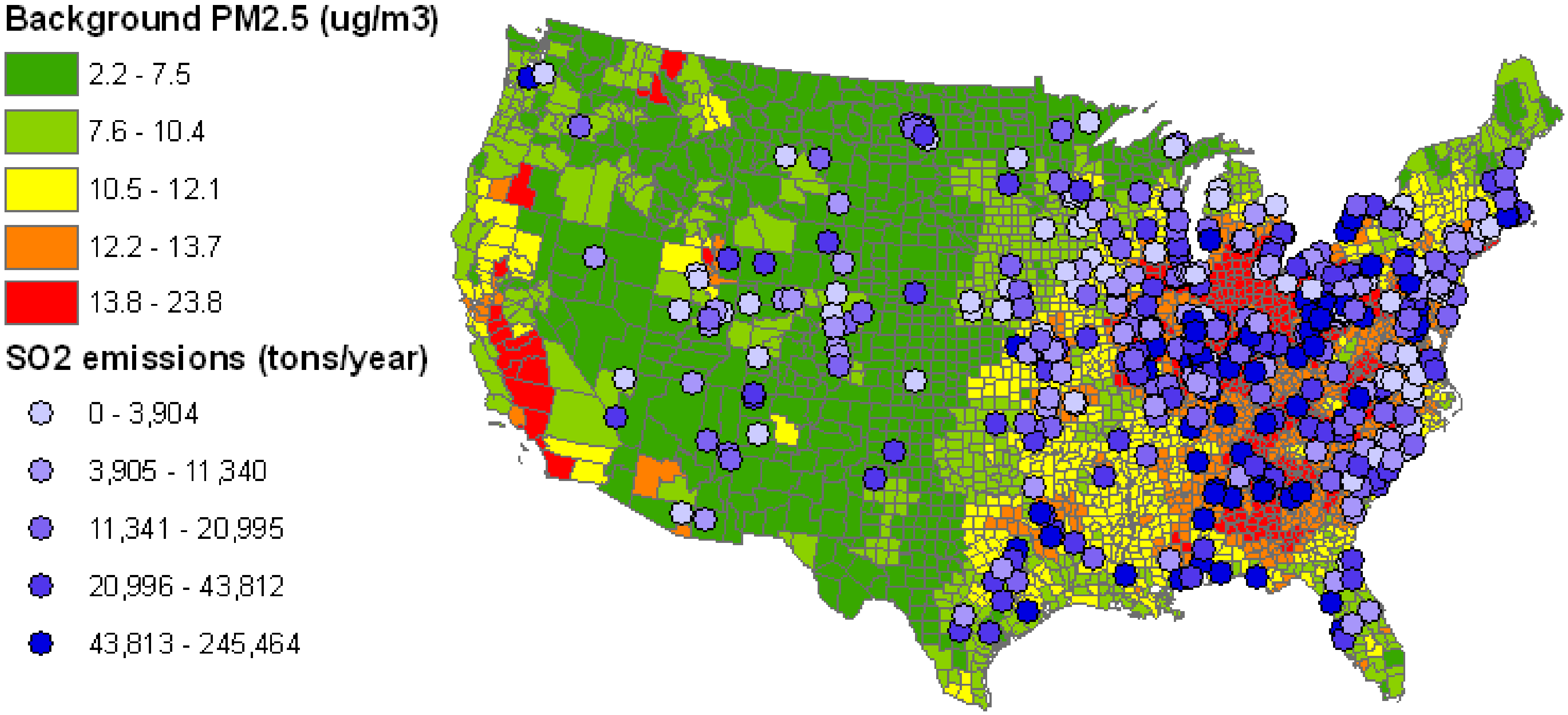
$$1-\left[\frac{1}{n}\sum_{i=1}^{n}\left[\frac{x_i}{\bar{x}}\right]^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}}$$

- Member of generalized entropy family (derived specifically to be decomposable)
- Fulfills all major axioms
- Societal preferences about inequality incorporated through ε
  - Higher ε = more weight on transfers at low end

Power plant case study

- What do optimal reductions given a national cap on power plant emissions look like, considering efficiency and equality?
  - Developed approaches by which 75% reductions in NOx, SO_2, and $PM_{2.5}$ emissions could be achieved, to span efficiency/equality space
    - Meant to be illustrative rather than realistic

