Pigouvian Income Taxation

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14th Toulouse Conference on the Economics of Energy and Climate
June 7, 2024

Context

Income-dependent policies #1

France: "To qualify for the social leasing program, French residents must have an annual income of no more than €15,400, travel more than 8,000 km per year, and live at least 15 km away from their workplace. If you are eligible, you can enjoy a three-year lease contract with the option to purchase at the end."

Income-dependent policies #2

U.S.: "You may qualify for a credit up to $7,500 [...] if you buy a new, qualified plug-in EV or fuel cell electric vehicle (FCV). [...] Your modified adjusted gross income (AGI) may not exceed:

- $300,000 for married couples filing jointly
- $225,000 for heads of households
- $150,000 for all other filers"

Income-dependent policies #3

California is planning to introduce income-based electricity charges under a system called the Income Graduated Fixed Charge (IGFC), which was mandated by Assembly Bill 205 in 2022. This plan aims to tie the fixed charges on electricity bills to consumers' incomes:

Tier 1 Customers enrolled in the California Alternate Rates for Energy program

Tier 2 Customers enrolled in the Family Electric Rate Assistance program or who live in affordable housing restricted to residents with incomes at or below 80 percent of Area Median Income

Tier 3 All other customers

Income-dependent policies #4

> *"So far, the standard way to think about carbon taxation has been in the context of uniform tax rate across individuals, i.e. whether rich or poor, individuals should pay the same carbon tax rate. [...] To accelerate carbon emissions reductions among the wealthiest,* **progressive carbon taxes** *can become a useful instrument"*
>
> – World Inequality Report Ch 6, 2022

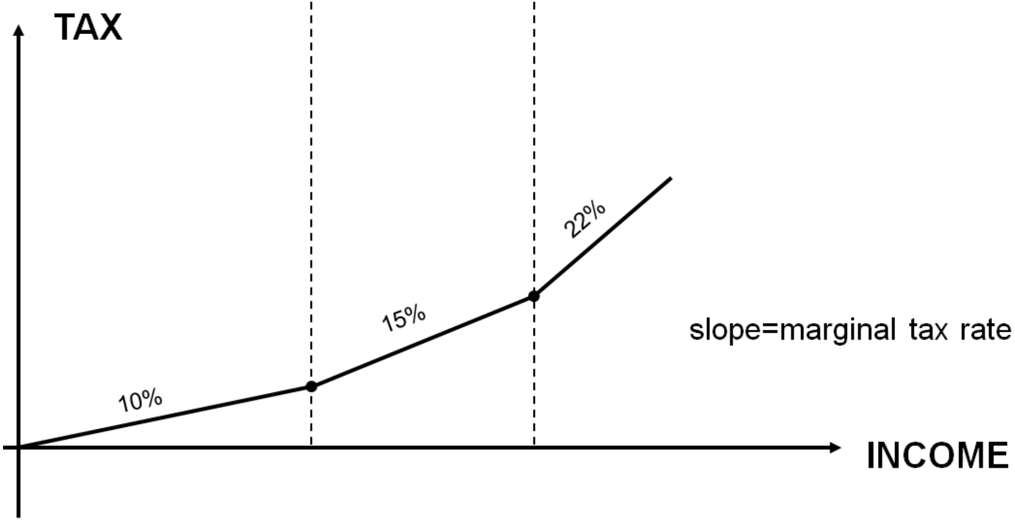
Why income-dependent?

