General Equilibrium Impacts of Air Quality Improvements: The Role of Spatial Resolution

Alex Marten

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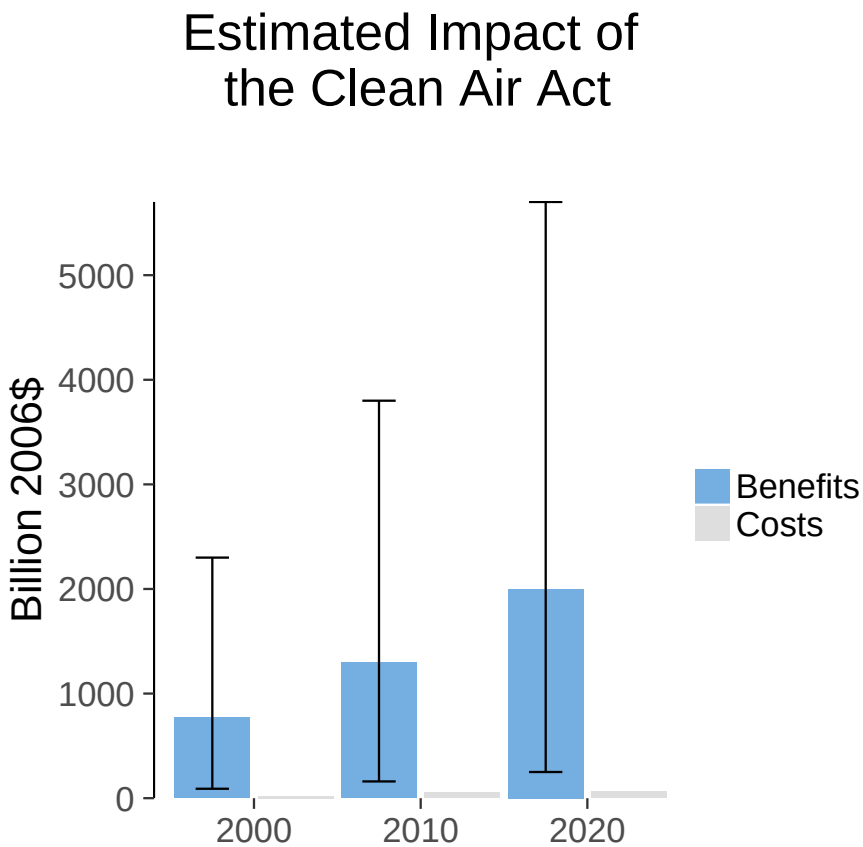
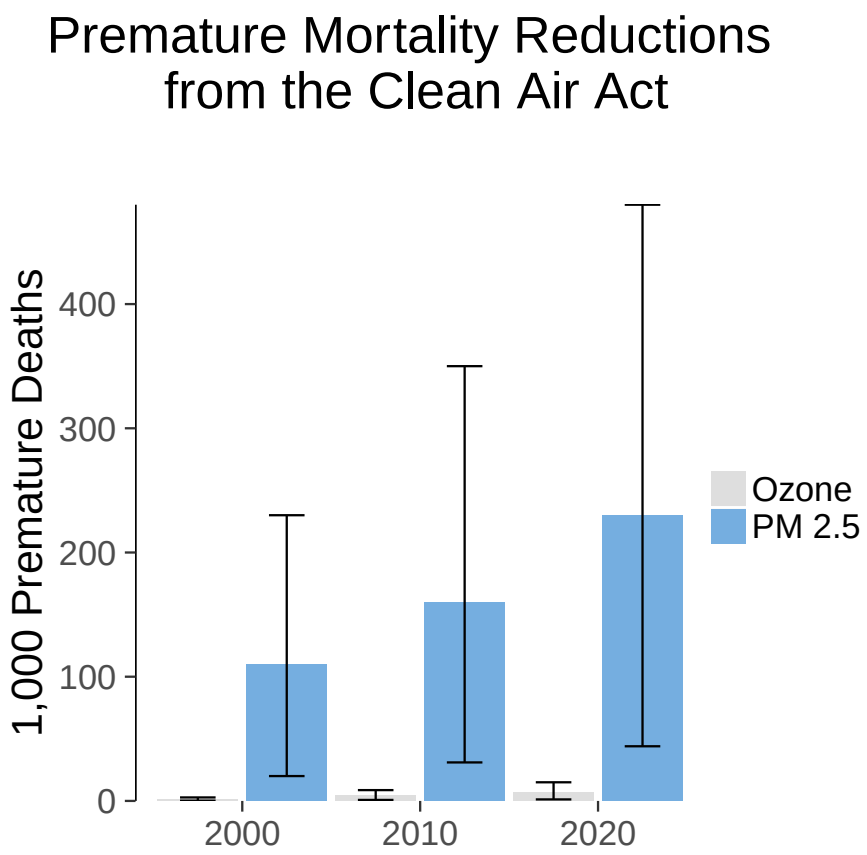
Benefits of Air Quality Improvements

- Improving air quality can have large impacts
- Focus has been on the GE component of costs
- "PE" estimates suggest benefits are *large*



