Carbon Taxes in Spatial Equilibrium

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Research Overview

Carbon emissions create well-recognized negative externalities

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Research Qs: How would a carbon tax impact US labor markets?

- How does incidence from carbon pricing vary across cities and sectors?
- What role does imperfect mobility play in determining the incidence?
- Spatial + sectoral equity-efficiency tradeoffs

Incidence

The incidence of carbon pricing varies across cities and sector for a few reasons:

1) Geographic industrial concentration varies across the US

2) Industries vary in energy-use intensities and input substitutability

- Differential impacts on labor markets from carbon pricing across industries & space

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4) Carbon efficiency of local power plants varies across the US

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Literature

I am not the first to recognize—or model—the **distributional impacts of carbon pricing**:

- Employment impacts from BC carbon tax (Yamazaki, 2018)
- Employment effects in general eq. (Hafstead & Williams, 2018)
- Equity and Efficiency from carbon tax (Goulder et al., (2018))
- CGE model w/ 15k HHs to recover incidence (Rausch et al., 2011)
- CGE model with two cases: perfect mobility and perfect immobility (Castellanos & Heutel, 2019)

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Quantitative Spatial Equilibrium Models:

- Endogeneous amenities and college wage premia (Diamond, 2015)
- Impacts of immigration on wages (Piyapromdee, 2019)
- Land Use regs and HH carbon emissions (Colas & Morehouse, 2021)

Model

Model Overview

Households

- Static; discrete choice: locations & sectors
- Consume numeraire, housing, and energy

Locations

- Wages, rents, and energy prices (endogenous)
- Carbon efficiency of power plants
- Amenities (location-specific consumption)

Firms

- Use energy, labor; produce numeraire
- Vary across sector by: Input use intensities & elasticities of sub

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    - Price Δ depends on **carbon efficiency of regional power plants**

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- Change in energy prices $\implies$ **change in wages**
  - This change varies by city + sector (due to **differences in prod. params**)

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  - This change varies by city + sector (due to differences in prod. params)
- Change in wages $\implies$ **sorting!** New location-sector choices further change prices.

Model: Households

Indirect utility for HH i of skill level e in city j, sector n:

$$V_{ijn} = \beta_e^w \log(\tilde{I}_{ejn}) - \beta_e^r \log R_j - \sum_m \alpha_{ej}^m \log P_j^m + f(\mathcal{D}(j, \mathcal{B}_i)) + \hat{\lambda}_{ijn}$$

where

- $\tilde{I}_{ejn}$ is income, R_j is rents
- P_j^m is price of energy type $m \in \{\text{elec,gas,oil}\}$
- $f(\mathcal{D}(j, \mathcal{B}_i))$ moving cost as a function of euclidean distance $\mathcal{D}$ from j to i's birthstate

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- $\hat{\lambda}_{ijn} = \xi_{ejn} + \epsilon_{ijn}$ amenities:
    - ξ_{ejn} unobserved (to me), shared by all agents in skill group/city/sector
    - ϵ_{ijn} iid pref shock

Model: Firms

Firms in perfectly competitive markets produce the output good with tech:

$$Y_{jn} = A_{jn} K_{jn}^{\eta} \mathcal{I}_{jn}^{1-\eta}$$

where

$$\mathcal{I}_{jn} = \left(\alpha_{jn} \mathcal{E}_{jn}^{\rho_{el}^{n}} + (1 - \alpha_{jn}) \mathcal{L}_{jn}^{\rho_{el}^{n}} \right)^{\frac{1}{\rho_{el}^{n}}}$$

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E and G: Energy and Gas consumed

ζ : city-sector electricity intensity

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S and U skilled and unskilled labor quantities

θ : city-sector educated labor intensity

$\sigma_l = \frac{1}{1-\rho_l}$: elasticity of sub between educ. levels

Model: Firms

Energy Demand

$$P_{jn}^{E} = \mathcal{A}_{jn}\mathcal{I}_{jn}^{1-\rho_{el}^{n}}\mathcal{E}_{jn}^{(\rho_{el}^{n}-\rho_{e}^{n})}\alpha_{jn}\zeta_{n}E_{jn}^{\rho_{e}^{n}-1}$$

$$P_{jn}^{G} = \mathcal{A}_{jn}\mathcal{I}_{jn}^{1-\rho_{el}^{n}}\mathcal{E}_{jn}^{(\rho_{el}^{n}-\rho_{e}^{n})}\alpha_{jn}(1-\zeta_{n})G_{jn}^{\rho_{e}^{n}-1}$$

