Inequalities and the Social Cost of Carbon

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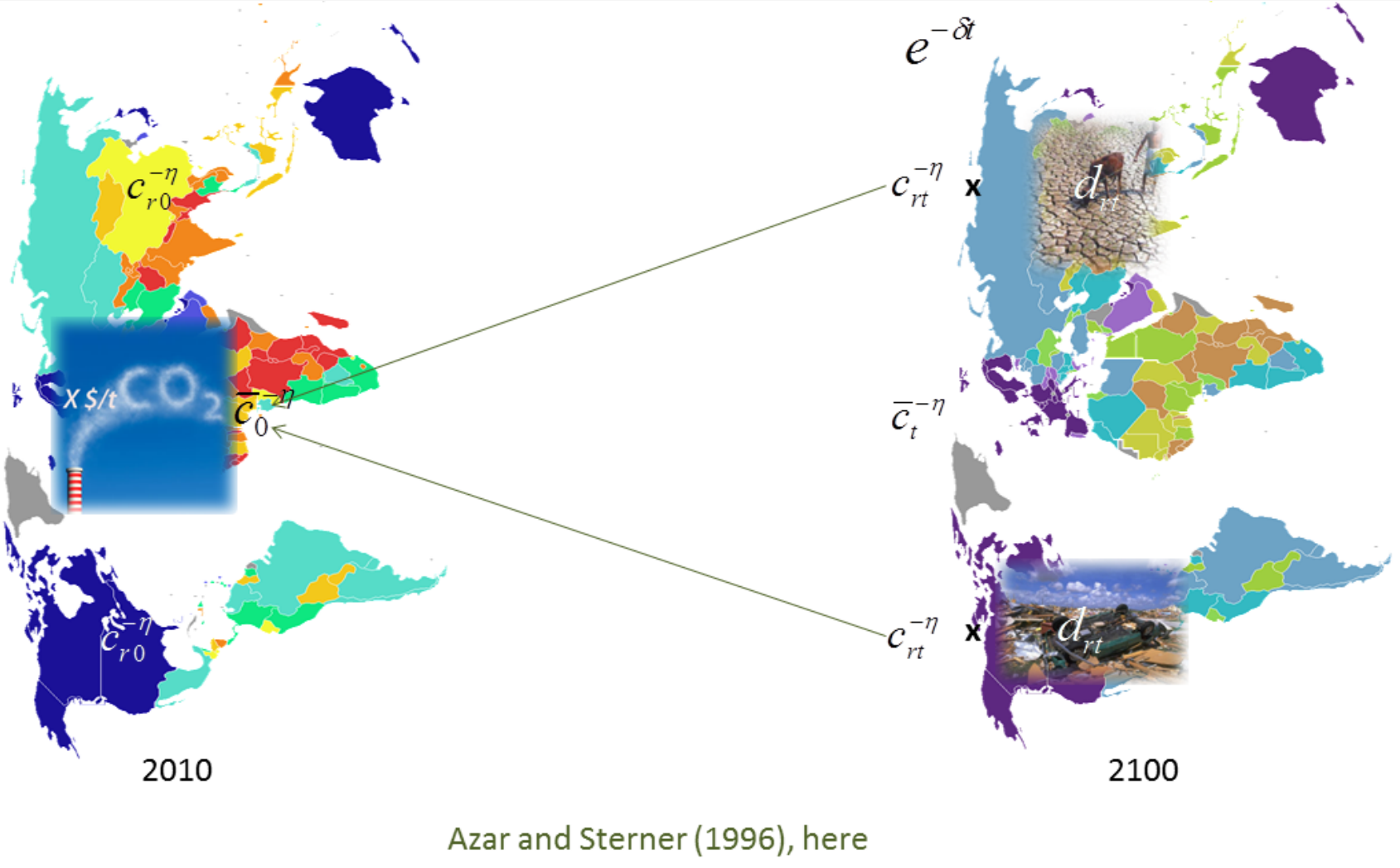
Motivation