Levy et al. 2007

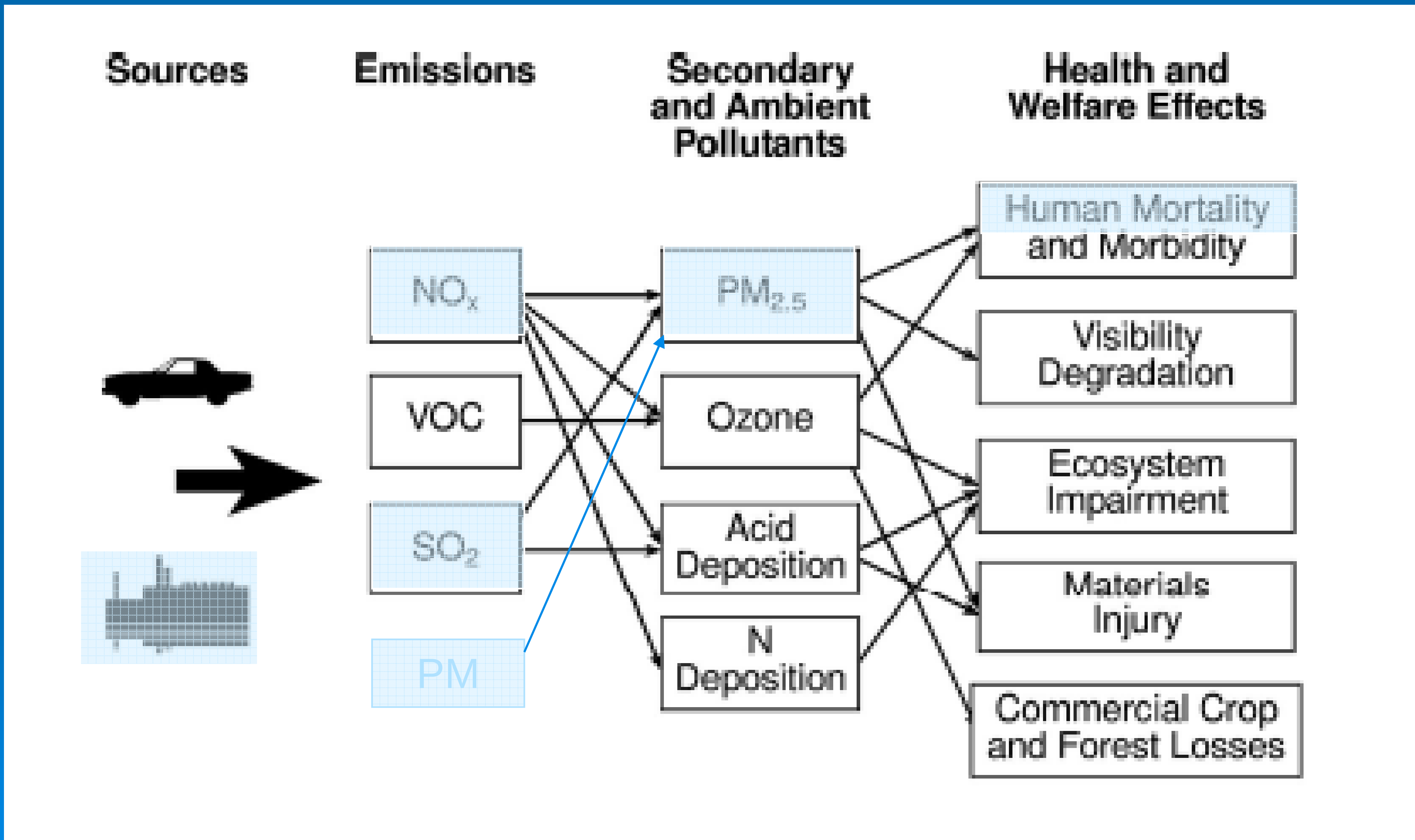


Levy et al. 2007

Extracted from EGRID, NEI for 425 plants

S-R matrix, county resolution

