Valuing Air Pollution's Impact on Labor Productivity in General Equilibrium

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Disclaimer:

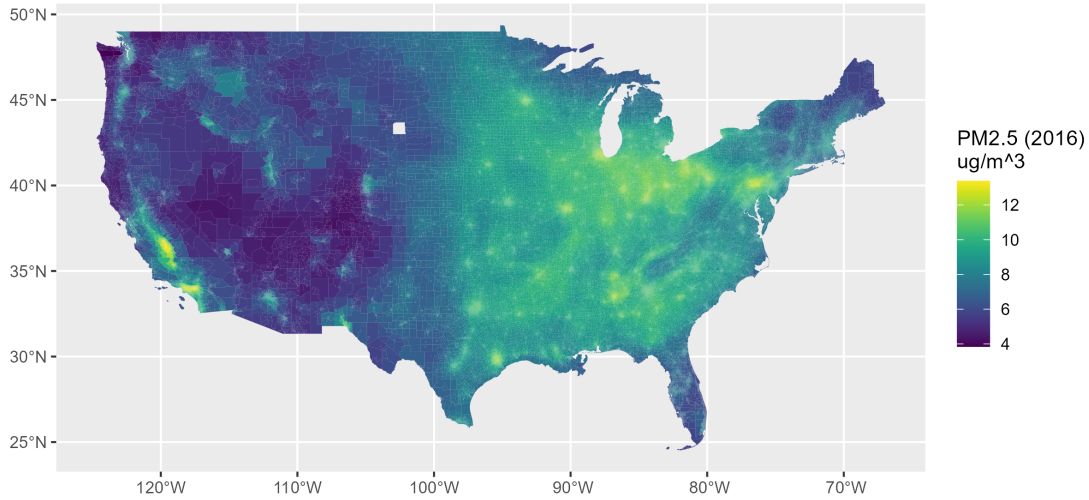
The views expressed are those of the authors and do not necessarily reflect the views or policies of the U.S. EPA.

This work is experimental and presupposes a change in labor productivity. This work does not imply that U.S. EPA assesses that changes in air quality cause changes in labor productivity or that changes in labor productivity are appropriate for consideration in regulatory benefit-cost analysis.

Air Pollution Has Large Negative Effects

- $PM_{2.5}$ causes about 8% of global mortality (Cohen et al, Lancet, 2017)
- $PM_{2.5}$ also causes non-fatal harm including heart attacks, strokes, worsened mental health and decision making
- One way effect is reduced workplace productivity
- Use in regulatory analysis?

Figure: $PM_{2.5}$ is Ubiquitous



What do we do?

1. Calculate the effect of a change in $PM_{2.5}$ on labor productivity
2. Run a Computable General Equilibrium (CGE) model with baseline and changed labor productivity, across several sensitivity scenarios
   - CGE models simulate the whole economy and captures social welfare.
   - We can simulate how a change would reverberate through the economy, *unlike partial equilibrium models.*
   - Forces you to think about impact channels, contrary to reduced form econometric evidence.
3. Compare results

Results Preview

1. A one $\mu g/m^3$ reduction in $PM_{2.5}$ has a benefit of \$500 per household per year in our central estimate, with low and high estimates of \$200 and \$1500.
   - Average ambient $PM_{2.5}$ has gone from 13.5 $\mu g/m^3$ to 8 $\mu g/m^3$ since 2000.
   - Our central estimate is $\approx$ 20% of the value of mortality risk reduction.
2. The benefits increase with income.
3. Benefits are approximately linear with the size of the pollution change.
4. Aggregate welfare impacts are insensitive to several modeling sensitivities.

Calculating an Average Change in Productivity

Main scenario: 1 $\mu g/m^3$ uniform reduction in $PM_{2.5}$ across the United States.

