Fehr–Schmidt Inequality Aversion in the RICE Integrated Assessment Model

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Slides:

Climate Policy Is Distributional, Both Across Regions and Generations

- Abatement is costly and climate damages fall unevenly across regions
- So climate policy changes the distribution of consumption across regions and over time
- Standard IAM welfare values those consumption differences with constant relative risk aversion (CRRA) utility
- CRRA is natural for intertemporal smoothing
- But in a regional IAM, the same curvature parameter also moves
  - interregional equity
  - intergenerational weighting
- This paper separates those two levers and asks what changes

How I Separate Interregional Equity Concerns From Intergenerational Weighting

- Bring Fehr–Schmidt preferences into RICE
- Model interregional inequality through Fehr–Schmidt comparison terms
- Interregional equity no longer has to move with intergenerational weighting
- Study both homogeneous parameters and calibrated regional heterogeneity
- Compare planner, Nash, and coalition outcomes

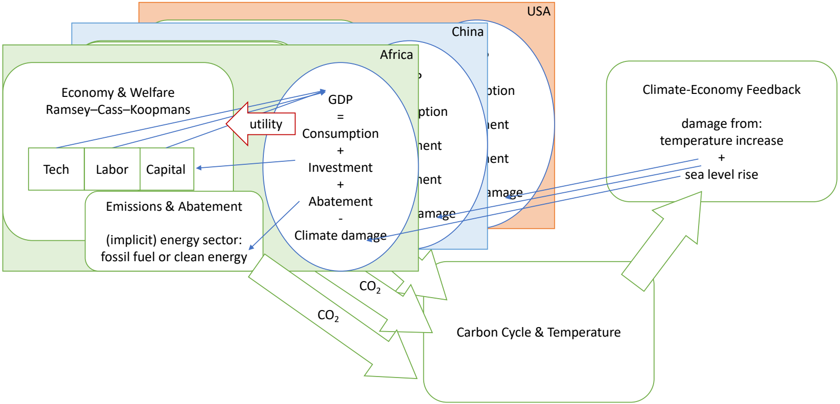
  In the planner, FS is normative. In strategic settings, it models concern for relative regional outcomes

Roadmap

- Setup: RICE, CRRA vs. Fehr–Schmidt, implementation, calibration
- Planner: Who should abate?
- Nash: How do equity concerns affect incentives to free ride?
- Coalitions: Does equity help stability?

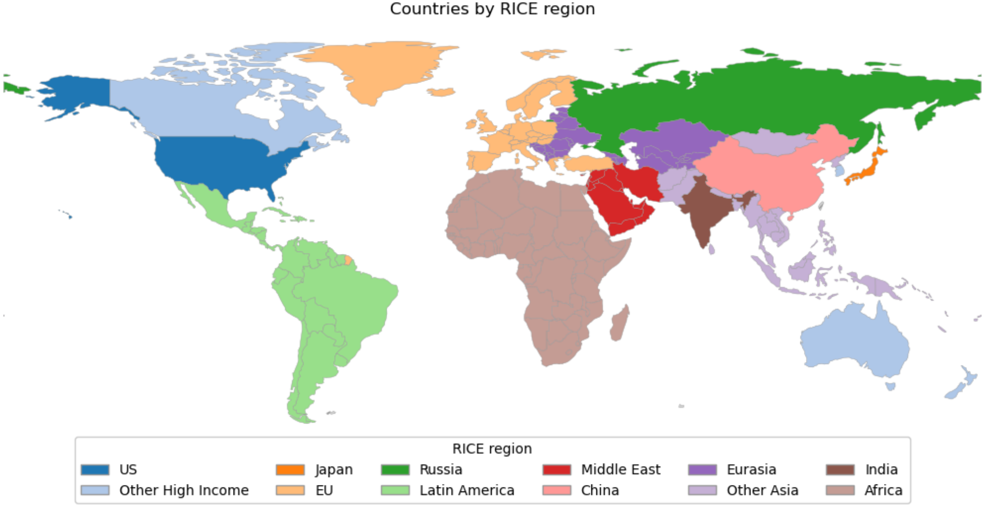
RICE Environment

Many Economies, One Planet



- Many economies, one planet → climate is a public good
- Heterogeneity in technology, capital stock, damages, and abatement costs
- Regional heterogeneity makes distribution unavoidable in RICE

RICE Aggregates the World Into 12 Regions



Regions in RICE Are Highly Unequal

Rank	Region	Consumption per capita in 2015	US = 100
1	USA	36,883	100
2	Other High Income	28,035	76
3	Japan	27,779	75
4	EU	24,731	67
5	Russia	12,973	35
6	Latin America	8,866	24
7	Middle East	8,572	23
8	China	6,714	18
9	Eurasia	5,490	15
10	Other Asia	2,971	8
11	India	2,827	8
12	Africa	1,938	5

- Interregional equity concerns matter because regions start from very different consumption levels

Future Generations Are Much Richer

Rank	Region	Consumption per capita in 2115, 2015 = 100
1	USA	321
2	Other High Income	350
3	Japan	350
4	EU	376
5	Russia	446
6	Latin America	607
7	Middle East	515
8	China	619
9	Eurasia	727
10	Other Asia	1,029
11	India	944
12	Africa	1,037

- Intergenerational weighting matters because future generations are much richer than current ones

Climate Policy Is the Distributional Channel in RICE

- In RICE, there are no direct transfers between regions or generations
- Distribution follows from climate policy choices

Across regions

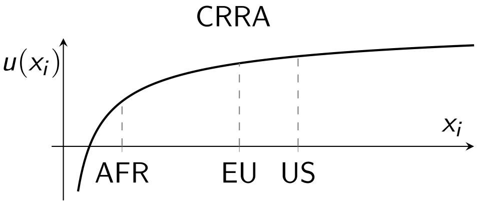
- Shifting abatement burden between poor and rich regions
- Total abatement translates differently into avoided damages

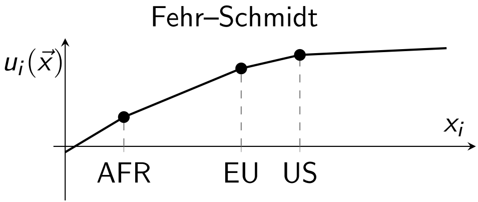
Across generations

- Saving and abatement shift consumption over time
- Abatement: Forgone consumption now, avoided damages later

Preferences and Calibration

CRRA and FS Value Outcomes Differently





$$u_i(x_i) = \frac{x_i^{1-\eta} - 1}{1 - \eta}$$

$$\begin{aligned} u_i(\vec{x}) = \quad & x_i && \text{(own consumption)} \\ & - \alpha_i \cdot \frac{1}{N-1} \cdot \sum_{j \neq i} \max\{x_j - x_i, 0\} && \text{(envy)} \\ & - \beta_i \cdot \frac{1}{N-1} \cdot \sum_{j \neq i} \max\{x_i - x_j, 0\} && \text{(guilt)} \end{aligned}$$

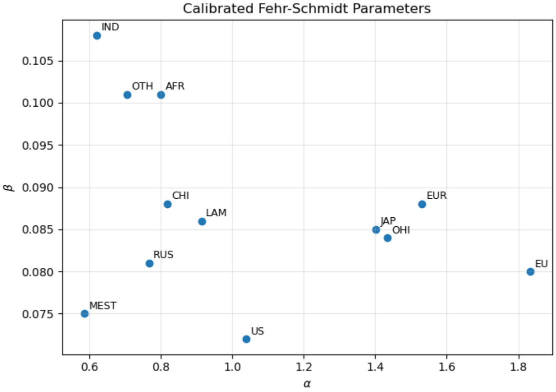
Under CRRA, all inequality concerns enter only through consumption curvature; under FS, interregional comparisons enter directly

How Fehr–Schmidt Enters RICE

- Comparison object: regional consumption per capita
- Comparison across regions: weighted by population
- Numerical solution: smooth approximation to the $\max\{\cdot, 0\}$ terms
- Quantitative exercises:
  - homogeneous (α, β) sweeps for comparative statics
  - calibrated heterogeneous regional parameters

Calibrated Regional Fehr–Schmidt Parameters

- Domestic redistribution identifies overall inequality aversion
- Foreign aid helps separate envy and guilt
- Representative countries map calibrated parameters to RICE regions



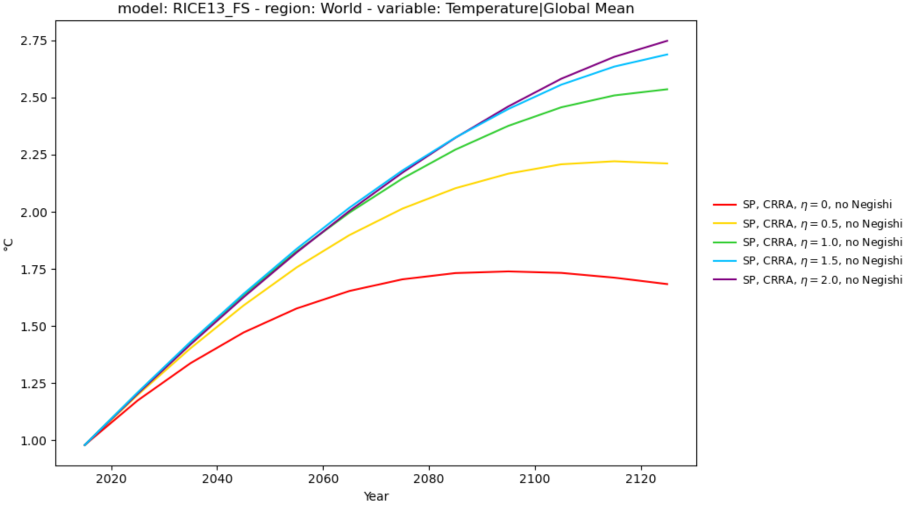
Solution Concept I: Social Planner (Cooperation)