C-R function from ACS, county mortality



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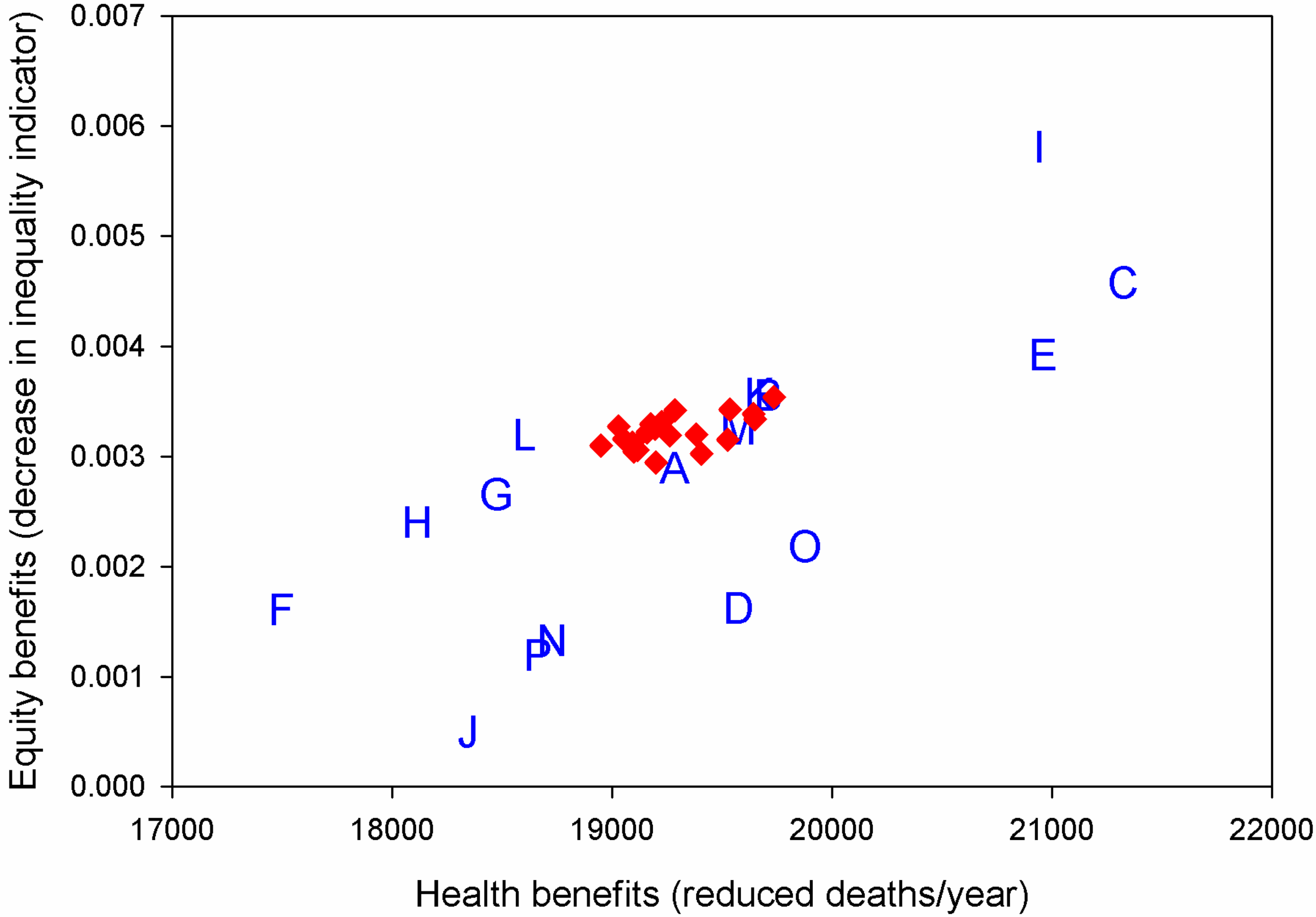
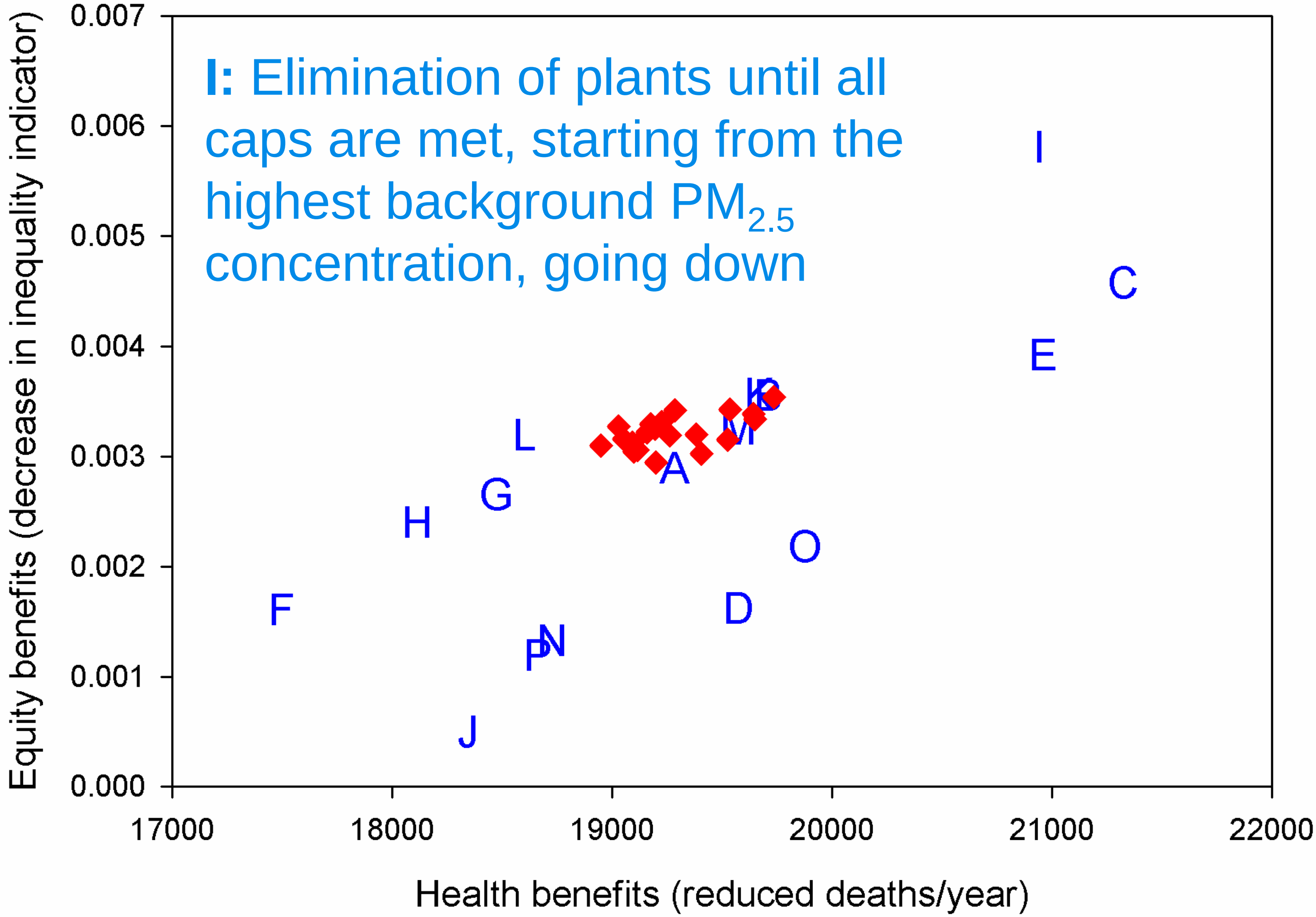


