Unequal Climate Policy in an Unequal World

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This Paper

Unequal Climate Policy in an Unequal World

- This paper studies climate policy in an economy with heterogeneous households, clean and dirty consumption, and a climate externality from the dirty good. Three parts:

  - DATA. We document low-income households have higher carbon intensity per dollar spent (carbon tax regressive).

  - THEORY. We build a model that captures this fact and characterize optimal carbon tax rules, that capture inequality.

  - QUANTITATIVE. We embed the simple model in a heterogeneous agents climate-model calibrated to US economy, and quantify the effects of taxes on the economy, climate, and welfare.

Motivation

Why does Inequality Matters for Climate Change?

- Climate change is the problem of an externality. ´Easy' fix.
- CLIMATE CHANGE IS A PROBLEM BECAUSE THERE IS INEQUALITY: across countries, across generations, ACROSS HOUSEHOLDS.

The Empirical Fact

that motivates this paper

The Dataset

We build a dataset combining expenditure data (CEX 2019) with emissions data from the Environmental Protection Agency (EPA)

- What we do:

1. We construct CEX-NAICS CONCORDANCE MAP (671 expenditure category into 394 industry codes)

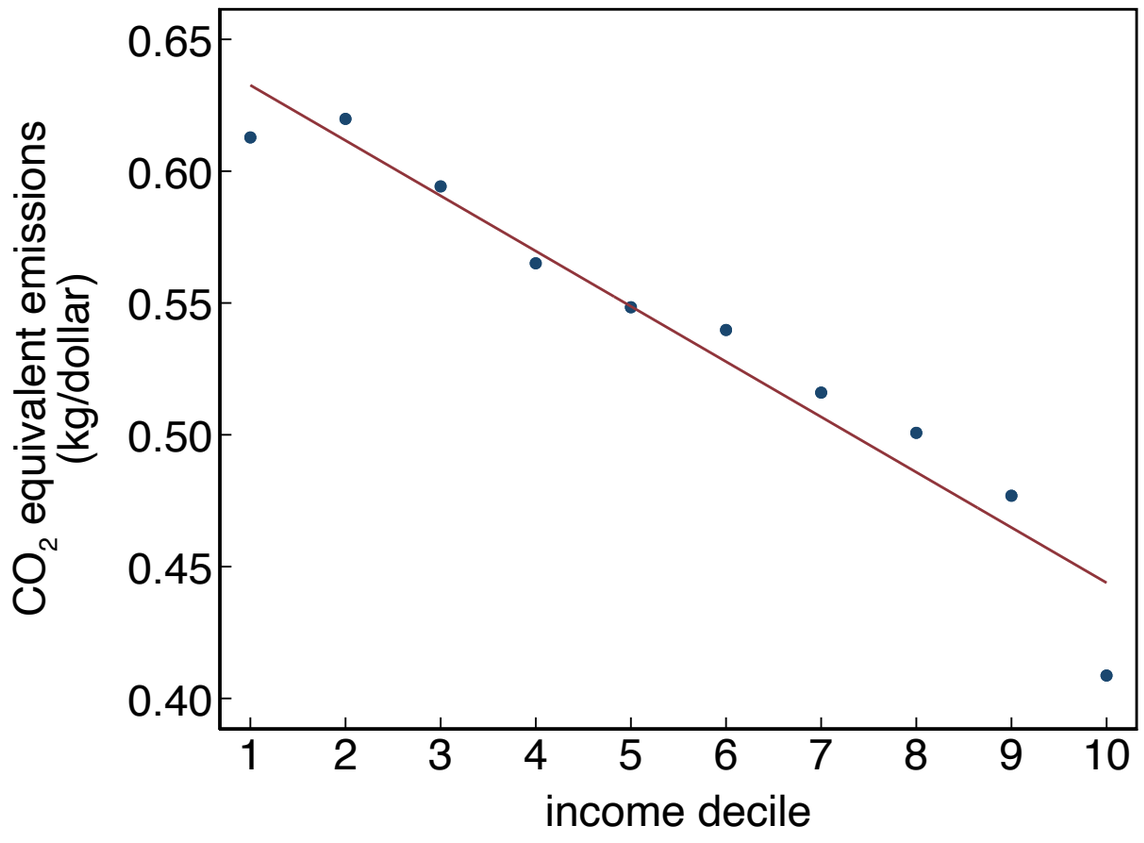
2. And COMPUTE CO_2-EQUIVALENT EMBODIED EMISSIONS PER DOLLAR SPENT, for each household

The Empirical Fact

Carbon Taxes can be Regressive

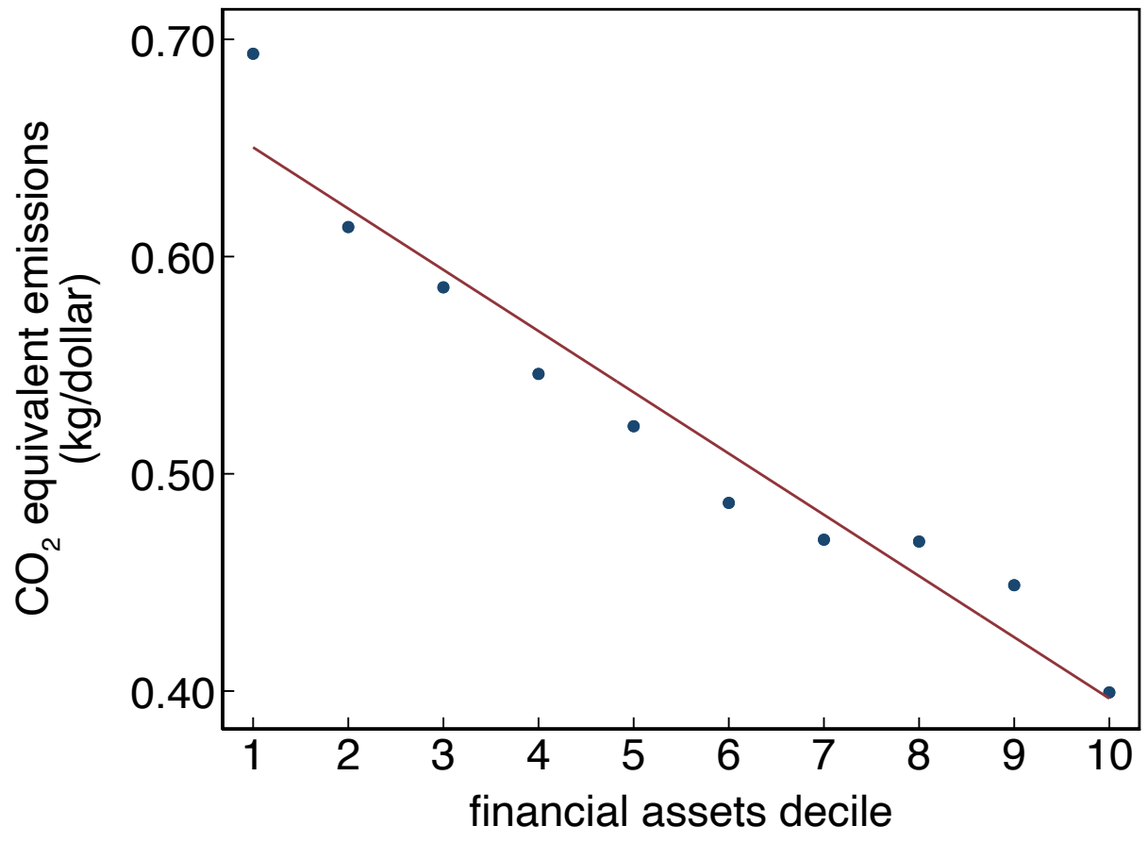
- The emission intensity of household expenditures (emissions per dollar spent) is decreasing in both income and wealth

(a) Income



Low-income households have 20 additional Kg of CO_2 equivalent per 100 dollars spent

(b) Wealth



* Average embodied emissions per dollar spent

Key Elements of the Model

- Climate externality built over consumption; low income households consume a relatively more polluting basket.
- Climate policy to fix the externality. Not for redistribution.
- But, climate policy has redistributive effects (can potentially hurt the poor).
- WE LOOK FOR TAXES THAT ARE NEUTRAL IN TERMS OF THE INITIAL INCOME DISTRIBUTION.

(Climate policy fix the climate externality + undo any distributional effect associated with it)

A win-win Climate Policy

A result

- The benefits from a better climate (reduce in global temperature) compensate the disutility from the changes in the consumption bundle

- There are no income effects, by construction.

- Thus, carbon taxes are a win-win climate policy leading to welfare gains in the aggregate but also for every individual.

- Everybody is better-off.

Literature Review

- Carbon taxation with representative agent: Nordhaus and Boyer (2003), Nordhaus (2007), Golosov et. al. (2014), Barrage (2018), Belfiori (2017), many others.