- Econometrics studies find a 0.6%-1.9% reduction in productivity or production per unit of $PM_{2.5}$
  - Chang et al (2016 AEJ:Pol), Dechezleprêtre et al. (2019 WP), Fu et al (2021 EJ), Borgschulte et al. (2022 ReStat)
  - Maybe a central tendancy around 0.8%?
- We use three different estimates of the percent reduction in productivity per unit of $PM_{2.5}$: 0.1, 0.3, and 0.9.
- In CGE model, modeled by reducing the labor required to produce one unit of output for each sector.

$$f(l,k) = \left(\theta^l \left(\frac{l}{\phi \bar{l}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta^l)\left(\frac{k}{\bar{k}}\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

Design of SAGE

We use EPA's intertemporal (perfectly foresighted) CGE model, called SAGE (Marten et al., 2024). Key design features:

- Labor-leisure choice
- Representative households to model each income quintile
- Multiple regions of the US
- Pollution-intensive manufacturing and energy are modeled in more detail than less pollution-intensive sectors
- Households maximize PV of utility (function of discretionary consumption and leisure
- Marginal and average tax rates
- Behavioral parameters estimated or taken from literature

Scenarios

Scenarios driven by both input uncertainties and model structure uncertainties.

- Labor productivity effect: 0.1%, 0.3%, 0.9%
- Experiments:
  1. `Core`: uniform shock to economy-wide labor productivity
  2. `Sector Differentiated`: sectorally heterogeneous labor productivity shocks dependent on outdoor exposure
  3. `Occupational Frictions`: occupationally heterogenous labor productivity shocks with labor market frictions in occupational mobility
- Labor/leisure choice [not shown here]: labor only, leisure only, labor/leisure

Core Model Results

The labor productivity costs of air pollution are large:

- A one unit change in $PM_{2.5}$ is worth \$500 in equivalent variation (EV) annually (per household) in our central estimate, with a range of \$200-1500
- Running EPA's BenMAP, the associated mortality benefit is \$2500.
  - In EPA rules, mortality impacts typically make up about 90% of the total health benefits.

Welfare impacts are approximately linear with the shock:

Shock size	Annualized EV	% Full Consumption
0.1%	\$168	0.104%
0.3%	\$505	0.313%
0.9%	\$1515	0.943%

Comparison with back of the envelope calculation

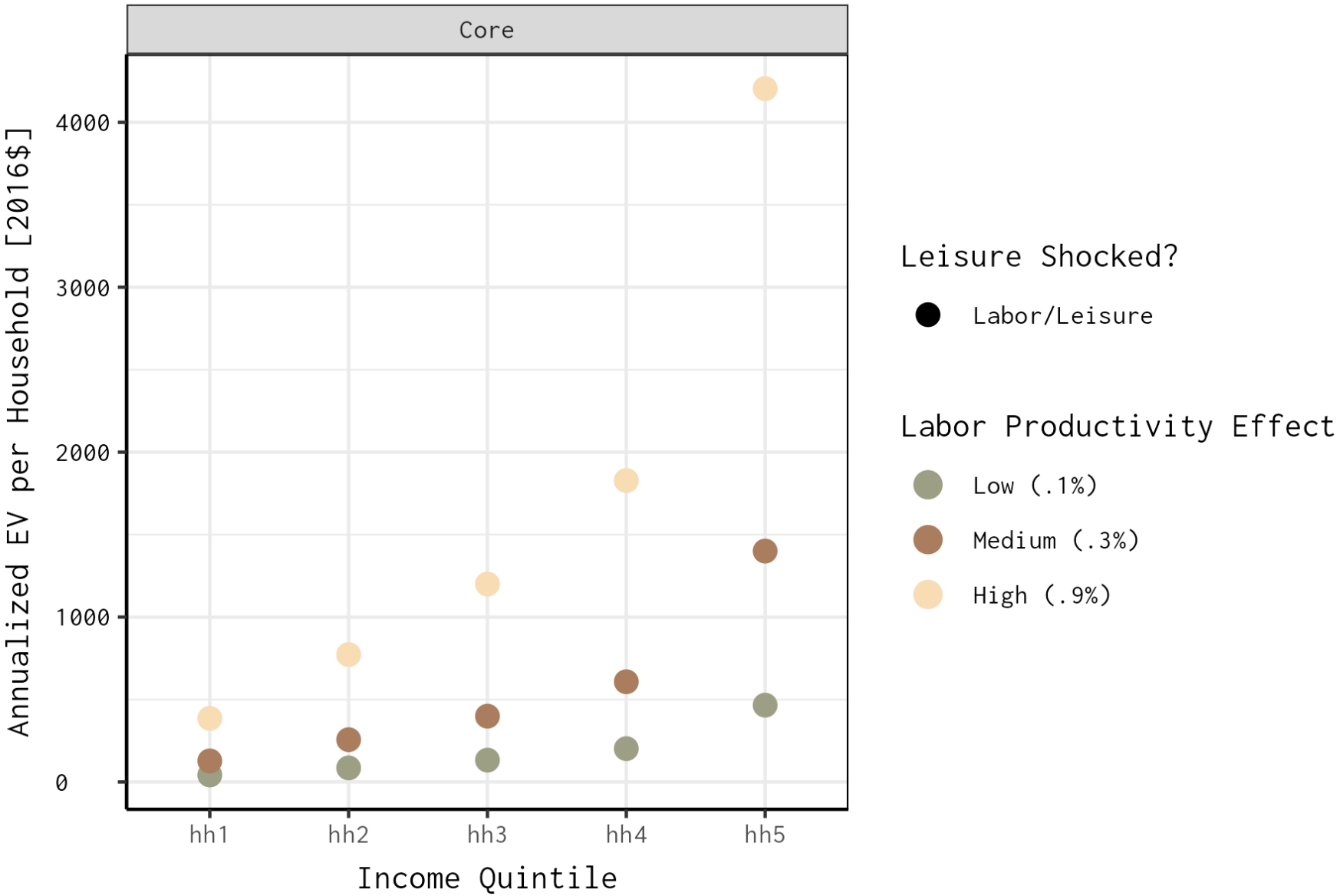
A back of the envelope calculation of the effect might be to multiply the change in productivity by baseline projections of the labor share of GDP:

