Geography versus Income: The Heterogeneous Effects of Carbon Taxation

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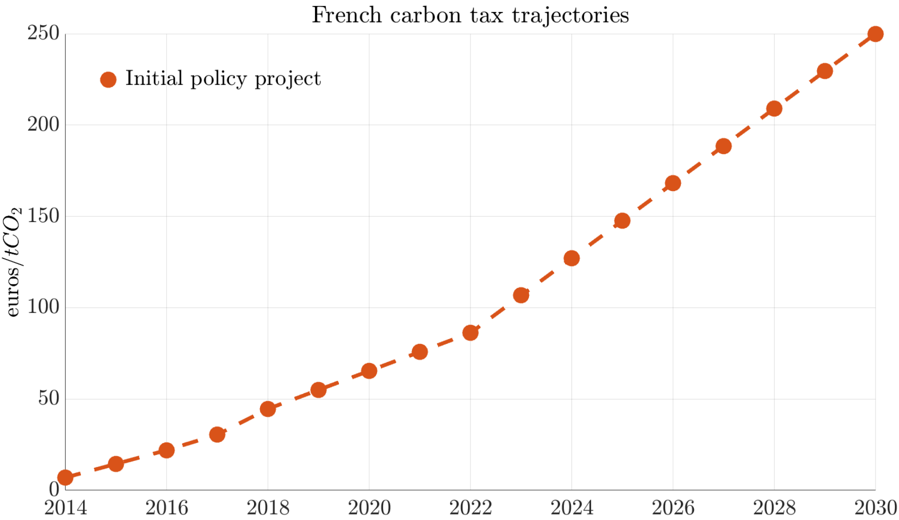
Motivation: social acceptability



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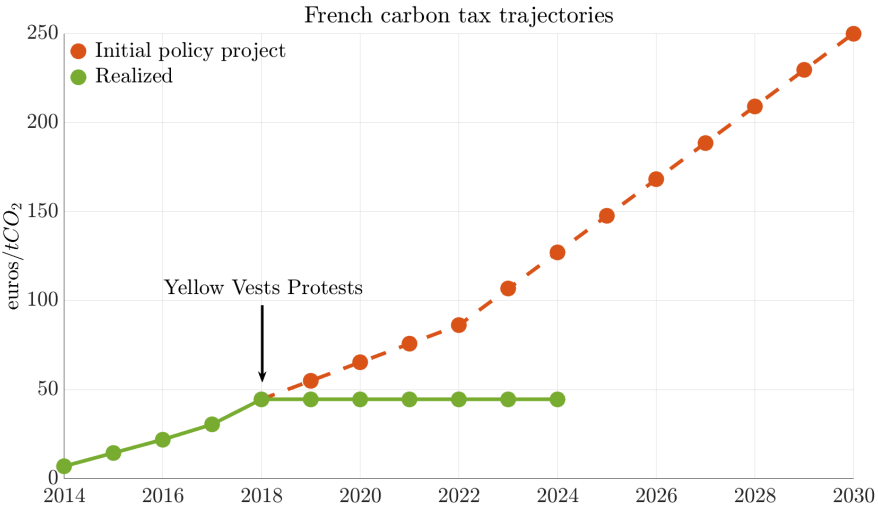