- Carbon taxation with heterogeneous agents: Jacobs and Van Der Ploeg (2019), Douenne, Hummel and Pedroni (2023), Belfiori and Macera (2024), Fried et al. (2018, 2023), Krusell and Smith (2022), Känzig (2022), Bourany (2024).

- (Contained-efficiency; climate efficiency + careful consideration of redistributive climate tools)

- Distributional role of carbon tax revenue: Rausch et al. (2011), Pizer and Sexton (2019), Fullerton and Monti (2013), Goulder et. al. (2019).

- Inequality and Carbon Emissions: Sager (2019), Levinson and O'Brien (2019), Grainger and Kolstad (2010).

Structure of the Paper

(And this Talk)

1. Propose a SIMPLE MODEL with key elements to characterize optimal carbon taxes in heterogeneous economy:

   A. Unconstrained-efficient with transfers

   B. Constrained-efficient, with no resource transfers across households

   C. Uniform constrained-efficient, with uniform carbon taxation across households.

2. Embed the simple model in a QUANTITATIVE HA MODEL

   (3.a) Estimate carbon taxes

   (3.b) Policy effect on economy and climate variables

   (3.c) Welfare effects

A Simple Model

- Economy populated by a continuum of households, indexed by i with measure μ_i
- Two consumption goods, clean and dirty: (c^i_{ct}, c^i_{dt})
- Consumption of the dirty good adds carbon to the atmosphere, S_t. Carbon evolves according to:

$$S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt} \tag{1}$$

The climate externality is built over consumption

- Households' preferences over consumption and atmospheric carbon are given by

$$\sum_{t=0}^{\infty} \beta^t \left[u(c_{ct}, c_{dt}) - x(S_{t+1}) \right]$$

where $x(S)$ is the CLIMATE DAMAGE FUNCTION with $x'(S) > 0$ and $x''(S) > 0$ and

$$u(c_{ct}, c_{dt}) = \frac{[(c_{ct} + \bar{c})^{\gamma} c_{dt}^{1-\gamma}]^{1-\kappa}}{1-\kappa}$$

- Households are endowed ε^i (supplied inelastically)

γ: preference over clean consumption

$\bar{c}$: non-homotheticity parameter

To capture Empirical Fact

Optimal Climate Policy

A representative agent framework

Given Pareto weights $\{\alpha_i\}_{\forall i}$ with $\sum_i \alpha_i = 1$, the SOCIALLY OPTIMAL ALLOCATION $\{c^i_{jt}, S_t\}^{\infty}_{t=0, j=c,d, \forall i}$ solves the social planner's problem, which is to maximize

$$\sum_i \alpha_i \left[\sum_{t=0}^{\infty} \beta^t \left(u(c^i_{ct}, c^i_{dt}) - x(S_{t+1}) \right) \right] \quad \text{s.t.:}$$

- (Carbon cycle): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt}$ (σ_t)
- (Feasibility Constraints): $\sum_i \mu_i (c^i_{dt} + c^i_{ct}) \leq \sum_i \mu_i \varepsilon^i$ (λ_t)

(shadow prices of carbon and consumption)

Optimal Climate Policy

A representative agent framework

Given Pareto weights $\{\alpha_i\}_{\forall i}$ with $\sum_i \alpha_i = 1$, the SOCIALLY OPTIMAL ALLOCATION $\{c^i_{jt}, S_t\}^{\infty}_{t=0, j=c,d, \forall i}$ solves the social planner's problem, which is to maximize

$$\sum_i \alpha_i \left[\sum_{t=0}^{\infty} \beta^t \left(u(c^i_{ct}, c^i_{dt} \right.\right.$$

TO PRICE THE EXTERNALITY WE DO:

$$\text{SCC} = \frac{\sigma_t}{\lambda_t}$$

- (Carbon cycle): $S_{t+1} = (1-\delta)$ $\qquad (\sigma_t)$

$$\sum_i$$

- (Feasibility Constraints): $\sum_i \mu_i (c^i_{dt} + c^i_{ct}) \leq \sum_i \mu_i \varepsilon^i \qquad (\lambda_t)$

(shadow prices of carbon and consumption)

Uniform Carbon Taxes

- The planner incorporates the social cost of dirty consumption in the relative price between clean and dirty:

$$\forall t, i \qquad \frac{u^i_{dt}}{u^i_{ct}} = 1 + \frac{\nu \sigma_t}{\lambda_t}$$

with

$$\sigma_t = \sum_{j=1}^{\infty} \left[\beta(1-\delta)\right]^{j-1} x'(S_{t+j})$$

$$\lambda_t = \sum_i \alpha_i u^i_{ct}$$

Uniform Carbon Taxes

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$$\lambda_t = \sum_i \alpha_i u^i_{ct}$$

Uniform Carbon Tax
The Social Cost of Carbon

$$\tau_t^\star = \frac{\nu \sigma_t}{\sum_i \alpha_i u^i_{ct}}$$

Price of carbon in units of consumption (pricing at average consumption)

Non-uniform transfers:

$$t^i_t(\alpha_i) = (1+\tau_t^\star) c^i_{dt} + c^i_{ct} - \varepsilon^i$$

Constrained-Optimal Climate Policy

Given Pareto weights $\{\alpha_i\}_{\forall i}$ with $\sum_i \alpha_i = 1$, the CONSTRAINED-OPTIMAL ALLOCATION $\{c^i_{jt}, S_t\}^{\infty}_{t=0, j=c,d, \forall i}$ solves the social planner's problem, which is to maximize

$$\sum_i \alpha_i \left[\sum_{t=0}^{\infty} \beta^t \left(u(c^i_{ct}, c^i_{dt}) - x(S_{t+1}) \right) \right] \quad \text{s.t.:}$$

- (Carbon cycle): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt}$ $\qquad (\sigma_t)$

- (Budget Constraints): $c^i_{dt} + c^i_{ct} \leq \varepsilon^i$ $\qquad (\lambda^i_t)$

Constrained-Optimal Climate Policy

Given Pareto weights $\{$

Optimal Allocation $\{c_{jt}^{i}$

planner's problem, whi

$$\sum_i \alpha_i \left[\sum_{t=0}^{\infty} \right.$$

Constrained-efficient Climate policy: Focus on Efficiency

1. Utilitarian planner: $\alpha_i = \mu_i$
2. No net transfers of resources across households (no direct redistribution)

$\left.\right]$

- (Carbon cycle): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c_{dt}^i \qquad (\sigma_t)$

- (Budget Constraints): $c_{dt}^i + c_{ct}^i \leq \varepsilon^i \qquad (\lambda_t^i)$

Constrained-Optimal Carbon Tax

- Now, the shadow price of the externality incorporates the private valuation (hh´s marginal utility)

$$\forall t, i \qquad \frac{u^i_{dt}}{u^i_{ct}} = 1 + \frac{\nu \sigma_t}{\lambda^i_t}$$

with

$$\sigma_t = \sum_{j=1}^{\infty} \left[\beta(1-\delta)\right]^{j-1} x'(S_{t+j})$$

$$\lambda^i_t = u^i_{ct}$$

Non-Uniform Carbon Tax. The Social Cost of Carbon

$$\tau^i_t = \frac{\nu \sigma_t}{u^i_{ct}}$$

Price of carbon in units of consumption (pricing at private valuation)

The Theory Results

Constrained-efficient carbon tax formulas

PROPOSITION 1. (CONSTRAINED-OPTIMAL CARBON TAX). Let $\{c_{dt}^i, c_{ct}^i, S_t\}_{t=0,\forall i}^{\infty}$ be the constrained-optimal allocation. Then, there exists a sequence of prices $\{p_t\}_{t=0}^{\infty}$ such that the allocation is a competitive equilibrium with taxes given by

$$\tau_t^i = \frac{\nu\sigma}{u_{ct}^i} \quad ; \quad t_t^i = \tau_t^i c_{dt}^i \qquad \forall t \forall i$$

1. τ_t^i is higher for wealthier households because they have a lower marginal utility

2. The policy preserves the initial distribution of resources across households; some redistribution occurs through the implementation of differential tax rates

Remark 1.

The constrained-efficient carbon tax in an heterogeneous economy is heterogeneous

(And progressive)

Can we make it homogeneous?

- Most policy proposals consider uniform carbon taxes. Can we make the carbon tax homogeneous in a heterogeneous economy?