Cooperation Benchmark: The Planner Chooses Regional Abatement

- Full cooperation: A social planner chooses all regional abatement paths
- Savings paths are held fixed at the benchmark CRRA solution
- Comparison: CRRA versus Fehr–Schmidt utility

$$W = \sum_{t=1}^{T} \sum_{r=1}^{12} \frac{1}{(1+\rho)^t} N_{rt} L_{rt} u(c_{rt})$$

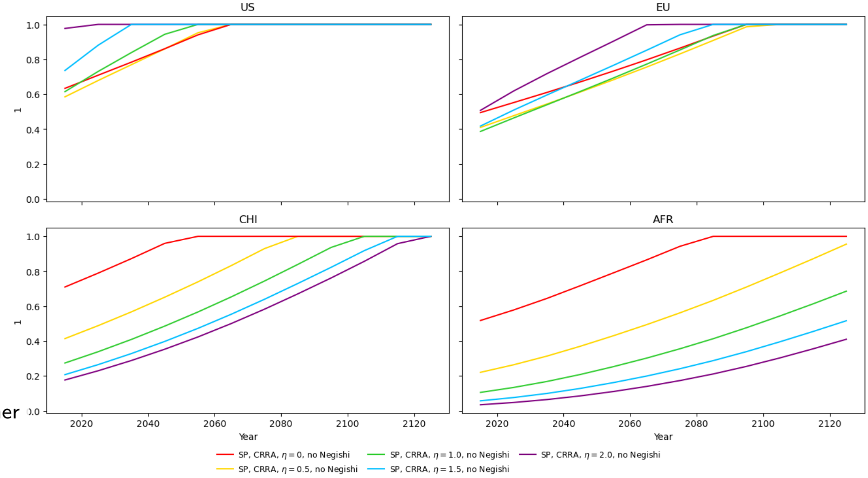
A Surprising CRRA Result: Higher η Raises Temperature



Solution: Planner
Utility: CRRA
Negishi: off

Higher η Affects Both Interregional Equity and Intergenerational Weighting

- Poor regions: The two forces both lead to less current abatement
- Rich regions: The two forces point in opposite directions
- In the aggregate, intergenerational weighting dominates



Solution: Planner
Utility: CRRA
Negishi: off

CRRA Moves Two Levers at Once

- Increasing η moves interregional equity and intergenerational weighting at once
- In CRRA, these two margins cannot be varied separately: The same curvature parameter governs both

$$r^{\mathrm{CRRA}} \approx \rho + \eta g$$

Across Regions

- richer regions have lower marginal welfare contribution
- abatement burden shifts toward richer regions

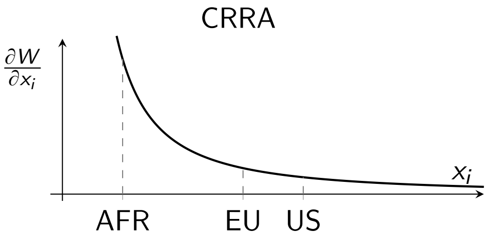
Across Generations

- richer future generations have lower marginal welfare contribution
- together with pure time preference, this reduces current abatement

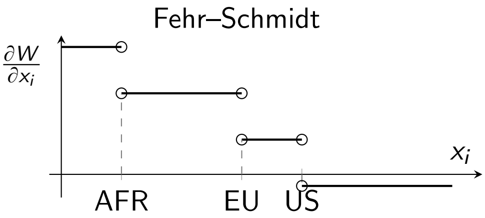
FS Determines Interregional Equity Concerns

- CRRA: smooth weighting by own consumption
- Fehr–Schmidt: **within-period** rank and comparison effects
- For now: no growth-based intergenerational weighting

Welfare contribution of individual consumption:



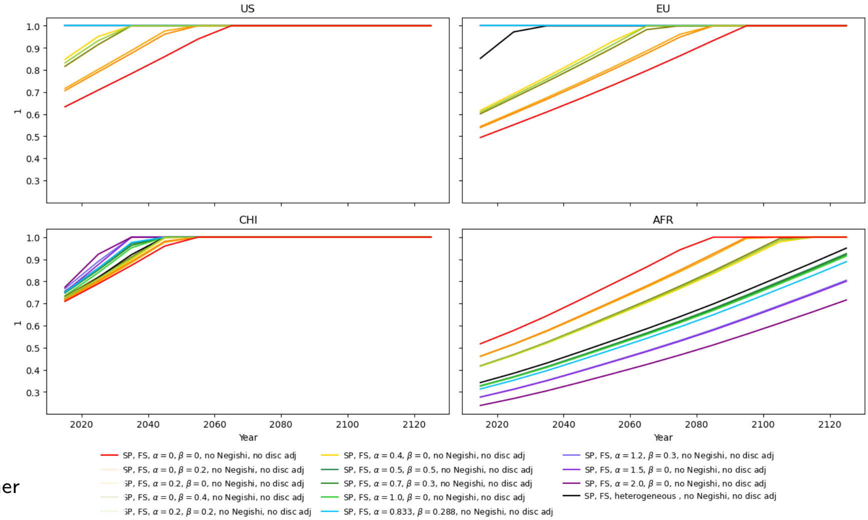
Smooth in own income



Rank and comparison effects

Stronger FS Inequality Aversion Shifts Abatement Toward Richer Regions

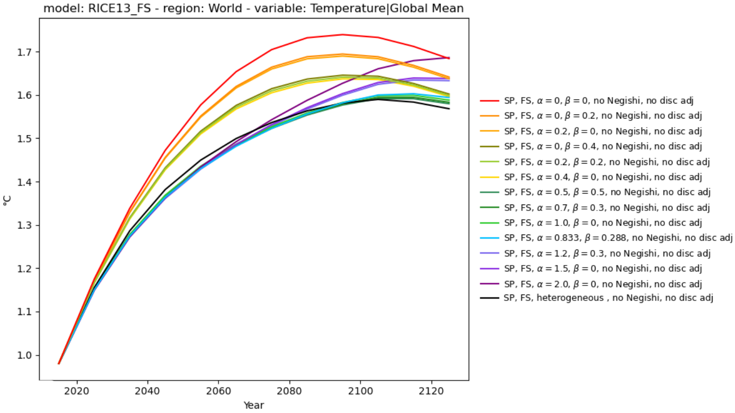
Higher α or β: A shift of burden from poorer to richer regions



Solution: Planner
Utility: FS
Negishi: off · Disc. adj.: off

Raw FS Changes Aggregate Mitigation, but Is Not Yet Comparable to CRRA

- Poorer regions are hit harder → higher FS inequality aversion raises abatement benefits
- Later reversal once richer regions approach the full-abatement cap



Solution: Planner
Utility: FS
Negishi: off · Disc. adj.: off

Raw FS is missing growth-based intergenerational weighting

Discounting Adjustment: Match CRRA's Intertemporal Weighting

- Raw FS isolates interregional equity, but has no growth-based intergenerational weighting
- Keep FS for **within-period** comparisons
- Choose ρ_{rt}^{FS} so FS matches the CRRA benchmark's one-period social discount factor

$$\frac{1}{1 + r_{r,t+1}^{CRRA}} = \frac{1}{1+\rho} \left(\frac{c_{r,t+1}^{CRRA}}{c_{rt}^{CRRA}} \right)^{-\eta} \qquad \text{(Simple Ramsey rule)}$$

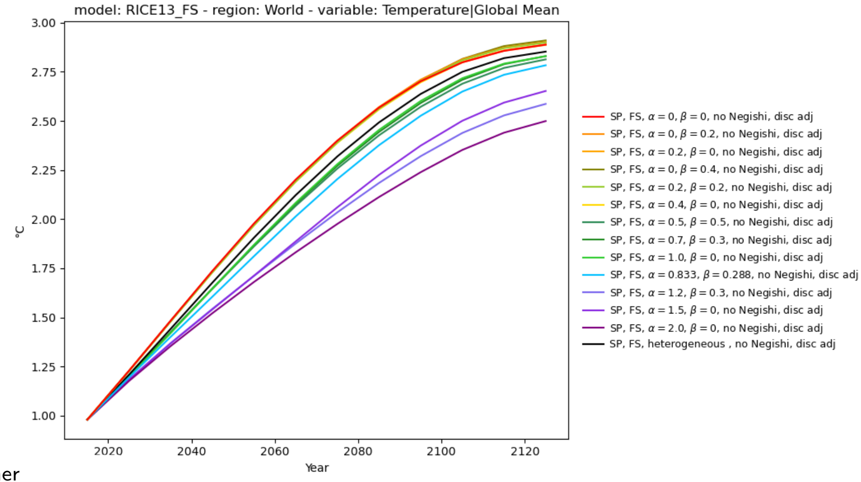
$$\frac{1}{1 + r_{r,t+1}^{FS}} = \frac{1}{1+\rho_{rt}^{FS}} \cdot \frac{MU_{r,t+1}^{FS}}{MU_{rt}^{FS}} \qquad \text{(corresponding FS object)}$$

Choose ρ_{rt}^{FS} so that $r_{r,t+1}^{FS} \overset{!}{=} r_{r,t+1}^{CRRA}$

- Equivalent view: Match the CRRA benchmark's welfare weights on future consumption

The Adjustment Brings FS Back Into the CRRA Aggregate Range

FS moves back into the CRRA range in the aggregate

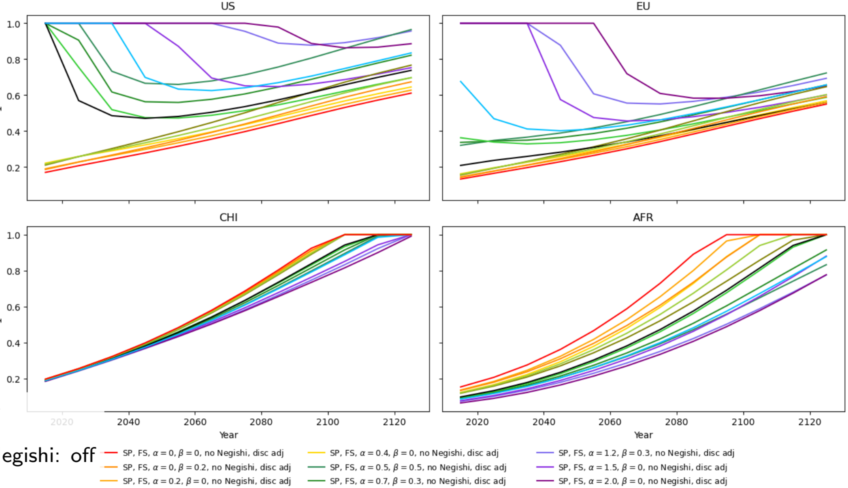


Solution: Planner
Utility: FS
Disc. adj.: on · Negishi: off

The Adjustment Preserves the Rich-Poor Ordering, but Changes Paths

Restored intergenerational weighting shifts abatement down overall

Some rich-region paths bend downward later because fast-growing poorer regions receive less future weight.



