Labor Mobility with Environmental Regulation

MIBB

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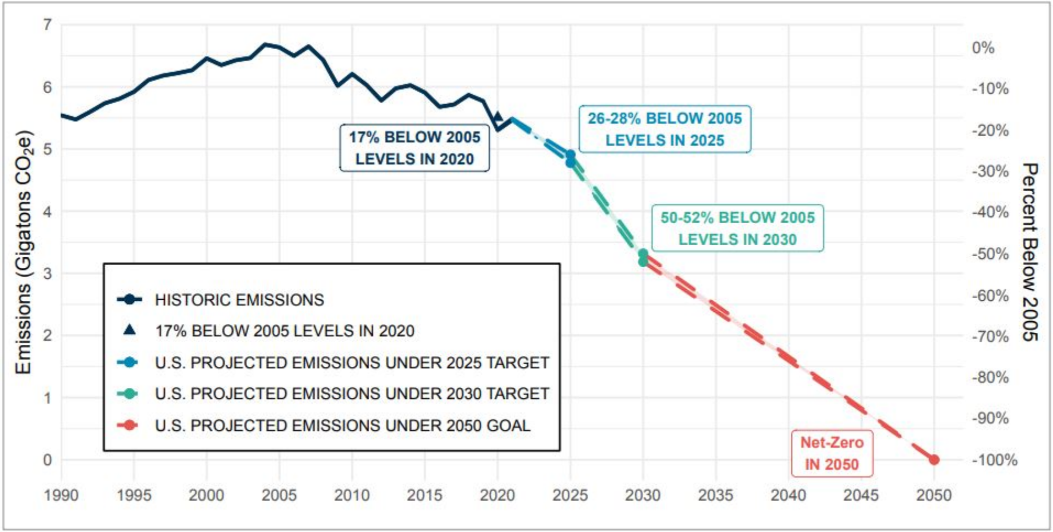
Motivation



Emissions (Gigatons CO_2e)
Percent Below 2005
7
6
5
4
3
2
1
0
0%
-10%
-20%
-30%
-40%
-50%
-60%
-70%
-80%
-90%
-100%
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
17% BELOW 2005 LEVELS IN 2020
26-28% BELOW 2005 LEVELS IN 2025
50-52% BELOW 2005 LEVELS IN 2030
Net-Zero IN 2050
HISTORIC EMISSIONS
17% BELOW 2005 LEVELS IN 2020
U.S. PROJECTED EMISSIONS UNDER 2025 TARGET
U.S. PROJECTED EMISSIONS UNDER 2030 TARGET
U.S. PROJECTED EMISSIONS UNDER 2050 GOAL

Political hesistancy

The 2015 Paris Agreement

The Yellow Vests

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Research question, Contribution and Related Literature

Research question

- **How are workers in the labor market affected by environmental regulation?**
- Sub-questions include
  - How does the costs of carbon taxes vary across workers of different initial industries, educations, ages and levels of tenure?
  - What compensating policies are necessary to compensate those who are worst off from environmental regulation?
  - To what extent are costs reduced when the policy is announced in advance or phased in gradually?
- How: Set up a general equilibrium dynamic discrete choice model with heterogeneous workers choosing which sector to work in and representative firms emitting greenhouse gasses from burning fossil fuels. Structurally estimate the model to capture historical patterns of labor market choices.

Why use a structural model?

- The reforms are often counterfactual in nature, few natural experiments exist.
- Structural approach circumvents identification issues of reduced-form papers.

Contribution and related literature

- Three relevant strands of literature
  - **Reduced form evidence** of the effects of environmental regulation on labor market earnings and job loss (Walker 2013; Yip 2018).
  - **Structural evidence** of the effects of carbon taxes on labor markets (Hafstead and Williams 2018) and income groups (Goulder et al. 2019).
  - **Dynamic discrete choice programming models** of the labor market. (Dix-Carneiro 2014; Ashournia 2018; Traiberman 2019; Humlum 2019) building on early papers by Rust (1987) and Keane and Wolpin (1997).

Related literature (1/2)

Reduced form evidence of Yip (2018):

- British Columbia in Canada, revenue neutral carbon tax implemented in 2008.
- Difference-in-differences with other provinces as control
- Issues: General equilibrium effects, financial crisis.

$\Rightarrow$ Structural approach can provide complementary evidence.

Structural evidence of Hafstead and Williams (2018):

- Search model with a clean sector, a dirty sector and unemployment.
- Issues: No heterogeneity between workers.

$\Rightarrow$ I include multiple dimensions of heterogeneity in a different model framework.