- We must impose uniformity of the tax rate as an additional constraint in the planning problem (it is not the natural solution)

- Using the optimality conditions, the constraint is:

A. $$\frac{u^i_{dt}}{u^i_{ct}} = \frac{u^j_{dt}}{u^j_{ct}} \qquad \forall t \forall i, j$$

Constrained-Optimal Climate Policy

Given Pareto weights $\{\alpha_i\}_{\forall i}$ with $\sum_i \alpha_i = 1$, the CONSTRAINED-OPTIMAL ALLOCATION $\{c^i_{jt}, S_t\}^{\infty}_{t=0, j=c,d, \forall i}$ solves the social planner's problem, which is to maximize

$$\sum_i \alpha_i \left[\sum_{t=0}^{\infty} \beta^t \left(u(c^i_{ct}, c^i_{dt}) - x(S_{t+1}) \right) \right] \quad \text{s.t.:}$$

- (Carbon cycle): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt}$ (σ_t)
- (Budget Constraints): $c^i_{dt} + c^i_{ct} \leq \varepsilon^i$ (λ^i_t)
- $\frac{u^i_{dt}}{u^i_{ct}} = \frac{u^j_{dt}}{u^j_{ct}}$ (η^i_t)

PROPOSITION 2. CONSTRAINED-OPTIMAL UNIFORM CARBON TAX.

Suppose $\{c_{dt}^i, c_{ct}^i, S_t\}_{t=0,\forall i}^{\infty}$ solves the the constrained-optimal allocation with constraint (A). Then, there exists a sequence of prices $\{p_t\}_{t=0}^{\infty}$ such that the allocation is a competitive equilibrium with taxes given by

$$\tau_t = \frac{\upsilon \sigma_t}{\sum_i \frac{\mu_i c_t^i}{\sum_j \mu_j c_t^j} u_{ct}^i} \quad ; \quad t_t^i = \tau_t c_{dt}^i \qquad \forall t \forall i \,.$$

1. The constrained-optimal uniform carbon tax uses a WEIGHTED AVERAGE OF MARGINAL UTILITIES TO PRICE THE CLIMATE EXTERNALITY

2. LOWER THAN THE UNCONSTRAINED-UNIFORM CARBON TAX: the consumption-weighted average marginal utility is higher than the marginal utility of average consumption

Remark 2.

If we were to impose a uniform carbon tax in a heterogeneous economy, a consumption-weighted average of marginal utilities must be used to price the climate externality

(THE TAX IS LOWER THAN THE UNCONTRAINED-UNIFORM CARBON TAX)

An Alternative Decentralization
avoids individual tax rebates

COROLLARY 1. UNIFORM CARBON TAX, CLEAN SUBSIDY AND TRANSFER.
The uniform constrained-optimal allocation is also implementable as a competitive equilibrium with an all-uniform climate policy $\{\tau_{dt}, \tau_{ct}, t_t\}$ given by:

$$\tau_{dt} = \gamma\mu_t \quad ; \quad \tau_{ct} = (1-\gamma)\frac{\mu_t}{1+\mu_t} \quad ; \quad t_t = \tau_{ct}\bar{c}$$

with $\mu_t \equiv \dfrac{\upsilon\sigma_t}{\sum_i \dfrac{\mu_i c_t^i}{\sum_j \mu_j c_t^j} u_{ct}^i}$

This all-uniform policy can arguably be a more feasible alternative to the uniform-constrained carbon tax with individual transfers.

Quantitative Model

- We embed the simple model into a standard heterogeneous agents model with idiosyncratic labor income risk and incomplete markets.

- Households choose $\{(c^i_{ct}, c^i_{dt}), n^i_t, k^i_{t+1}\}_{t=0}^{\infty}$ to maximize

$$\mathbf{E}_0 \sum_{t=0}^{\infty} \beta^t \left[u(c^i_{ct}, c^i_{dt}) - v(n^i_t) - x(S_{t+1})\right]$$

s.t. $$p_t(1+\tau_t)c^i_{dt} + c^i_{ct} + k^i_{t+1} - k^i_t \leq w_t \varepsilon^i_t n^i_t + (r_t - \delta_k)k^i_t$$

$$k^i_{t+1} \geq 0$$

- Extra margin: share between clean and dirty consumption.

- $Y_{jt} = F(N_{jt}, K_{jt})$

PROPOSITION 3. The constrained optimal carbon tax for the quantitative economy follows the rule in PROPOSITION 1:

$$\tau_t^i = \frac{\nu\sigma}{u_{ct}^i} \qquad \forall t \forall i$$

Also, the uniform carbon tax follows the rule in PROPOSITION 2:

$$\tau_t = \frac{\upsilon\sigma_t}{\sum_i \frac{\mu_i c_t^i}{\sum_j \mu_j c_t^j} u_{Ct}^i} \qquad \forall t$$

1. The tax rules from the simple model remain unchanged in the quantitative economy.

Quantitative Analysis

1. Take an economy with a tax structure empirically motivated to replicate the US: (PROGRESSIVE EARNINGS TAX, CAPITAL INCOME TAX)

2. The Business-as-usual economy is the US economy with taxes (to match income distribution); without a carbon tax. (CONSUMERS ARE NOT PRICING THE EXTERNALITY).

3. To this economy:

   - Add the consumption decision (c_{ct}, c_{dt}) calibrating preference parameters to match the empirical fact: (CARBON INTENSITY 30% HIGHER FOR LOW-INCOME HOUSEHOLDS)

   - Add a carbon tax to make consumers price the externality according to the rules we derived. (KEEP DOING WHATEVER YOU ARE DOING BUT PRICE IN CARBON)

Calibration: Preferences

- Utility function:

$$u(c_c, c_d, \ell) = \frac{[(c_c + \bar{c})^{\gamma} c_d^{1-\gamma}]^{1-\kappa}}{1-\kappa} - \phi \frac{(1-\ell)^{1-\nu}}{1+\nu}$$

Parameters	Values	Targets / Source
Discount factor β	0.97	Wealth-to-GDP: 4.8 (2014)
Risk aversion κ	2	Standard value
Labor disutility, ϕ	29.6	Average hours: 30 percent
Frisch elasticity $1/\nu$	0.5	Standard value
Clean share γ	0.97	\$50/ton carbon tax leads to 0.8 degree reduction from BAU
Non-homotheticity $\bar{c}$	0.16	emissions intensity 31% higher for low-income than high-income households

Calibration: Climate

- Temperature function: $T_t = \dfrac{\lambda}{\log(2)} \log\left(\dfrac{S_t}{\overline{S}}\right)$ (Golosov et.al. 2014)
- Climate damage function: $x(S) = \dfrac{\psi}{2} S^2$

Parameters	Values	Targets / Source
Carbon absorption, δ	1/300	average life of carbon: 300 years
Carbon intensity, υ	326.4	1.4 degree increase by 2100 under BAU
Climate disutility, ψ	0.04	welfare loss from 2.5 degree increase $\approx$ 1.74 percent output reduction
Temperature parameters		
climate sensitivity, λ	3	doubling of carbon $\Rightarrow$ 3-degree increase
initial carbon, $\overline{S}$	581	pre-industrial carbon stock (gigatons)

Calibration: Technology and Shocks

- Production: $F(K,N) = K^{\alpha}N^{1-\alpha}$
- Productivity shocks: $log(\varepsilon_t^i) = log(\varepsilon_{t-1}^i) + \xi_t^i \;\; ; \;\; \xi_t^i \sim N(0,\sigma_\varepsilon^2)$
- Superstar state ε_{sup} to match wealth/earnings distribution

Parameters	Values	Targets / Source
Capital weight, α	0.36	capital income share: 36%
Capital depreciation, δ_k	0.05	standard value
Productivity persistence ρ	0.94	author estimates
Standard deviation, σ_ε	0.20	earnings Gini: 0.47
Superstar parameters		
productivity, $\varepsilon_{sup}/\varepsilon_{med}$	163	wealth share top 1.0%: 34%
persistence, $\pi(\varepsilon_{sup}, \varepsilon'_{sup})$	0.94	wealth Gini: 0.83
entry probability, $\pi(1:9, \varepsilon'_{sup})$	6e-5	fraction of superstars: 0.1%

Calibration: Government

- Progressive earnings tax (Benabou, HSV, Daruich-Fernandez, ...)