Solution: Planner
Utility: FS
Disc. adj.: on · Negishi: off

Planner Answer: FS Lets Me Vary Equity and Discounting Separately

- Under CRRA, interregional equity and intergenerational weighting are intertwined
- FS isolates the interregional equity margin
- In the planner, stronger inequality aversion shifts burden toward richer regions
- The discounting adjustment adds intergenerational weighting back separately

Under Cooperation, Homogeneous FS Runs Through $\alpha + \beta$

- In the homogeneous planner case, each pairwise consumption comparison enters welfare from both sides:
  - the poorer region feels envy α
  - the richer region feels guilt β
- Because the planner takes into account both, only total inequality aversion $(\alpha + \beta)$ matters
- So planner comparative statics run through $\alpha + \beta$

$\implies$ $\alpha + \beta$ are only sufficient under cooperation! Without cooperation, the split between envy and guilt matters strategically

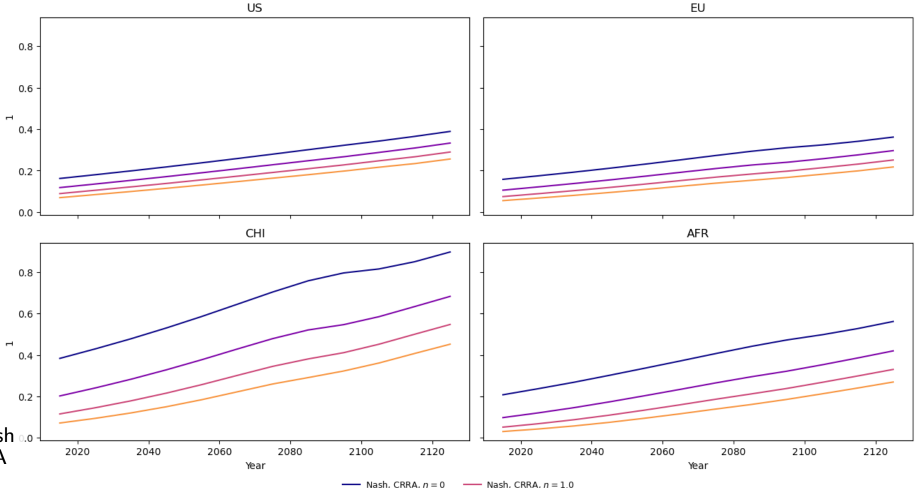
Solution Concept II: Nash (No Cooperation)

From Planner Weights to Strategic Incentives

- Planner: The modeler aggregates regional welfare into a global objective
- Nash: Each region takes others' abatement as given and maximizes its own objective
- Under CRRA, that objective depends only on own consumption over time
- Under FS, relative regional outcomes also enter the objective
- Question: Once regions act strategically, do envy and guilt affect their incentives to free ride?

Under CRRA, Nash Only Has the Intertemporal Channel

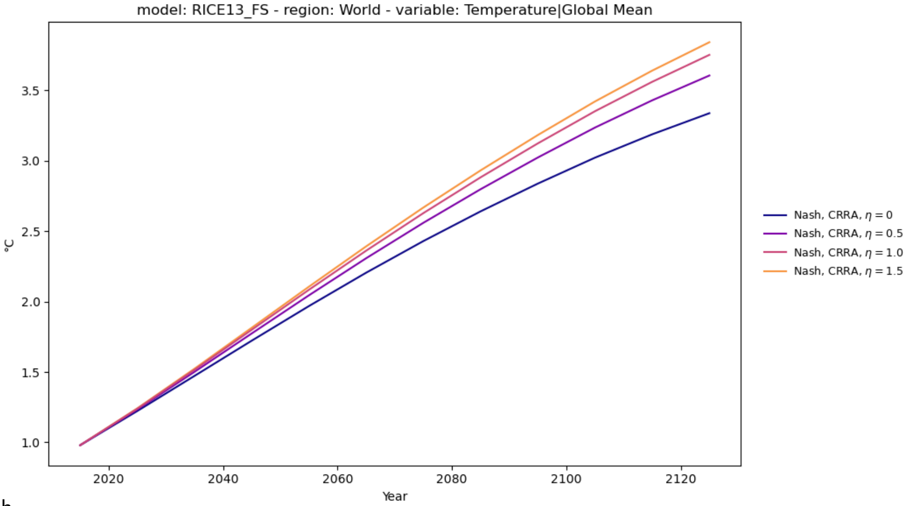
- Each region responds only to its own intertemporal trade-off
- There is no concern for interregional equity
- As η rises, richer future utility gets less weight, so abatement falls in all regions



Solution: Nash
Utility: CRRA

Nash Under CRRA: Temperature Increase

Therefore, higher η makes the global temperature go up



Solution: Nash
Utility: CRRA

Under Nash, Envy and Guilt Move Abatement in Opposite Directions

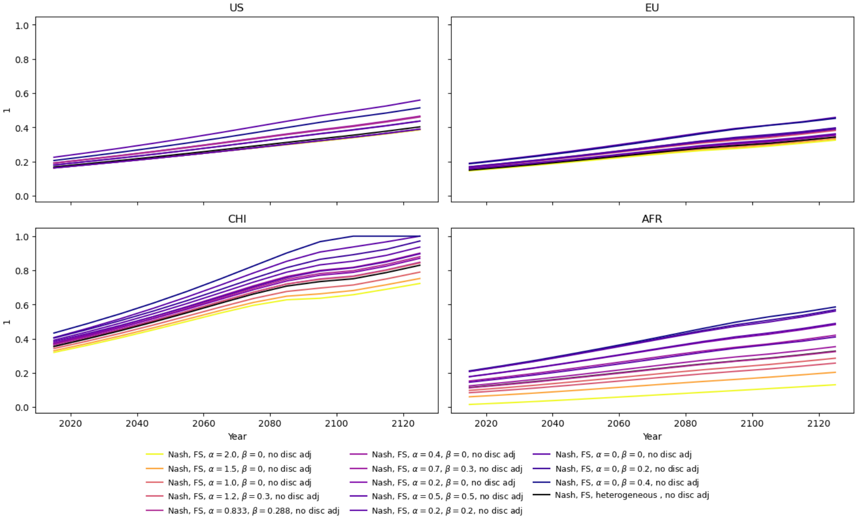
- Regions still maximize their own utility, but utility now contains social comparison
- FS now works through strategic incentives (instead of welfare aggregation)
- Envy: Consuming more closes the gap and lower abatement harms the richer regions

  $\alpha \uparrow$: less abatement
- Guilt: Consuming less closes the gap and higher abatement helps the poorer regions

  $\beta \uparrow$: more abatement

The Relative Strength of α and β Depends on the Income Rank

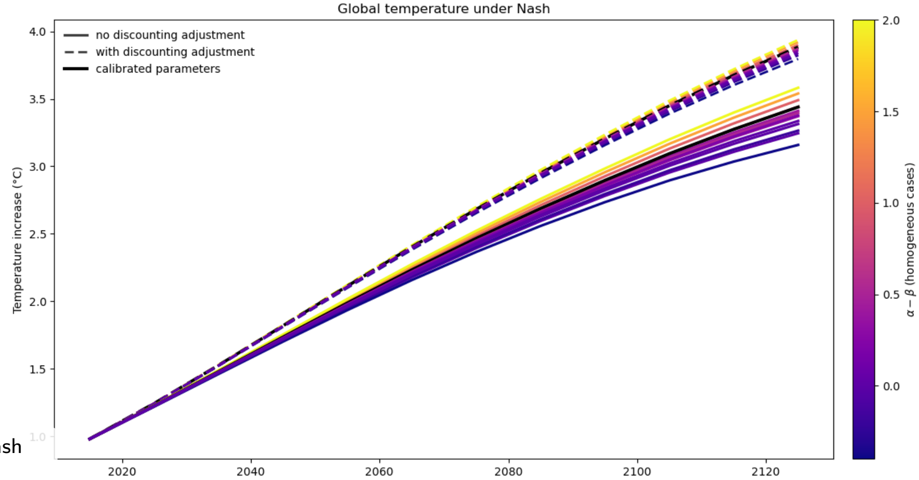
- Richer regions are driven more by guilt β, poorer regions more by envy α
- For the richest region, US, only β matters. For the poorest region, Africa, only α matters



Solution: Nash
Utility: FS
Disc. adj.: off

FS Adds an Aggregate Margin That CRRA Does Not Have

- Under Nash, the envy-guilt balance changes equilibrium temperature
- The discounting adjustment raises temperature overall, but does not undo this FS ordering



Solution: Nash
Utility: FS
Disc. adj.: on/off

Nash Takeaway: The α/β Split Matters, but Free-Riding Remains

- Under CRRA, Nash only has the intertemporal channel
- Under FS, envy lowers abatement and guilt raises it, so the α/β split matters strategically
- In the calibrated benchmark, envy dominates slightly, so pure Nash remains too warm

	Nash
FS, $\alpha = \beta = 0$, no disc	$T = 3.02$
FS, no disc	$T = 3.09$
CRRA	$T = 3.42$
FS, $\alpha = \beta = 0$, disc	$T = 3.42$
FS, disc	$T = 3.45$

Nash outcomes in 2105 for the calibrated FS parameters. $\alpha = \beta = 0$ removes interregional equity concerns from FS. T = Temperature (°C).