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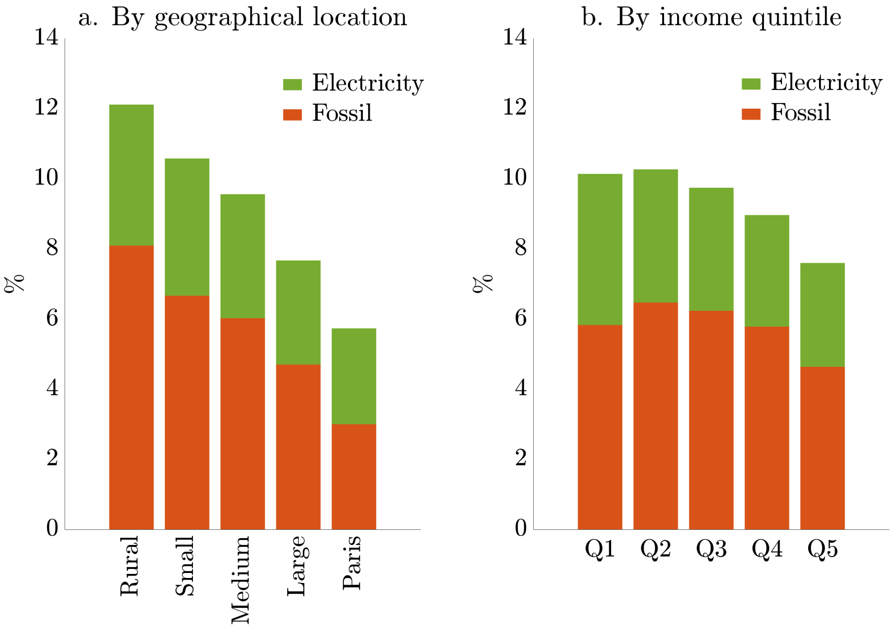
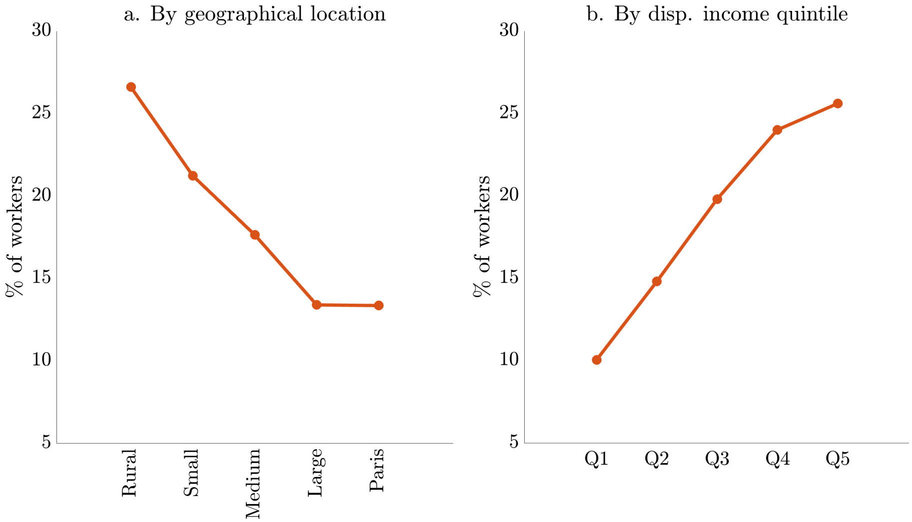
1. Energy is a final good for HHs and an intermediate good for firms
2. Geography matters:
   - Energy share depends on income but also on geographical location
   - Workers in different areas work in sectors with different intensity
3. Carbon taxes create additional revenue for the government

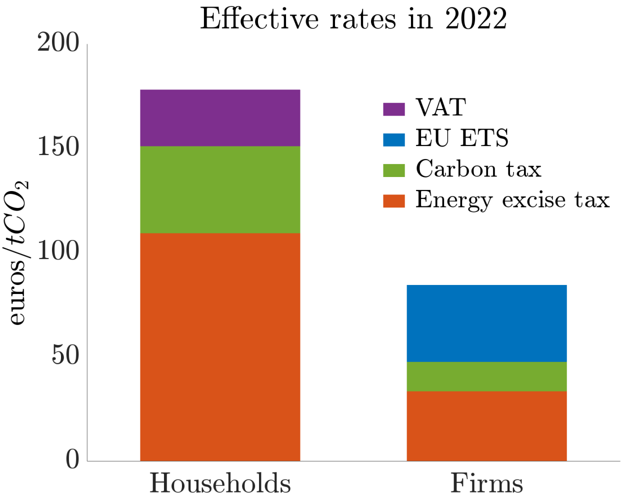
Energy share in total consumption, France



Share of workers in emission intensive sectors



Effective carbon tax rates for households and firms



Our results

1. Taxing households' energy consumption is regressive, while taxing firms' energy consumption is progressive
2. Geography is more relevant than income to assess welfare losses
3. Optimal rebating policy should target poor and rural households