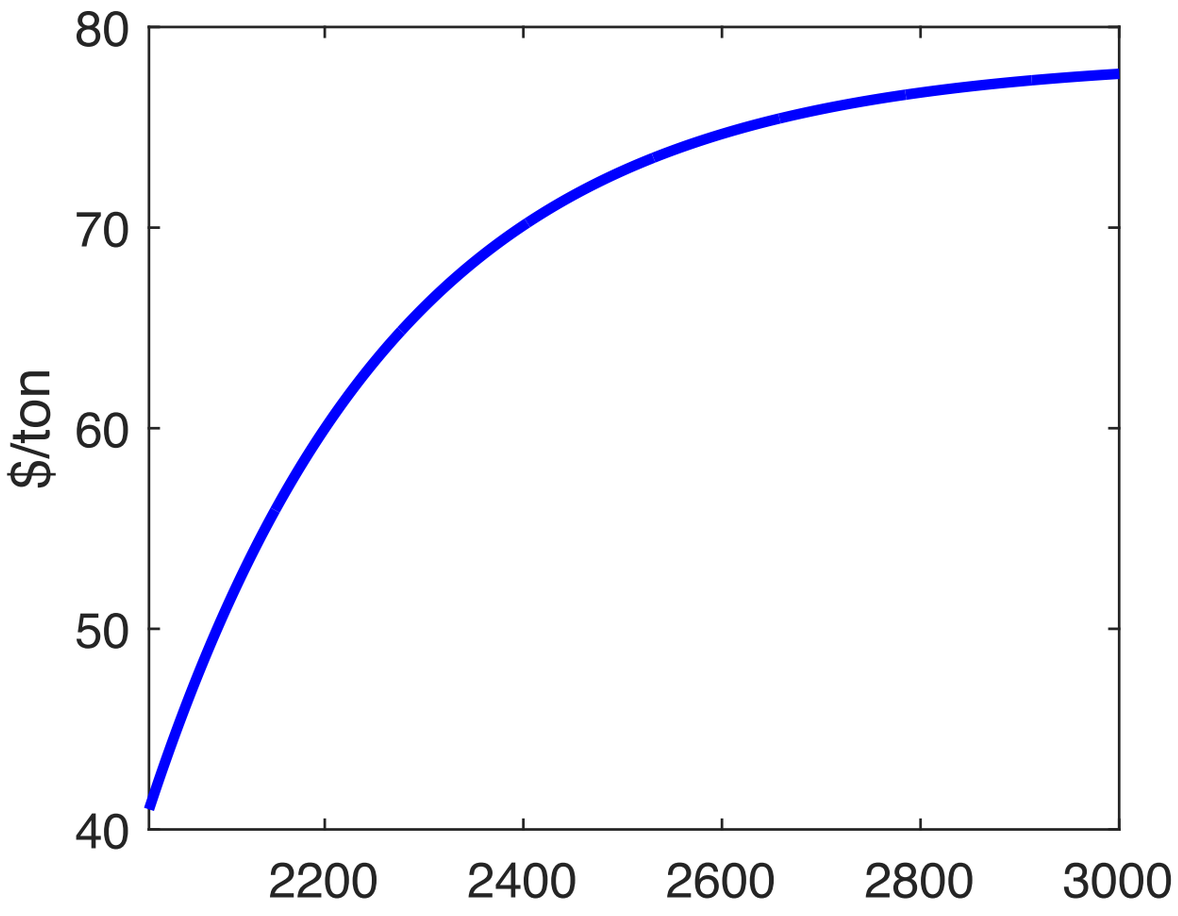
$$T(y) = y - \tilde{y}^{\nu_y} \frac{1-\tau_y}{1-\nu_y} y^{1-\nu_y}$$

where $\tilde{y}^{\nu_y}$ is average earnings.

Parameters	Values	Targets / Source
Average tax parameter, τ_y	0.23	average labor income tax: 13%
Progressivity parameter, ν_y	0.17	37.9% marginal tax rate on top 1% earners
Capital income tax, τ_k	0.27	Carey and Rabesona (2002)

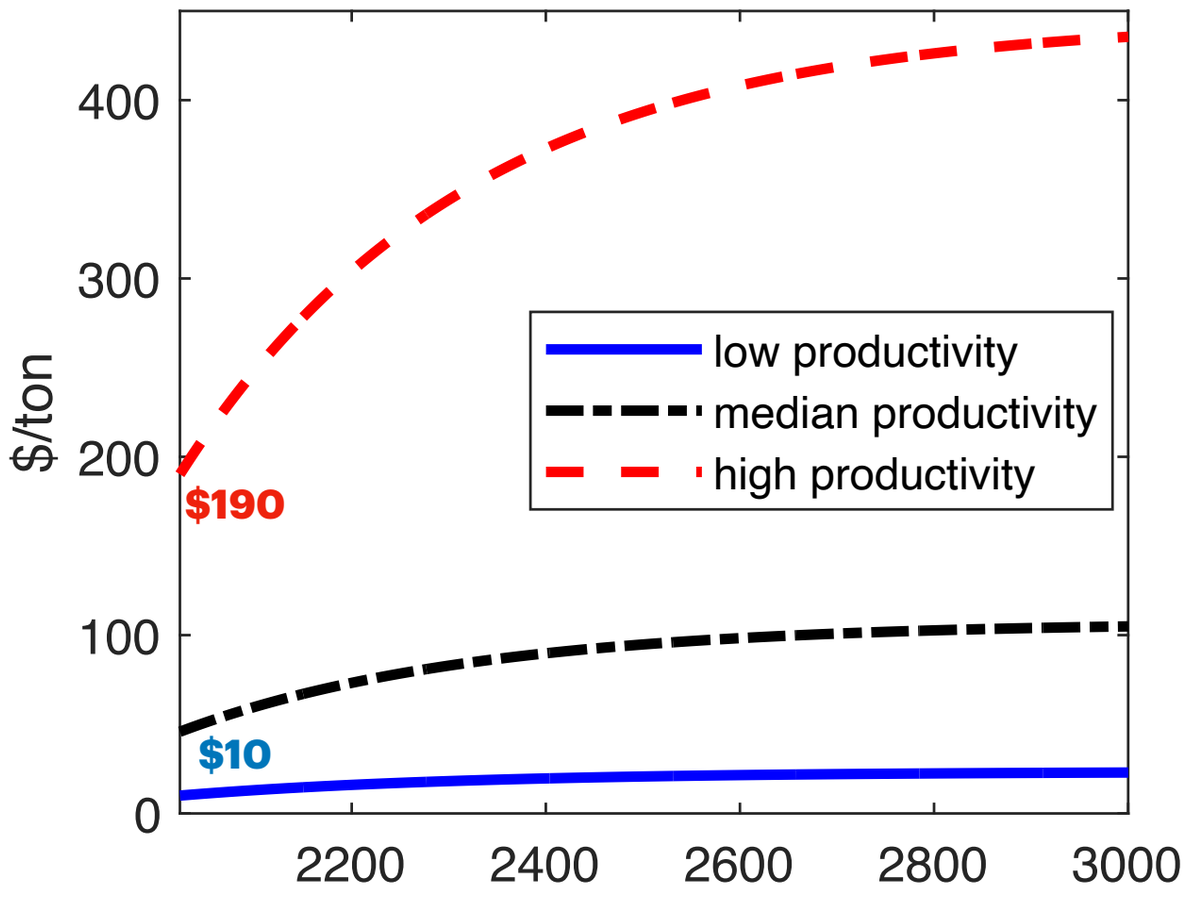
Carbon Tax

(a) Uniform



- Rather low modest tax ($41; $78 LR).
- Compatible with RA version Nordhaus/Golosov ($57/ton)