- Equity aspects in the evaluation of Climate Change
  - Inter-generational Equity ("**discounting**", alternative approaches (maxmin, LRS)
  - Intra-generational Equity ("**equity weighting**")
- Social preferences in the two dimensions might be different (Atkinson et al. 2009)
- Integrated Assessment Models capture inequity aversion through a single utility function
- Inequality is considered only between (arbitrarily cut) regions

Motivation

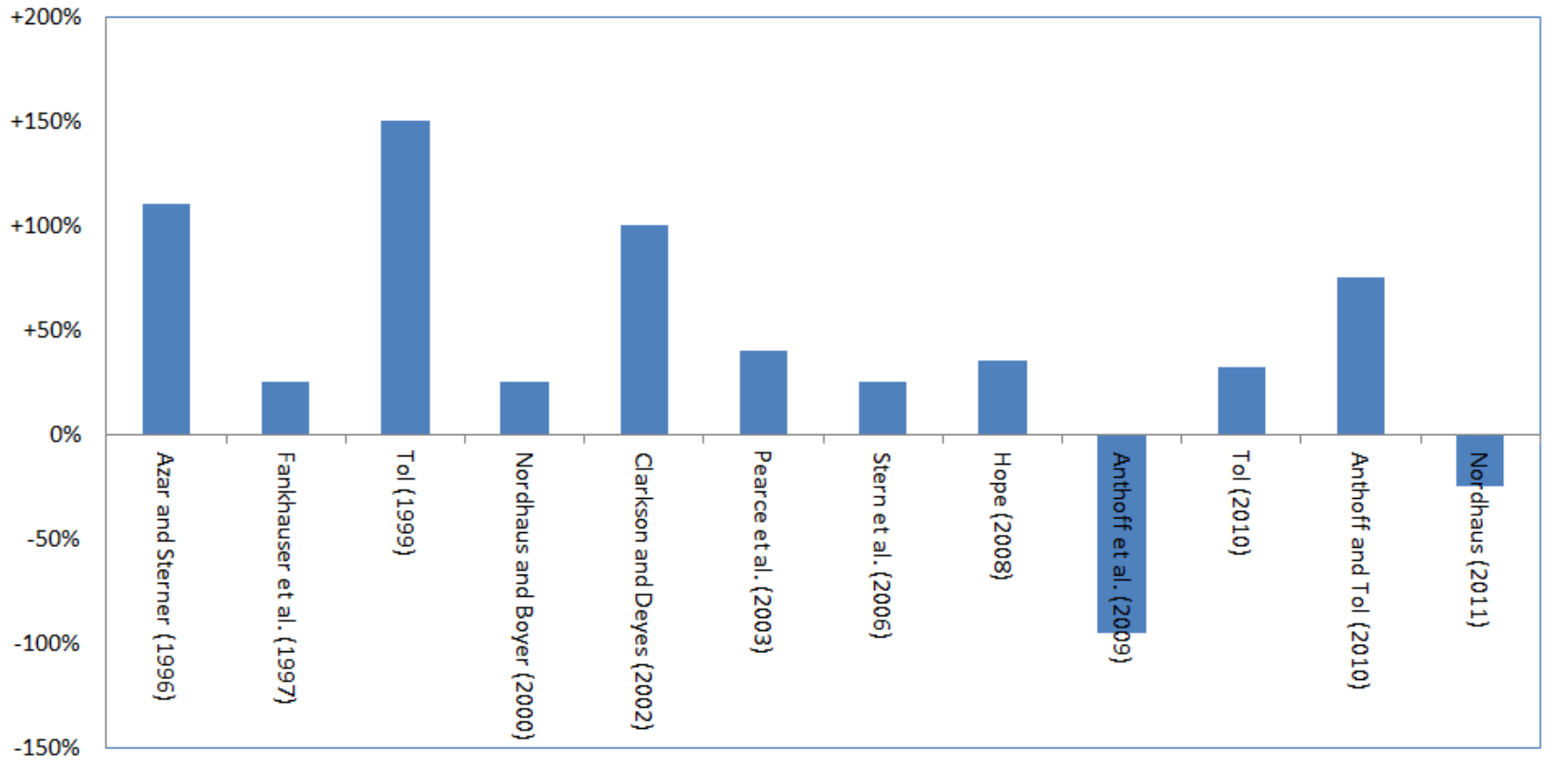
- Discounting and equity weighting *jointly* is a complex picture



Azar and Sterner (1996), here

The effect of Equity Weighting

- Does equity weighting increase or decrease the Social Cost of Carbon?