Model

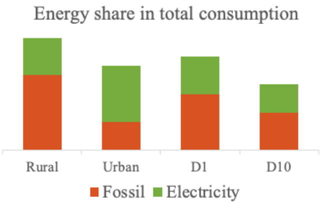
Stylized representation of the model

Government

$$G + T = \tau^h F^h + \tau^f F^f$$

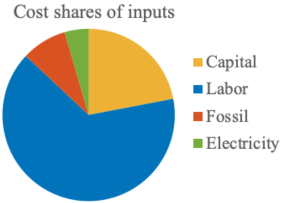
Households: 40% of emissions

$$u(c, H, e^h - \bar{e})$$
$$e^h = CES(F^h, N^h)$$



Firms: 60% of emissions

$$Y = f(k, l, e^f)$$
$$e^f = CES(F^f, N^f)$$



Fossil: imported from the rest of the world

Electricity
$$N = f(k, l)$$

Households with location choice (k)

1. Households choose living areas (k), consumption of c, e^h and H
2. There are 5 living areas (k) associated with
   - energy requirement $\bar{e}(k)$
   - fossil share $\gamma_h(k)$
   - wage $w(k)$
   - housing price $p^h(k)$
   - productivity process $z(k)$

Household's problem

Household's problem:

$$\max_{\{a_{t+1}, k_{t+1}, c_t, e_t^h, H_t, F_t^h, N_t^h\}_{t=0}^{+\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{u_t^{1-\theta} - 1}{1-\theta} \right\}$$

such that

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such that

1. Implicit utility function:

$$\Lambda_C^{\frac{1}{\sigma}} \left(\frac{c_{i,t}}{u_{i,t}^{\epsilon C}} \right)^{\frac{\sigma-1}{\sigma}} + \Lambda_E^{\frac{1}{\sigma}} \left(\frac{e_{i,t}^h - \bar{e}(k_{i,t})}{u_{i,t}^{\epsilon E}} \right)^{\frac{\sigma-1}{\sigma}} + \Lambda_H^{\frac{1}{\sigma}} \left(\frac{H_{i,t}}{u_{i,t}^{\epsilon H}} \right)^{\frac{\sigma-1}{\sigma}} = 1$$

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$$\max_{\{a_{t+1}, k_{t+1}, c_t, e_t^h, H_t, F_t^h, N_t^h\}_{t=0}^{+\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{u_t^{1-\theta} - 1}{1-\theta} \right\}$$

such that

1. Implicit utility function
2. Energy is a CES bundle of fossil F^h and electricity N^h:

$$e_{i,t}^h = \left[(1-\gamma_h(k))^{\frac{1}{\epsilon_h}} (N_{i,t}^h)^{\frac{\epsilon_h - 1}{\epsilon_h}} + \gamma_h(k)^{\frac{1}{\epsilon_h}} (F_{i,t}^h)^{\frac{\epsilon_h - 1}{\epsilon_h}} \right]^{\frac{\epsilon_h}{\epsilon_h - 1}}$$

Household's problem

Household's problem:

$$\max_{\{a_{t+1}, k_{t+1}, c_t, e_t^h, H_t, F_t^h, N_t^h\}_{t=0}^{+\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{u_t^{1-\theta} - 1}{1-\theta} \right\}$$

such that

1. Implicit utility function
2. Energy is a CES bundle of fossil F^h and electricity N^h
3. Budget constraint:

$$\underbrace{(1+\tau^{VAT})\left[c + p^N N + (p^F + \tau^h)F^h\right] + p^h(k)h}_{\text{Total consumption expenditures}} + \underbrace{a' - a}_{\text{Savings}}$$

$$= \underbrace{\Gamma(z(k)w(k)l)}_{\text{Net labor income}} + \underbrace{(1-\tau^k)ra}_{\text{Net capital income}} + \underbrace{T(k)}_{\text{Transfers}} - \underbrace{\kappa(k,k')}_{\text{Migration cost}}$$