Source: Second CAA Prospective Analysis

Mortality Impacts of the CAA



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- Most CAA benefits are from mortality risk (95%)
- Potentially large effect on the labor force
- Potentially large effect on household savings

GE Analyses w/ Health Benefits

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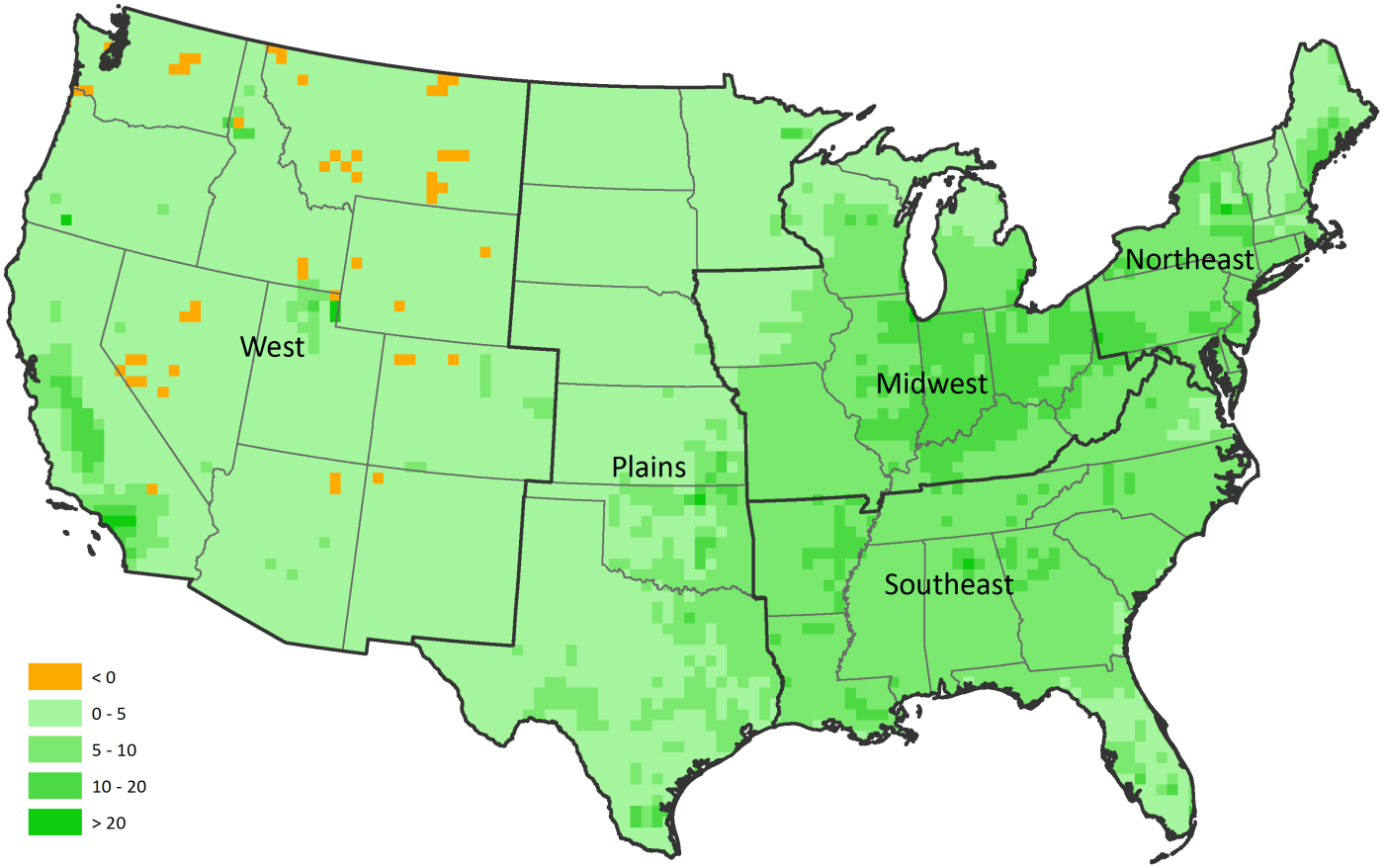
- Effect of a CO_2 tax on criteria air pollutants
  - Chung-Li (2002), Mayeres and Regemorter (2008)
- Historic impact of ozone and PM_{10} levels
  - Matus et al. (2008), Nam et al. (2010), Matus et al. (2012)
- Forecast effect of the Clean Air Act Amendments
  - EPA (2011), Carbone and Smith (2013)

Spatial Resolution in Previous US Studies

- US modeled as a single region
  - Matus et al. (2008): Historic impact of ozone and PM_{10}
  - Selin et al. (2009): Future impact of climate change on ozone
  - Carbone and Smith (2013): SO_2 and NO_X effect of CAAA
- US modeled with five regions in EPA (2011)
  - North, South, Midwest, Plains, West

Spatial Resolution of Benefits Analysis

Change in 2020 $PM_{2.5}$ Concentration from Clean Air Act



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- Need to capture correlation between concentration and population spatial heterogeneity $\rightarrow$ 12km to 36km spatial grid

Research Question

- How does the spatial resolution of a CGE model affect estimates of air quality improvement benefits?