- Next question: Individually, not sufficient guilt, but can it stabilize partial cooperation?

Solution Concept III: Climate Coalitions (Partial Cooperation)

Coalitions Mix Cooperation Inside and Nash Outside

- Regions can join a coalition or stay outside
- Inside the coalition, members choose abatement jointly
- Outside the coalition, regions choose abatement individually
- Coalition and outsiders then interact strategically

Stable Coalitions Are Usually Small and Weak

- Internally stable: no member wants to leave unilaterally
- Externally stable: no outsider wants to join unilaterally
- Fully stable: both

- Standard benchmark: Barrett's paradox

"When cooperation is possible, it does not matter, and when it does matter, cooperation is not possible." (Jeppesen et al., 1998, p. 70)

Can FS Relax Barrett's Paradox?

- In public-good settings, guilt can help sustain cooperation
- But the calibrated world here is not especially guilt-rich, so we should not expect large stability effects
- Under the CRRA benchmark, no coalition with more than two regions is internally stable
- Most FS specifications remain similarly pessimistic
- Exception: with FS, discounting adjustment, and Negishi weights computed after the adjustment, larger stable coalitions appear
  - 7 internally stable coalitions with more than two members
  - 1 fully stable coalition with seven members

$$(\mathrm{US}, \mathrm{JAP}, \mathrm{RUS}, \mathrm{CHI}, \mathrm{MEST}, \mathrm{LAM}, \mathrm{OTH})$$

Coalition Takeaway: Some Exceptions From Barrett's Paradox

- Under CRRA, stable coalitions stay close to Nash
- Under FS, coalitions are stable in a few cases
- In the benchmark FS specification, the best stable coalition improves on Nash, but remains far from the planner

	CRRA benchmark $\eta = 1.5$, Negishi	**FS benchmark** calibrated, disc. adj., Negishi after
Nash	$T = 3.42$	$T = 3.45$
Best fully stable coalition	$T = 3.35$	$T = 3.20$
Planner	$T = 2.76$	$T = 2.79$

Coalition outcomes in 2105. T = temperature increase (°C).

Conclusion

What Changes Once Equity and Discounting Are Separated?

- Novelty: Fehr–Schmidt preferences let interregional equity vary separately from growth-based intergenerational weighting in RICE
- In a regional IAM, the implications of inequality aversion depend on the cooperation regime
- Planner: Stronger interregional equity shifts burden from poorer to richer regions and can raise aggregate abatement up to a point
- Nash: Envy lowers abatement and guilt raises it; with the calibrated parameters, envy dominates slightly
- Coalitions: Stable cooperation remains rare, but FS can relax Barrett's paradox in some cases

Backup Slides

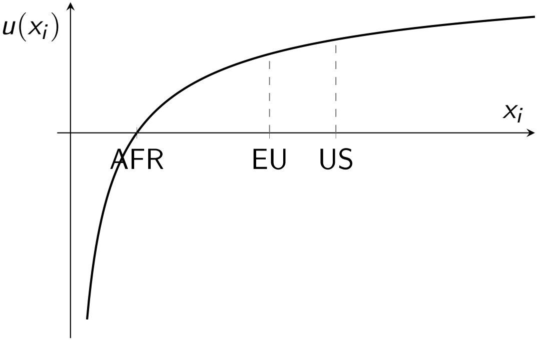
Fehr–Schmidt Preferences

$$
\begin{aligned}
u_i(\vec{x}) = \quad & x_i && \text{(own consumption)} \\
& - \alpha_i \cdot \frac{1}{N-1} \cdot \sum_{j \neq i} \max\{x_j - x_i, 0\} && \text{(envy)} \\
& - \beta_i \cdot \frac{1}{N-1} \cdot \sum_{j \neq i} \max\{x_i - x_j, 0\} && \text{(guilt)}
\end{aligned}
$$

- Envy: others doing better hurts
- Guilt: doing better than others hurts
- Standard restriction: $\alpha_i \geqslant \beta_i \geqslant 0$
- Strategic implication: willingness to pay to reduce payoff differences relative to oneself

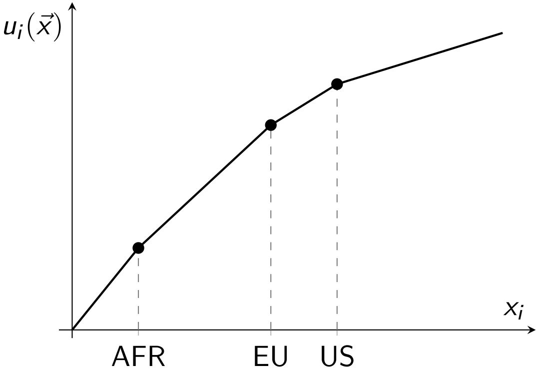
How CRRA and FS Differ

CRRA



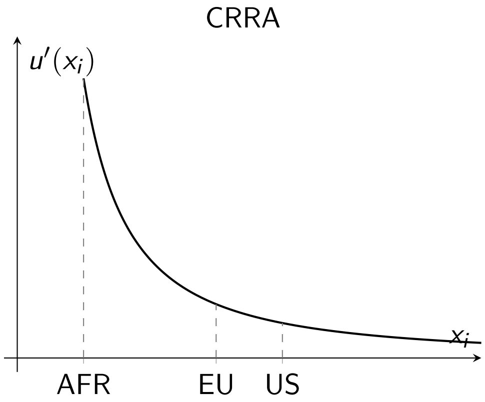
$$u(x) = \frac{x^{1-\eta} - 1}{1 - \eta}$$

Fehr–Schmidt

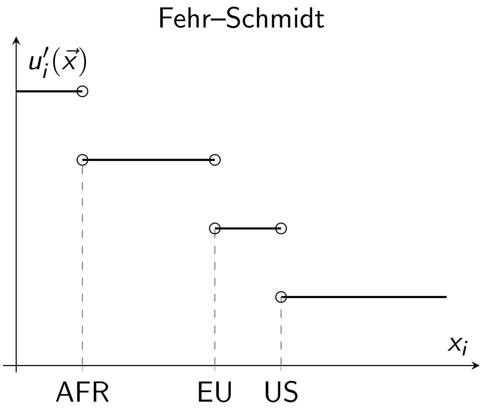


depends on others' incomes,
kinks when the rank changes

Marginal Utilities and Planner Redistribution



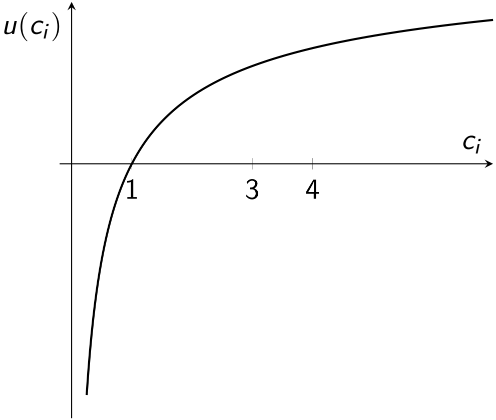
CRRA: marginal welfare contribution depends on own consumption

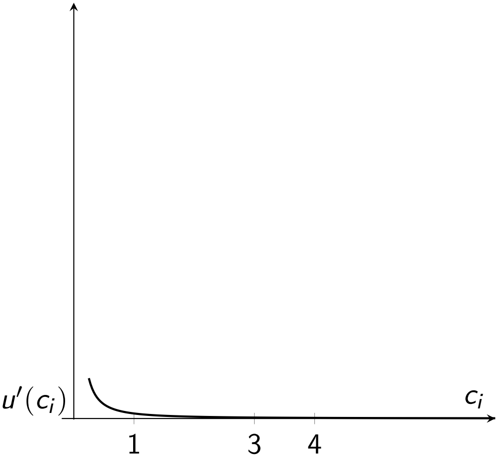


FS: marginal welfare contribution depends on relative position and on comparison effects on others

CRRA Utility (Backup)

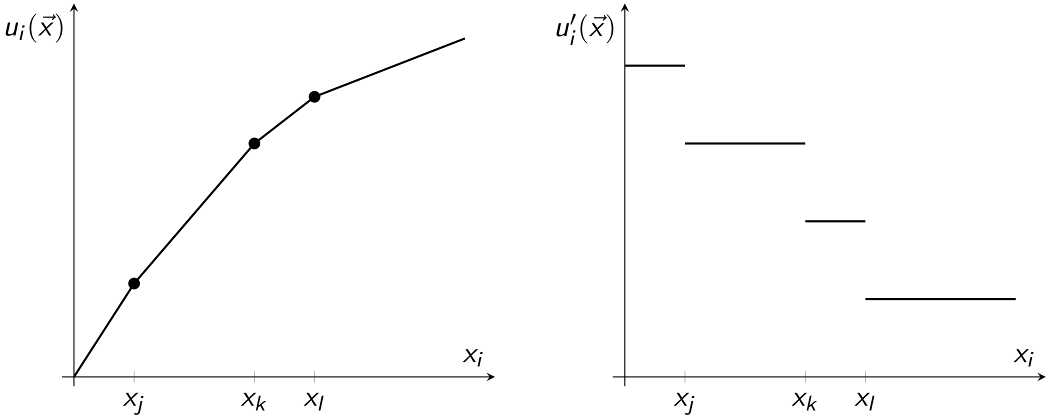
$$u(c) = \frac{c^{1-\eta} - 1}{1 - \eta}, \qquad u'(c) = c^{-\eta}.$$