Levy et al. 2007



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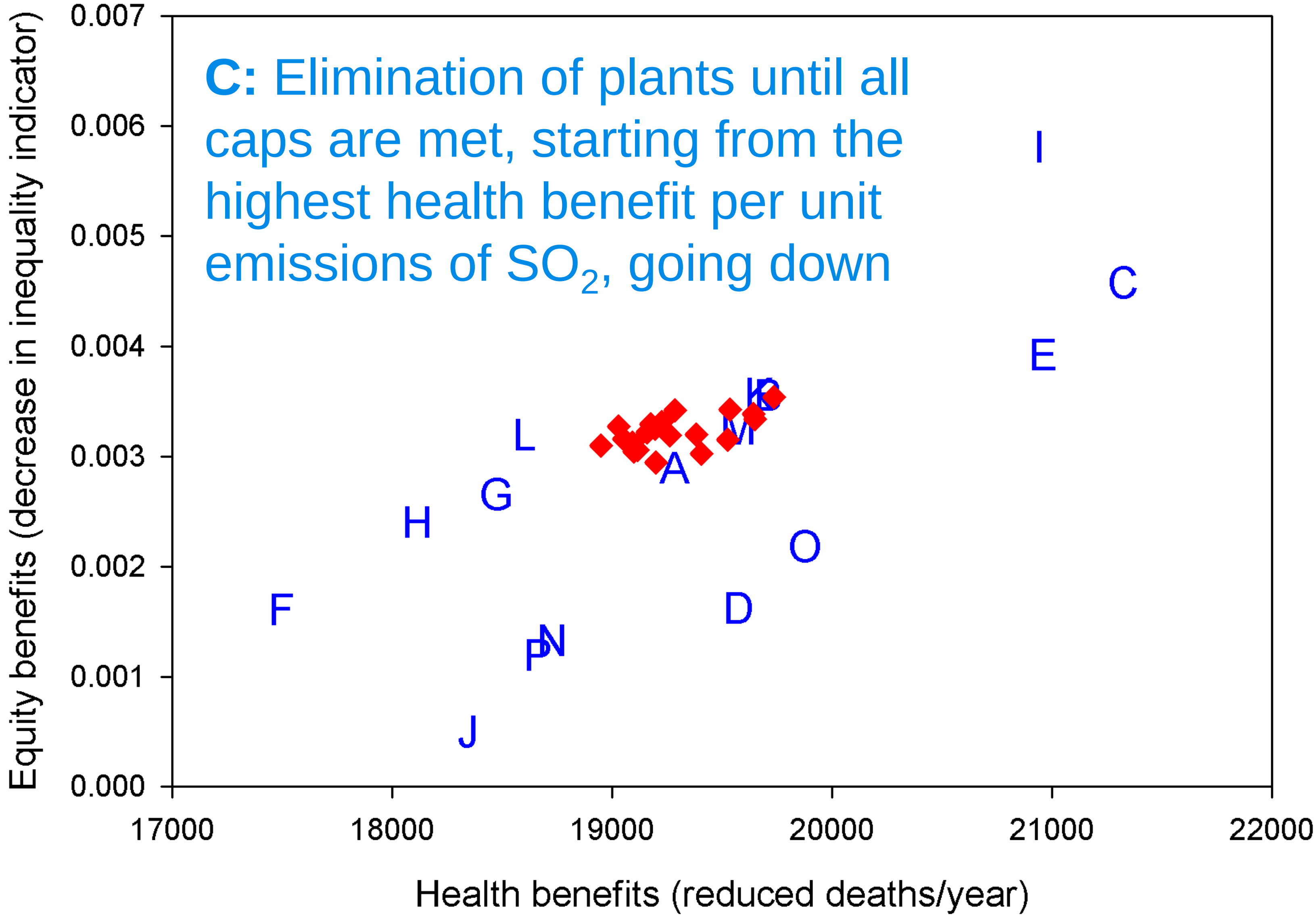
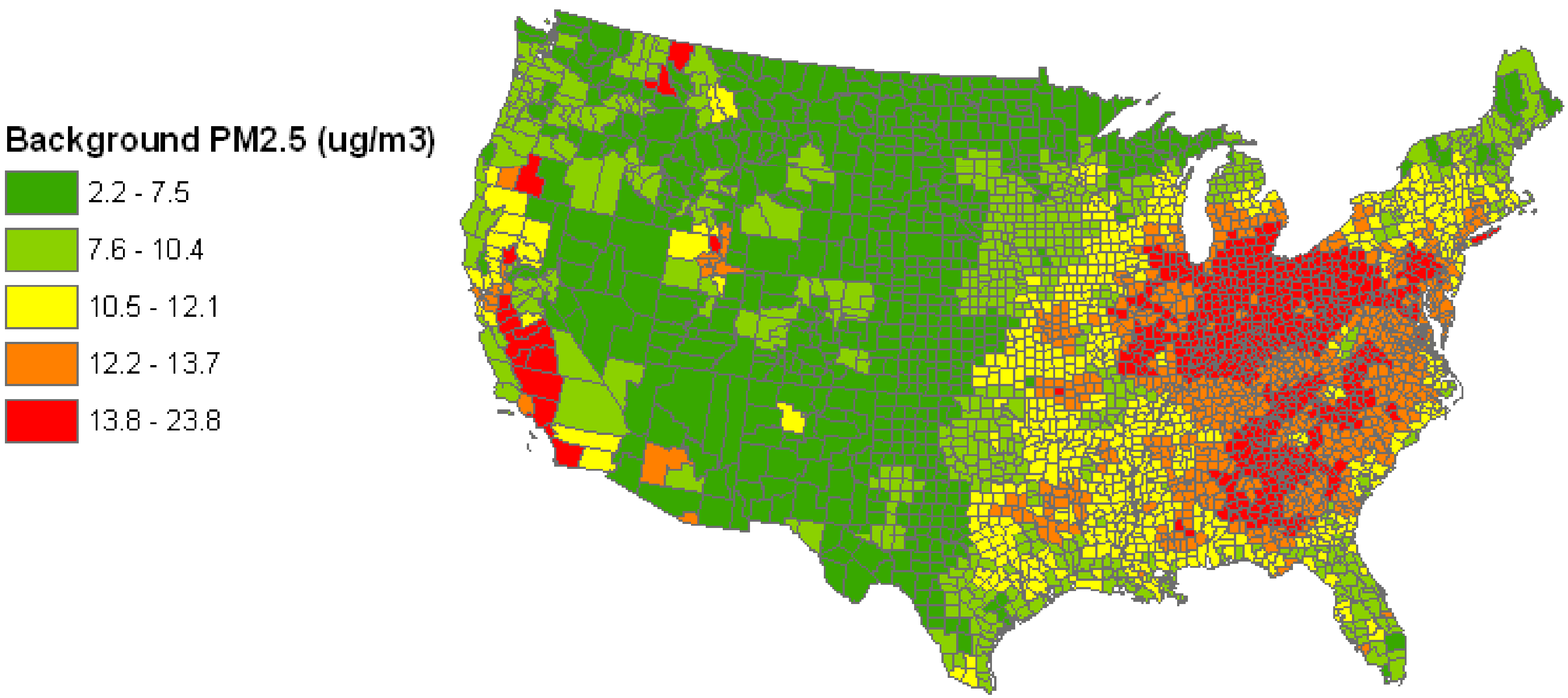