Related literature (2/2)

Structural evidence of Goulder et al. (2019):

- CGE model with many sectors, labor-leisure supply decision, households differ across income quintiles, but not in labor supply decisions.
- No labor market frictions, no heterogeneity in human capital.

$\Rightarrow$ I include worker heterogeneity

Discrete choice dynamic programming models (Dix-Carneiro 2014; Ashournia 2018; Humlum 2019; Traiberman 2019):

- Previous subjects include import competition, offshoring, education, automation.

$\Rightarrow$ I adapt it for questions about environmental regulation.

Data

Data sources

- Register-based linked worker-firm data for Denmark (1996 - 2016)
- Worker data on education, choice of sector, gender, tenure, unemployment transfers
- Firm/sector data on value added, carbon emissions, wage bill, capital stock, energy use, input-output tables
- Prices on energy (not certain yet, could be backed out from unit values)

Data patterns (1/2)

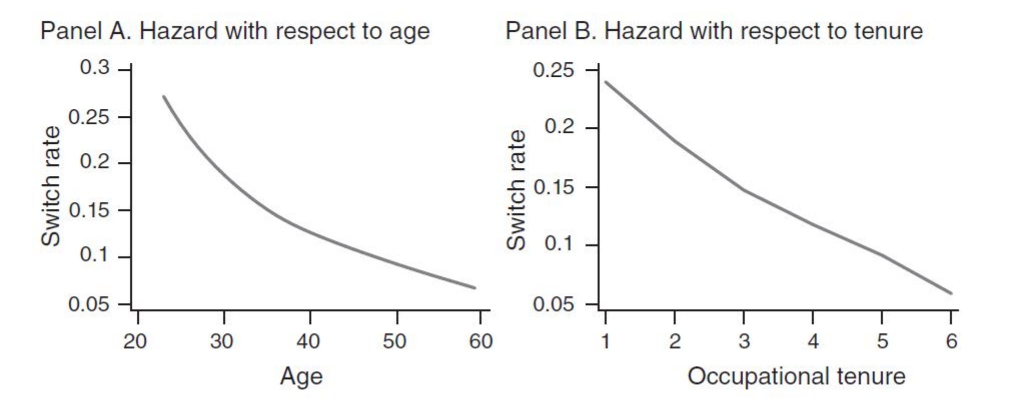

Figure 1: From Traiberman (2019)

Data patterns (2/2)

Average Yearly Transition Rates

From ↓ , to →	(0)	(1)	(2)	(3)	(4)	(5)
(0)	0.4794	0.0141	0.1053	0.0436	0.1046	0.2531
(1)	0.0409	0.8447	0.0281	0.0228	0.0265	0.0370
(2)	0.0294	0.0017	0.9090	0.0080	0.0249	0.0271
(3)	0.0290	0.0042	0.0208	0.9009	0.0191	0.0261
(4)	0.0227	0.0016	0.0226	0.0063	0.9144	0.0324
(5)	0.0182	0.0009	0.0075	0.0026	0.0111	0.9596

Notes. Sectors: (0) unemployment; (1) agriculture/mining; (2) manufacturing; (3) construction; (4) trade/utilities/transportation/communication; (5) services.

Figure 2: From Ashournia (2018)

Model

Firms and emissions

One representative firm for each sector s in each year t produces using four inputs:

- Human capital, H, with price r^H
- Physical capital, K, with price r^K
- Clean energy, E, with price p^E
- Dirty energy, O, with price p^O and carbon tax τ_s

It has the production function

$$Y = AH^{\alpha_1} K^{\alpha_2} (\text{Energy})^{\alpha_3}, \qquad \text{Energy} \equiv \left(E_{st}^{\theta_s} + O_{st}^{\theta_s} \right)^{\frac{1}{\theta_s}} \tag{1}$$

and emits carbon dioxide emissions Z according to

$$Z = \eta_s O. \tag{2}$$

Workers: Utility maximization problem

Worker i's problem:

- Discrete choice between sectors.
  - No intensive margin, no saving/borrowing.
- Active in the labor market from age (a_{it}) 30 to 65.