Society already has tools to address inequality

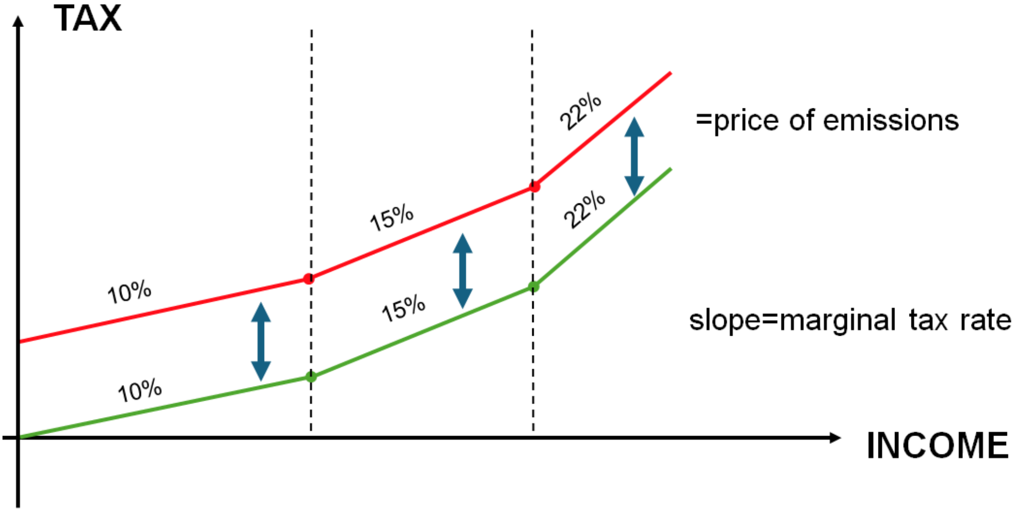
(a) progressive income taxation (b) transfers for redistribution

Shouldn't (a)&(b) deal with inequalities from grand externalities like climate change?