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- How does the spatial resolution of a CGE model affect estimates of air quality improvement benefits?
  - By definition it will impact the ability to analyze the spatial incidence of GE benefits measures
  - But is higher spatial resolution of the economic model necessary for national level welfare estimates?

Role of Spatial Resolution in Water

- Similar questions about spatial resolution have been raised in the water context
  - Water resources do not always follow administrative boundaries
  - Watersheds can cross regional boundaries
  - Larger regions can include many watersheds
- Liu et al. (2015) examine effect of including sub-national watersheds in study of future water scarcity
  - Relevant for some results, but minimal affect on national welfare changes

Air vs. Water Context

- Analogous in spirit to water resources
- Difference is in resource endowment effected by policy
  - Water vs. Labor
- Labor can also cross administrative boundaries
  - Like water cannot easily be moved across time
  - But costs of moving across space may be less

Reasons Spatial Resolution May Matter

- Reallocation costs/immobility of human and physical capital
- Heterogeneity in production and utility functions
- Heterogeneity in taxes
- Intra-national trade costs

Modeling Setup

- Static state-level (50 region) CGE model of the United States
  - 11 sectors/commodities
  - Endogenous leisure
  - Matching national benchmark for model
- 2007 IMPLAN benchmark
- CES/CRTS production and utility function
  - Elasticities based on new literature review
- Labor, capital, consumption, and production taxes
- Armington trade specification - commodity specific elasticities

Capturing Relevant Spatial Heterogeneity

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- Intra-national trade costs
  - Captured via CET for output
  - No explicit source/destination based trade margins

Experimental Setup - Policy Shock

- Shock (Δ) to the time endowment (le_r) to represent the impact of mortality risk reductions

$$le_r^{'} = le_r + \alpha_r \Delta \sum_r le_r$$

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- Aggregate shock equal across state-level and national models
  - Δ is held constant between state-level and national model runs
  - $\sum_r \alpha_r = 1$ in the state-level model runs

Experimental Setup - Incidence

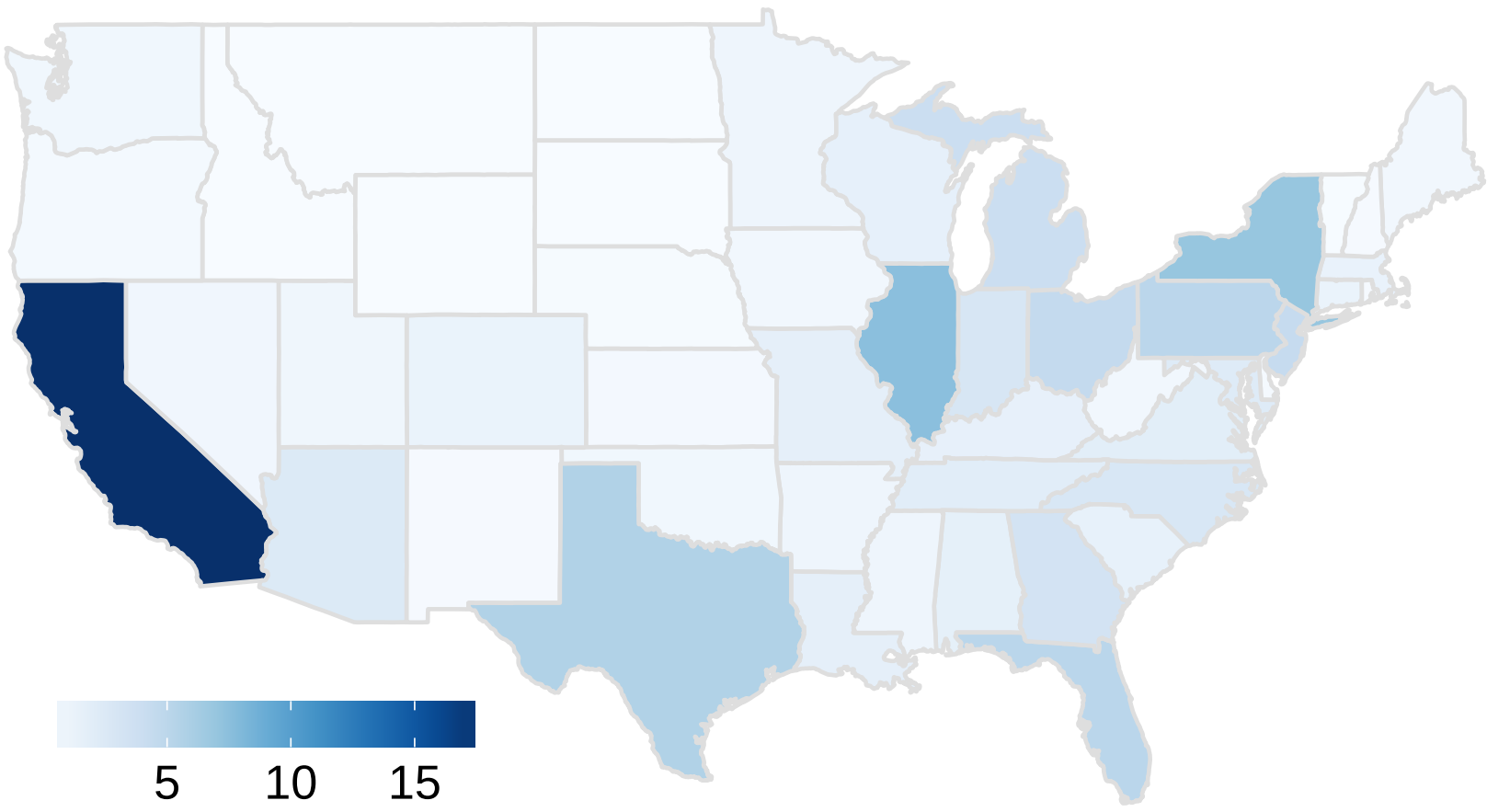
- Shock (Δ) to the time endowment (le_r) to represent the impact of mortality risk reductions