Fehr–Schmidt Utility (Backup)

- Piecewise linear in own consumption within a given rank
- Kinks at others' consumption levels
- No CRRA-style growth-based decline in marginal utility within a rank



Negishi Calculation Example

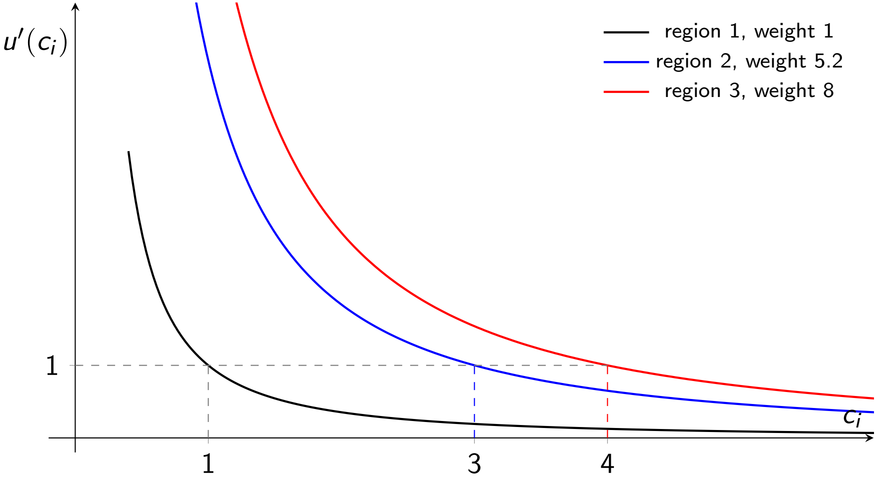
$$\eta = 1.5, \qquad u'(c) = c^{-1.5}.$$

$$u'(1) = 1 \qquad u_1(c) := 1 \cdot u(c)$$

$$u'(3) = 3^{-1.5} \approx 0.19 \Rightarrow \frac{u'(1)}{u'(3)} \approx 5.2 \qquad u_2(c) := 5.2 \cdot u(c)$$

$$u'(4) = 4^{-1.5} = 0.125 \Rightarrow \frac{u'(1)}{u'(4)} = 8 \qquad u_3(c) := 8 \cdot u(c)$$

How Negishi Weights Work (Backup)



→ weighted marginal utilities line up at the benchmark allocation.

Discounting Adjustment: Full Derivation

Match one-period welfare weights:

$$\frac{1}{1+\rho_{rt}^{FS}} \cdot \frac{MU_{r,t+1}^{FS}}{MU_{rt}^{FS}} \overset{!}{=} \frac{1}{1+\rho} \cdot \left(\frac{c_{r,t+1}^{CRRA}}{c_{rt}^{CRRA}}\right)^{-\eta}.$$

Solving for the adjusted FS discount factor gives

$$1+\rho_{rt}^{FS} = (1+\rho) \cdot \frac{MU_{r,t+1}^{FS}}{MU_{rt}^{FS}} \cdot \left(\frac{c_{r,t+1}^{CRRA}}{c_{rt}^{CRRA}}\right)^{\eta}.$$

RICE Equations: Economy

$$
\begin{aligned}
Q_{r,t} &= A_{r,t} K_{r,t}^{\gamma_r} \left(\frac{L_{r,t}}{1000} \right)^{1-\gamma_r} \\
AB_{r,t} &= \theta_{1,r,t} \mu_{r,t}^{\theta_{2,r}} Q_{r,t} \\
Y_{r,t} &= Q_{r,t} - AB_{r,t} - D_{r,t} \\
I_{r,t} &= s_{r,t} Y_{r,t} \\
C_{r,t} &= Y_{r,t} - I_{r,t} = (1 - s_{r,t}) Y_{r,t} \\
c_{r,t} &= 1000 \cdot \frac{C_{r,t}}{L_{r,t}} \\
K_{r,t+1} &= (1 - \delta_r^K)^{\Delta} K_{r,t} + \Delta I_{r,t}
\end{aligned}
$$

RICE Equations: Climate

$$
\begin{aligned}
E_t &= \sum_r \Big[\sigma_{r,t}(1-\mu_{r,t})Q_{r,t} + E_{r,t}^{land} \Big] \\
M_{t+1}^{at} &= b_{11}M_t^{at} + b_{21}M_t^{up} + \Delta E_t \\
M_{t+1}^{up} &= b_{12}M_t^{at} + b_{22}M_t^{up} + b_{32}M_t^{lo} \\
M_{t+1}^{lo} &= b_{23}M_t^{up} + b_{33}M_t^{lo} \\
F_t &= \eta \log_2 \left(\frac{M_t^{at}}{M_{1900}} \right) + f_t^{ex} \\
T_{t+1}^{at} &= T_t^{at} + c_1 \Big(F_t - c_2 T_t^{at} - c_3 (T_t^{at} - T_t^{lo}) \Big) \\
T_{t+1}^{lo} &= T_t^{lo} + c_4 (T_t^{at} - T_t^{lo})
\end{aligned}
$$

In the RICE equations, η is "Estimated forcings of equilibrium CO2 doubling" (while the CRRA curvature is α)

RICE Equations: Sea-Level Rise and Damages

$$\mathrm{SLR}_t = \mathrm{SLR}_t^{TE} + \mathrm{SLR}_t^{GSIC} + \mathrm{SLR}_t^{GIS} + \mathrm{SLR}_t^{AIS}$$

$$D_{r,t} = Q_{r,t} \frac{\Phi_{r,t}}{1 + \Phi_{r,t}^{\omega^D}}$$

$$\Phi_{r,t} = \Phi_{r,t}^{T} + \Phi_{r,t}^{SLR}$$

$$\Phi_{r,t}^{T} = 0.01 \left[d_{1,r} T_t^{at} + d_{2,r} (T_t^{at})^{d_{3,r}} + \chi_r \left(\frac{T_t^{at}}{\bar{T}_r} \right)^{\xi_r} \right]$$

$$\Phi_{r,t}^{SLR} = \psi_r \left(d_{1,r}^{SLR} \mathrm{SLR}_{t-1} + d_{2,r}^{SLR} \mathrm{SLR}_{t-1}^2 \right) \left(\frac{Q_{r,t-1}}{Q_{r,0}} \right)^{1/\varepsilon_{SLR}}$$

Planner Outcomes in 2105

	No Negishi	**Negishi before**	**Negishi after**
FS, no disc	$T = 1.59$	$T = 1.64$	–
CRRA	$T = 2.56$	$T = 2.76$	–
FS, disc	$T = 2.75$	$T = 2.78$	$T = 2.79$

T = temperature increase in 2105 (°C).

Nash Outcomes in 2105

	Nash
FS, $\alpha = \beta = 0$**, no disc**	$T = 3.02$
FS, no disc	$T = 3.09$
CRRA	$T = 3.42$
FS, $\alpha = \beta = 0$**, disc**	$T = 3.42$
FS, disc	$T = 3.45$

T = temperature increase in 2105 (°C).

Coalition Stability Details

- 12 regions imply $2^{12} - 1 = 4{,}095$ non-empty coalitions
- CRRA benchmark: no coalition with more than two regions is internally stable
- FS without Negishi and without discounting adjustment: $(\mathrm{RUS}, \mathrm{EUR}, \mathrm{AFR})$ is fully stable
- FS with discounting adjustment and Negishi after: 7 larger internally stable coalitions; the best fully stable coalition has seven members

Program Settings I: Horizon, Tags, Paths

```yaml
# RICE-2013 --- Main Config
# Example usage:
# python -m RICE13_V2.cli --config RICE13_V2/config.yaml --log-level "DEBUG"

# --- Horizon (data available up to 59 decades = 590 years) ---
T: 59   # integer, must be <= 59. No tstep (decadal is implicit).

# --- Tags (for use in the pyam scenario analysis) ---
tags:
fs_params:
fs_disc_param: onepass
crra_params:
note:

# --- Paths ---
project_root: .
data_path: ./RICE13_V2/Data
results_dir: ./RICE13_V2/nodisc_A15
diagnostics_dir: ./RICE13_V2/Diagnostics
output_dir: ./RICE13_V2/nodisc_A15
```

Program Settings II: Negishi and FS Options

```
# --- Negishi (used by planners and coalitions if enabled) ---
negishi_use: false
negishi_source: bau   # 'bau' | 'fs_after_disc' | 'file'
negishi_file_crra_path: ./RICE13_V2/exogenous_negishi_crra_test.csv
negishi_file_fs_path: ./RICE13_V2/exogenous_negishi_fs_test.csv

# --- FS-specific option (for Fehr--Schmidt aggregation only) ---
population_weight_envy_guilt: true
fs_disc_enabled: false
fs_disc_mode: file    # off | file | one_pass | two_pass
fs_disc_file: ./RICE13_V2/exo_disc_path.csv
```

Program Settings III: BAU and Cooperative Planners

```
# =========================
# 1) BAU
# =========================
run_bau: true

# =========================
# 2) Cooperative planners
# =========================

# 2a) CRRA planner
run_planner_crra: true
planner_crra_S_mode: bau   # 'optimal' | 'bau' | 'file'
planner_crra_S_file: ./RICE13_V2/exogenous_S_test.csv

# 2b) FS planner
run_planner_fs: true
planner_fs_S_mode: bau     # 'optimal' | 'bau' | 'crra' | 'file'
planner_fs_S_file: ./RICE13_V2/exogenous_S_test.csv
```