- Different approaches, inequality aversion parameters, discount rates

Contributions of the paper

- Inequality aversion between and within generations (Nordhaus, 2011)
- Disentangling resistance to intertemporal substitution (η) and inequality aversion (γ)

  $\Longrightarrow$allows discounting and equity weighting to be separable

- The level of disaggregation
  - Inequality on the between-country level, not between (arbitrary) regions
  - Allow for non-constant per-capita damages within regions

Outline

What does utility as log of consumption imply?

- Intertemporal Substitution:
  - Completely altruistic Social Planner should discount future cash flows just at the growth rate of consumption
- Risk aversion
  - The lottery of having 1 or 2 Mio. with eqal probability is equivalent to a certain amount of 1.41 Mio.
- Inequality aversion
  - One dollar to a Chinese is around ten times "worth" a dollar to an American

Discounting and Inequality

- Discount factor: weight based on marginal utility

$$DF_{rt} = \frac{c_{rt}^{-\eta}}{c_{r0}^{-\eta}}(1+\rho)^{-t}$$

- Choice of the appropriate discount rate not obvious when considering inequality

$\Longrightarrow$inequality-adjusted discount rate (Gollier 2010, Emmerling 2010) r_t^{in}

- Convergence $\Longrightarrow$higher discount rate $\Longrightarrow$SCC lower

Equity weighting

- Reasons for the use of Equity Weights in CBA
  - income distribution might not be optimal
  - transfers implied by optimality might not be carried out
  - one dollar = one vote
- Equity Weighting:
  - weighty based on a Utilitarian SWF and CRRA utility
  - weights $w_{it} = \frac{U'(c_{it})}{U'(\overline{c}_t)} = \left(\frac{\overline{c}_t}{c_{it}}\right)^{\eta}$ based on marginal utility of income
- similar to the discount factors presented before

Equity weighting

- Consider R different regions r at time t: marginal impacts or "damages" d_{rt} to compute the Social Cost of Carbon V_x

$$V_x = \sum_{t=1}^{T} \sum_{r=1}^{R} P_{rt} \underbrace{(1+\rho)^{-t} \frac{c_{rt}^{-\eta}}{c_{r0}^{-\eta}}}_{e^{-r_{rt} t}} \underbrace{\frac{c_{rt}^{-\eta}}{\overline{c}_{rt}^{-\eta}}}_{\text{weights } w_{rt}} d_{rt}$$

- The use of region-specific discount rates does not seem justifiable
- "Intertemporal approach"

$$V_x = \sum_{t=1}^{T} \sum_{r=1}^{R} P_{rt} \frac{c_{rt}^{-\eta}}{c_{x0}^{-\eta}} (1+\rho)^{-t} d_{rt}$$

- Monetarization with marginal utility of consumption in region x today

Disentangling both concepts

- The curvature of U , i.e., η, determines risk aversion, inequality aversion, and resistance to intertemporal substitution
- Separation of the three dimensions in the spirit of Kreps-Porteus (1978) / Epstein-Zin (1989, 1991)
- Standard Welfare function:

$$W = \sum_{t=1}^{T} \sum_{r=1}^{R} P_{rt} U(c_{rt})(1+\rho)^{-t}$$

- Disentangling:

$$W^R = \sum_{t=1}^{T} V \left[P_t U^{-1} \left(\sum_{r=1}^{R} \frac{P_{rt}}{P_t} U(c_{rt}) \right) \right] (1+\rho)^{-t}$$

- Isoelastic specification to disentangle inequality aversion across space(γ) and time(η)

Disentangling both concepts

$$S^R = \sum_{t=1}^{T} \sum_{r=1}^{R} P_{rt} \underbrace{\left(\frac{c_{rt}/c_t^{ede}}{c_{r0}/c_0^{ede}} \right)^{\eta-\gamma}}_{\Omega_{rt}} \underbrace{\frac{c_{r0}^{-\gamma}}{c_{x0}^{-\gamma}}}_{EW} \underbrace{\frac{c_{rt}^{-\eta}}{c_{r0}^{-\eta}} (1+\rho)^{-t}}_{DF_{rt}} d_{rt}$$