Household's problem

Household's problem:

$$\max_{\{a_{t+1},k_{t+1},c_t,e^h_t,H_t,F^h_t,N^h_t\}_{t=0}^{+\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{u_t^{1-\theta}-1}{1-\theta} \right\}$$

such that

1. Implicit utility function
2. Energy is a CES bundle of fossil F^h and electricity N^h
3. Budget constraint
4. Earning process:

$$\ln z_{i,t+1} = (1-\rho_z)\mu_z(k) + \rho_z \ln z_{i,t} + \epsilon_{i,t+1}$$

$$\epsilon_{i,t+1} \sim \mathcal{N}(0, \sigma_z(k))$$

Household's problem:

$$\max_{\{a_{t+1}, k_{t+1}, c_t, e_t^h, H_t, F_t^h, N_t^h\}_{t=0}^{+\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{u_t^{1-\theta} - 1}{1-\theta} \right\}$$

such that

1. Implicit utility function
2. Energy is a CES bundle of fossil F^h and electricity N^h
3. Budget constraint
4. Earning process
5. Borrowing constraint:

$$a_{i,t+1} \geq \underline{a}$$

Firms: Goods & Services sector

Final good y: in each region k, a firm produces consumption goods using capital, labor and energy

$$\max_{\{y, K^y, l^y, F^y, N^y\}} \Pi^y = y - (r+\delta)K^y - w(k)l^y(k) - (p^F + \tau^f)F^y - p^N N^y$$

such that

$$y = \left[(1-\omega_y(k))^{\frac{1}{\sigma_y}} \left((K^y)^\alpha (l^y)^{1-\alpha} \right)^{\frac{\sigma_y - 1}{\sigma_y}} + \omega_y(k)^{\frac{1}{\sigma_y}} (e^y)^{\frac{\sigma_y - 1}{\sigma_y}} \right]^{\frac{\sigma_y}{\sigma_y - 1}}$$

$$e^y = CES(N^y, F^y)$$

Firms – Energy sectors

Electricity sector N: produced using capital and fossil fuel

$$\max_{\{N,K^N,F^N\}} \Pi^N = p^N N - (r+\delta)K^N - (p^F + \tau^f)F^N$$

$$\text{s.t. } N = \left(K^N\right)^{\eta}\left(F^N\right)^{1-\eta}$$

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Fossil fuel sector F:

- imported from the rest of the world at an exogenous price p^F:

$$p^F = \bar{p}F^{\delta^F}$$

- the rest of the world uses the fossil fuel revenue $p^F(F^Y + F^N + F^h)$ to import goods and services X from the domestic economy:

$$X = p^F(F^Y + F^N + F^h)$$

Government

$$
\begin{aligned}
T_t^{\text{targeted}} + G_t + r_t \bar{d} = & \int_0^1 \left(z_{i,t} w_t l - \Gamma\left(z_{i,t} w_t l\right)\right) \mathrm{d}i \\
& + \tau^{\text{VAT}} \int_0^1 \left(c_{i,t} + p_t^N N_{i,t}^h + p_t^F F_{i,t}^h\right) \mathrm{d}i \\
& + \tau^k r_t \int_0^1 a_{i,t} \mathrm{d}i \\
& + \tau_t^h (1 + \tau^{\text{VAT}}) \int_0^1 F_{i,t}^h \mathrm{d}i + \tau_t^f \left(F_t^y + F_t^N\right)
\end{aligned}
$$

- Progressive labor income tax: $\Gamma(x) = \lambda x^{1-\tau}$
- Benchmark scenario: carbon tax revenue used in G
- We then allow for targeted transfers

Market clearing conditions

Segmented labor markets clearing conditions:

$$\forall k \ , \ l^y(k) = \int_{i=k} l_i \mathrm{d}i$$

Segmented housing markets clearing conditions:

$$\forall k \ , \ H^{\text{supply}}(k) = H_k \left(p^h(k)\right)^{\delta^h} = \int_{i=k} h_i \mathrm{d}i$$

Asset market clearing:

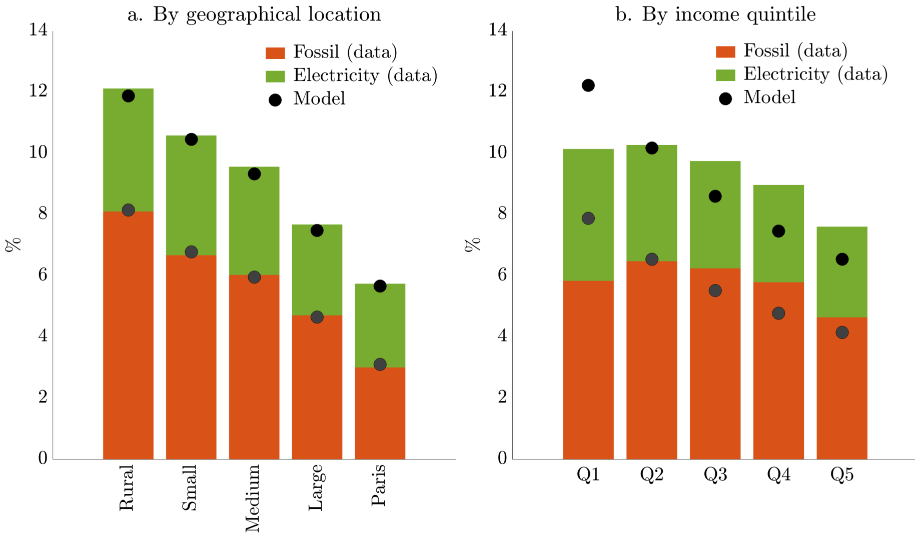
$$\int_i a_i \mathrm{d}i = \bar{d} + \sum_k H^{\text{supply}}(k) + \sum_k K^y(k) + K^N$$

Algorithm

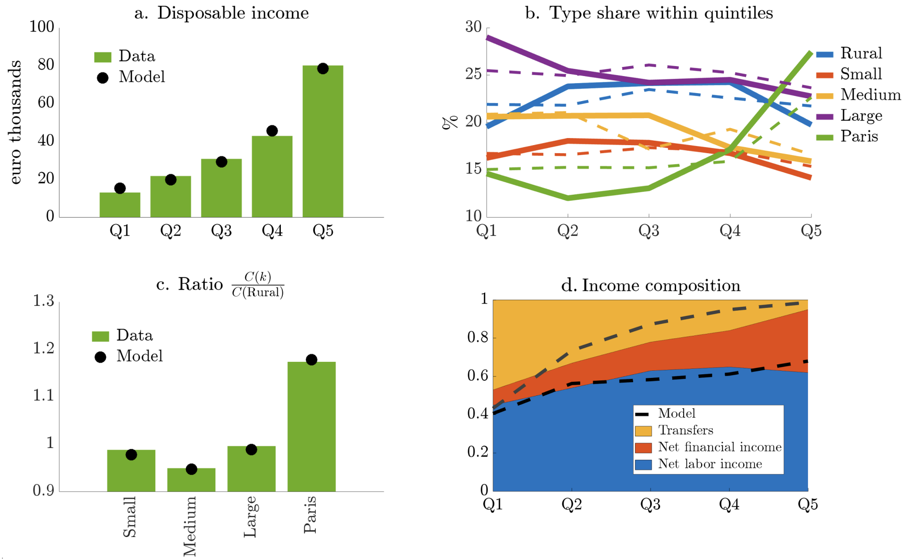
1. We use a global solution method in MATLAB
2. Steady state: quasi-Newton method with Broyden algorithm
   - 13 guesses: $\left\{r, G, p^N, \{p^H(k), w(k)\}_{k \in [\![1;5]\!]}\right\}$
   - Calibration: same method with 40 guesses
3. Transition: non-linear quasi-newton method, fake-news algorithm from Auclert et al. (2021)