- Under .3% scenario, $\approx$ \$330 annually (per household), compared to $\approx$ \$500 in modeled equivalent variation.

The model captures several important channels missed by the back of the envelope calculation:

- Value of leisure
- Wage/price effects
- Tax interaction effects
- Output effects and changes to investment

Benefits Increase with Income

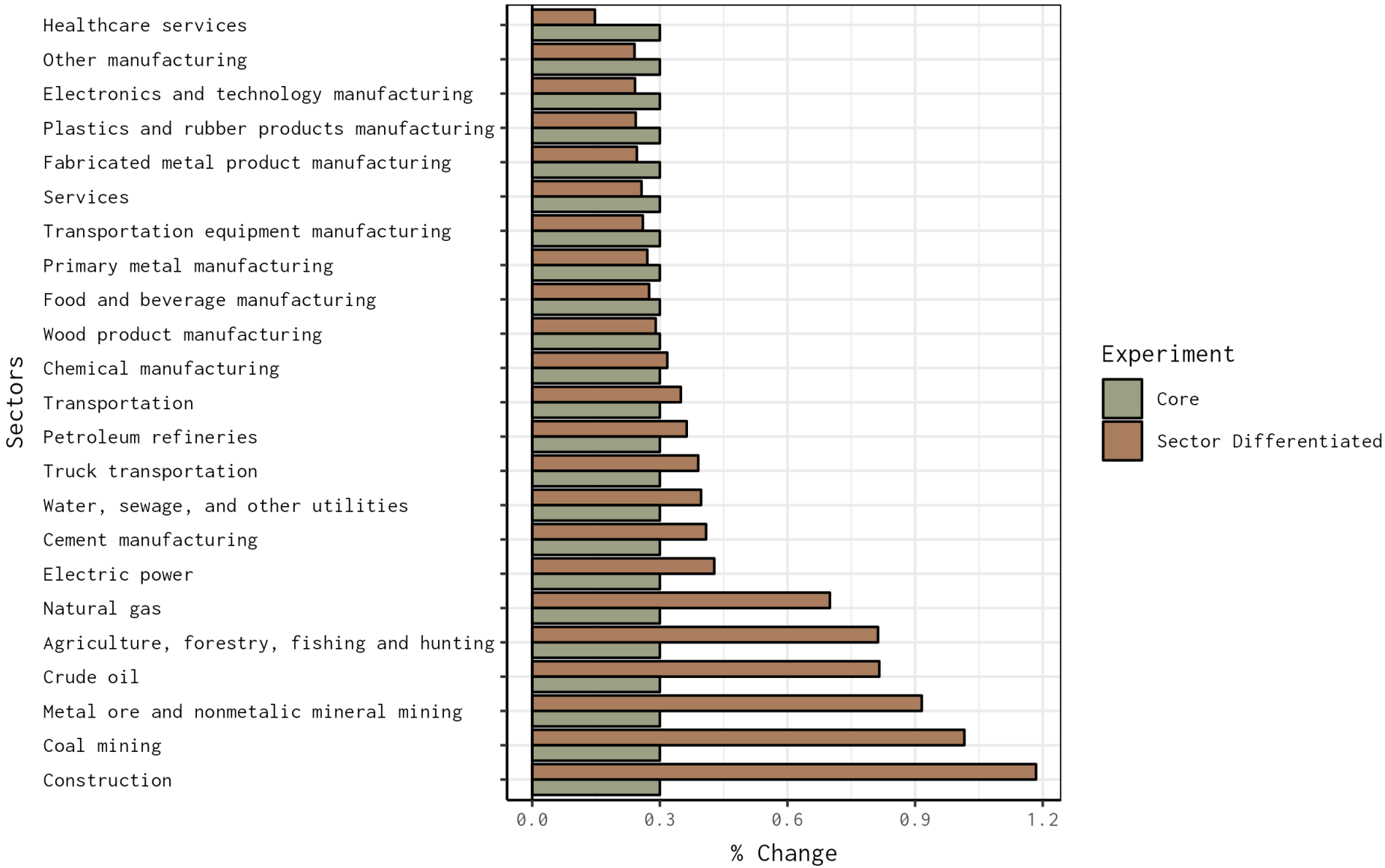


Modeling Heterogeneity

Consider two key areas of potential data/model uncertainty:

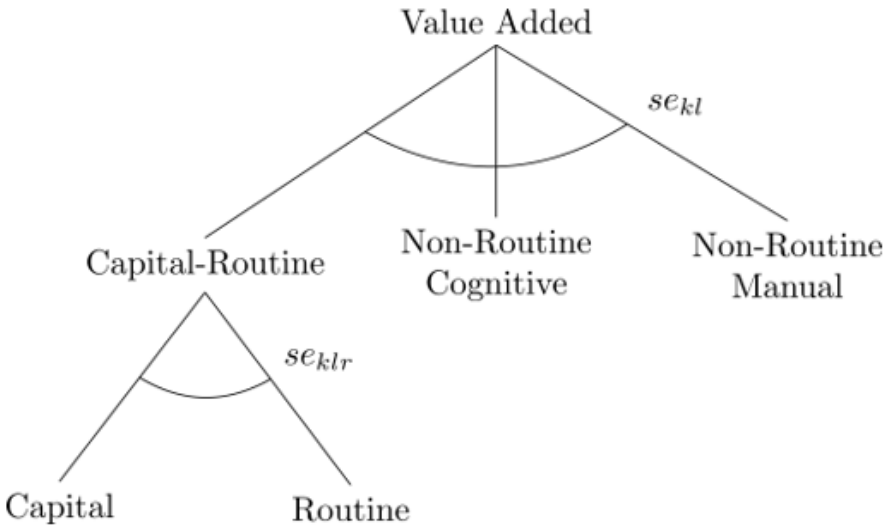
- Variation in the impact of air pollution across work settings [`Sector Differentiated`]
  - Calculate fraction of work time outdoors for occupations based on DoL O*Net data
  - Average to sectors based on BLS sector-occupation mapping
  - Scale productivity shocks based on sectoral exposure while maintaining mean shock
- Labor market rigidities in switching to more productive occupations [`Occupational Frictions`]
  - Adapt Marten et al. (2024) that restricts occupational mobility in a CGE model calibrated to Cortes (2016)
  - Routine vs. non-routine cognitive occupations

Sector Differentiated Shock (0.3%)