$$le_r^{'} = le_r + \alpha_r \Delta \sum_r le_r$$

- Two methods of distributing the impact across states
  - Uniform: each state receives the same impact ($\alpha_r = 1/50$)
  - Varied: α_r equal to state's share of forecast 2020 national mortality impacts of CAA (Second 812 Prospective)

Spatial Distribution of Benefits

- Distribution of 2020 PM mortality impacts in 812 Prospective



Experimental Setup - Magnitude

- Shock (Δ) to the time endowment (le_r) to represent the impact of mortality risk reductions

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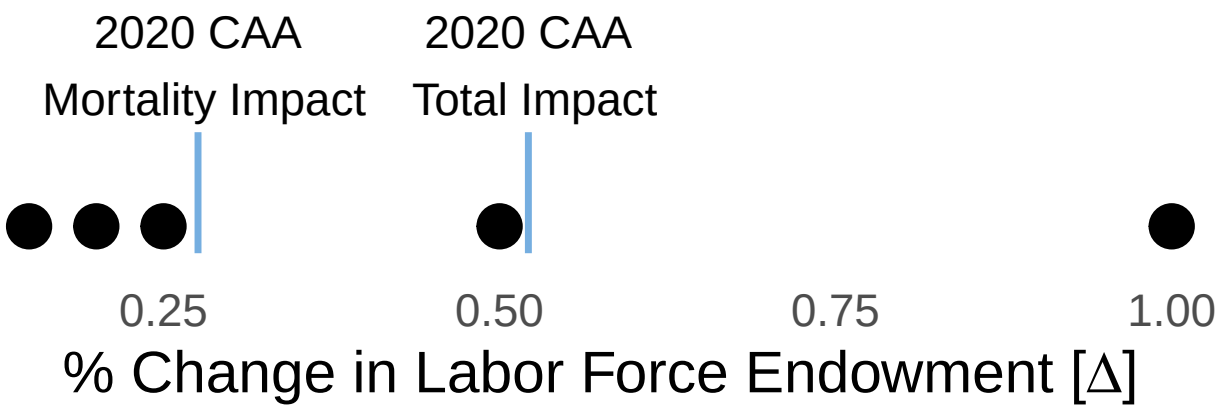
- Test the sensitivity of the results to size of the shock