(b) Heterogeneous

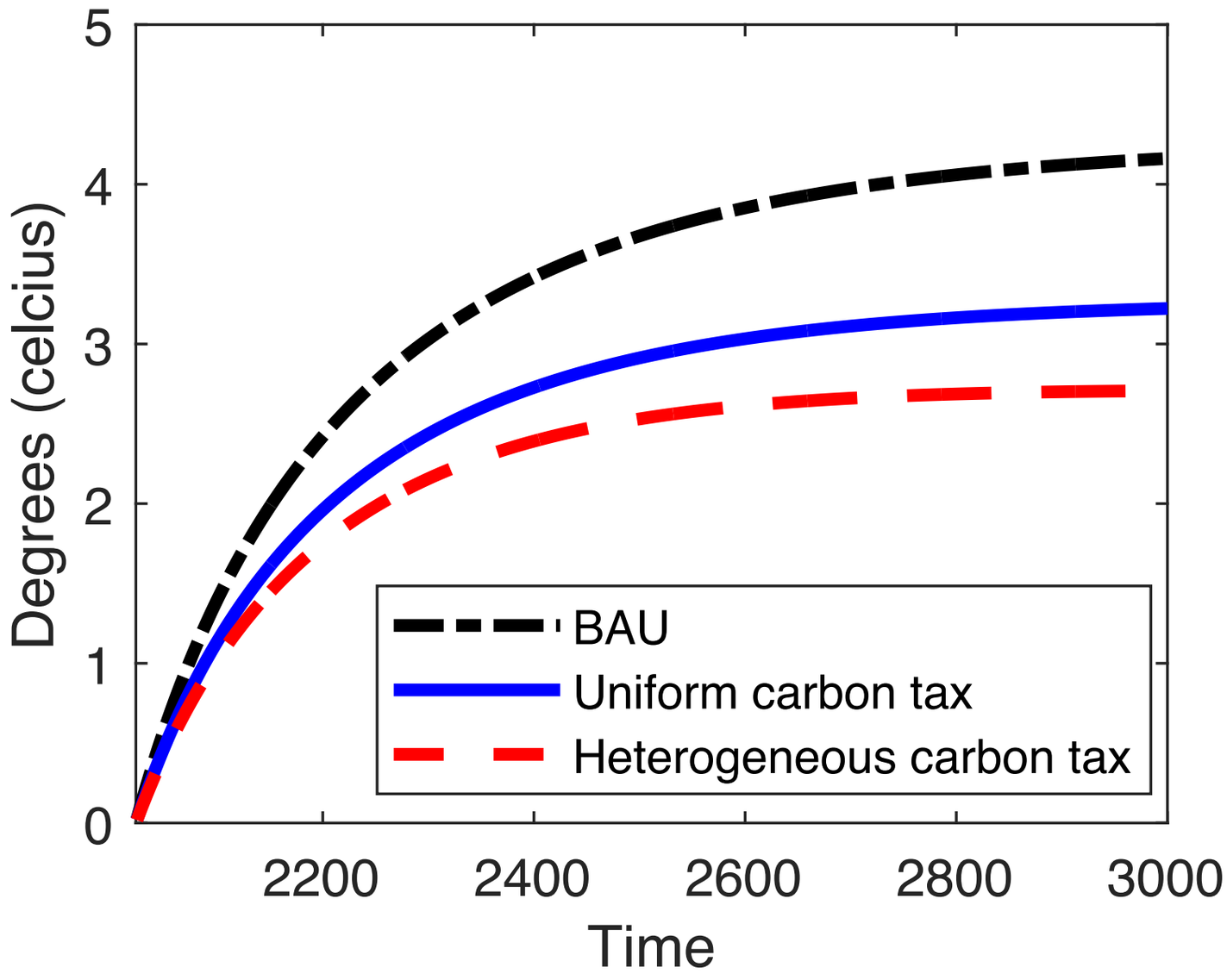


- Comes from climate damages estimation. Recent calculations much higher (Bilal&Kanzig, 2024)

Global Temperature

The carbon tax leads to a 0,5C degree decrease in the temperature compared to BAU over 100yrs