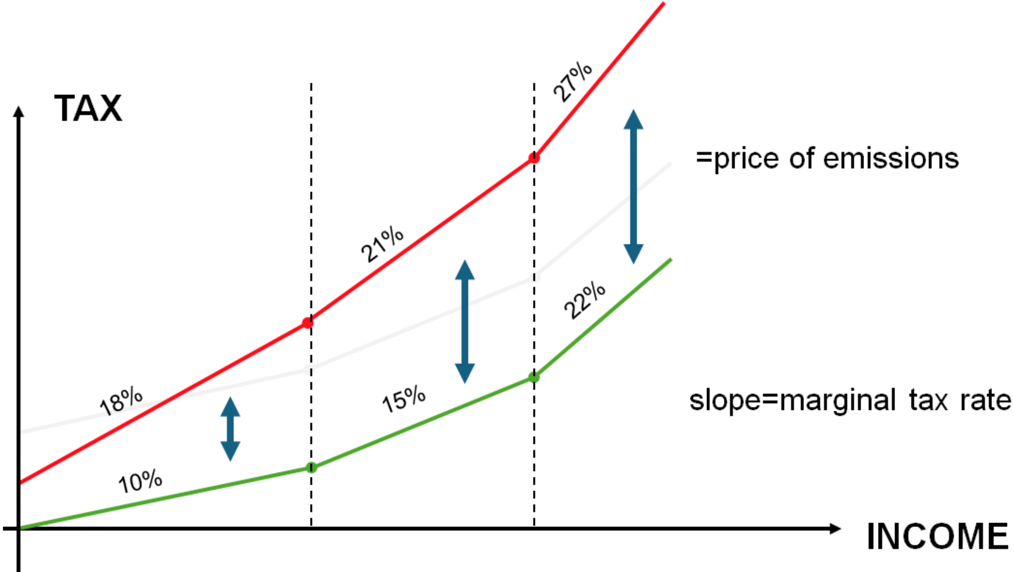
An income tax schedule



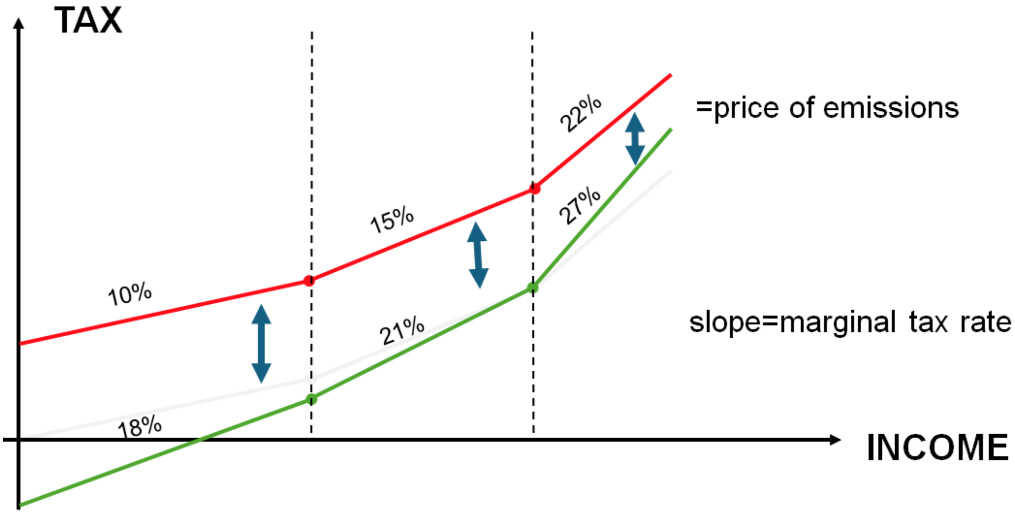
Corrective policy



Corrective policy (progressive)



Corrective policy (regressive)



Our approach

A mechanism design for externalities and redistribution

- **Individuals** with private information on (i) labor market productivity, (ii) cost of compliance and (iii) impact from externalities
- **Government** with a weighted utilitarian objective that flexibly captures preferences for redistribution, aversion to inequality (classical) & to policy burdens
- **Mechanism** implemented through tax schedules for incomes and externalities – welfare-optimal allocation decentralized through income taxation, defining income-dependent externality payments.

Results: theory

- **Pigouvian income taxation generally optimal:** ties together incomes and corrective policies for gains in both efficiency and equity

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Three determinants:

1. **Classical aversion to inequality**
   - The poor/rich more elastic emissions? If the rich inelastic, tax their emissions for transfers. If the poor inelastic, reduce their burden. $\rightarrow$ corrective tax deviates from Pigou

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3. **Behavioral elasticities** of earnings and emissions
   - vary across income brackets: $\rightarrow$ progressive/regressive corrective tax

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Income tax schedules: Adjusted to maintain original progressivity

Results: empirics

Two applications, both using register data

Electricity consumption

- polluters receive a relatively low weight: tax $>$ Pigouvian, regressive

Electric vehicles

- polluters receive a relatively high weight: tax $<$ Pigouvian, progressive

Outline

Model

Individuals

Mechanism assigns earnings $y(\theta)$, actions $x(\theta)$ and transfers $t(\theta)$ to each θ.

An agent's payoff is quasi-linear:

$$u(\theta; y(\theta), x(\theta), t(\theta)) = \underbrace{y(\theta)}_{\text{earnings}} - \underbrace{k(y(\theta), n)}_{\substack{\text{earnings} \\ \text{effort cost}}} - \underbrace{x(\theta)q}_{\substack{\text{private action} \\ \text{cost}}} - \underbrace{t(\theta)}_{\text{transfer}} + \underbrace{b\mathbb{E}[x(\theta)]}_{\substack{\text{aggregate action} \\ \text{benefit}}}$$

- Note: type $\theta = (n, q, b)$

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- Note: type $\theta = (n, q, b)$
- Result: mechanism only conditions transfers on ability n and cost q, but not benefits b
- Assumption: focus on deterministic mechanisms
- Assumption: $x \in \{0, 1\}$ (but extension)

Government

Each individual has weight $\omega \in \mathbb{R}_{++}$, with $\mathbb{E}[\omega] = 1$. Only joint distribution for (θ, ω) known.
The government maximizes weighted-welfare:

$$\mathbb{E}[\omega u(\theta)]$$

subject to (i) budget and (ii) IC constraints

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subject to (i) budget and (ii) IC constraints