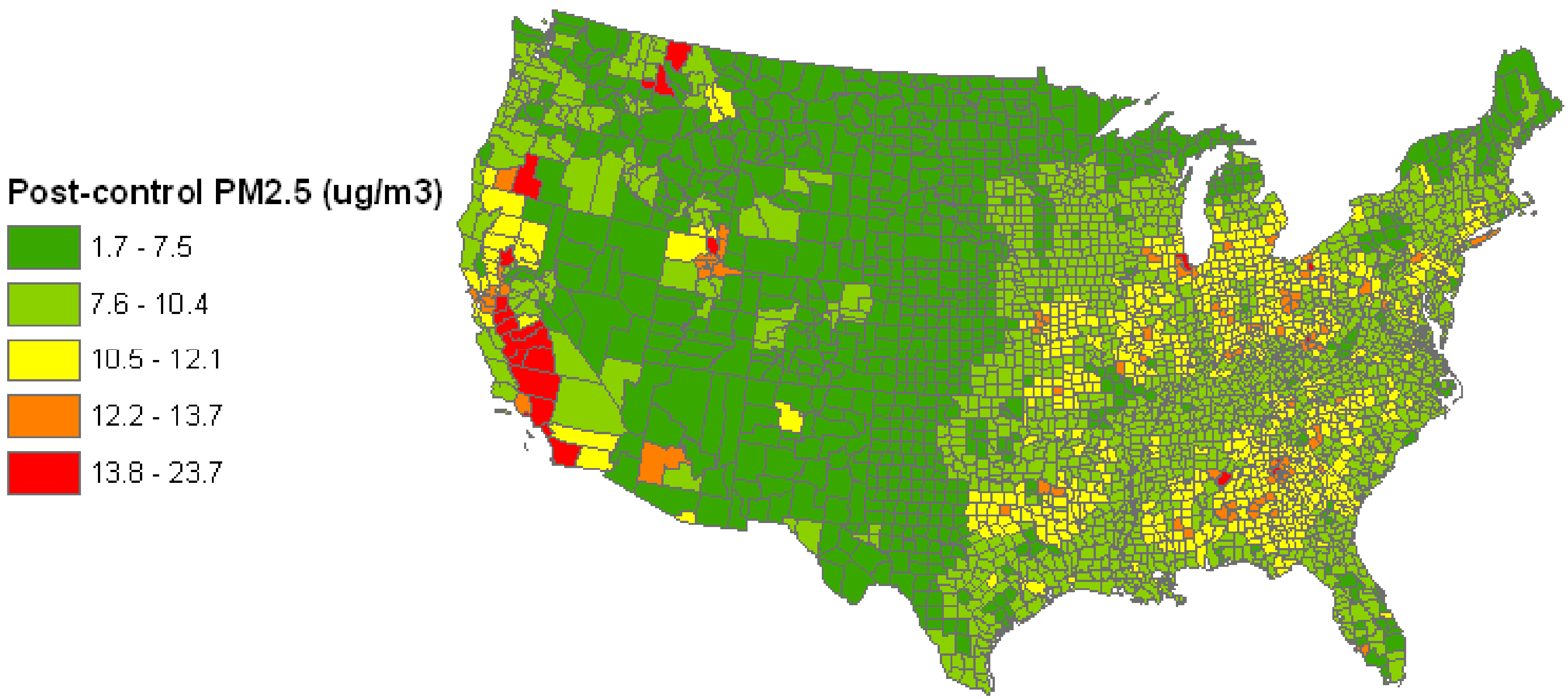
Levy et al. 2007

Baseline concentrations



Levy et al. 2007

Post-control baseline concentrations
(High SO_2 health benefit per unit emissions)



Levy et al. 2007

What did we conclude?

- For power plants and PM, strong concordance between the more efficient and more equitable strategies
- Sensitivity analyses show conclusions robust across numerous indicators and formulations, but properly accounting for baseline/background conditions very important

What's missing?

- Economics of power plant control
  - Plausibility of control options
  - Economic efficiency/equality considerations
    - Could calculate net benefits on "efficiency" axis; not relevant for stylized example
- Factors influencing variability in risk (effect modifiers, differential susceptibility)
- Inequality other than spatial inequality (if relevant)
- Consideration of local perspective
  - Answers questions most relevant to national policymakers but not necessarily for local policymakers or individual communities

Urban bus case study

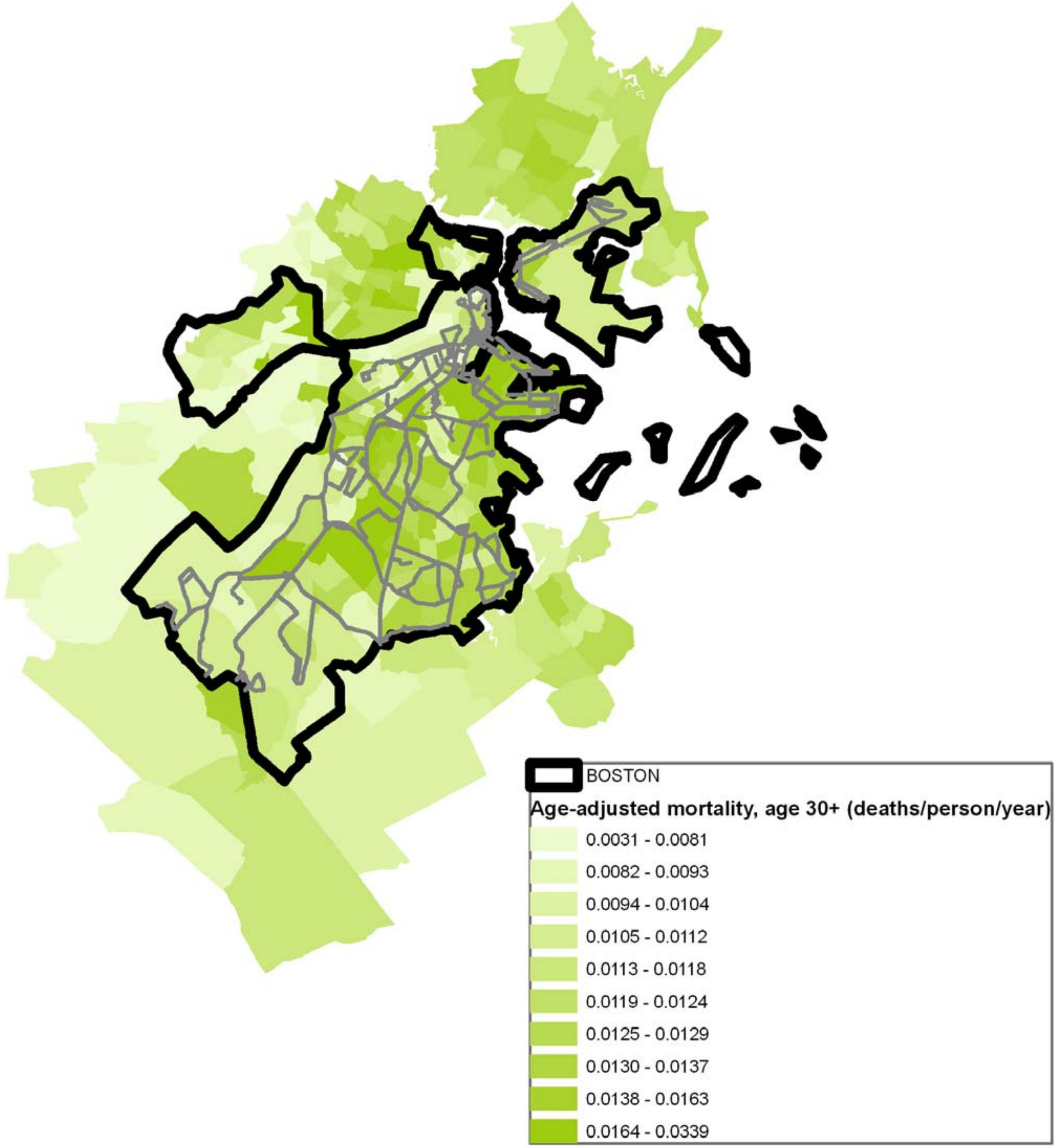
- Local rather than national policy decision
- Pollutants with steep rather than gradual concentration gradients
- Large spatial variability in vulnerability
  - Does the framework still hold?
  - Are the conclusions similar?