(b) Temperature increase

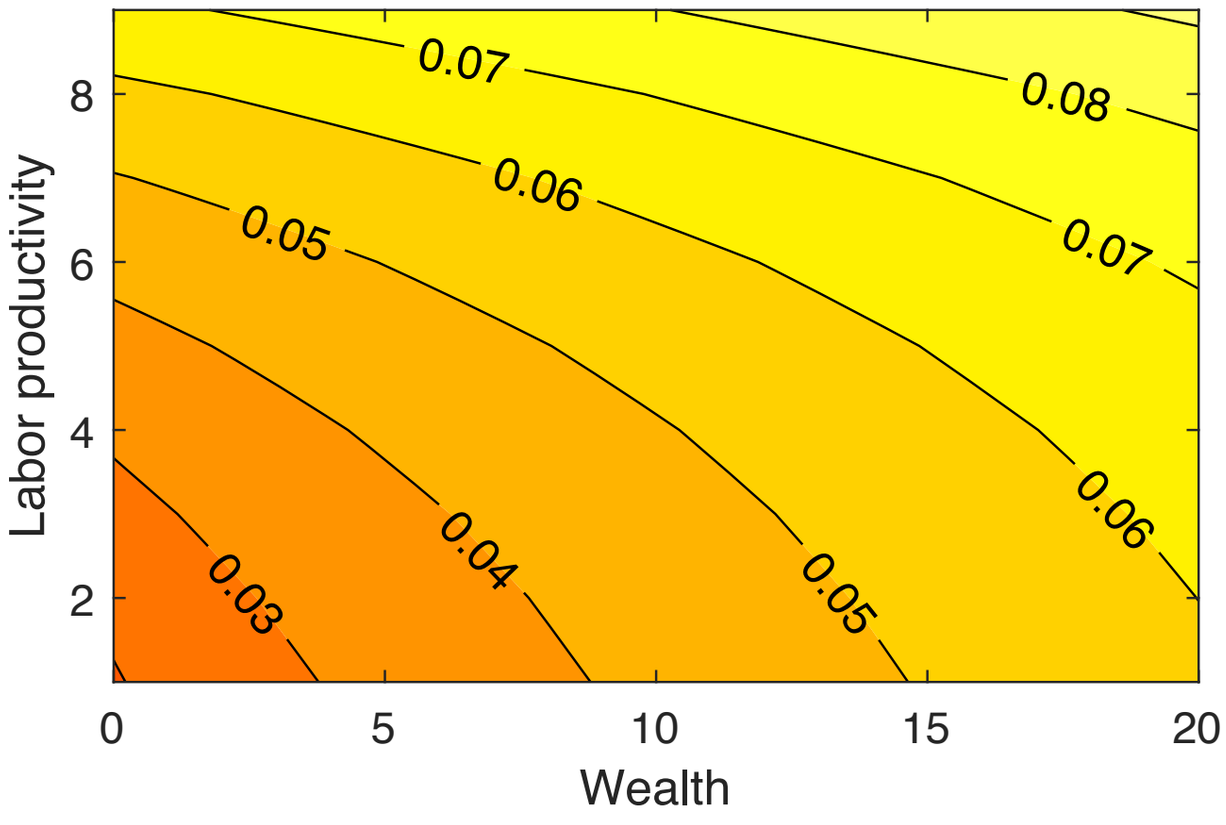


Welfare Gains: Win-Win Climate Policy

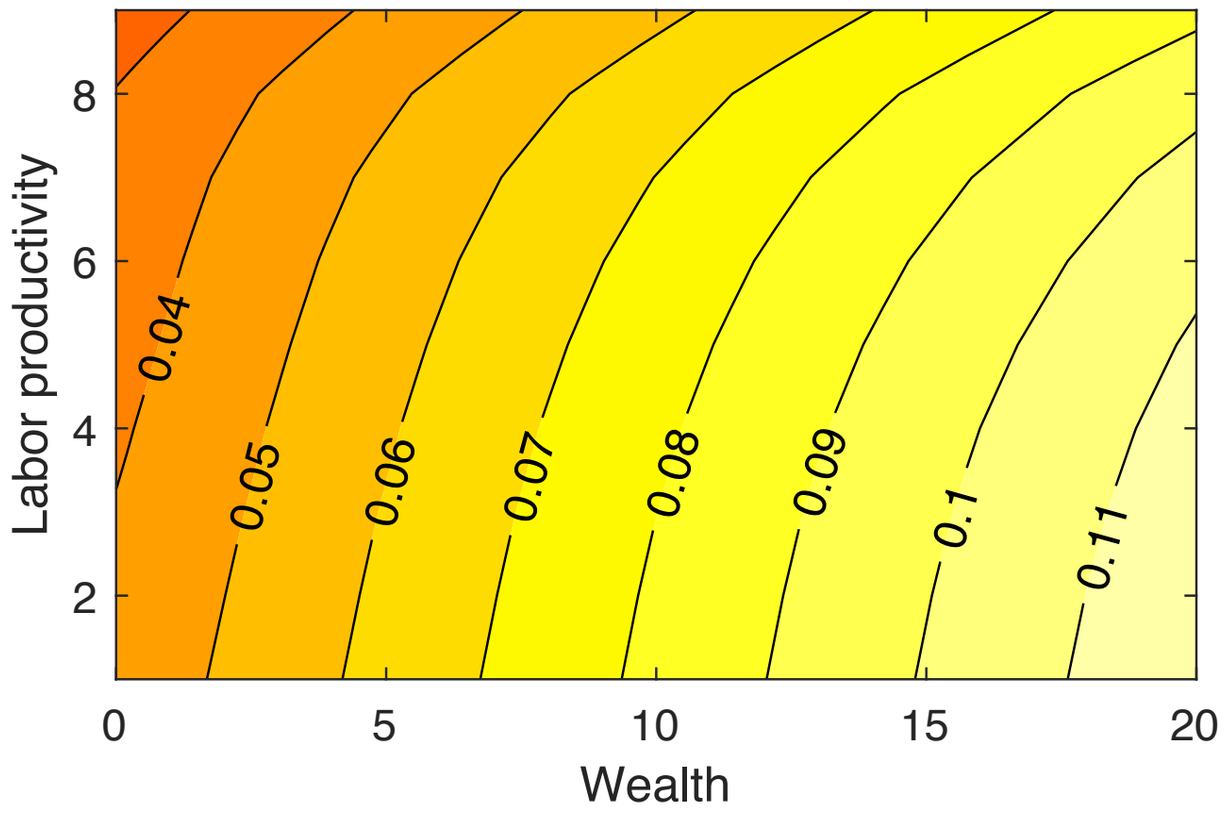
Initial Welfare Distribution

Welfare gains (relative to BAU) positive for all! Especially for the wealthy

(a) Uniform



(b) Heterogeneous

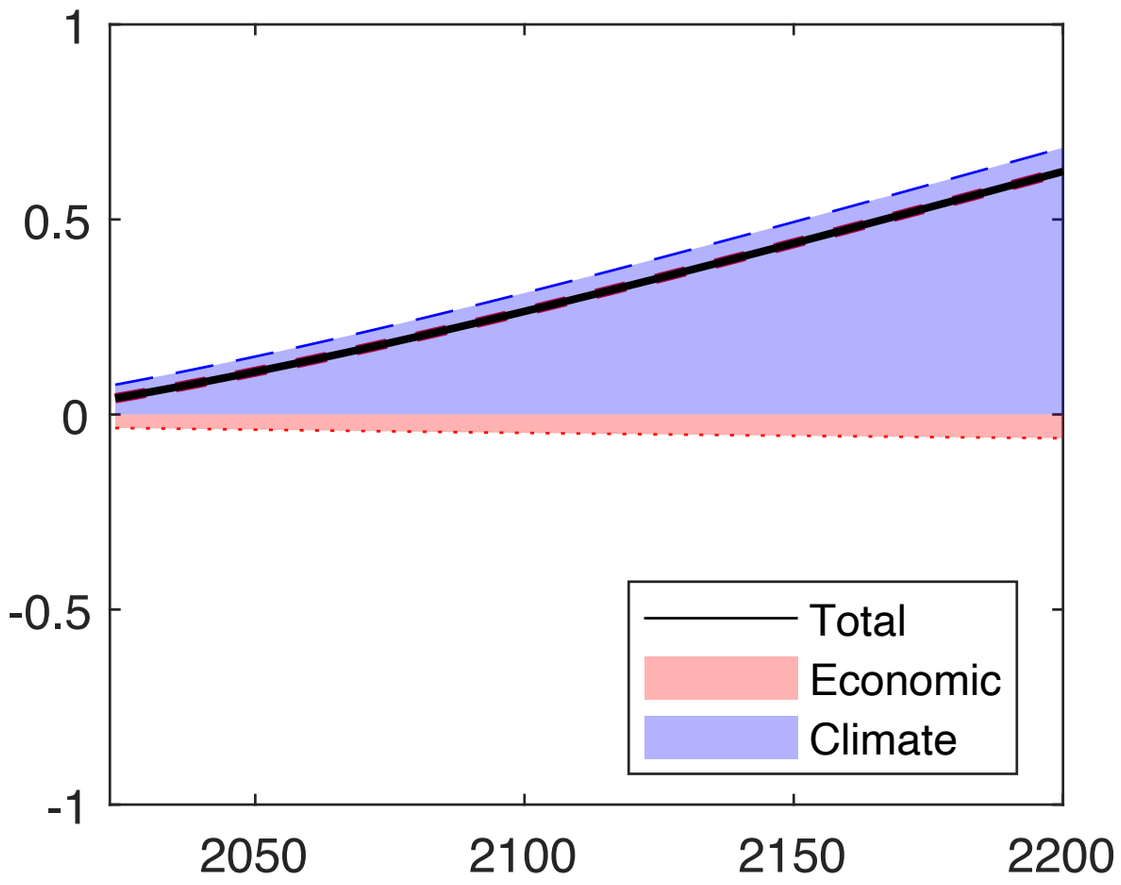


Units: Permanent consumption equivalents (percent)