The welfare weights $\mathbb{E}[\omega|n, q]$ capture:

- **Classical inequality concern:** $\mathbb{E}[\omega|n]$ non-increasing in productivity n.
- **Concern for cost burdens:** $\mathbb{E}[\omega|n, q]$ increasing, decreasing or constant in cost q, and correlation with n

Reinterpretation

From IC and resource constraints,

$$\mathbb{E}[\omega u(\theta)] = \mathbb{E}[\underbrace{y(n,q) - k(y(n,q),n)}_{\text{output}} + \underbrace{(\mathbb{E}[b\omega] - q)1_{q \leq \bar{q}(n)}}_{\text{externality}} + \underbrace{(\omega - 1)\mathcal{R}(n,q)}_{\text{redistribution}}] \quad (1)$$

Rents $\mathcal{R}(n,q)$ in two dimensions:

- high ability n (Mirrlees)
- low cost q (new)

Decentralization

- Mechanism can be implemented through tax function

$$t(y,x) = \underbrace{T(y)}_{\text{Income tax}} + (1-x) \underbrace{\tau(y)}_{\substack{\text{Income-dependent} \\ \text{externality price}}}$$

Outline

First theorem

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Benchmark: constant τ by assumption. Income tax follows Diamond's ABC ABC formula and the externality tax τ is

$$\tau = \underbrace{\mathbb{E}[\omega b]}_{\substack{\text{externality}\\ \text{impact}}} + \underbrace{\frac{1 - \mathbb{E}[\omega | q > \tau]}{h(\tau)}}_{\text{redistribution}}$$

where $\mathbb{E}[\omega b] = \mathbb{E}[\omega]\mathbb{E}[b] + Cov(\omega, b)$ and h is the semi-elasticity of abatement.

Interpretation

$$\tau = \underbrace{\mathbb{E}[\omega b]}_{\substack{\text{externality} \\ \text{impact}}} + \underbrace{\frac{1 - \mathbb{E}[\omega | q > \tau]}{h(\tau)}}_{\text{redistribution}}$$

Assume classical preference: the poor have higher $\mathbb{E}[\omega]$

- **impact:** $\tau > \mathbb{E}[b]$ iff the poor hurt more by the externality, $Cov(\omega, b) > 0$
- **redistribution:** collect funds from polluters and redistribute to all
  - ⋆ $1 - \mathbb{E}[\omega | q > \tau] < 0$ iff high weights to polluters
  - ⋆ classical inequality aversion or concern for cost burdens, either one alone gives the result

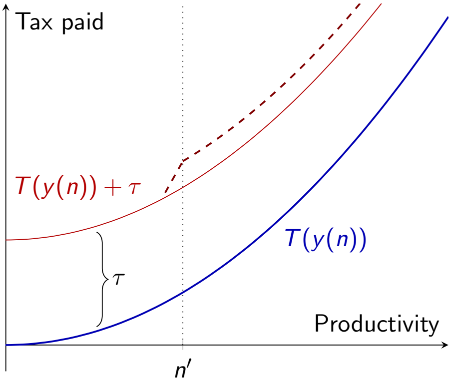
Outline

Second theorem

A simple reform

Consider a small reform to the optimal tax system with an income-independent externality price: increase the externality price slightly above some income threshold $y(n')$ through a small increase in $\tau'(y)$ around $y(n')$. 3 effects:

1. Increase in emission reductions of the rich
2. Redistribution from rich polluters to others
3. Labor market distortion for polluters at n'



A progressivity (regressivity) reform at n' is welfare-improving if $(i) + (ii) + (iii) > 0$ (< 0) where

(i) $(\overline{\omega}_{n' \geq n} - \overline{\omega}^0_{n' \geq n}) - (\overline{\omega} - \overline{\omega}^0)$, captures a social preference for caring more about low-income polluters' cost burdens