- Standard discount factor and equity weights as before for $\eta = \gamma$
- If $\gamma \neq \eta$:
  - If $\gamma < \eta$: $\Omega_{rt} > 1$ for regions that are relatively richer in the future
  - If $\gamma > \eta$: $\Omega_{rt} > 1$ for *relatively poorer* regions at $t \Longrightarrow$ equity weighting becomes more important
- As $\gamma \to 0$, normalization disappears, implying a unique carbon price

Inequality between countries

- Spatial resolution of IAMs very broad (RICE: 13, PAGE: 8, FUND: 16)
- (downward?) biased estimate of the optimal Social Cost of Carbon
- Geographical distribution should be taken into account of
  - **income** (Stern (2006), Anthoff et al. (2009), , UNDP (2010))
  - **impacts** (Kverndokk and Rose (2008), Mendelsohn (1994, 2011)
- Disaggregate region r by assuming a distribution of consumption: $c_{rt} \sim F_{rt}$

Inequality between countries

- Measure inequality using Atkinson class of inequality indices

$$I_{rt}(\gamma) = 1 - \frac{c_{rt}^{ede}}{c_{rt}} \text{ where } c_{rt}^{ede} = \left(\int c^{1-\gamma} dF_{rt}\right)^{\frac{1}{1-\gamma}}$$

- c_{rt}^{ede}: equally-distributed equivalent consumption
- Consistent with using a Utilitarian SWF with isoelastic utility function

- Analytical solutions: Taylor Approx. or lognormal income distribution (Atkinson and Brandolini, 2010)

Equal distribution of impacts

- SCC formula: Only equity weights are changed

$$\frac{c_{rt}^{-\gamma}}{c_{x0}^{-\gamma}} \Longrightarrow \frac{c_{rt}^{-\gamma}}{c_{x0}^{-\gamma}}(1 - I_{rt}(\gamma))^{-(\gamma+1)}$$

- Role of Prudence ($RP = \gamma + 1$) or "downside inequality aversion"
- For negative impacts, higher inequality implies unambiguously a higher SCC ($\frac{\partial S^{RC}}{\partial I_{rt}} > 0$)
- So far: impacts are assumed to be equally distributed between countries (on per-capita basis)

Un-equal distribution of impacts

- Impacts modeled as damage function: $d_{rt} = D(c_{rt})$, e.g., $D(c_{rt}) \propto c_{rt}^{\alpha}$
- can be combined to finally yield for the SCC

$$S^{RCD} = \sum_{t=1}^{T} \sum_{r=1}^{R} P_{rt} \left(\frac{c_t^{ede}}{c_0^{ede}} \right)^{\gamma-\eta} \frac{c_{rt}^{-\gamma}}{c_{x0}^{-\gamma}} \underbrace{(1 - I(\gamma)_{rt})^{-\frac{(\gamma-\alpha)((\gamma-\alpha)+1)}{\gamma}}}_{\Delta_{rt}} (1+\rho)^{-t} d_{rt}$$