Levy et al. 2009

Case study assumptions

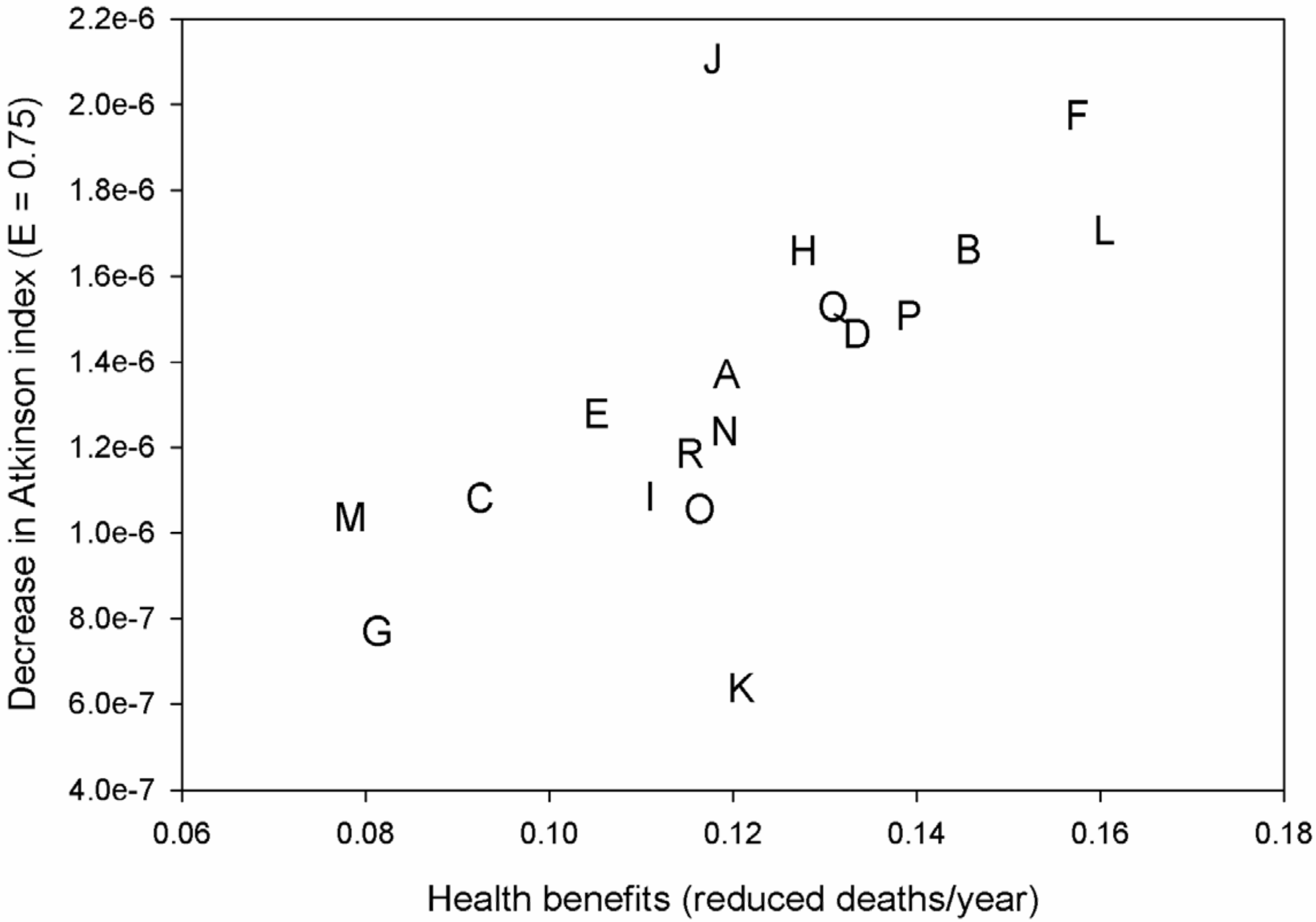
- All 45 MBTA bus routes entirely within Boston are candidates to have diesel buses retrofit with diesel particulate filters (DPFs)
- Funding exists to retrofit half of these buses
- Buses travel on the same route each day, so retrofitting a bus reduces emissions on a defined route
- The mortality effects of $PM_{2.5}$ will dominate the benefits of DPFs
- Decision makers are concerned both with maximizing public health benefits (equivalent to maximizing net benefits given identical control costs across control scenarios) and minimizing health inequality