Labor Demand

$$W_{jn}^{S} = \mathcal{A}_{jn}\mathcal{I}_{jn}^{1-\rho_{el}^{n}}\mathcal{L}_{jn}^{(\rho_{el}^{n}-\rho_{l})}(1-\alpha_{jn})(\theta_{jn})S_{jn}^{\rho_{l}-1}$$

$$W_{jn}^{U} = \mathcal{A}_{jn}\mathcal{I}_{jn}^{1-\rho_{el}^{n}}\mathcal{L}_{jn}^{(\rho_{el}^{n}-\rho_{l})}(1-\alpha_{jn})(1-\theta_{jn})U_{jn}^{\rho_{l}-1}$$

Model: Firms

Energy Demand

$$P^E_{jn} = \mathcal{A}_{jn}\mathcal{I}_{jn}^{1-\rho^n_{el}}\mathcal{E}_{jn}^{(\rho^n_{el}-\rho^n_e)}\alpha_{jn}\zeta_n E_{jn}^{\rho^n_e-1}$$

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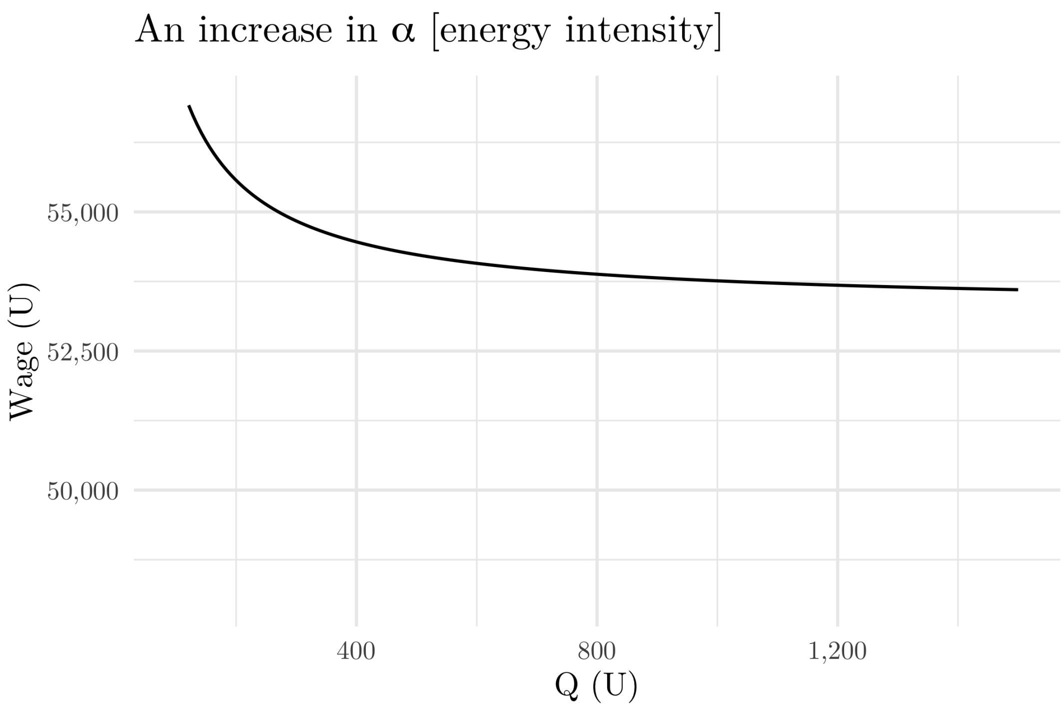