Utility is the sum of three parts

- Wages, w_{ist}
- Sector switching costs, $M(s_t, s_{t-1}, \Omega_{it})$
- Sectoral preference shocks (unobserved to the econometrician), ε_{ist}

Bellman equation and state space

The Bellman equation is

$$V_t(\Omega_{it}) = \max_s V_{st}\left(\Omega_{it}\right). \tag{3}$$

with sector-specific value functions given by

$$V_{st}(\Omega_{it}) = \begin{cases} w_{ist} - M(s_t, s_{t-1}, \Omega_{it}) + \varepsilon_{ist} + \rho E_{\varepsilon}\left[V_{t+1}\left(\Omega_{it+1}\right)|d_{ist}\right] & \text{for } a_{it} < 65 \\ w_{ist} - M(s_t, s_{t-1}, \Omega_{it}) + \varepsilon_{ist} & \text{for } a_{it} = 65 \end{cases} \tag{4}$$

The state space includes age, previous sector, education, tenure and the expectation of future skill prices:

$$\Omega_{it} = \left\{a_{it}, s_{it-1}, \text{educ}_i, \text{ten}_{it}, \left\{r_{st+\iota}\right\}_{\iota=0}^{65-a_{it}}\right\}. \tag{5}$$

Wages, skill prices and human capital

- Wage offer for each s and t is the product of two parts:

$$w_{ist} = \underbrace{H_s(a_{it}, \text{educ}_i, \text{ten}_{it}, s_{it-1})}_{\text{Human capital that } i \text{ offers } s} \quad \times \quad \underbrace{r_{st}}_{\text{Unit price of skill}} \quad . \tag{6}$$

- Human capital function:

$$\begin{aligned} H_s(a_{it}, \text{educ}_i, \text{ten}_{it}, s_{it-1}) \equiv \exp\Big(&\beta_s^0 a_{it} + \beta_s^1 (a_{it})^2 + \\ &\boldsymbol{\beta_s^{educ}} \textbf{educ}_i + \beta_s^5 \text{ten}_{it} \mathbf{1}(s = s_{it-1})\Big) \end{aligned} \tag{7}$$

- Sector-specific knowledge (tenure):

$$\text{ten}_{it+1} = \begin{cases} \text{ten}_{it} + 1 & \text{if} \quad s_{it} = s_{it-1} \\ 1 & \text{if} \quad s_{it} \neq s_{it-1} \end{cases} \tag{8}$$

Switching costs, $M(s_t, s_{t-1}, \Omega_{it})$

- Switching sectors is costly, parameterized as

$$M(s_t, s_{t-1}, \Omega_{it}) = \begin{cases} m_1\left(s_t, s_{t-1}\right) m_2\left(\Omega_{it}\right) & \text{if } s_t \neq s_{t-1} \\ 0 & \text{if } s_t = s_{t-1} \end{cases} \tag{9}$$

with

$$m_1\left(s_t, s_{t-1}\right) = \exp\left(\xi^{out}_{s_{t-1}} + \xi^{in}_{s_t}\right). \tag{10}$$

$$m_2\left(a_{it}, \text{educ}_i\right) = \exp\left(\kappa_0 a_{it} + \kappa_1 (a_{it})^2 + \boldsymbol{\kappa}_{\text{educ}} \textbf{educ}_i\right) \tag{11}$$

Solving the model

- Distributional assumption on ε_{ist}:

$$\varepsilon_{ist} \sim \text{Gumbel}(-0.57721\sigma, \sigma) \tag{12}$$

- Perfect foresight of skill prices $\{r_{st+\iota}\}_{\iota=0}^{65-a_{it}}$ as in Lee (2005).
- Equilibrium skill prices $\{r_{st+\iota}\}_{\iota=0}^{65-a_{it}}$ are determined in equilibrium,

$$H_{st}^{supply}(\{\boldsymbol{r}_{t+\iota}\}_{\iota=0}^{65-30}) = H_{st}^{demand}(r_{st}) \tag{13}$$

Closing the model

- Previously shown models parts are sufficient for estimation.
- Counterfactual simulations, requires endogenizing output prices.
- For tradeables: Small country assumption to exogenize output prices p_s^Y.
- Cobb-Douglas utility of consumption

$$u(C_{1t}, \ldots, C_{st}, \ldots, C_{S-1t}) = \prod_{s=1}^{S-1} C_{st}^{\mu_s}. \tag{14}$$

giving, for non-tradeables,

$$p_s^Y Y_s = p_s^Y C_s = \mu_s \sum_{j=1}^{S-1} p_j^Y Y_j. \tag{15}$$

- Assumption on the supply of physical capital needed too.

