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:

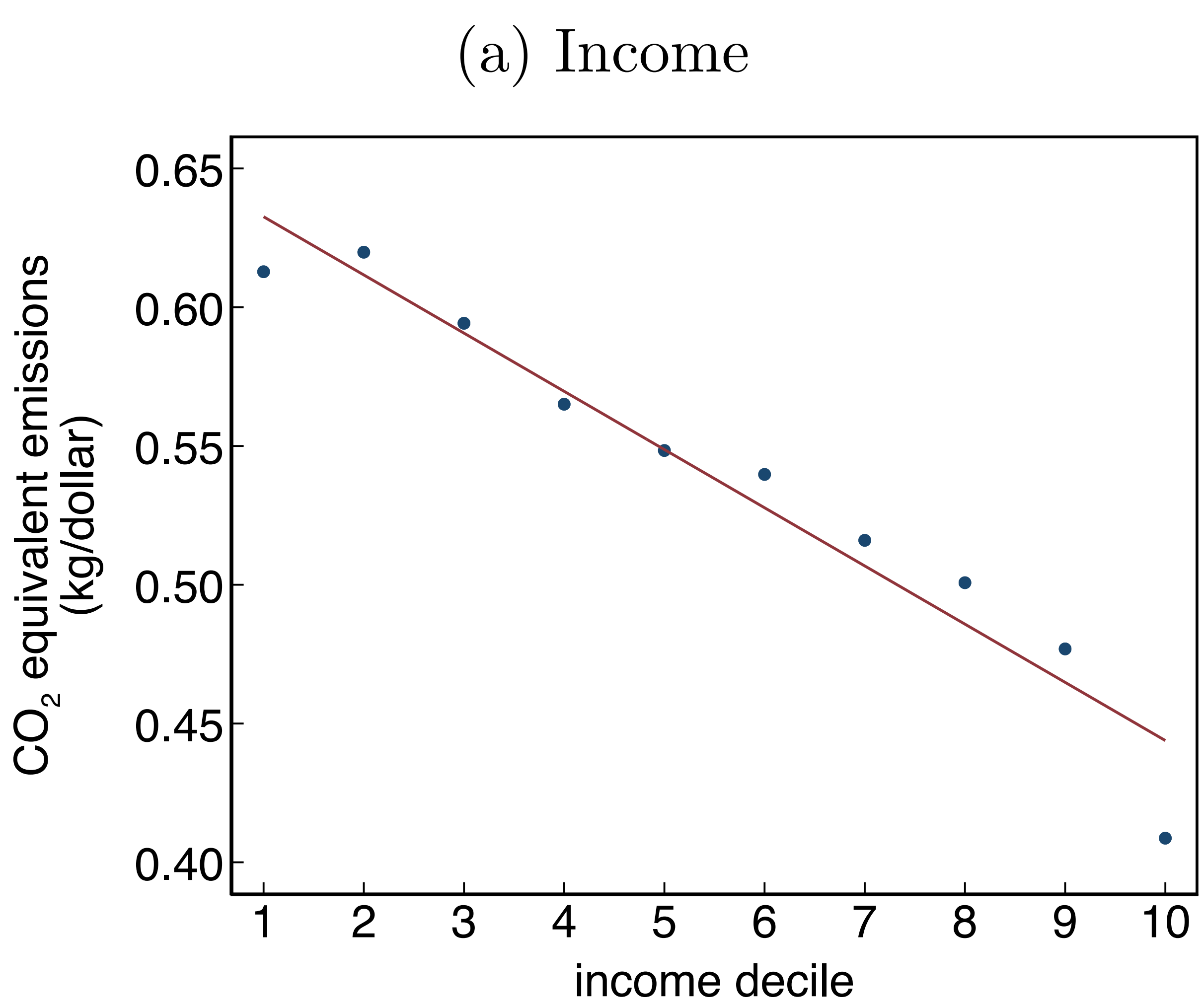
1. We construct CEX-NAICS CONCORDANCE MAP (671 expenditure category into 394 industry codes)