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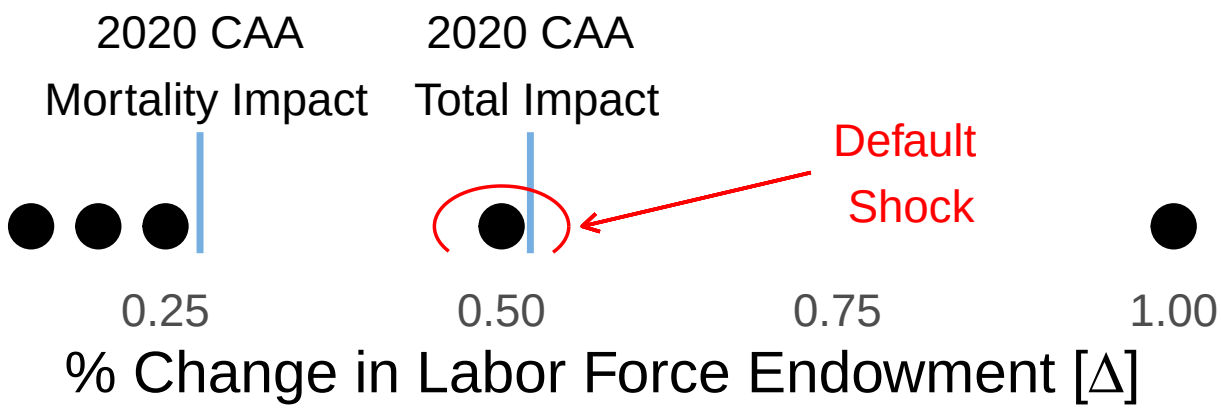