Estimation

Estimation (1/2)

Estimation proceeds in three steps (calibration, regression, structural):

- Step 1: Calibration (follows Ashournia 2018)
  - Cobb-Douglas factor reward shares in production (α)
  - Discount factor, $\rho = 0.96$
  - Cobb-Douglas consumption shares μ based on input-output data
  - Dirty energy emission intensity η_s
- Step 2: OLS regression to identify the energy elasticity θ_s
  - From the first order conditions of the firm's problem (and adding an error term):

$$\log\left(\frac{E_{st}}{O_{st}}\right) = \frac{1}{\theta_s - 1}\log\left(\frac{p_t^E}{\eta_s \tau_{st} + p_s^O}\right) + \epsilon_{st} \qquad \forall\ t \tag{16}$$

Estimation (2/2)

Step 3: Structural estimation using maximum likelihood

- Initial period is 1996, terminal period is 2016
- Keep nominal output fixed, $p_{st}^{Y} Y_{st} = \overline{p_{st}^{Y} Y_{st}}$.
- Solve model for a given set of parameters, calculate likelihood function and optimize.

Counterfactual simulations

Simulating forward, initial conditions

- To simulate individuals forward, I make the following assumptions:
  - The initial state of the economy in 1996 is exogenous (can be relaxed e.g. following Wooldridge (2005))
  - Entering cohorts in the future have the same composition as entering cohorts in 2016

Possible extensions

Possible extensions

- Unemployment can be specified to reflect the Danish transfer system at the expense of additional state variables (Ashournia 2018)
- Emissions tied also to output and endogenous carbon capture and storage (CCS)
- Endogenous technology upgrade choice for firms (Humlum 2019)
- Increased worker heterogeneity (more state variables): Gender, make education categories more granular
- Add a wage shock unobserved to the econometrician (Dix-Carneiro 2014; Ashournia 2018)
- Apply estimation technique of Traiberman (2019) to retrieve switching cost parameters without having to solve the model by canceling continuation values
- Add a geographic dimension to the choice, so a worker chooses g as well as s
- Make foreign production more sophisticated for "carbon leakage" effects
- Different consumption shares for different workers (Känzig 2021)

Weak points

Weak points

- The small country assumption making some prices fully exogenous.
- Measuring prices of outputs and inputs is not straightforward.
- External validity (Denmark vs. US)?
- Indirect links between firms are not present. Electricity (clean energy) price will go up when carbon tax does.
- Educational choice is exogenous in the model.

Thank you.

Feedback and comments: jl@econ.ku.dk

Appendix

Closed form solutions

- Closed-form solutions for continuation values

$$E_{\varepsilon}\left[V_t(\Omega_{it})\right] = \sigma \log\left(\sum_s \exp\left(\frac{w_{ist} - M(s_t, s_{t-1}, \Omega_{it}) + \rho E_{\varepsilon}\left[V_{t+1}(\Omega_{it+1})|d_{ist}\right]}{\sigma}\right)\right). \tag{17}$$

and conditional choice probabilities:

$$P(d_{ist} = 1|\Omega_{it}) = \frac{\exp\left(\frac{w_{ist} - M(s, s_{t-1}, \Omega_{it}) + \rho E_{\varepsilon}\left[V_{t+1}(\Omega_{it+1})|d_{ist}\right]}{\sigma}\right)}{\sum_j \exp\left(\frac{w_{ijt} - M(j, s_{t-1}, \Omega_{it}) + \rho E_{\varepsilon}\left[V_{t+1}(\Omega_{it+1})|d_{ijt}\right]}{\sigma}\right)}. \tag{18}$$

Equilibrium on the market for human capital

- The equilibrium skill prices r_{st} are determined in equilibrium in s in each t.
- Definitions:
  - MASS_t: Mass of individuals in economy at time t.
  - $\widetilde{\Omega}$: Collection of all possible points in state space (exlcuding r_{st}), indexed by ω.
  - $D_t(\omega)$: The share of individuals in the population characterized by the point ω at time t.
  - $P\left(d_{\omega st} = 1 | \, \omega, \{\boldsymbol{r}_{t+\iota}\}_{\iota=0}^{65-30}\right)$: The probability that an individual, defined by the state space point ω as well as the expectation of future skill prices, chooses to work in sector s at time t.
- Equilibrium condition

$$H_{st}^{supply}(\{\boldsymbol{r}_{t+\iota}\}_{\iota=0}^{65-30}) = H_{st}^{demand}(r_{st})$$

$$\text{MASS}_t \sum_{\omega \in \widetilde{\Omega}_t} D_t(\omega) P\left(d_{\omega st} = 1 | \, \omega, \{\boldsymbol{r}_{t+\iota}\}_{\iota=0}^{65-30}\right) = \alpha_{st}^1 p_{st}^Y \frac{Y_{st}}{r_{st}} \qquad \forall \; s, t. \quad (19)$$