(ii) $\big(\xi_2 - 1\big)(\overline{\omega}^0 - 1)$ measures behavioral response of emissions among high-income earners

(iii) $\big(\xi_1 - 1\big)(\overline{\omega}_{n' \geq n} - 1)$ links to the earnings distortion

Term ξ_1 is the relative share of polluters at n compared to the average share for $n' \geq n$. We have $\xi_1 > 1$ if high-income earners above the cut-off, $n' \geq n$, pollute less on average than incomes at the cut-off. Term ξ_2 measures the behavioral response of emissions as the mean semi-elasticity among high incomes in comparison to that in the full population, with $\xi_2 > 1$ for more response among the high-income earners.

Second theorem

Theorem 2 characterizes the welfare-maximizing tax schedule $(T(y), \tau(y))$: Tax formulas

Properties

- Level of the externality price: results from Theorem 1 carry over
- Progressivity of the externality price: follow the intuition presented in the small reform
- The mean income tax progression is preserved.

Extensions

- **Continuous externality choice**

  → Results from the small tax reform generalize (with *emissions-weighted welfare weights*)
- **General labor supply function**

  → Results from the simple tax reform generalize
- **Social welfare function**

  → We can re-interpret the exogenous weights as endogenous weights stemming from a social welfare function
- **Tagging**

  → Group the population into sub-populations based on exogenous characteristics; tax formulas hold group-wise—transfers from low-weight to high-weight groups
- **Public investment**

  → Our model produces a welfare-adjusted Samuelson rule

Outline

Empirical applications

Plan

- **Carbon emissions** in two key sectors, transportation and electricity
- Finnish **individual-level administrative data** on incomes, pollution measures, and financial burdens
  - net incomes $\rightarrow$ individual-level welfare weights (using CRRA, U.S. circular A-4)
  - do polluters have higher/lower weights?
- Quantifying **a sufficient statistics**:
  - should the current CO_2 tax be reformed?

Descriptive statistics: Vehicles

Table: Descriptive statistics: vehicles

Variable	N	Mean	Sd	p10	p90
Car fleet					
annual fuel exp. (EUR/year)	2,152,443	1569	1593	397	2912
daily kilometers	2,152,443	46	41	11	86
consumption (liter/100 km)	2,152,443	7.2	1.79	5.1	9.3
Disposable income (EUR/year)	2,152,443	27,684	15,609	13,100	43,400
Transaction data 2023, q1-q3					
annual fuel exp. (EUR/year)	44,360	1789	1707	634	3143
daily kilometers	44,360	57	44	20	101
consumption (liter/100 km)	44,360	6.6	1.8	4.7	9
Disposable income (EUR/year)	44,360	37,981	21,834	18,300	63,000

Data from the Statistics Finland's 2021 FOLK longitudinal dataset which is linked to the 2023 vehicle register from TRAFICOM (Finnish transportation and communications authority). Annual fuel expenditure, kilometers, and consumption for each car owner are based on 2016 kilometers (vehicle register) and final fuel prices (Statistic Finland). Disposable income of a car owner is net of taxes and transfers. Transaction data 2023 is from quarters 1-3, new car purchases. Variable definitions are the same as for the car fleet but the sample restricted to new car buyers.

Descriptive statistics: Electricity

Table: Descriptive statistics: Electricity use

	N	Mean	Sd	p10	p90
Electricity consumption (kWh)					
September 2022	2,530,334	367.8	408.9	61.6	881.0
October 2022	2,536,155	435.5	487.1	65.5	1077.9
November 2022	2,536,947	542.0	634.5	46.9	1412.9
December 2022	2,536,992	708.4	859.0	46.8	1916.2
January 2023	2,538,713	668.8	807.8 9	68.0	1796.3
Household-level data					
Disposable income (Eur/year)	2,530,334	41848.8	54.863	13993.2	74919.5
Household size	2,501,503	2.100	1.263	1	4

Data from the Statistics Finland's 2020 FOLK longitudinal dataset which is linked to Fingrid Datahub -consumption data based on the person whose name the contract was on. Electricity consumption data is observed monthly and summed over all properties owned by a household. Disposable-income is per household and net of taxes and transfers. Household size is the number of people living in the household.