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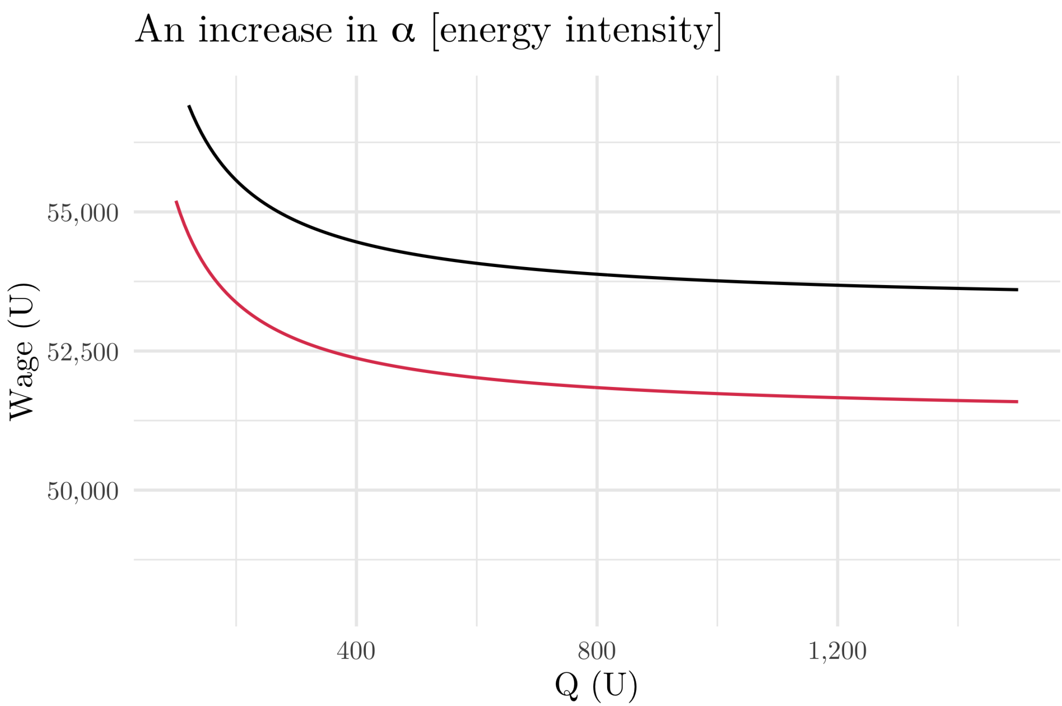

Everything else

Rents: Upward sloping supply curve. Slope is a function of land available for dev and local regulations

Electricity: Regional (NERC) upward sloping curve

Emissions: Energy use $\implies$ carbon emissions!

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Electricity: Regional (NERC) upward sloping curve

Emissions: Energy use $\implies$ carbon emissions!

- Emissions for natural gas and oil are constant across space
- Electricity emissions is the weighted average carbon intensity of all plants in the region

Estimation + Results

Estimation + Calibration

The model has a ton of parameters. Some details:

Factor Demands:

- Solve for factor intensities using relative demand curves
- Calibrate elasticities of sub

Rents:

- Calibrate inverse supply elasticities by CBSA
- Calculate intercepts to match data

Electricity:

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Labor Supply: Gets a whole slide 😄

Estimation

I'll focus briefly on labor supply. I use a **two-step** estimation procedure

1) Treat locations-sectors as "products" with characteristics by skill group

- Recover moving cost parameters using "**micro-BLP**" (Berry, 1995)
- Use repeated cross-sections of census. Estimate parameters and corresponding mean utilities for 4 sample years
  - **Note:** even with a very powerful GCE VM, estimating on full sample is still not computationally feasible