Calibration: taking the model to the data

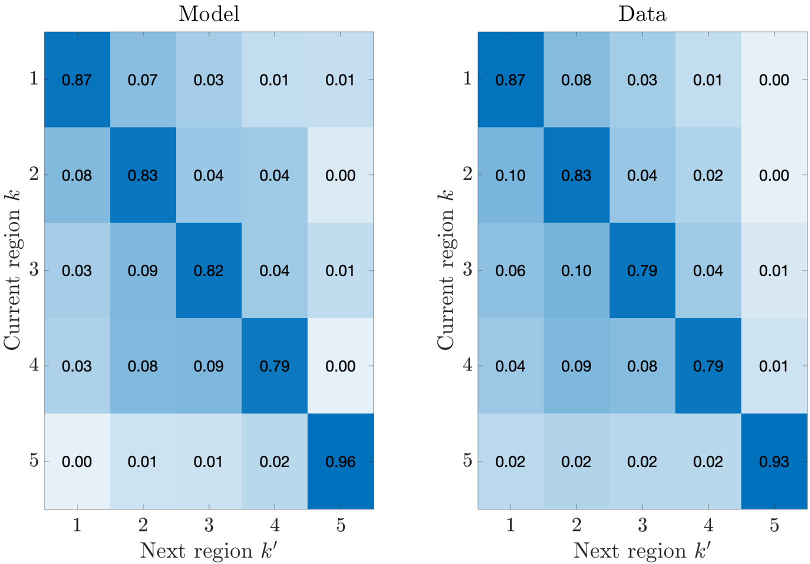
Energy share in total consumption



Calibration of heterogeneity



Migration matrix: $\kappa(k, k')$



Aggregate targets

Table: Empirical targets vs Model results

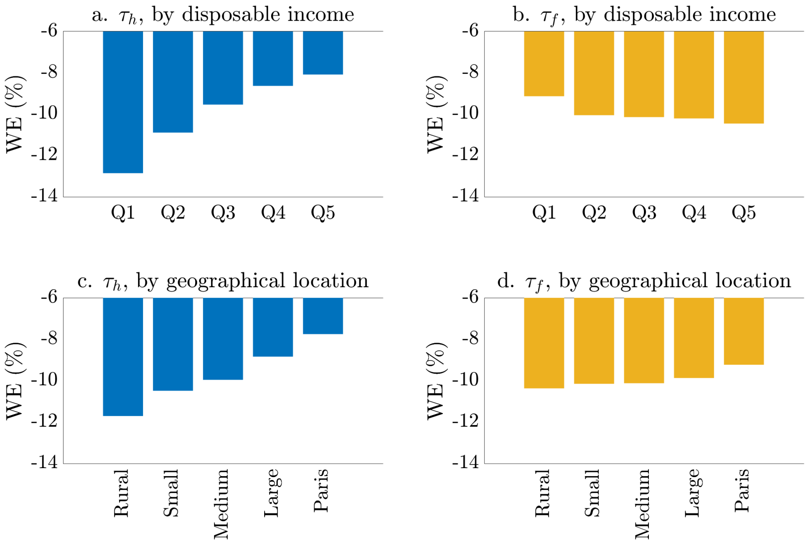
	Model	Target	Parameter	Value	Sources & notes
a/GDP	402%	400%	β	0.94	Piketty and Zucman (2014)
F_N/F	1%	1%	η	0.9813	Insee – EAE survey
wl/GDP	65%	65%	α	0.28	Cette et al. (2019)
Population	–	–	$H(k)$	–	Administrative data
$F_{k,y}/F$	–	–	$\omega_y(k)$	–	PLF 2023 appendix
N_y/E_y	33%	33%	γ_y	0.78	PLF 2023 appendix
$p^F F/\text{GDP}$	6%	6%	p^F	0.1	Government data
G/GDP	29%	29%	λ	0.6	Auray et al. (2022)
Elasticity of substitution c-e_h			σ	0.28	Estimation of σ
Elasticity of substitution KL-e_y			σ_y	0.32	Werf (2008)
Elasticity of substitution N-F			ϵ_h, ϵ_y	0.2	Authors' choice

Quantitative results

Experiment: permanent increase in carbon taxes

1. Permanent change in carbon taxes
2. We compare τ_h and τ_f for the same aggregate welfare loss
3. We compare rebating policies with a 20% emissions reduction target