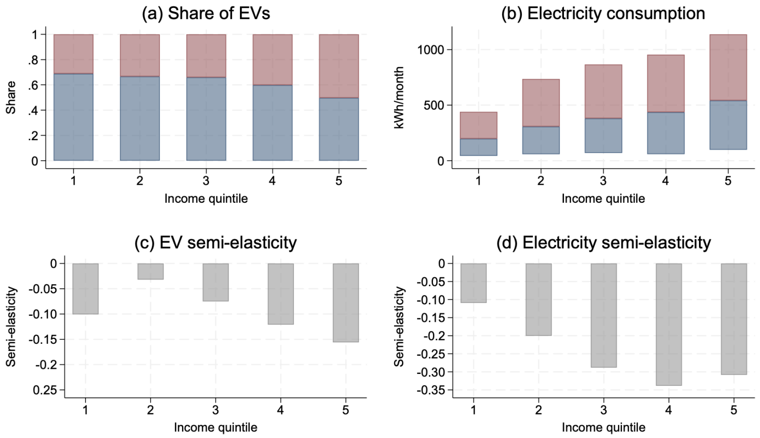


FIGURE 1. **Finnish registry data on vehicles and electricity.**

Note: All data by households' disposable income quintile. Figure shows (a) the share of electric vehicles (EVs) for new transactions in q1-q3 of 2023 ($N = 44,360$ transactions), (b) electricity consumption for October 2022 - January 2023 for Finnish households ($N = 2,530,334$ households), (c) the semi-elasticity of the number of non-EVs by households, taken from the literature (Halse *et al.*, 2024), (d) the semi-elasticity of electricity consumption by income group estimated based on the Finnish registry data ($N = 2,530,334$ households).

Empirical application: electric vehicles

			Income quintile			
		All	2	3	4	5
Average weight	$\overline{\omega}_{n' \geq n}$	1	0.876	0.791	0.695	0.583

Progressive reform!

Empirical application: electric vehicles

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Share of polluters	$n' \geq n$	0.689	0.687	0.681	0.667	0.652

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Share of polluters	$n = n$	0.741	0.745	0.743	0.695	0.652

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Concern for burdens	$(\overline{\omega}_{n' \geq n} - \overline{\omega}^0_{n' \geq n}) - (\overline{\omega} - \overline{\omega}^0)$	0	0.010	0.020	0.027	0.028
Behavioral response of emissions	$\big(\xi_2 - 1\big)(\overline{\omega}^0 - 1)$	0	-0.001	0.0016	0.033	0.047
Earnings distortion	$\big(\xi_1 - 1\big)(\overline{\omega}_{n' \geq n} - 1)$	0	-0.011	-0.019	-0.013	0
Sum	Net effect	0	-0.001	0.017	0.048	0.750

Empirical application: electric vehicles

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Progressive reform!

Empirical application: electricity

Table: Simple tax reform for electricity

		Income quantile				
		All	2	3	4	5
Average weight	$\overline{\omega}_{n' \geq n}$	1	0.679	0.505	0.397	0.294
Average polluter weight	$\overline{\omega}^0_{n' \geq n}$	0.652	0.497	0.389	0.316	0.243
Consumption (kWh/mo)	$n' \geq n$	374	416	454	490	542
Consumption (kWh/mo)	$n = n$	208	310	382	437	542
Semi-elasticity	$n' \geq n$	0.249	0.284	0.312	0.324	0.309
Concern for burdens	$(\overline{\omega}_{n' \geq n} - \overline{\omega}^0_{n' \geq n}) - (\overline{\omega} - \overline{\omega}^0)$	0	-0.166	-0.232	-0.267	-0.297
Behavioral response of emissions	$\big(\xi_2 - 1\big)(\overline{\omega}^0 - 1)$	0	-0.049	-0.088	-0.104	-0.083
Earnings distortion	$\big(\xi_1 - 1\big)(\overline{\omega}_{n' \geq n} - 1)$	0	0.082	0.079	0.065	0
Sum	Net effect	0	-0.133	-0.241	-0.306	-0.380

Empirical application: electricity

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Regressive reform!