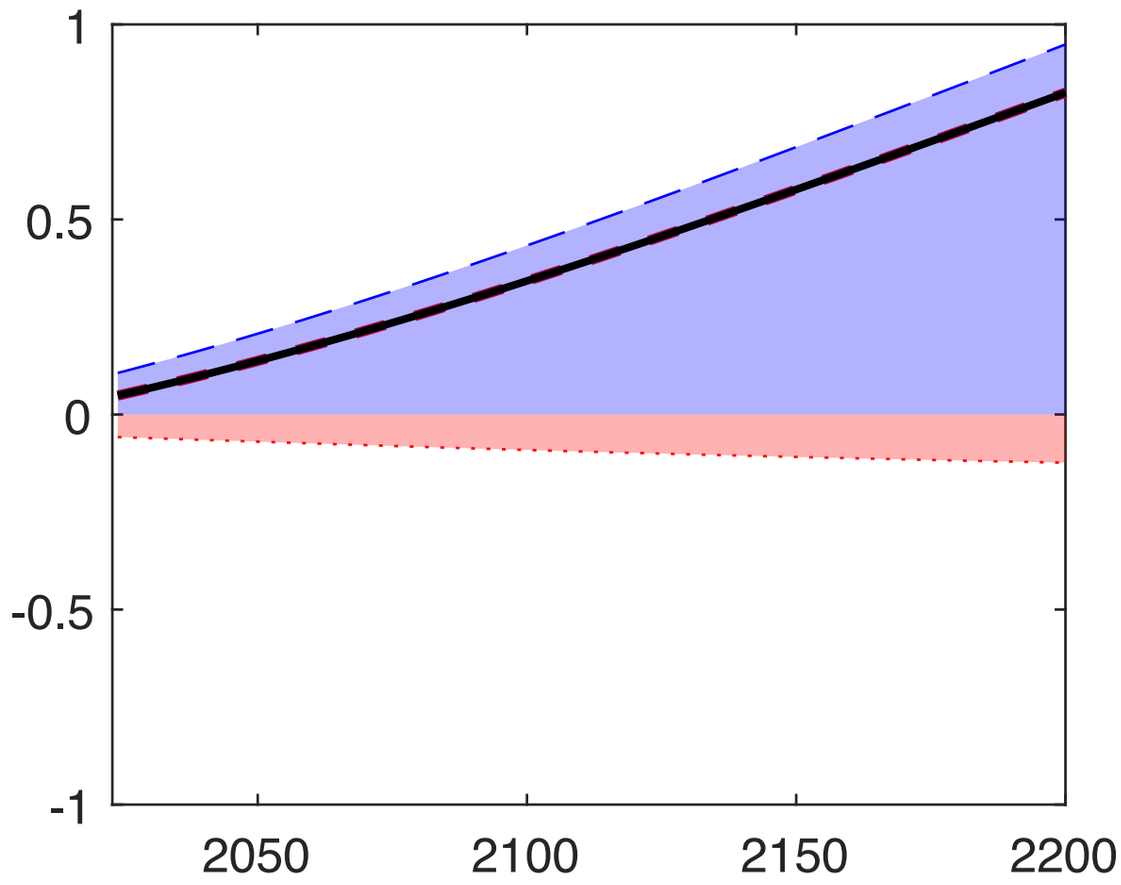
Average Welfare Decomposition

Average welfare gains become large over time

(a) Uniform



(b) Heterogeneous



Average Welfare Gains

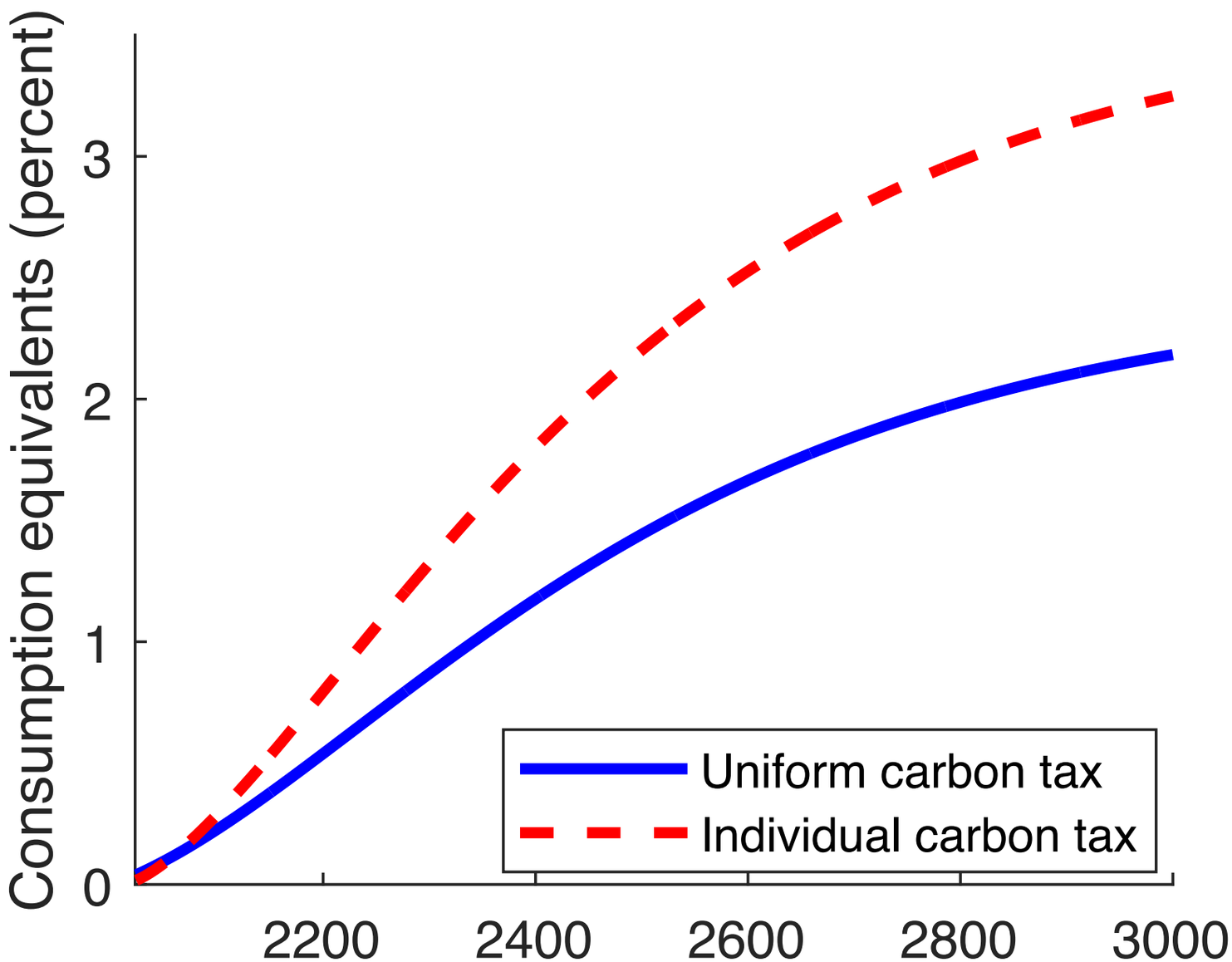
Constrained-efficient vs alternatives

Average Welfare in Consumption Equivalence (%

Policy	$t = 1$	$t = 100$	Support
Heterogeneous tax with rebate	0.049	0.447	100.0
Uniform tax with rebate	0.042	0.356	100.0
Uniform tax with subsidy + transfer	0.044	0.346	100.0
Constant tax ($98/ton) with rebate	0.003	0.524	52.2

Average Welfare Gains

Average welfare gains larger for the heterogeneous carbon tax, both initially and throughout the transition.



Concluding Remarks

In this paper, we derive optimal carbon tax rules for economies with inequality. We apply them in a heterogeneous agents climate-economy to quantify the carbon tax effects on the climate & welfare. We find a Pareto-improving result.

FUTURE WORK:

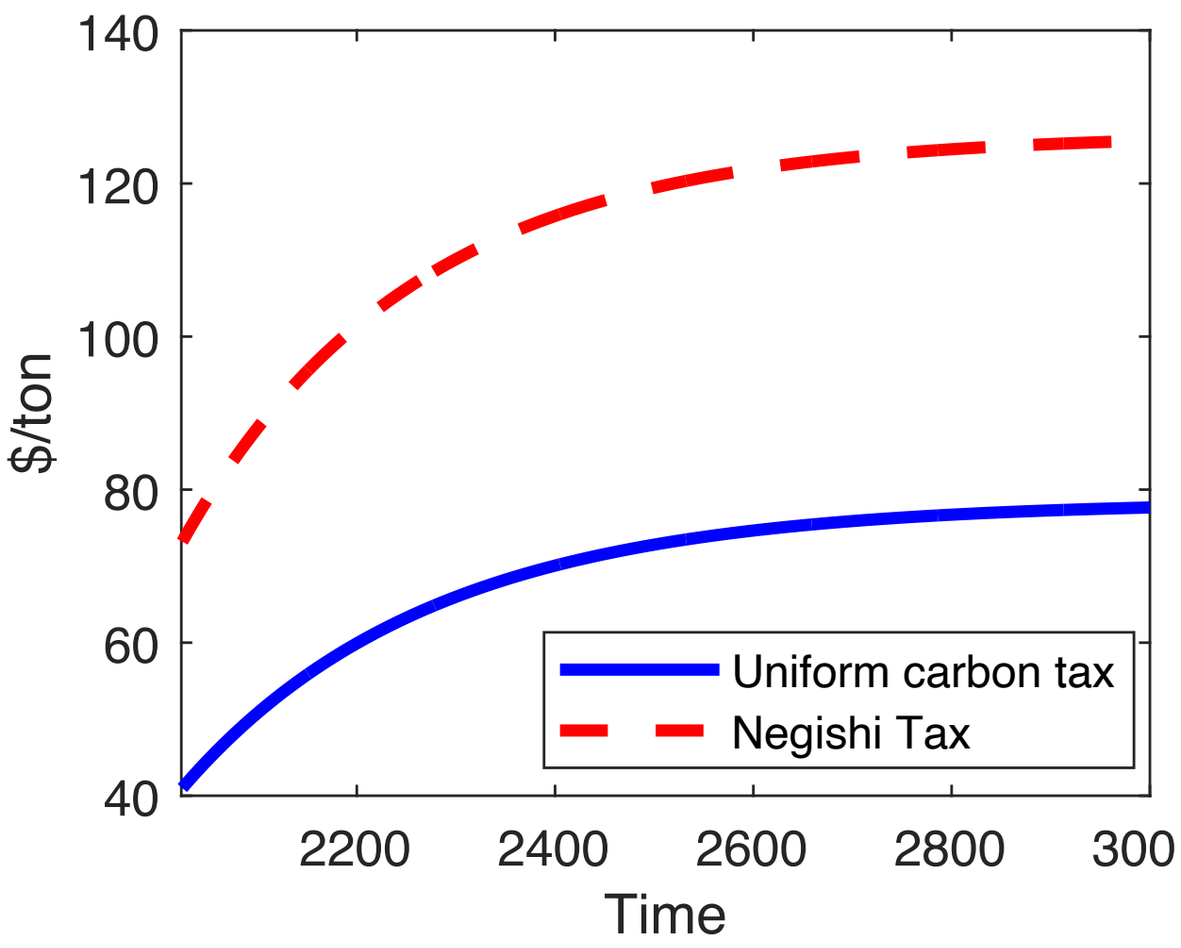
- Heterogeneous climate damages (more vulnerable low-income households, more room for a Pareto-improvement)
- Involve the production side of the economy.
- Working on implementability: clean subsidy and dirty tax; progressive taxes?
- Implementation of constrained-efficient allocation with climate targets.

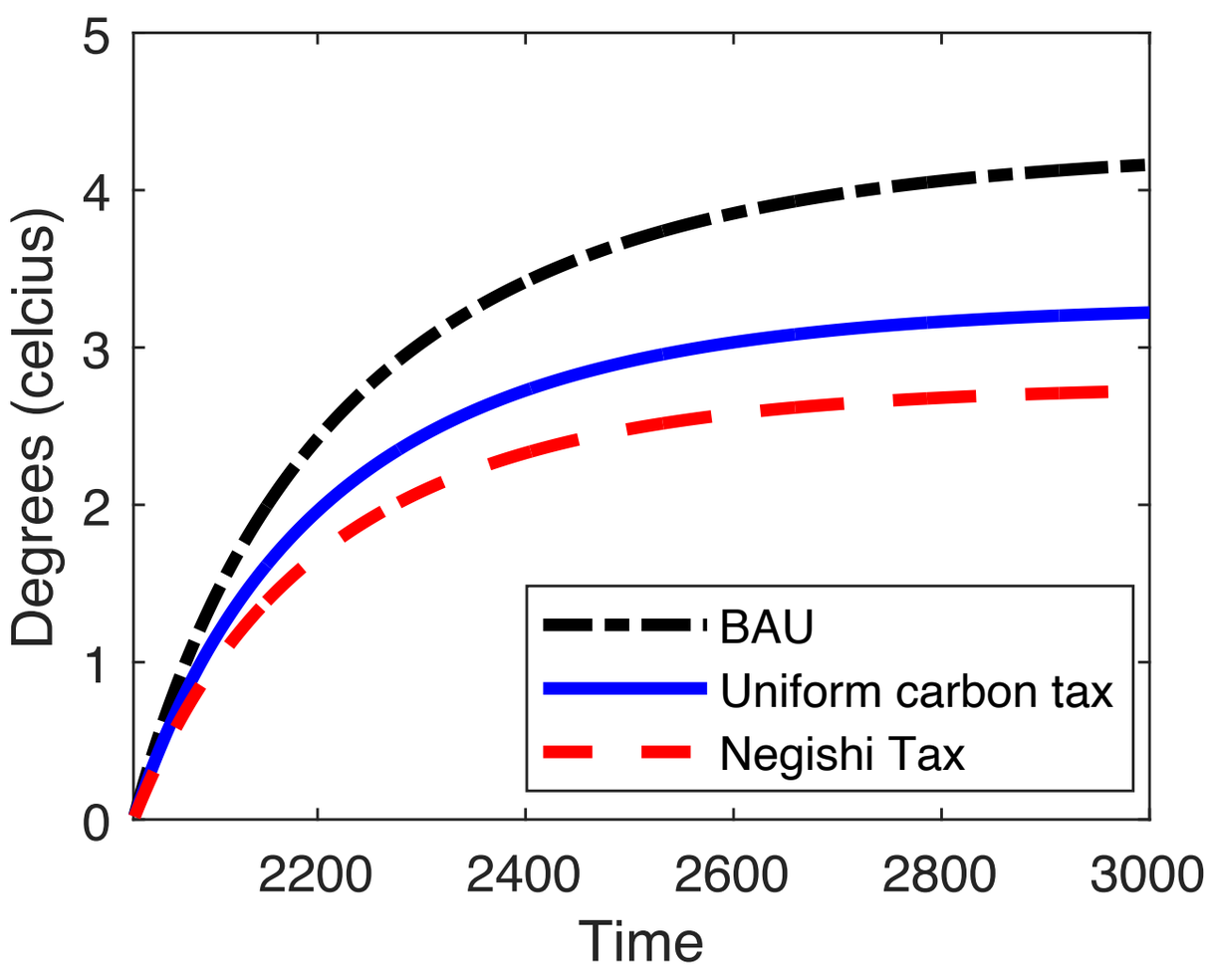
Additional Slides

Alternative Welfare Criteria

Negishi Pareto Weights

- More weight on high-income consumers lead to a more aggressive climate policy (higher tax and temperature decrease)