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

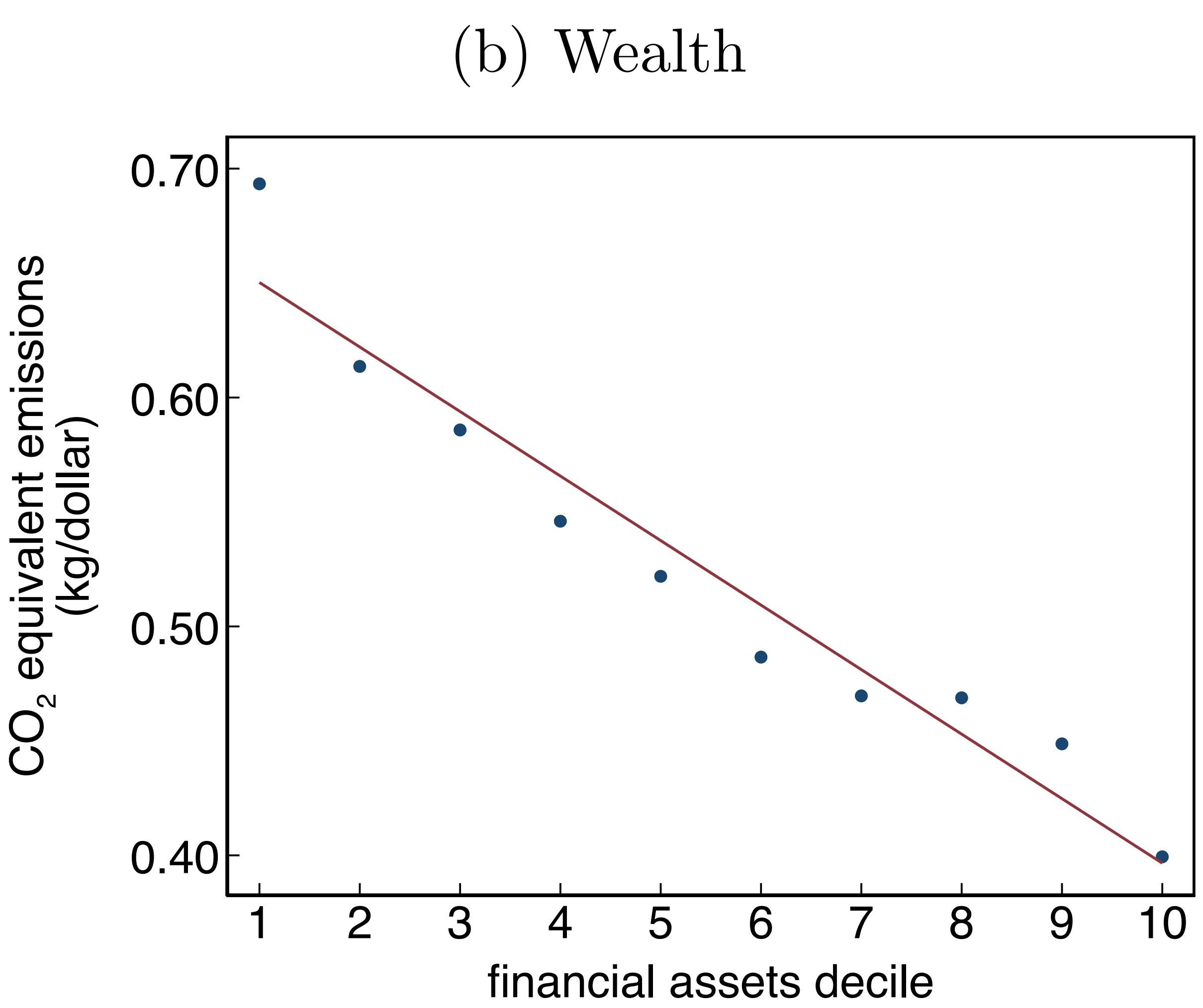
The Empirical Fact

Carbon Taxes can be Regressive

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



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



* 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

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

γ: preference over clean consumption

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

To capture Empirical Fact

- Households are endowed ε^i (supplied inelastically)