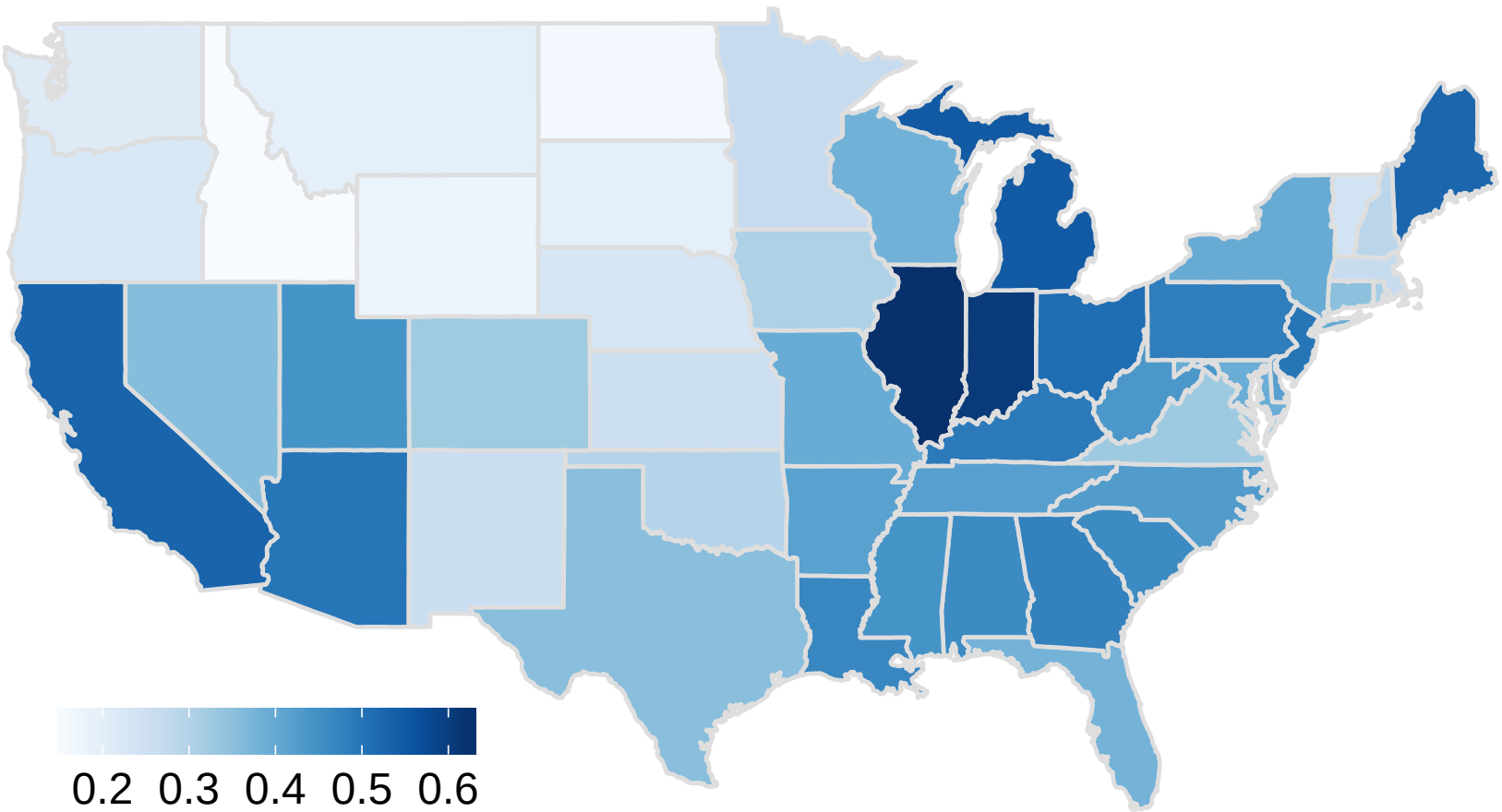
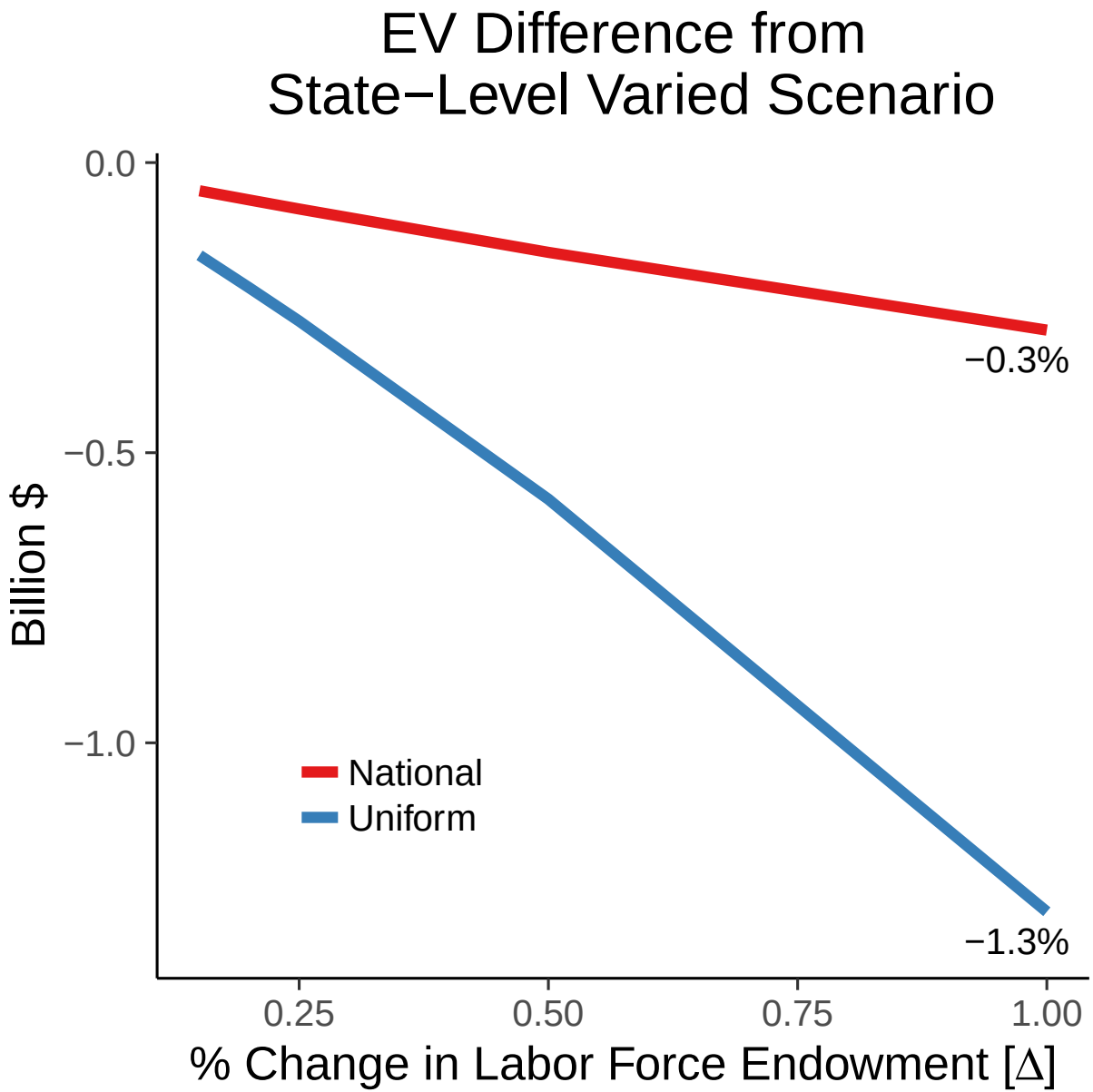