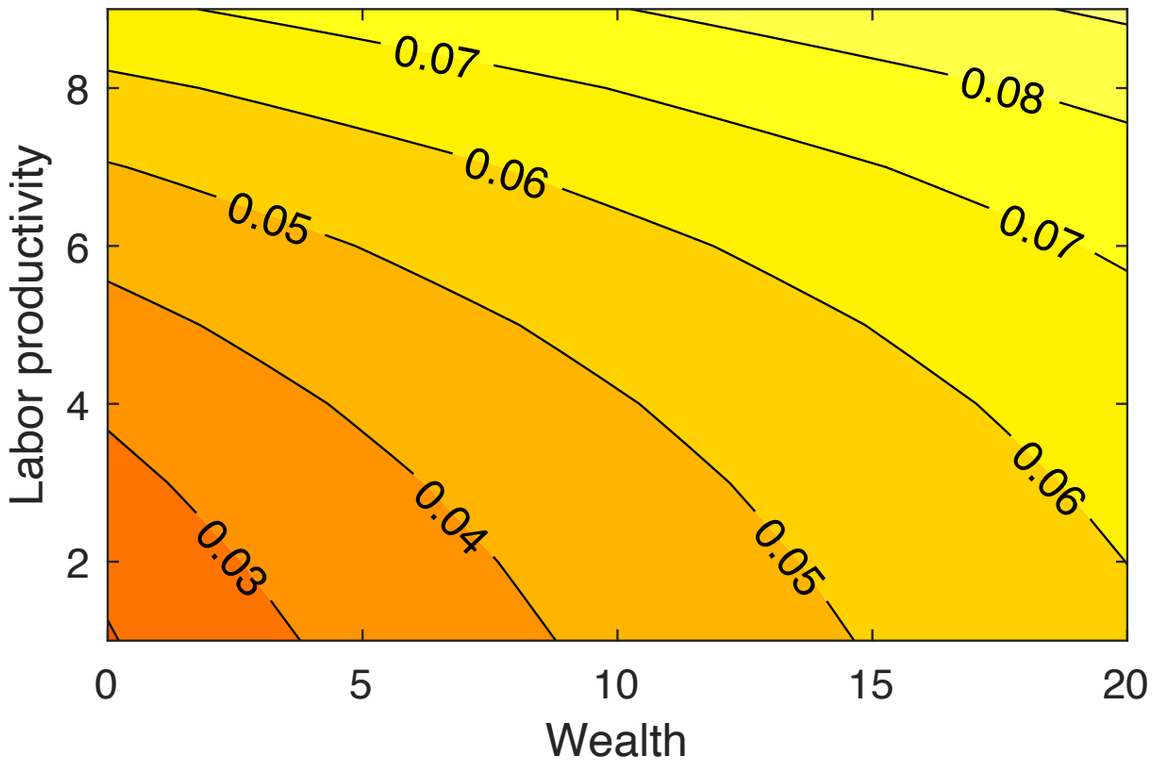


Alternative Welfare Criteria

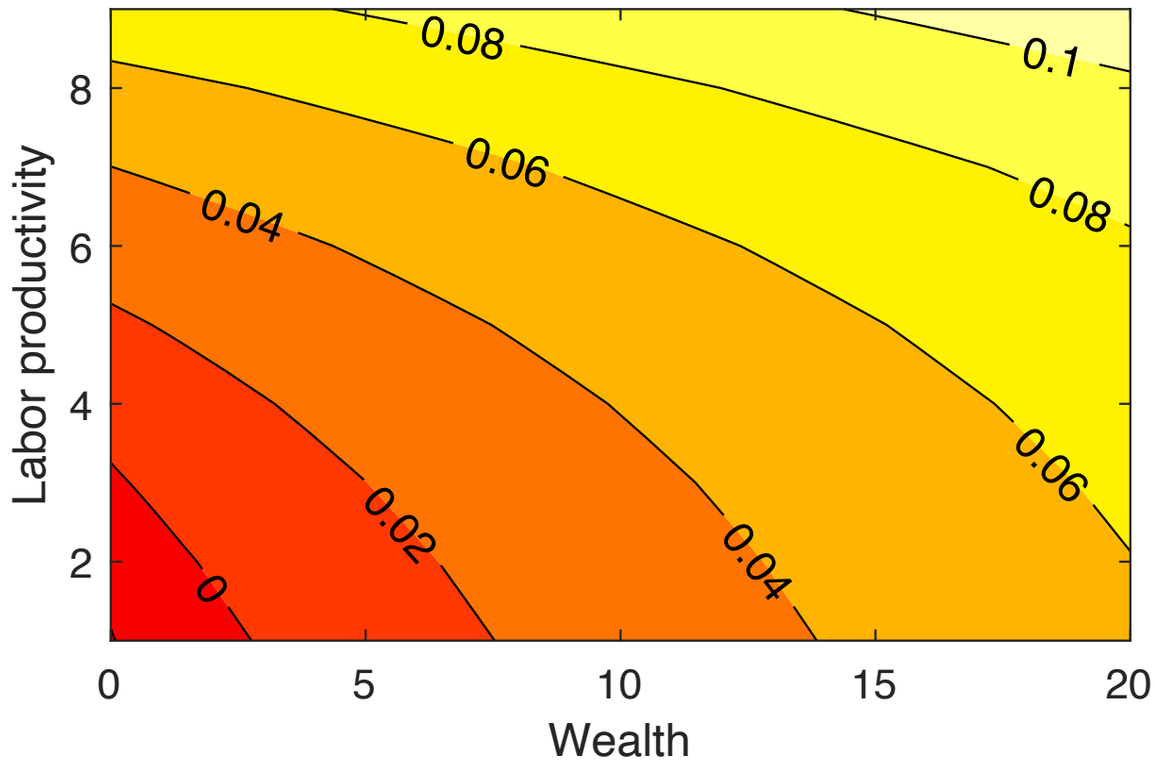
Negishi Pareto Weights

- Not Pareto-improving, even with tax rebates. Low-income households lose.

(a) Uniform carbon tax



(b) Negishi carbon tax



The Dataset

We build a dataset combining expenditure data (CEX) with emissions (EPA)

- Consumer Expenditure Survey (CEX, 2019)
  - 671 expenditure categories; 5000+ working-age households
- Environmental Protection Agency (EPA)
  - Industry level; embodied emissions for 460 commodities (covering cradle → factory gate →shelf). (CO_2, Methane, Nitroux Oxide)
- What we do:

1. We construct CEX-NAICS CONCORDANCE MAP (671 expenditure category into 394 industry codes)
2. And COMPUTE CO_2-EQUIVALENT EMBODIED EMISSIONS PER DOLLAR SPENT, for each household

The Empirical Fact

Carbon Taxes can be Regressive

- The emission intensity is higher because low-income households spend relatively more on high-intensity goods

Table 1: Embodied emissions and expenditure shares

Expenditure category	Embodied emissions (CO_2 kg/dollar)	Expenditure shares (percent)	
		Low income	High income
Utilities	1.71	9.1	5.1
Transportation	1.16	18.4	16.0
Food and beverages at home	0.80	14.1	7.7
Other expenditures	0.11	58.4	71.2

High and low income correspond to the top and bottom deciles of income, respectively, conditional on working age.

The result is robust to controlling for education, age, and family size

Market Economy

- Households choose $\{c^i_{ct}, c^i_{dt}\}$ to maximize utility subject to the following set of budget constraints for every t

$$p_t(1+\tau_t)c^i_{dt} + c^i_{ct} \leq \varepsilon^i + t_t$$

  p_t: relative price of dirty to clean consumption; τ_t: carbon tax; t_t is a lump-sum transfer.

- Optimality implies:

$$\frac{u^i_{dt}}{u^i_{ct}} = 1 + \tau_t \qquad p_t = 1$$