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

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

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

(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:

SCC = $\dfrac{\sigma_t}{\lambda_t}$

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

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

$$\tau^\star_t = \frac{\nu \sigma_t}{\sum_i \alpha_i u^i_{ct}}$$

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

NON-UNIFORM TRANSFERS:

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

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

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

- (Carbon cycle): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt}$ $\quad (\sigma_t)$
- (Budget Constraints): $c^i_{dt} + c^i_{ct} \leq \varepsilon^i$ $\quad (\lambda^i_t)$

Constrained-Optimal Climate Policy

Given Pareto weights $\{$

Optimal Allocation $\{c^i_{jt}$

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)

- (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)

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 $\{c^i_{dt}, c^i_{ct}, S_t\}^{\infty}_{t=0,\forall i}$ be the constrained-optimal allocation. Then, there exists a sequence of prices $\{p_t\}^{\infty}_{t=0}$ such that the allocation is a competitive equilibrium with taxes given by

$$\tau^i_t = \frac{\nu\sigma}{u^i_{ct}} \quad ; \quad t^i_t = \tau^i_t c^i_{dt} \qquad \forall t \forall i$$

1. τ^i_t 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): $S_{t+1} = (1-\delta)S_t + \nu \sum_i \mu_i c^i_{dt}$ $\quad (\sigma_t)$
- (Budget Constraints): $c^i_{dt} + c^i_{ct} \leq \varepsilon^i$ $\quad (\lambda^i_t)$
- $\dfrac{u^i_{dt}}{u^i_{ct}} = \dfrac{u^j_{dt}}{u^j_{ct}}$ $\quad (\eta^{ij}_t)$

Proposition 2. Constrained-Optimal Uniform Carbon Tax.
Suppose $\{c^i_{dt}, c^i_{ct}, S_t\}^{\infty}_{t=0,\forall i}$ solves the the constrained-optimal allocation with constraint (A). Then, there exists a sequence of prices $\{p_t\}^{\infty}_{t=0}$ such that the allocation is a competitive equilibrium with taxes given by

$$\tau_t = \frac{\upsilon \sigma_t}{\sum_i \frac{\mu_i c^i_t}{\sum_j \mu_j c^j_t} u^i_{ct}} \quad ; \quad t^i_t = \tau_t c^i_{dt} \qquad \forall t \forall i\,.$$

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

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

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

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

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, ...)

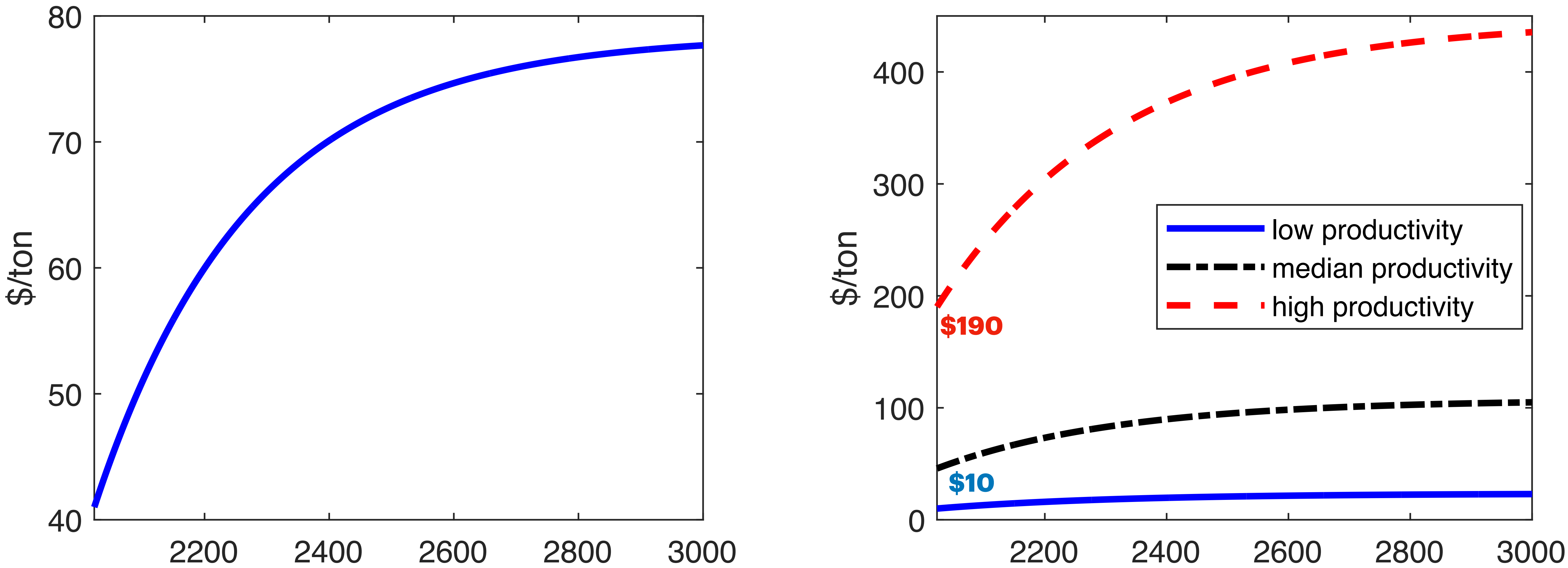
$$T(y) = y - \tilde{y}^{\nu_y} \frac{1-\tau_y}{1-\nu_y} y^{1-\nu_y}$$