Results - Welfare

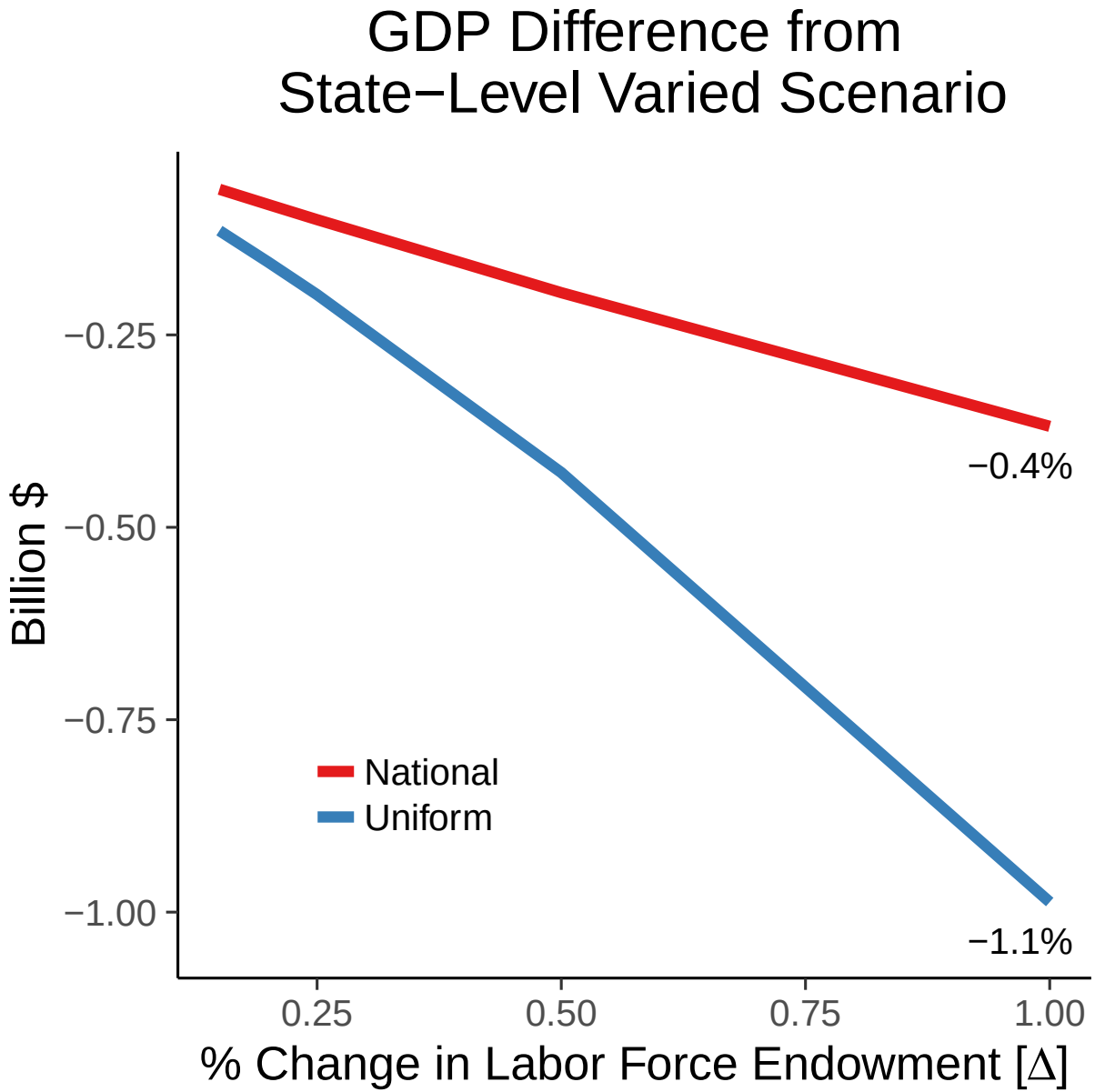
EV [% of Benchmark Welfare]