Outline

Literature

Empirical literature: carbon pricing and redistribution

- Hassett et al., 2009; Grainger and Kolstad, 2010; Williams et al., 2015; Fischer and Pizer, 2019; Davis and Knittel, 2019; Cronin et al., 2019; Pizer and Sexton, 2020; Douenne, 2020; Känzig, 2023

  ⇒ We link empirics to theory

Public finance: Commodity/externality taxation in the presence of optimal income taxation

- Atkinson & Stiglitz 1976; Cremer et al. 1998; Saez 2002; Cremer et al. 2003; Jacobs & De Mooij 2015

  ⇒ More general instruments, in particular income-dependent externality prices

Micro theory: Mechanism design & redistribution

- Dworczak et al., 2021; Akbarpour et al., 2022; Kang, 2022; Pai & Strack, 2022

  ⇒ Incomes are observable and policies can be conditioned on them

Concluding remarks

- Distributional considerations often shape the design of corrective policies.
- We offer a formal framework that brings together calls for efficiency and distributional concerns.
- We show that distributional considerations may well be a valid reason for externality price distortions and income-adjusted externality prices.
- But whether the distortion should be up or down and whether the rich should face a lower or higher price is not necessarily obvious and depends on elasticities and redistributional tastes.

Income tax follows Diamond's ABC formula:

$$\frac{T'(y)}{1 - T'(y)} = \left(1 + \frac{1}{\epsilon}\right)\left(1 - \mathbb{E}[\omega | n' \geq n]\right)\frac{1 - F_n(n)}{f_n(n)n}$$

Back to theorem 1.

Second Theorem

ABC formula for the marginal income and externality taxes:

$$\frac{T'(y^0)+\tau'(y^0)}{1-T'(y^0)-\tau'(y^0)} = \left(1+\frac{1}{\epsilon}\right)\frac{\mathbb{E}[(1-w^0)(1-F_{q|n}(\bar{q}|n')) + (B^\omega - \tau^n)f_{q|n}(\bar{q}|n')|n' \geq n]}{n(1-F_{q|n}(\bar{q}|n))h_n(n)}$$

$$\frac{T'(y^1)}{1-T'(y^1)} = \left(1+\frac{1}{\epsilon}\right)\frac{\mathbb{E}[(1-w^1)F_{q|n}(\bar{q}|n') - \left(B^\omega - \tau^n\right)f_{q|n}(\bar{q}|n')|n' \geq n]}{nF_{q|n}(\bar{q}|n)h_n(n)}$$

Back to theorem 2.

Table: The impact of electricity prices on consumption

	Treatment (1)	Placebo (2)
Panel A: Average treatment effect		
ATT	-0.2420	-0.0202
	(0.0068)	(0.0070)
N	2,252,016	2,246,030
Panel B: Treatment effect by income group		
1st quintile	-0.1094	-0.0237
	(0.0167)	(0.0177)
2nd quintile	-0.2004	-0.0005
	(0.0147)	(0.0154)
3rd quintile	-0.2884	-0.0180
	(0.0146)	(0.0144)
4th quintile	-0.3386	-0.0569
	(0.0152)	(0.0146)
5th quintile	-0.3085	-0.0332
	(0.0145)	(0.0146)
N	2,252,016	2,246,030
Fixed effects	Month-province Individual-meter	Month-province Individual-meter

Back to estimation.