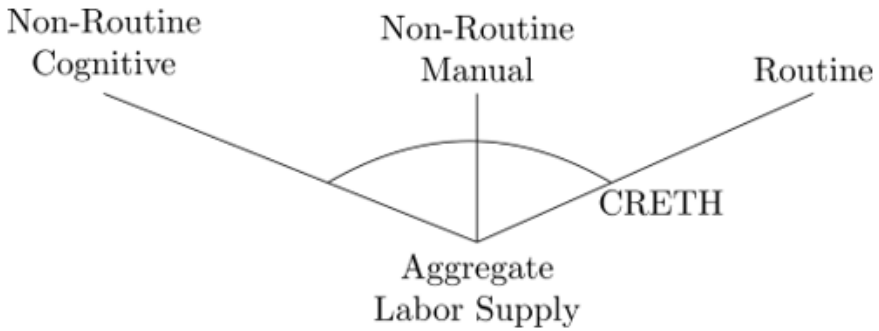


Occupational Frictions

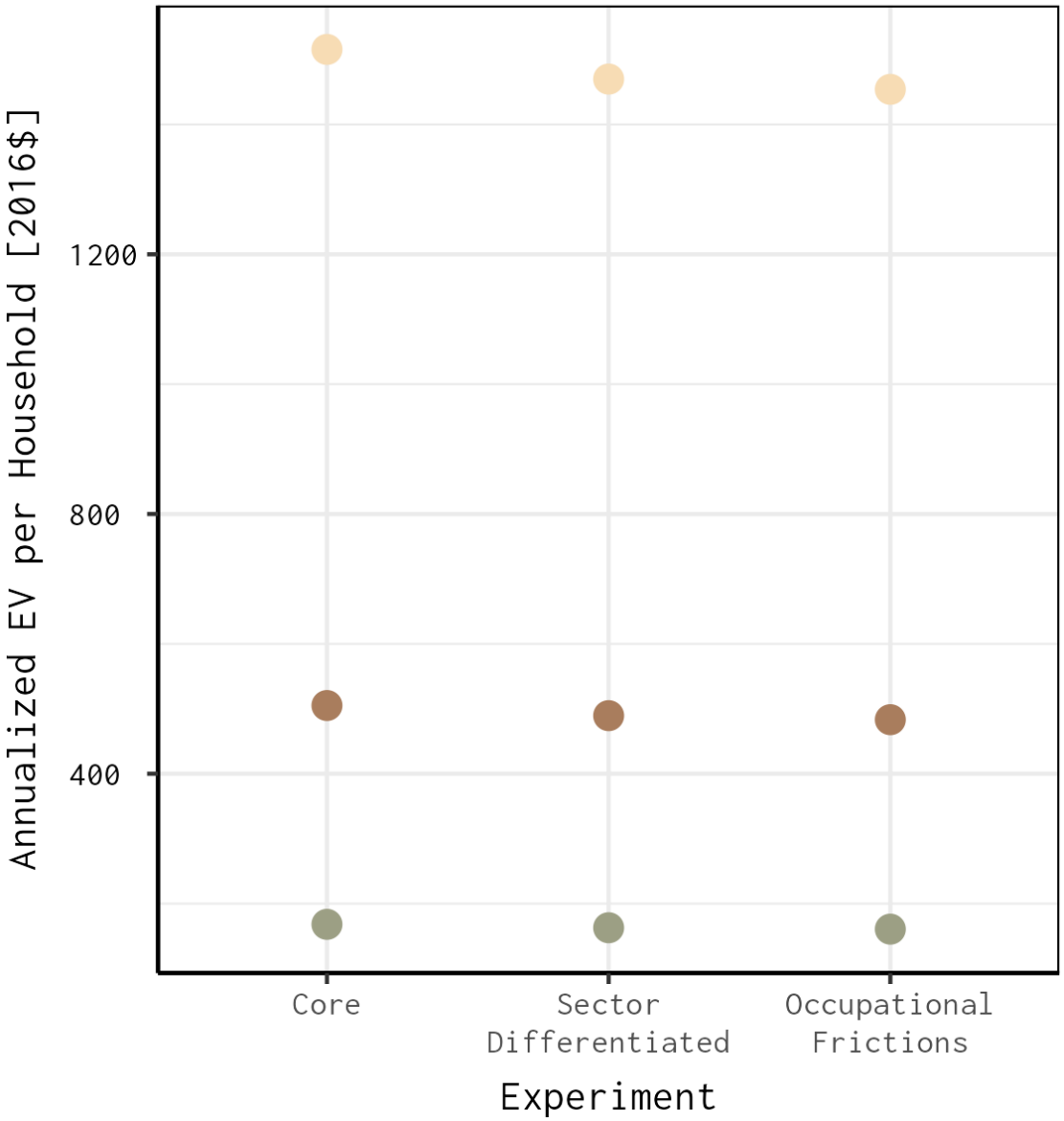
Labor Demand:



Labor Supply:

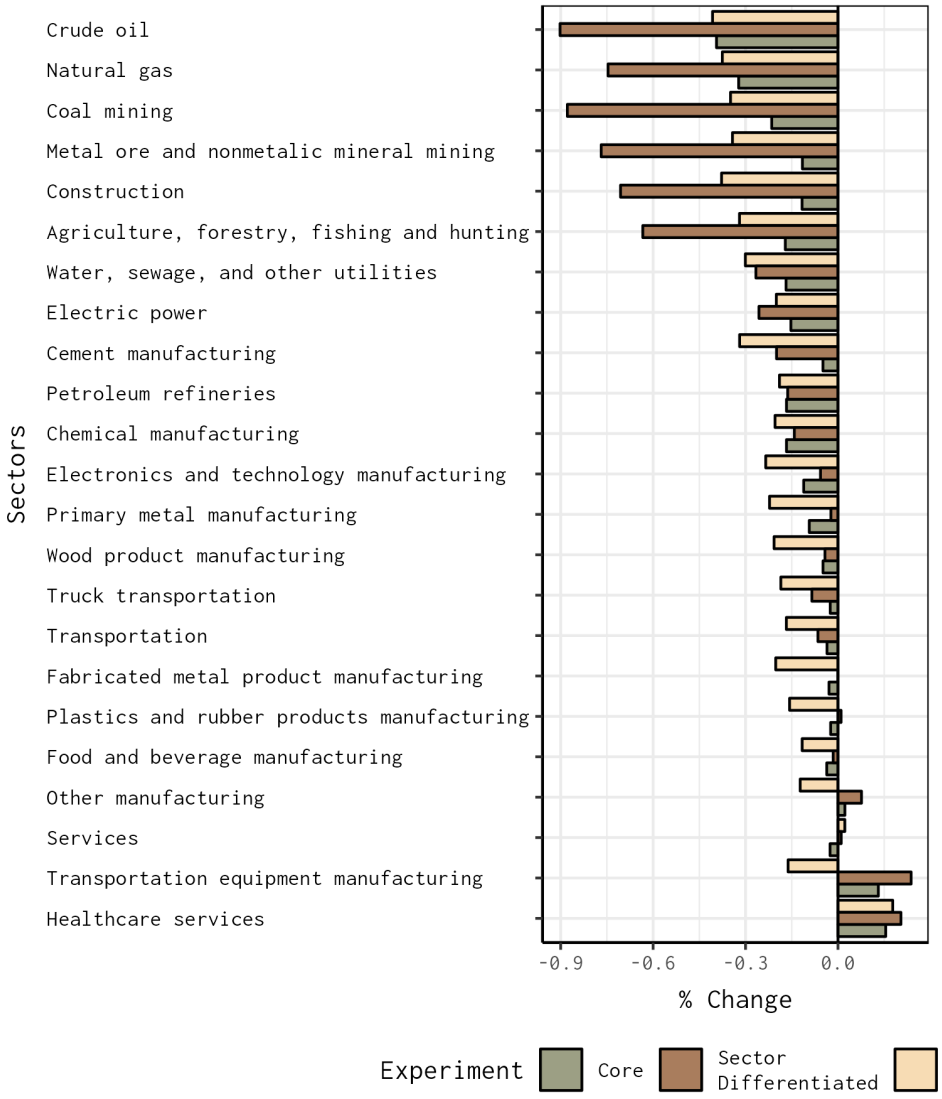


Heterogeneity Has Little Effect on Aggregate Results

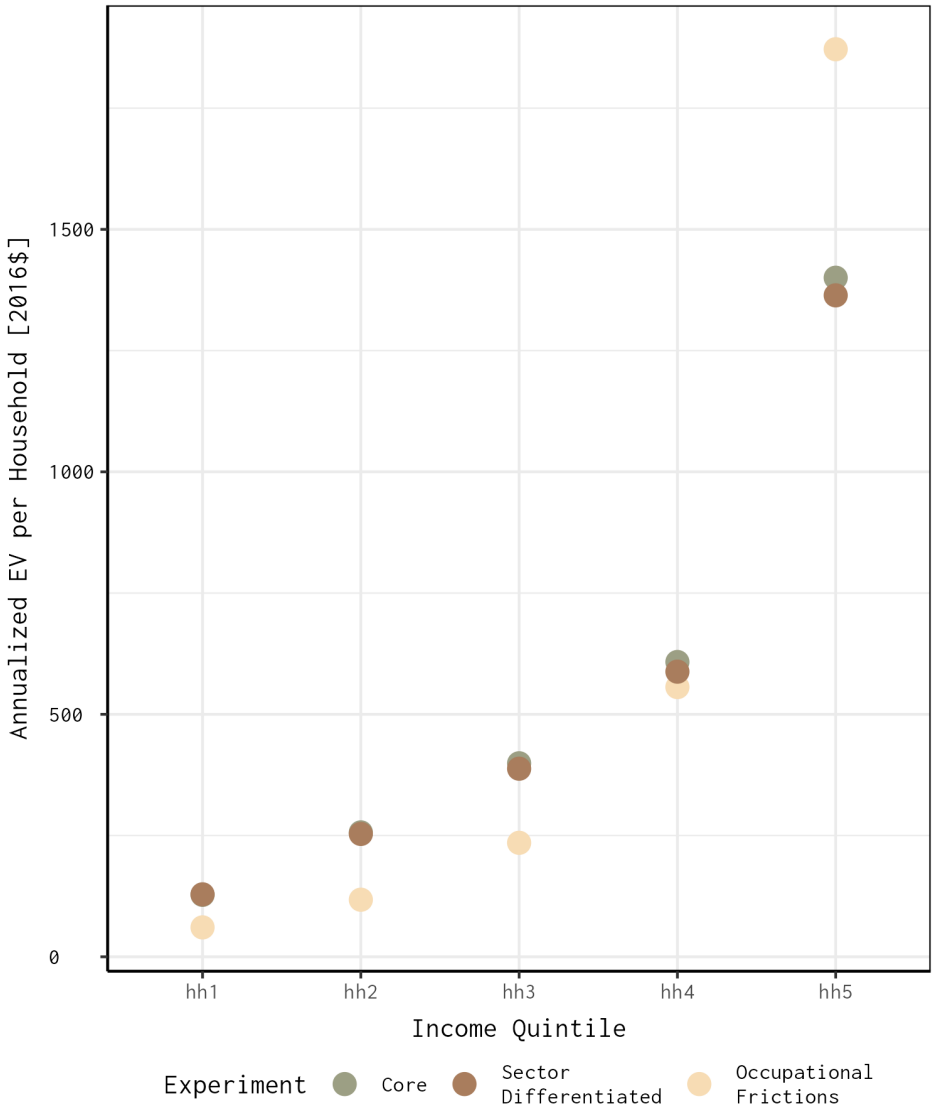


Heterogeneity Affects Sectoral/Distributional Results

Δ Labor Demand in 2031 (.3%)



Household EV (.3%)



Conclusions

- Air pollution has a range of sub-clinical effects which are often omitted from benefit-cost analyses.
- We monetize a subset of these effects which lead to changes in labor productivity.
- The effects are large - comparable in magnitude to value of avoided mortality risk.
- There remains substantial uncertainty driven by variation in estimates of how much air pollution effects productivity.
- This work assumes pollution exposures are exogenous.