τ_h is regressive, τ_f is progressive



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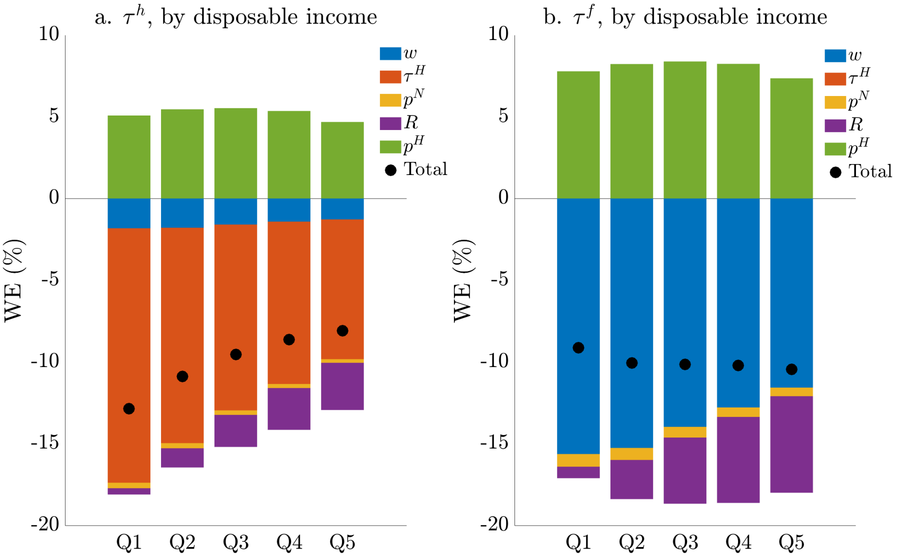
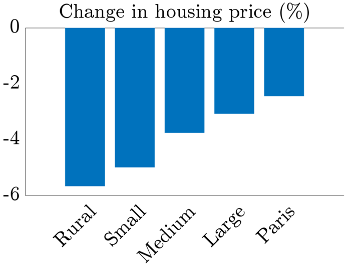
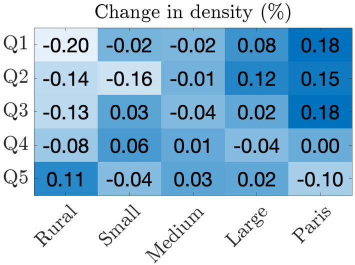


Migration results





How should we redistribute?

The planner maximizes welfare, neutralizing redistribution motive:

$$\max_{\chi_1,\chi_2} W^{\text{Planner}} = \int \alpha_i V(a,k,z)\mathrm{d}i \text{ with } \alpha_i = \underbrace{\left(\frac{\partial V_i(a_i,k,z)}{\partial a_i}\right)^{-1}}_{\text{Negishi weights}}$$

$$\text{s.t. } T_{i,t} = \left(\frac{(1+\chi_2 \times \bar{e}_{i,t})}{\text{disposable income}_{i,t}}\right)^{\chi_1}$$

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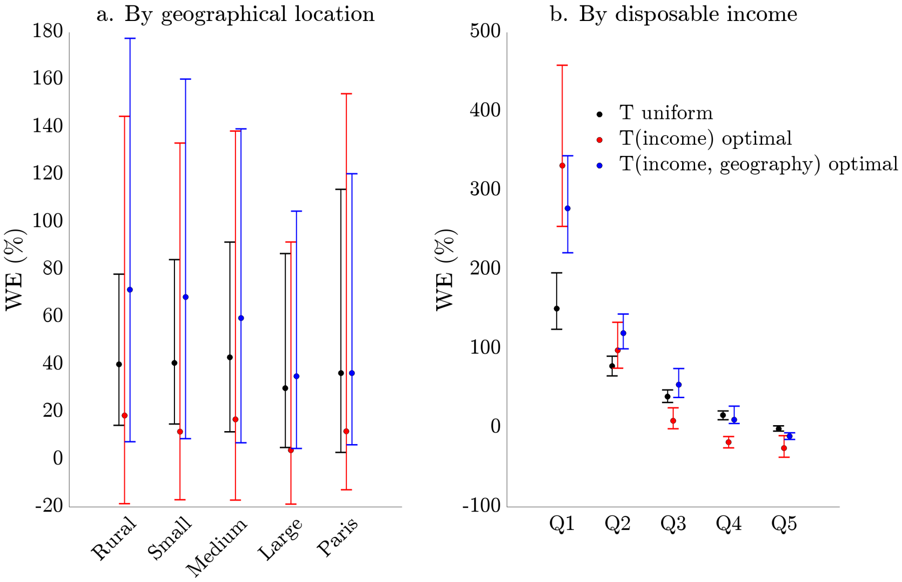

Conclusion

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Thank you !

References I

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