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 (b) Heterogeneous

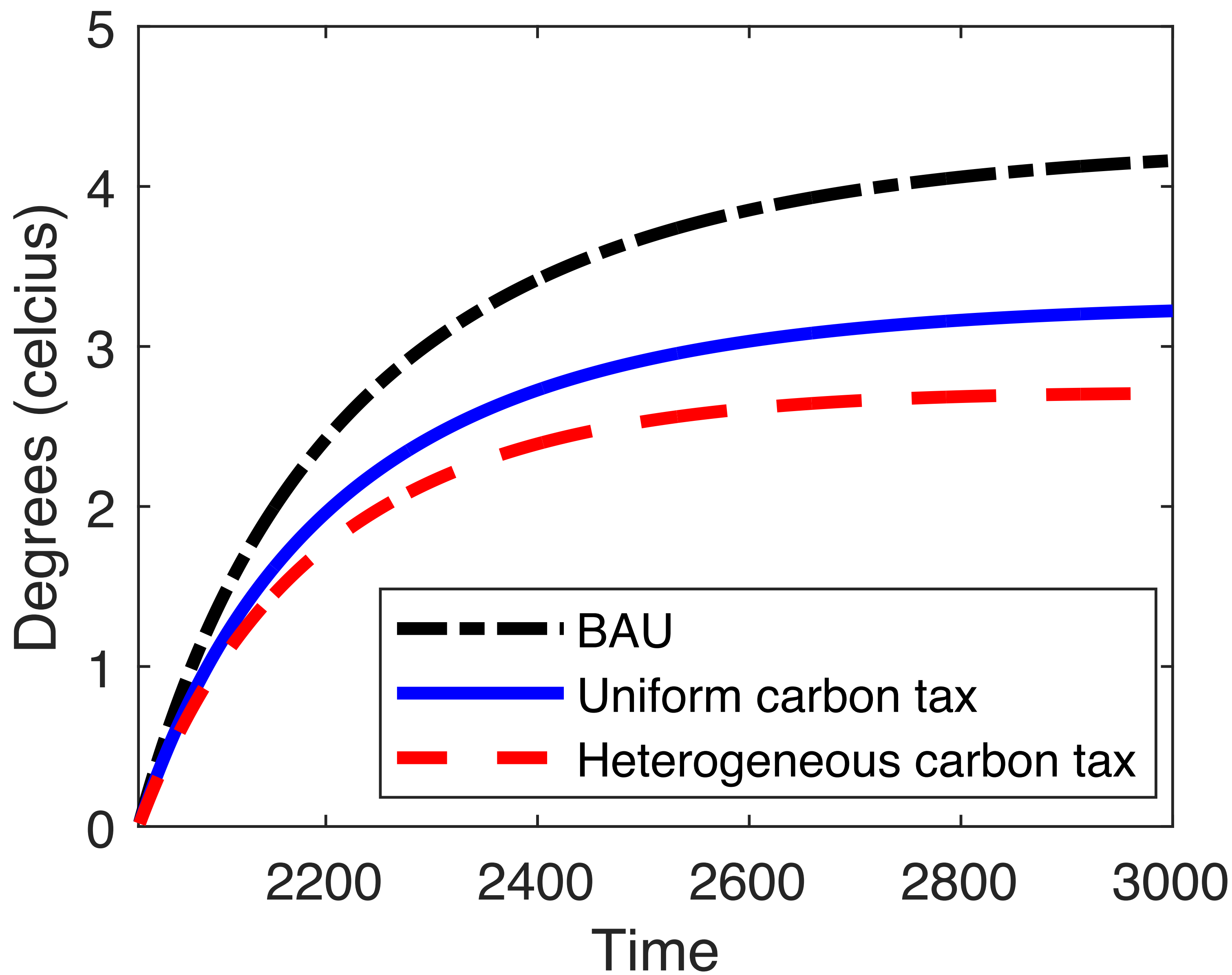


- Rather low modest tax ($41; $78 LR).
- Compatible with RA version Nordhaus/Golosov ($57/ton)
- Comes from climate damages estimation. Recent calculations much higher (Bilal&Kanzig, 2024)