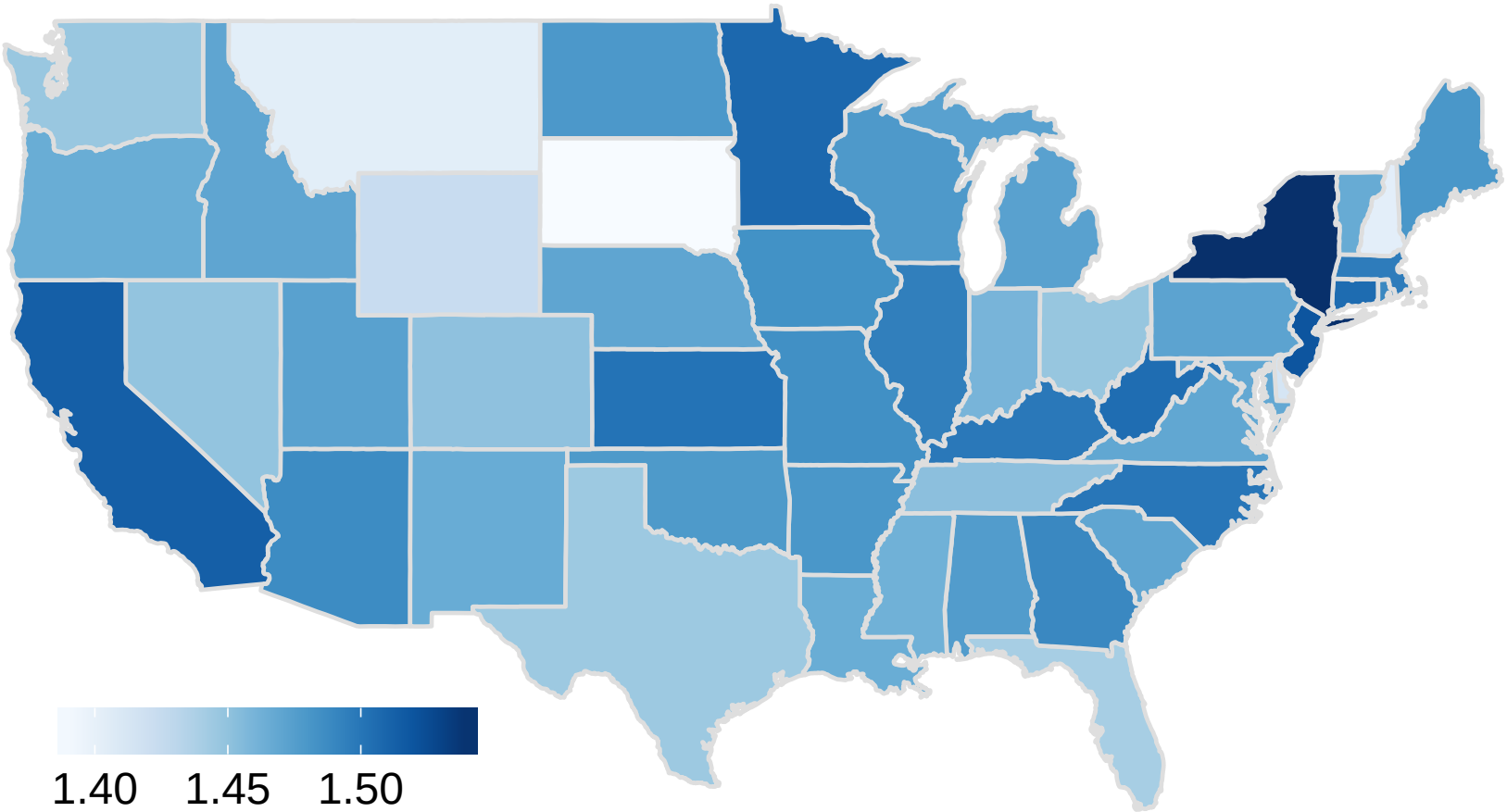
Effect of Spatial Resolution - EV



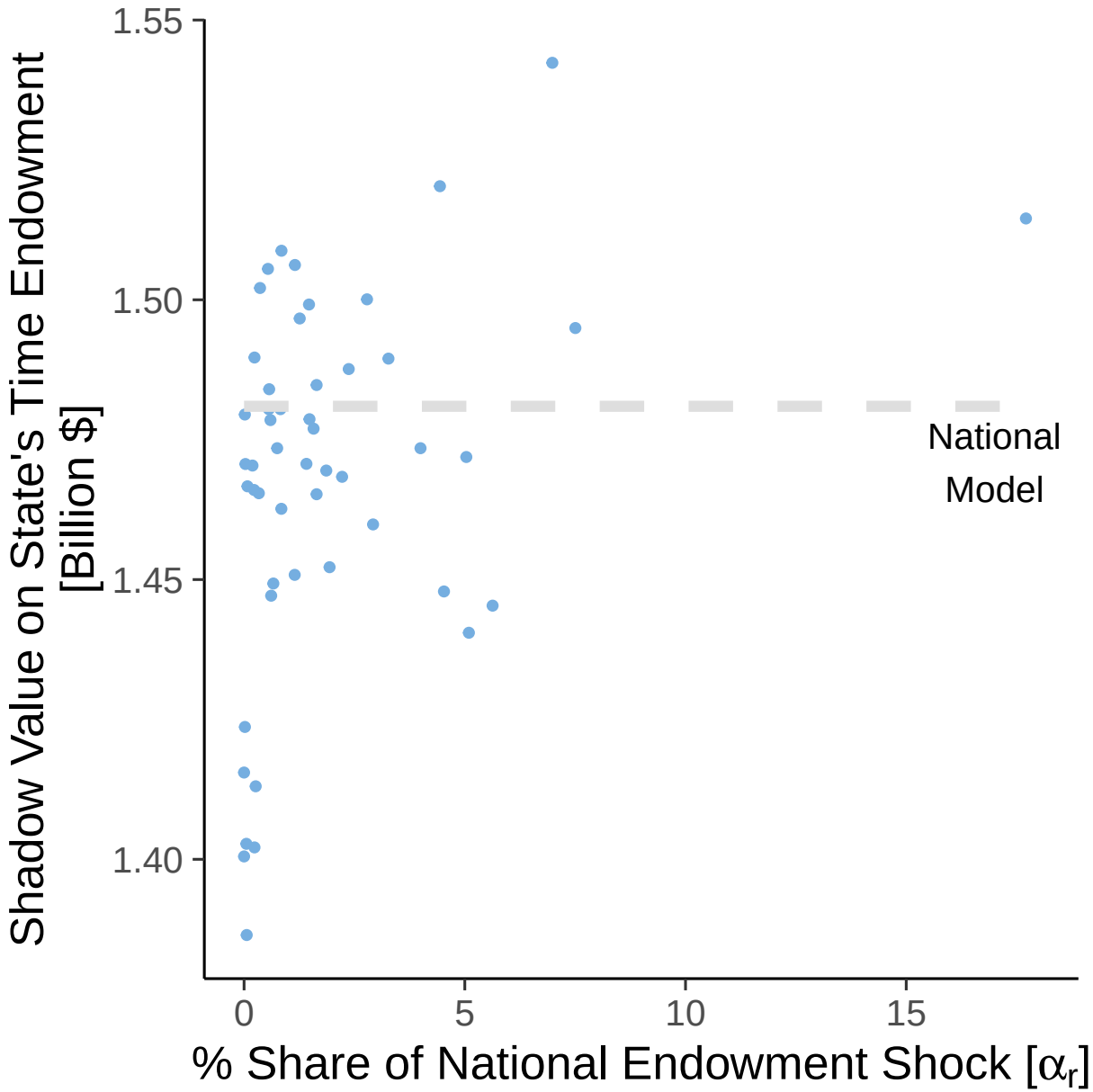
Effect of Spatial Resolution - GDP



Shadow Value of Time Endowment [Billion $]



Shadow Value of Time vs. Impact Share



Effect of Spatial Resolution

- Sub-national spatial resolution in the CGE model may not significantly change national EV estimates of benefits for health impacts of air quality improvements

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- Sub-national spatial resolution in the CGE model may not significantly change national EV estimates of benefits for health impacts of air quality improvements
- Conditional upon:
  - Expected distribution of health impacts
  - Sub-national resolution along state administrative boundaries
- Story may be different for bi-directional feedback analysis

Human Capital vs. WTP

- Existing CGE approach to mortality risk changes has been akin to human capital approach
- Willingness to pay approach has long been used in place of human capital and is significantly different
  - Human capital value for average middle aged US worker = \$0.75 million
  - VSL estimates range from \$2 to \$11 million (Cropper et al., 2011)
- If the VSL is an order of magnitude larger than the value of human capital, are there important GE effects associated with the difference?

Dynamics May be Important

- Consider a basic expected utility framework with annual mortality rate m_t

$$E[W] = \sum_{t=0}^{\infty} s_t \left(\frac{1}{1+r}\right)^t u(c_t),$$

$$s_t = \prod_{\tau=0}^{t} (1 - m_\tau)$$

- Mortality risk will influence savings of households - some empirical evidence
- Working to integrate this behavior into the model's households

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