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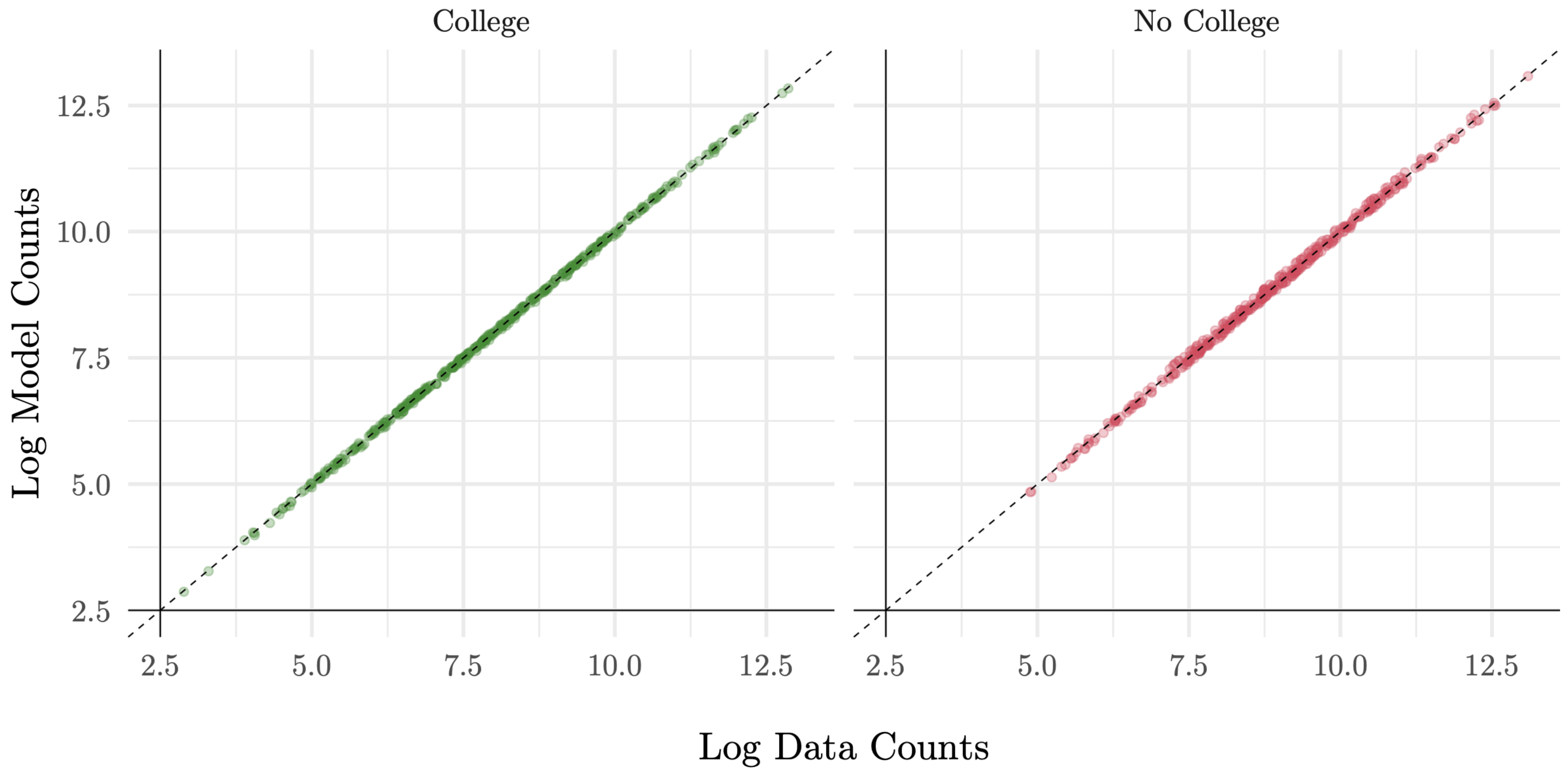
2) Estimate β_e^w and β_e^r in **first-differences with IV**

- Bartik labor demand shocks identifies β_w^e
- Bartik labor demand shocks $\times$ city housing supply elasticity identifies β_r^e

Model Fit


College
No College
Log Model Counts
Log Data Counts
2.5
5.0
7.5
10.0
12.5

Counterfactuals

I use the estimated model to solve for counterfactual **equilibrium** under two scenarios🦆

1: Baseline carbon tax, \$31 per ton (SCC à la Nordhaus (2017))

2: Carbon tax under a "no-coal" scenario

- I re-calculate $\delta_{\mathcal{R}}^{elec}$ *without coal* and implement a \$31 tax in the model

🦆 An **equilibrium** in this model is characterized by price vectors (wages, rents, and electricity prices) such that all relevant markets clear

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Compensating Variation: Dollar amount HH would need (yearly) to be indifferent between tax and no tax:

$$CV_i = \underbrace{(\mathbb{E}[V(\tau > 0)] - \mathbb{E}[V(\tau = 0)])}_{\%\Delta\text{Expected Utility}} \times \underbrace{\frac{w_i}{\beta^w}}_{\text{Wage conversion}}$$