Global Temperature

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

(b) Temperature increase

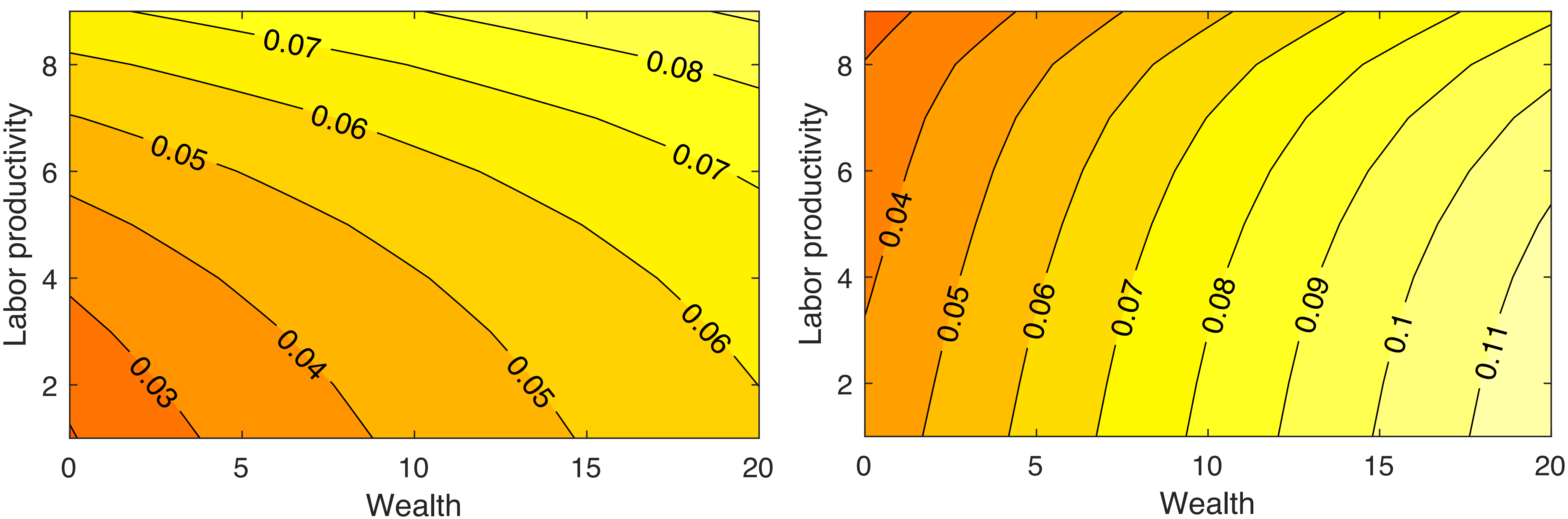


Welfare Gains: Win-Win Climate Policy

Initial Welfare Distribution

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