Levy et al. 2009

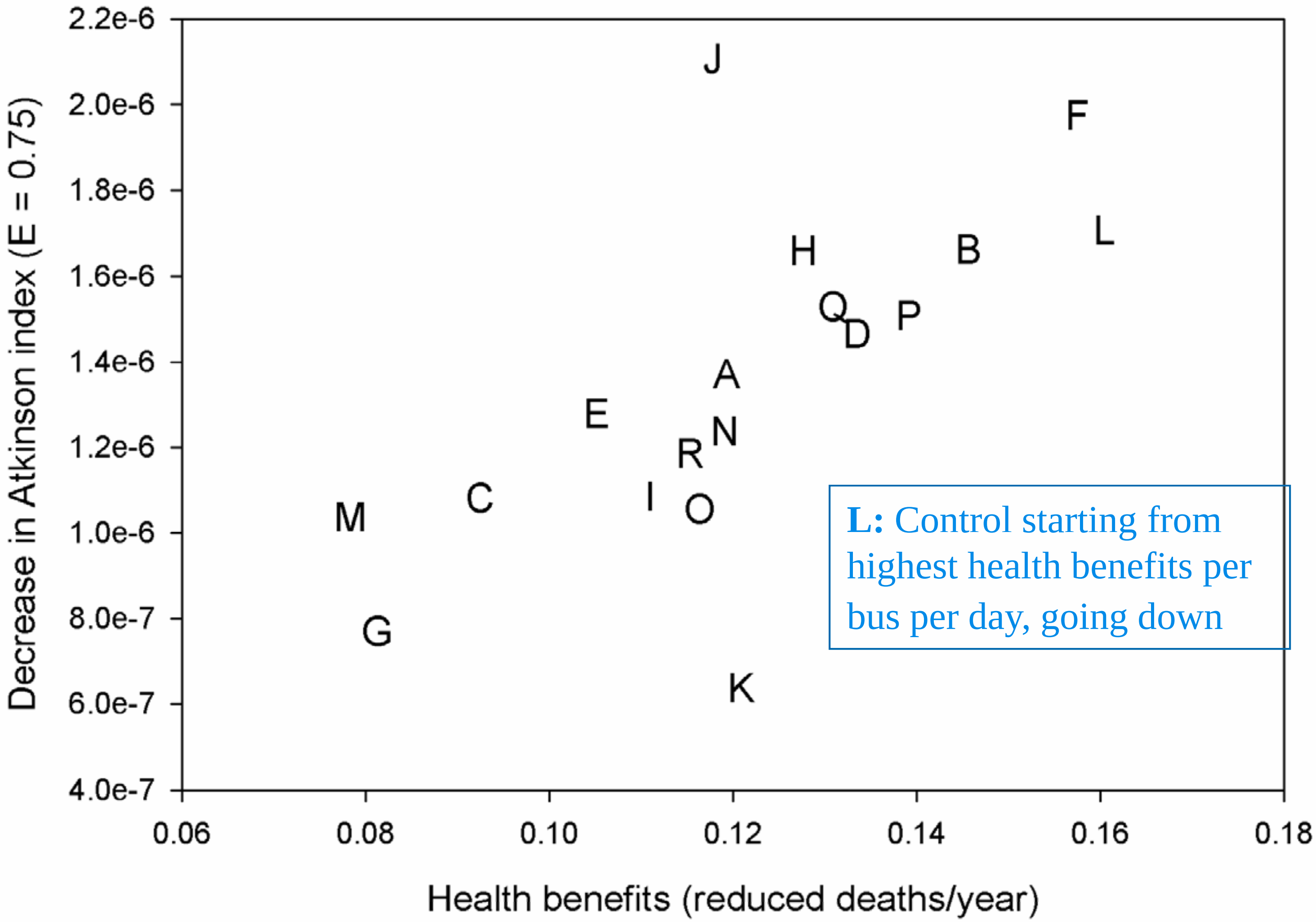

BOSTON
Age-adjusted mortality, age 30+ (deaths/person/year)
0.0031 - 0.0081
0.0082 - 0.0093
0.0094 - 0.0104
0.0105 - 0.0112
0.0113 - 0.0118
0.0119 - 0.0124
0.0125 - 0.0129
0.0130 - 0.0137
0.0138 - 0.0163
0.0164 - 0.0339

Key aspects of methodology

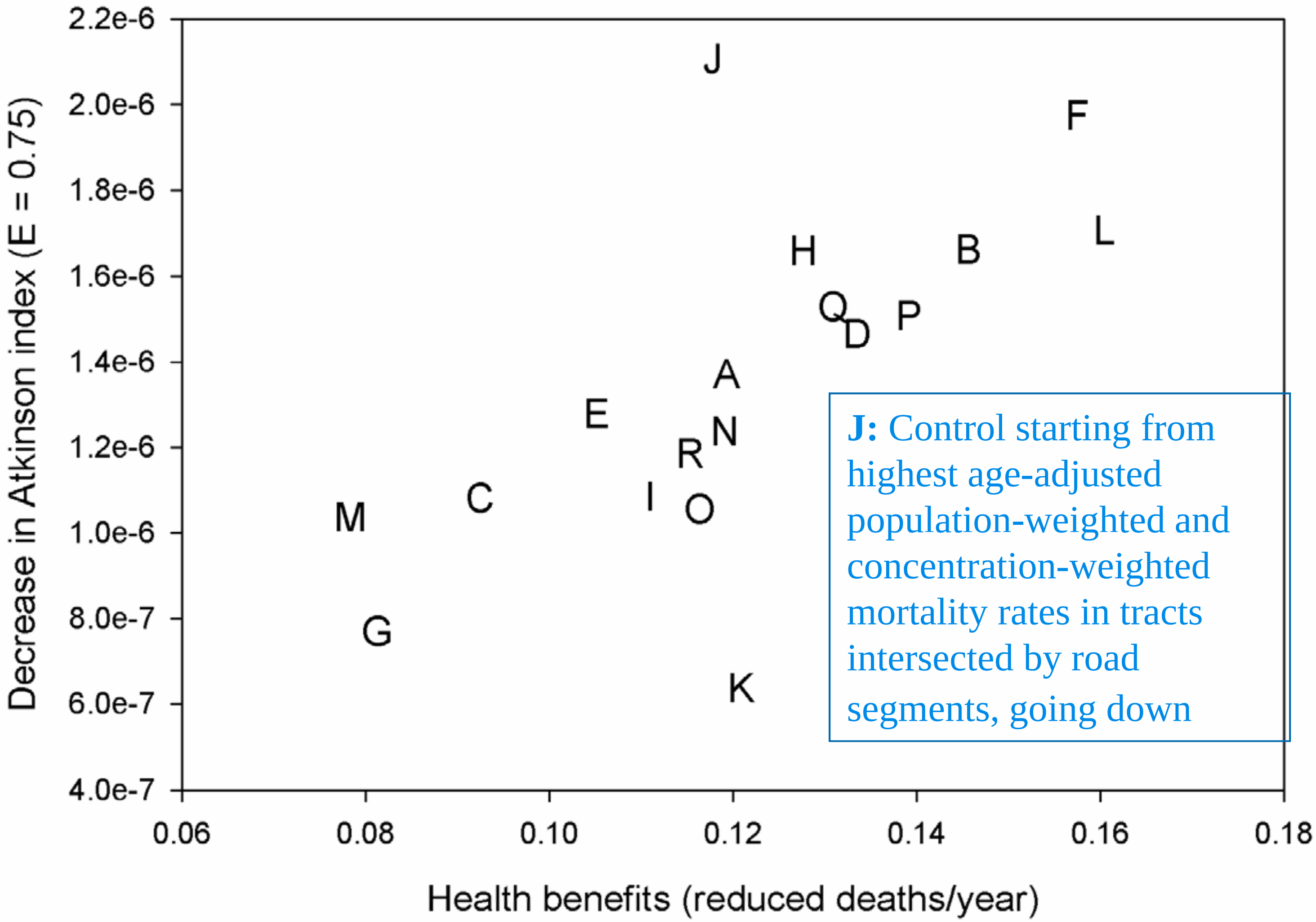
- Modeled contribution of emissions on each road segment (5,232 in total) to concentrations in each census block within 5000 m of roadway
  - CAL3QHCR w/interpolation
- Estimated background mortality rate by census tract by obtaining individual geocoded death records from MA DPH
  - Both raw and age-adjusted rates considered in equity analysis
- Applied Atkinson index to both risk and inverse of risk, to explore key differences between income and risk