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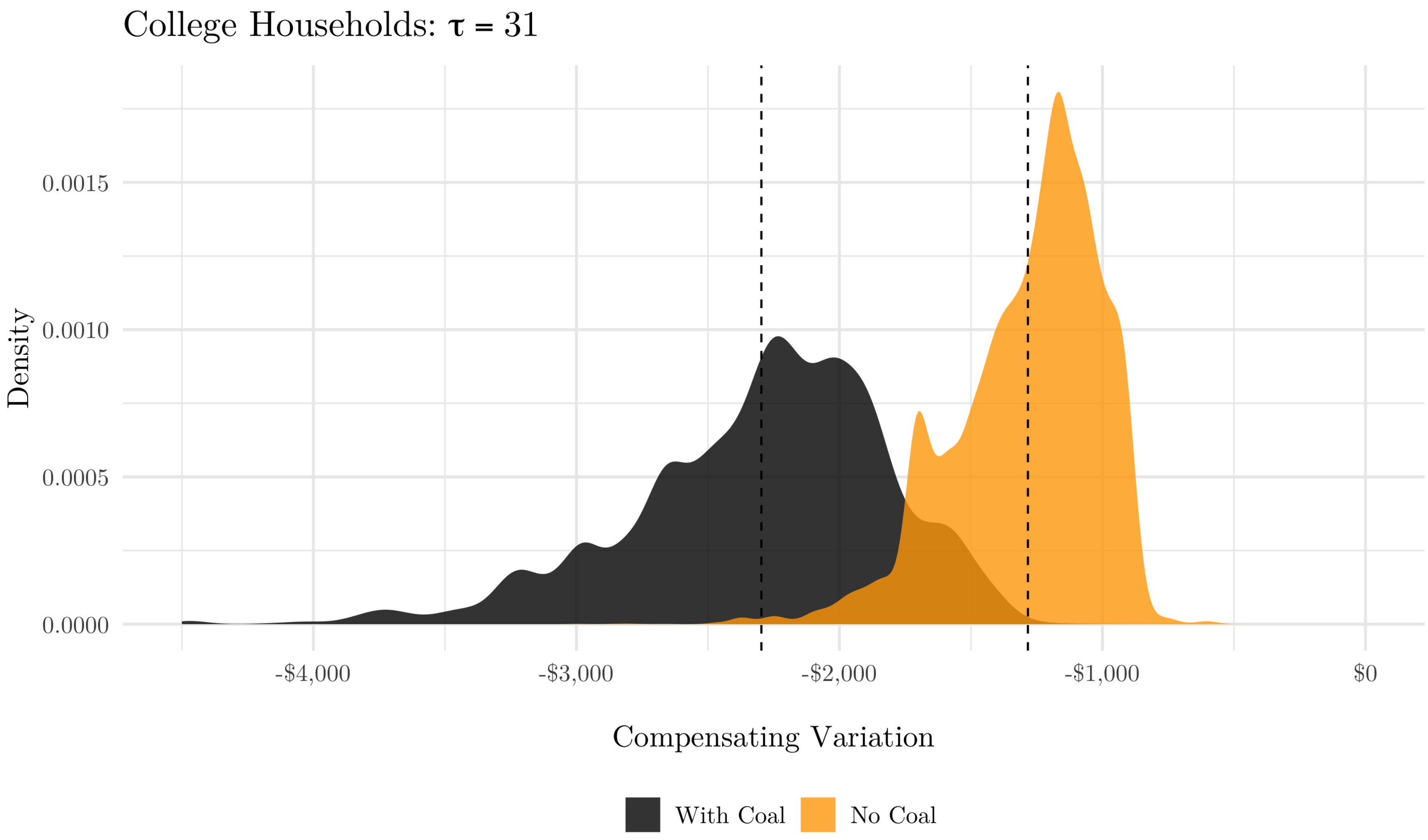
Results


College Households: τ = 31
Density
0.0015
0.0010
0.0005
0.0000
-$4,000
-$3,000
-$2,000
-$1,000
$0
Compensating Variation
With Coal
No Coal