Program Settings IV: Nash and Coalitions

```
# ========================
# 3) Noncooperative Nash
# ========================

# 3a) CRRA Nash
run_nash_crra: false
nash_crra_seed: data
nash_crra_S_mode: bau   # 'optimal' | 'bau' | 'file' | 'planner_crra' | 'planner_fs'
nash_crra_S_file: ./RICE13_V2/exogenous_S_test.csv

# 3b) FS Nash
run_nash_fs: false
nash_fs_seed: data
nash_fs_S_mode: bau     # 'optimal' | 'bau' | 'file' | 'planner_crra' | 'planner_fs'
nash_fs_S_file: ./RICE13_V2/exogenous_S_test.csv

# ========================
# 4) Coalitions
# ========================
run_coalition_crra: false
coalition_crra_S_mode: bau
coalition_crra_S_file: ./RICE13_V2/exogenous_S_test.csv

run_coalition_fs: false
coalition_fs_S_mode: bau
coalition_fs_S_file: ./RICE13_V2/exogenous_S_test.csv

mega_run: false
coalition: 'US, JAP, RUS, CHI, MEST, LAM, OTH'
```

Program Settings V: Diagnostics, Cache, Solver, Convergence

```
# --- Stability / diagnostics ---
stability_eps: 1.0e-7
diagnostics_level: false

# --- Parallelism ---
parallel: 5

# --- Coalition cache (SQLite) ---
cache_dir: ./RICE13_V2/Cache
cache_namespace: nodisc_A15
cache_allow_mismatch: false

# --- IPOPT / solver ---
ipopt_executable: null
tol_ipopt: 1.0e-7
max_iter_ipopt: 10000

# --- Iteration / convergence (Nash/coalition fixed-point loop) ---
max_iter_nash: 500
tol_mu_nash: 1e-5
nash_relax: 0.75
ignore_last_k_periods: 10
```

Calibration Logic

- Inequality aversion can be seen in the willingness to redistribute
- Domestically, there is redistribution through institutions, lenience in negotiating, taxes; diluting economic incentives (the Big Tradeoff Okun 1975)
- Internationally, there is foreign aid giving
- One anchor country is used to recover the common auxiliary parameters in the calibration.

Big Tradeoff: Preference Side

Under homogeneous FS preferences, the sum of individual utilities simplifies to a Sen-like object (Schmidt and Wichardt, 2018):

$$W(\mu, G) \approx \mu\big(1 - (\alpha + \beta)G\big).$$

Big Tradeoff: Cost Side

Leaky bucket (Okun, 1975):

- More equality comes at the cost of losing economic incentives to use resources efficiently
- Mean income gets reduced

Assume reducing the Gini coefficient is quadratically costly in terms of mean income,

$$\mu_0 - \frac{\kappa(1-G)^2}{2}\,\mu_0.$$

Assume: Same cost parameter for all countries!

Big Tradeoff: First-Order Condition

Then the implied first-order condition is

$$\big(\kappa(1-G)\mu_0\big)\big(1-(\alpha+\beta)G\big) - \left(\mu_0 - \frac{\kappa(1-G)^2}{2}\mu_0\right)(\alpha+\beta) = 0.$$

Lower Gini coefficient $\iff$ Larger $\alpha + \beta$

Foreign Aid and IDA

- World Bank's International Development Association collects money and donates or loans cheaply to the poorest countries
- Collective decisions and rules determine which country gets money

  ra rather inequality aversion than strategic reasons (Alesina and Dollar, 2000) for giving?

FS and Voluntary Giving

- Standard FS predicts very little voluntary giving: With many players, transfers barely reduces average guilt
- I therefore add an additional giving motive: Psychological guilt cleansing, parameterized by $\rho \geqslant 0$
- After showing that optimal giving is directed only to poorer countries, country i chooses only total giving per domestic inhabitant, $\widehat{T}_i$
- $\check{T}_i$ is received transfers per inhabitant

$$U_i = c_i - \alpha_i \sum_{j \neq i} \omega_{ij} \max\{c_j - c_i, 0\} - \beta_i \sum_{j \neq i} \omega_{ij} \max\{c_i - c_j, 0\} + \beta_i \rho \, \widehat{T}_i$$

$$c_i = x_i + \check{T}_i - \widehat{T}_i, \qquad \omega_{ij} = \frac{L_j}{L_{-i}}, \qquad L_{-i} = \sum_{k \neq i} L_k$$

Foreign Aid: Marginal Utility

In the voluntary-transfer / IDA contribution game, the marginal utility of giving one more dollar per domestic inhabitant is

$$\frac{\partial U_i}{\partial \hat{T}_i} = \underbrace{-1}_{\text{lower material utility}} \overbrace{-\alpha_i R_i}^{\text{larger envy from becoming poorer}} \underbrace{+\beta_i P_i}_{\text{lower guilt from becoming poorer}} \overbrace{+\beta_i \frac{L_i}{L_{-i}}}^{\text{lower guilt from making recipient richer}} \underbrace{+\beta_i \rho}_{\text{additional guilt cleansing}}$$

Assume: Same guilt-cleansing parameter for all countries!

- R_i: share of richer people in the rest of the world
- P_i: share of poorer people in the rest of the world
- L_i: domestic population
- L_{-i}: total foreign population

Back–Backup–up: Why does the term $\frac{L_i}{L_{-i}}$ appear?

Giving one more dollar per domestic inhabitant means:

$$\text{total transfer} = L_i \cdot 1 = L_i$$

If recipient j has population L_j, its per-capita consumption rises by

$$\frac{\partial c_j}{\partial t_{ij}} = \frac{L_i}{L_j}$$

Country j enters country i's FS comparisons with population weight

$$\omega_{ij} = \frac{L_j}{L_{-i}}$$

Hence the effect on the weighted guilt term is

$$\omega_{ij} \frac{\partial c_j}{\partial t_{ij}} = \frac{L_j}{L_{-i}} \cdot \frac{L_i}{L_j} = \frac{L_i}{L_{-i}}$$

- Larger recipient countries j get more weight in guilt
- But the same transfer is spread over more people in j
- These two effects cancel exactly

Foreign Aid: First-Order Condition

Within a fixed consumption-rank interval, the marginal utility of giving is constant:

$$\frac{\partial U_i}{\partial \widehat{T}_i} = -1 - \alpha_i R_i + \beta_i P_i + \beta_i \frac{L_i}{L_{-i}} + \beta_i \rho$$

If country i gives more, it may fall below another country in the consumption ranking. Then

$$R_i \uparrow, \qquad P_i \downarrow$$

so the marginal utility drops.
Hence, the marginal utility is a weakly decreasing step function in $\widehat{T}_i$.

This gives the optimum condition:

$$\widehat{T}_i = 0 \quad \Rightarrow \quad \left.\frac{\partial U_i}{\partial \widehat{T}_i}\right|_{0^+} \leqslant 0$$

$$\widehat{T}_i > 0 \text{ and no tie in consumption} \quad \Rightarrow \quad \frac{\partial U_i}{\partial \widehat{T}_i} = 0$$

Foreign Aid: How Does It Help to Calibrate α_i and β_i?

Within a rank, the marginal utility is

$$\frac{\partial U_i}{\partial \widehat{T}_i} = -1 - \alpha_i R_i + \beta_i P_i + \beta_i \frac{L_i}{L_{-i}} + \beta_i \rho$$

Comparative statics within a rank:

$$\frac{\partial}{\partial \alpha_i} \left(\frac{\partial U_i}{\partial \widehat{T}_i} \right) = -R_i < 0$$

$$\frac{\partial}{\partial \beta_i} \left(\frac{\partial U_i}{\partial \widehat{T}_i} \right) = P_i + \frac{L_i}{L_{-i}} + \rho > 0$$

So:

- more envy lowers the incentive to give
- more guilt raises the incentive to give

Anchor Country

Remaining problem: κ and ρ are unknown

Assume knowing the α and β of a region (that contributes to IDA) to back the parameters out from the FOCs

- Meta-study Nunnari and Pozzi (2025) collects dozens of FS experiments
- In their main regression of α and β, they have coefficients for all kinds of experimental settings, including *Location: US*
- Use this regression to predict the parameters of a median non-student person in the US
- Use the resulting predicted parameters as an anchor

$$\alpha^{US} = 1.039, \qquad \beta^{US} = 0.072.$$

These are then used to recover the common cost / guilt-cleansing terms in the calibration exercise

Table 6 from Nunnari and Pozzi (2025)