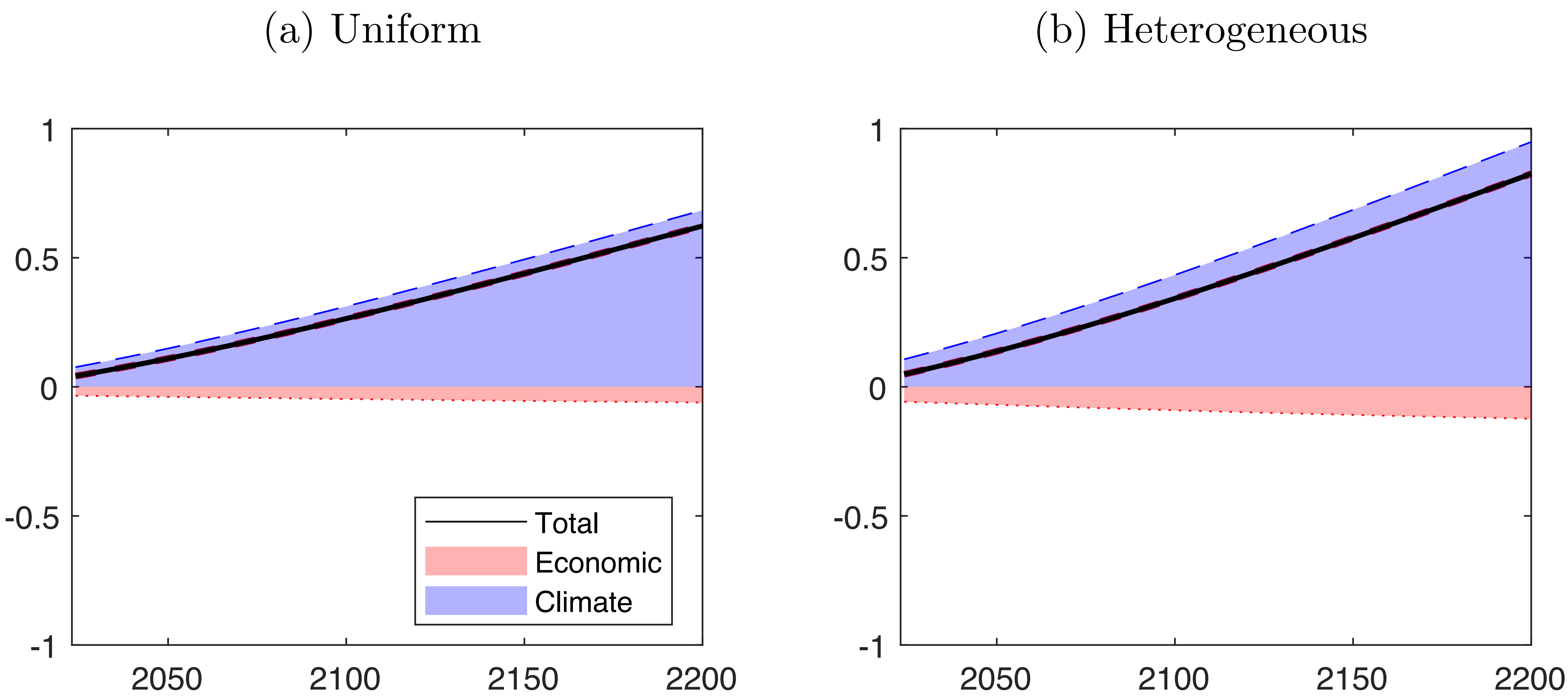
(a) Uniform (b) Heterogeneous



Units: Permanent consumption equivalents (percent)

Average Welfare Decomposition

Average welfare gains become large over time



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