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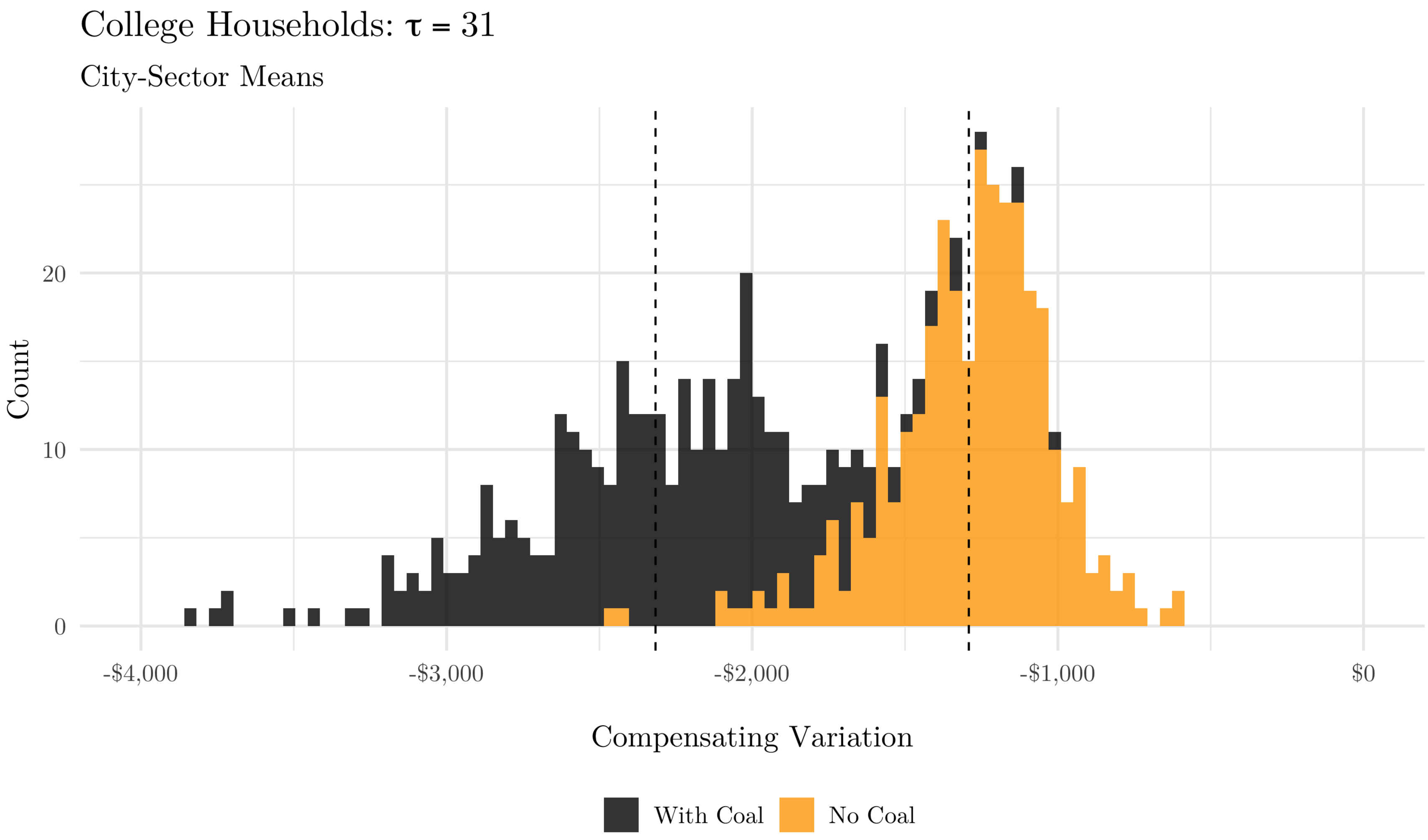

College Households: τ = 31
City-Sector Means
Count
20
10
0
-$4,000
-$3,000
-$2,000
-$1,000
$0
Compensating Variation
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No Coal