Levy et al. 2009



Levy et al. 2009



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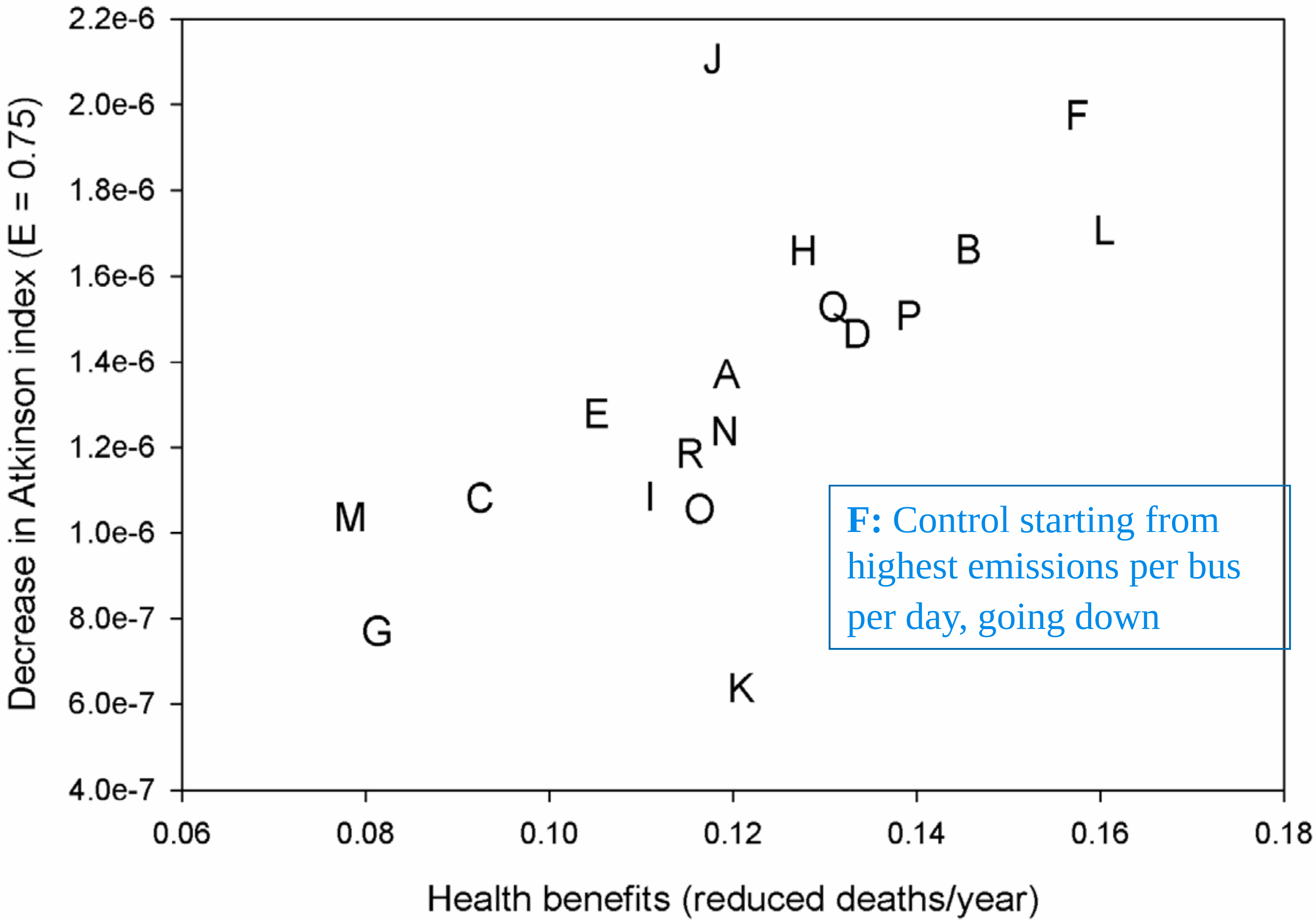

Levy et al. 2009

What did we conclude?

- For primary PM from diesel buses, as for the power plant case, reasonable concordance between more efficient and more equitable strategies
  - Concordance will exist when baseline disease rates vary, risk management options can target high-risk areas, and population density is reasonably uniform or positively correlated with baseline disease rates.
- Incorporating variability in background mortality rates can have a large influence on findings

What's still missing?

- Leveraging the strengths of the Atkinson index to separate spatial from socioeconomic inequality
- Incorporation of the cost side
- Moving beyond single-pollutant exposure characterization to multi-stressor exposure characterization (chemical and non-chemical)
- More systematic attempts to model interactions/synergies and to capture differential susceptibility

Concluding thoughts

- Quantitative indicators provided one approach for formally injecting health inequality into a benefit-cost analysis framework
- If baseline exposures and vulnerability are appropriately characterized, there may be many situations where the most efficient strategy is also preferred from equality (and equity?) perspective
- Future studies should capture more realistic scenarios, incorporate costs, consider decision-maker willingness to trade off efficiency and equality, and capture dimensions of interest to communities