Table 6: Explaining Heterogeneity

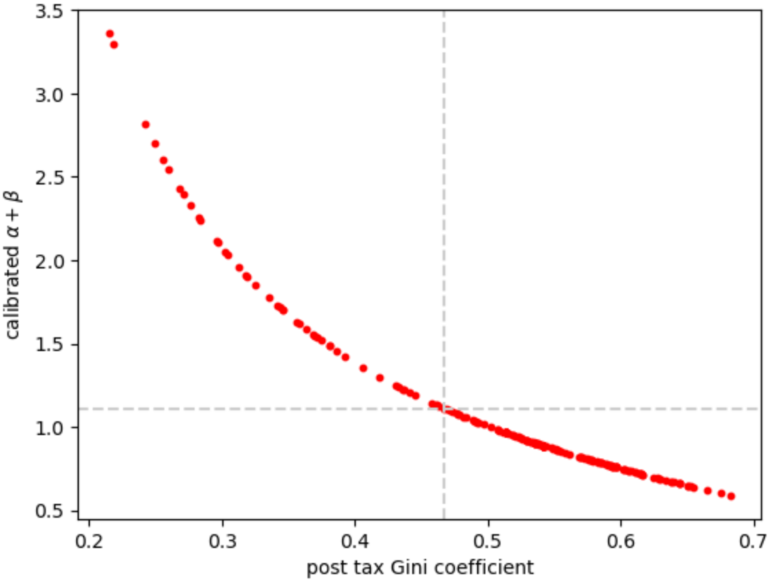
	Disadvantageous Inequality (α)				Advantageous Inequality (β)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	0.266***	0.363***	0.323***	0.496***	0.387***	0.367***	0.440***	0.452***
	(0.096)	(0.104)	(0.106)	(0.143)	(0.038)	(0.038)	(0.070)	(0.068)
Experimental Task: Strategic	0.461**	0.452**	0.489***	0.611***	-0.173**	-0.184**	-0.207**	-0.170*
	(0.192)	(0.189)	(0.146)	(0.195)	(0.074)	(0.075)	(0.101)	(0.098)
Type of Estimate: Median		-0.195*	-0.194*	-0.195*		0.007	0.007	0.005
		(0.105)	(0.105)	(0.108)		(0.033)	(0.034)	(0.033)
Type of Estimate: Aggregate		-0.183***	-0.186***	-0.141**		0.077*	0.072*	0.075
		(0.065)	(0.063)	(0.052)		(0.041)	(0.042)	(0.046)
Type of Estimate: Finite Mixture		-0.148**	-0.150**	-0.122**		0.027	0.032	0.033
		(0.059)	(0.056)	(0.050)		(0.031)	(0.034)	(0.039)
Geographic Location: North Europe			0.003	-0.096			-0.081	-0.096
			(0.148)	(0.193)			(0.094)	(0.087)
Geographic Location: USA			0.053	0.009			-0.028	-0.020
			(0.324)	(0.323)			(0.119)	(0.116)
Geographic Location: China			-0.481***	-0.462**			0.092	0.093
			(0.136)	(0.201)			(0.158)	(0.171)
Geographic Location: Multiple			-0.403**	-0.562**			0.201	0.175
			(0.189)	(0.221)			(0.157)	(0.155)
Implementation: Online			-0.295	-0.328			0.029	0.024
			(0.233)	(0.286)			(0.146)	(0.155)
Subject Population: Non Student			0.433**	0.474*			-0.168*	-0.167*
			(0.214)	(0.271)			(0.085)	(0.094)
Estimation: Logit				-0.356*				-0.028
				(0.202)				(0.069)
Estimation: Probit				0.051				0.016
				(0.109)				(0.132)
Estimation: Other				-0.399				-0.114
				(0.514)				(0.097)
I^2_{within}	8.47	8.82	8.10	8.67	38.45	40.48	42.90	41.10
$I^2_{between}$	91.52	91.17	91.89	91.32	60.97	58.93	56.48	58.31
$pseudo\text{-}R^2_{between}$	8.68	13.52	4.90	10.40	13.84	18.92	26.21	19.86
Observations	149	149	149	149	144	144	144	144

Calibration

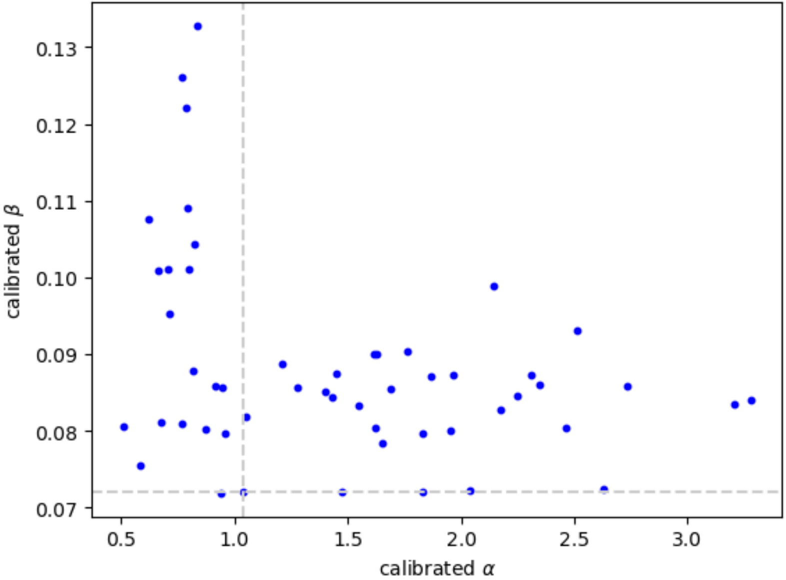
Combining both FOCs

- Domestic post-tax Gini coefficient pins down $\alpha + \beta$
- Contribution to IDA pins down how they are split
- No contribution to IDA $\rightarrow$ only get the sum and an upper bound for β

Calibrated $\alpha + \beta$ from Big Tradeoff



Calibrated α, β from Both



Calibration of Regional FS Parameters

- Domestic redistribution: post-tax Gini, assuming quadratic redistribution cost
- Foreign aid: IDA contributions, assuming additional guilt cleansing
- Anchor country: Estimate US values from meta study Nunnari and Pozzi, 2025
- RICE regions represented by dominant countries

RICE Region	Dominant country	α	β
US	USA*	1.039	0.072
EU	Germany	1.833	0.080
JAP	Japan	1.402	0.085
RUS	Russian Federation	0.766	0.081
EUR	Ukraine**	1.531	0.088
CHI	China	0.817	0.088
IND	India	0.620	0.108
MEST	Saudi Arabia	0.586	0.075
AFR	Egypt	0.800	0.101
LAM	Argentina	0.913	0.086
OHI	South Korea	1.433	0.084
OTH	Indonesia	0.704	0.101

- Ukraine**: No country in EUR contributes to IDA, so I set $\beta_{Ukraine}$ to the average
- All parameters in the range that is plausible for lab experiments, rather envious, little guilt

Inequality Across Regions

Rank	Region	Consumption per capita in 2015	US = 100
1	USA	36,883	100
2	Other High Income	28,035	76
3	Japan	27,779	75
4	EU	24,731	67
5	Russia	12,973	35
6	Latin America	8,866	24
7	Middle East	8,572	23
8	China	6,714	18
9	Eurasia	5,490	15
10	Other Asia	2,971	8
11	India	2,827	8
12	Africa	1,938	5

Inequality Across Generations

Rank	Region	Consumption per capita in 2105	2015 = 100
1	USA	118,499	321
2	Other High Income	98,141	350
3	Japan	97,161	350
4	EU	92,995	376
5	Russia	57,845	446
6	Latin America	53,817	607
7	Middle East	44,178	515
8	China	41,587	619
9	Eurasia	39,902	727
10	Other Asia	30,583	1,029
11	India	26,686	944
12	Africa	20,095	1,037

Why Negishi Weights?

Should climate policy also carry interregional redistribution motives?

- Negishi weights make the planner locally neutral to redistribution at the reference distribution
- They are calibrated so marginal welfare contributions are equal at that reference point
- Therefore, at that reference distribution, the planner has no first-order CRRA-style motive to redistribute across regions
- Away from that reference distribution, a redistribution motive reappears and points back toward it

A Simple Negishi Example

Three regions with reference consumption levels $c_A = 1$, $c_B = 3$, and $c_C = 4$, and CRRA utility with $\eta = 1.5$

$$u'(c) = c^{-1.5}$$

$$u'(1) = 1, \qquad u'(3) \approx 0.19, \qquad u'(4) = 0.125$$

Without welfare weights,

$$W = u_A + u_B + u_C$$

so the planner has a first-order incentive to shift consumption from B and C toward A

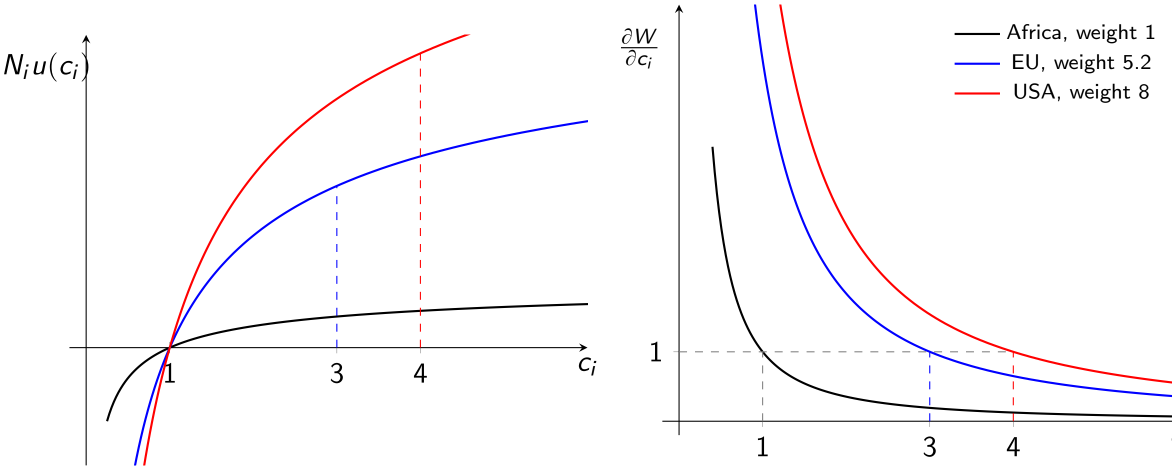
Choose Negishi weights to equalize marginal welfare contributions:

$$N(1) = 1, \qquad N(3) = \frac{1}{0.19} \approx 5.2, \qquad N(4) = \frac{1}{0.125} = 8$$

$$W = N(1) \cdot u_A + N(3) \cdot u_B + N(4) \cdot u_C$$

At the reference distribution, the planner has no reason to redistribute

Illustration of How Negishi Weights Work

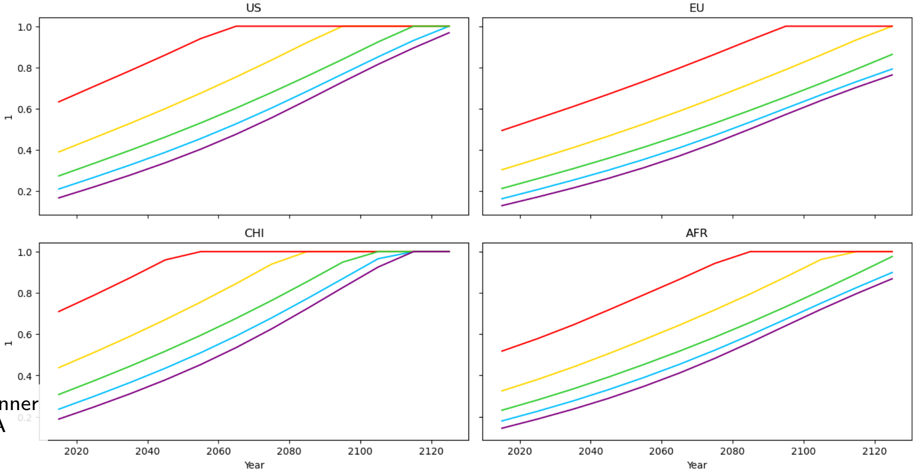


Negishi weights tilt the planner objective so that marginal welfare contributions are equal at the reference distribution