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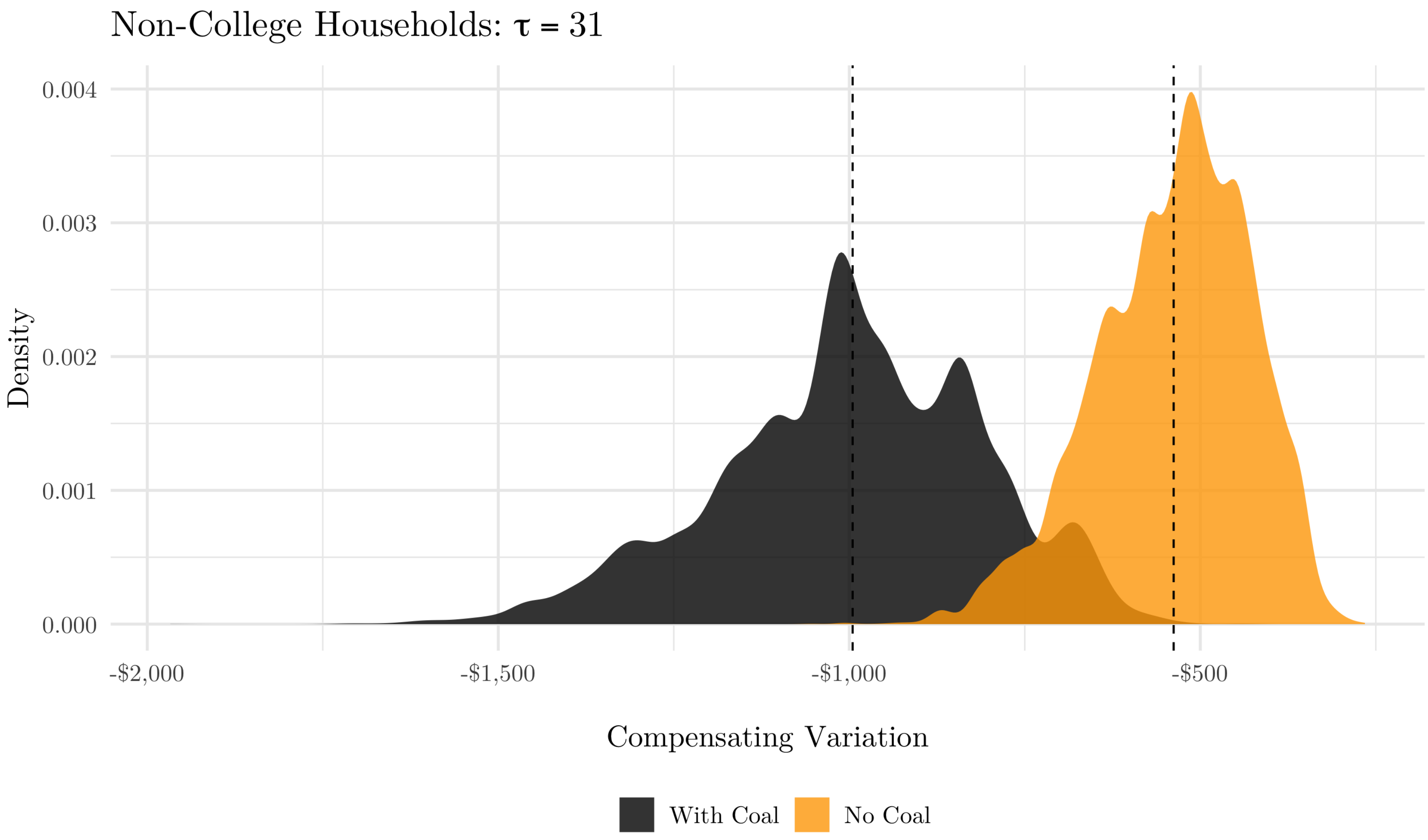