CRRA With Negishi: Mainly Intergenerational Weighting Remains

Negishi removes the benchmark CRRA redistribution motive, so higher η mainly strengthens intergenerational weighting

Abatement therefore falls more broadly across regions

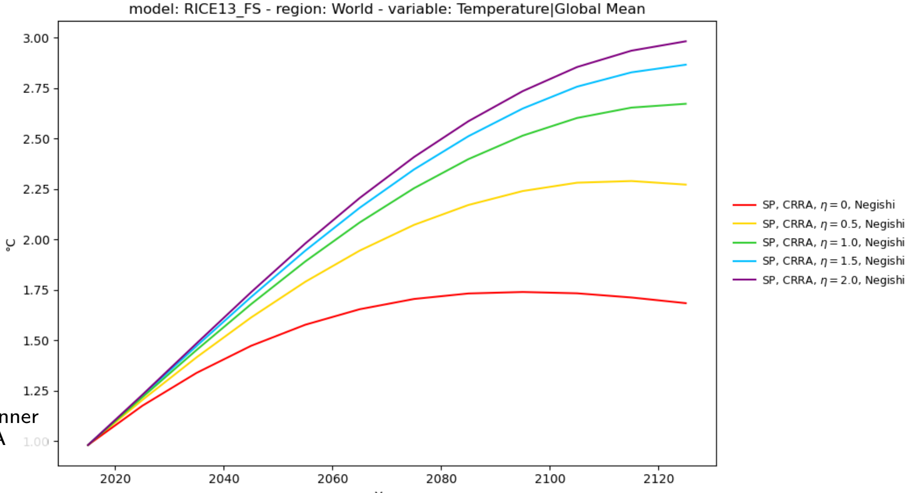


Solution: Planner
Utility: CRRA
Negishi: on

CRRA With Negishi: Total Temperature

Clearer ordering: Higher η leads to less abatement

Total temperature goes up as benefit of abatement, making poor regions richer, is weighted less

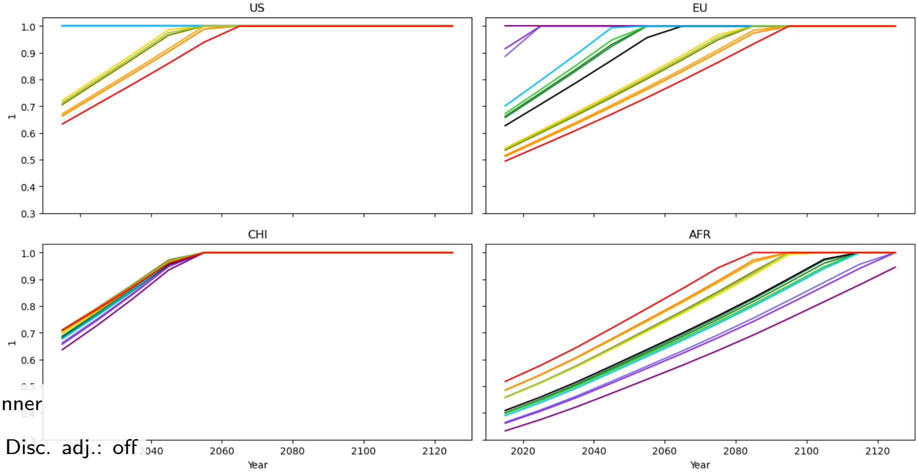


Solution: Planner
Utility: CRRA
Negishi: on

FS With Negishi: The Comparison Externality Survives

Negishi removes the CRRA-style marginal-utility redistribution channel, but not the FS comparison externality

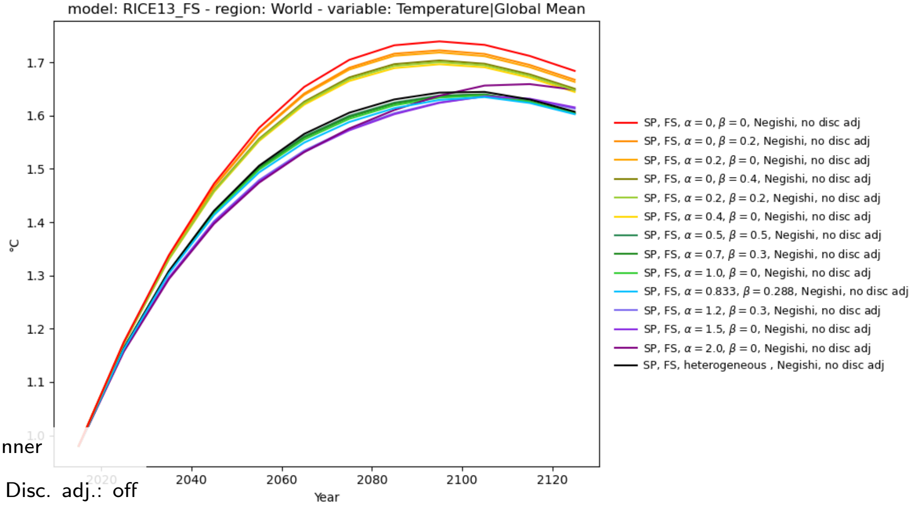
So stronger FS inequality aversion still shifts burden toward richer regions



Solution: Planner
Utility: FS
Negishi: on · Disc. adj.: off

FS With Negishi: Total Temperature

Because the interregional equity concerns are only weakened, total temperature is still non-monotone in the FS parameters

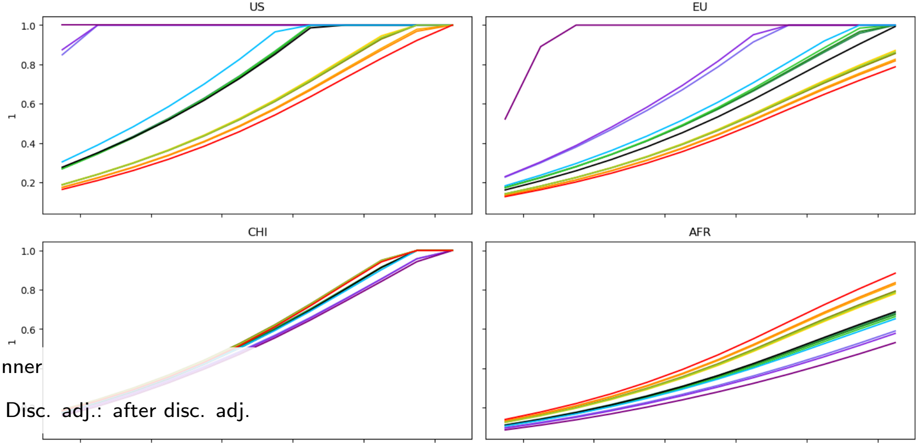


Solution: Planner
Utility: FS
Negishi: on · Disc. adj.: off

FS With Negishi and Discounting Adjustment

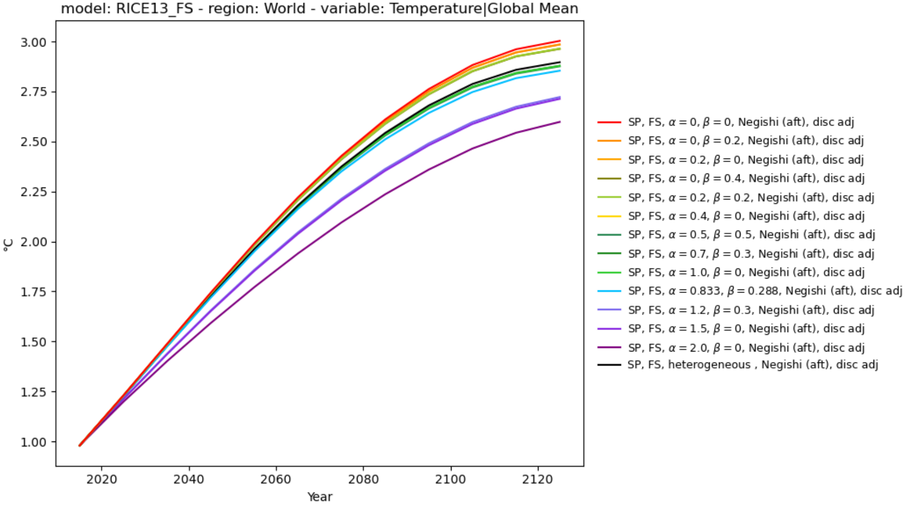
Adding back intergenerational weighting lowers abatement more broadly, while the rich-poor ordering remains

So Negishi changes the benchmark redistribution target, but it does not eliminate the two separate levers



Solution: Planner
Utility: FS
Negishi: on · Disc. adj.: after disc. adj.

FS With Negishi and Discounting Adjustment (after)



Solution: Planner
Utility: FS
Negishi: on · Disc. adj.: after disc. adj.

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