Non-College Households: τ = 31
Density
0.004
0.003
0.002
0.001
0.000
-$2,000
-$1,500
-$1,000
-$500
Compensating Variation
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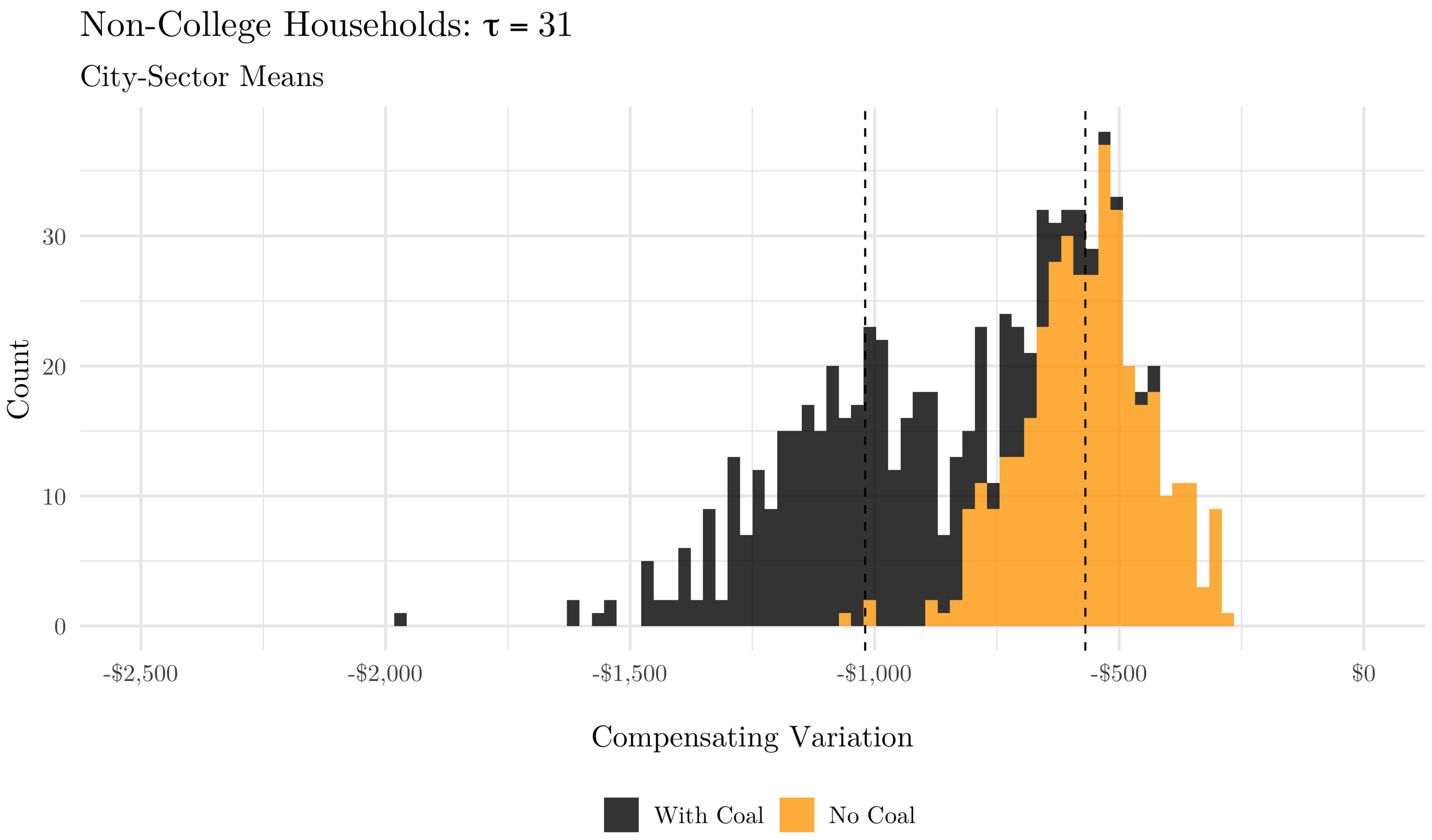
No Coal

Results



Non-College Households: τ = 31
City-Sector Means
Count
30
20
10
0
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-$1,000
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Conclusions

Main Takeaways:

- Recovered household level distribution of taxing carbon
- Significant heterogeneity in tax burden by individual, city, and sector
- Used the model to specifically ask: how much does coal contribute to tax burden?

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To do:

- Decompose results into direct + indirect effects
- Revenue recycling schemes: looking into equity-efficiency tradeoff in this setting
- A lot of robustness checks

Thank You!!

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