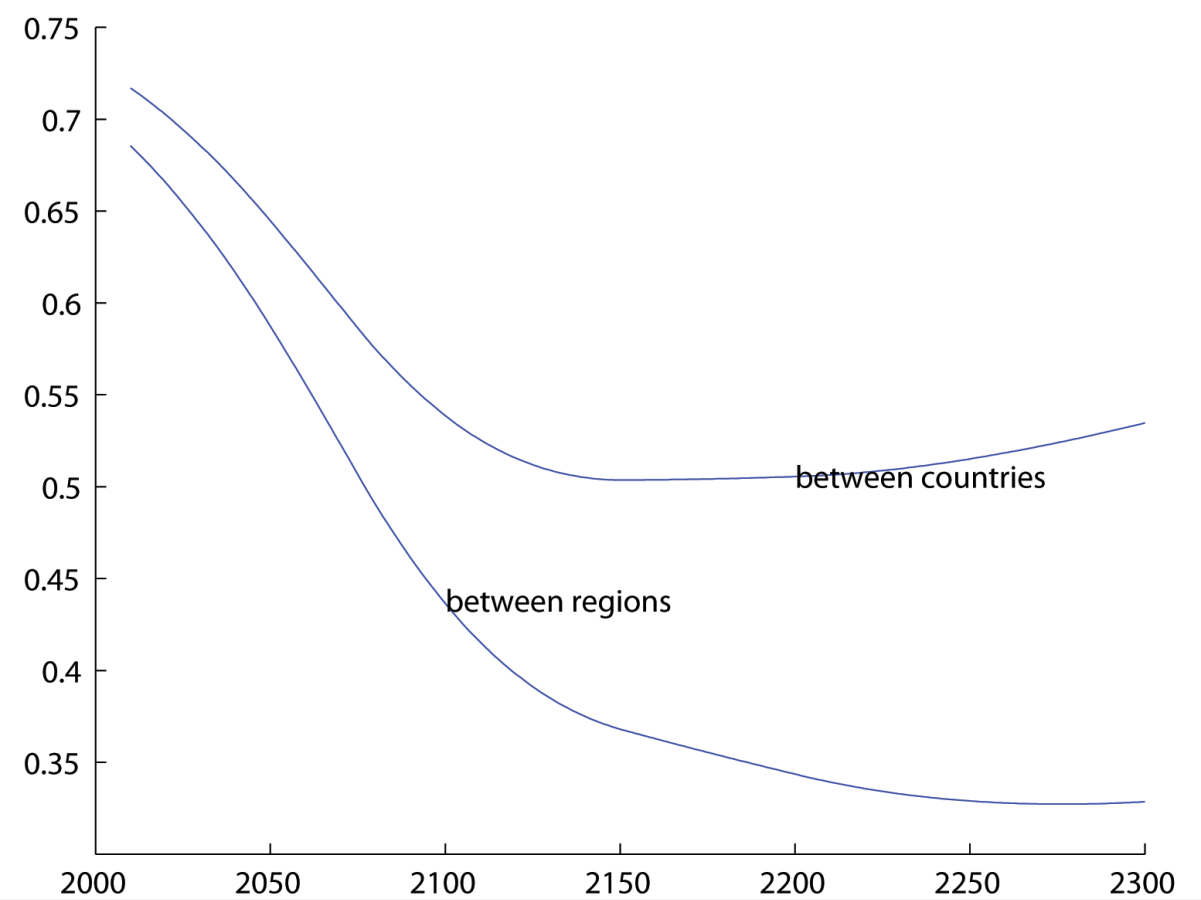
- equivalent to adjusting damages d_{rt} by the factor Δ_{rt}
- Depending on inequality aversion and the impact elasticity α:
  - $\alpha = 0$: $\Delta_{rt} < 1$ (as before: overall lower weights of impacts, i.e., lower SCC)
  - $\alpha \varepsilon [\gamma, \gamma+1]$: $\Delta_{rt} < 1$ (most realistic case)
  - $\gamma = 1$ and $\alpha = 1$: $\Delta_{rt} = 1$ (within-region inequality does not matter)

Values for η and γ

- From survey data/experiments: large variability
  Atkinson et al., 2009: $\eta \sim 9$, $\gamma \sim 2-3$ (and $RRA \sim 3-5$)
- Climate change literature: typically $\eta = 1-2$, recent tencendy towards $\eta = 1.5$
- From revealed social preferences (income tax schedule, ODA):
  - $\gamma \sim 1.4$ (Evans 2005)
  - $\gamma =$0.5 – 1.5 (Clarkson and Deyes, 2002)
  - $\gamma = 0.25-0.75$ (U.S. Bureau, 2006)
  - $\gamma \sim 0.7$ (Tol 2010)
- A lower value for γ than for η and RRA seems a robust finding
- Elasticity of impacts (α) between 0.9 and 1.3, mean very close to one (Anthoff and Tol, 2011)

Income inequality predictions

- Convergence mainly between world regions
- Forecasting increasing inequality within regions based on historical variance of log income (σ^2)



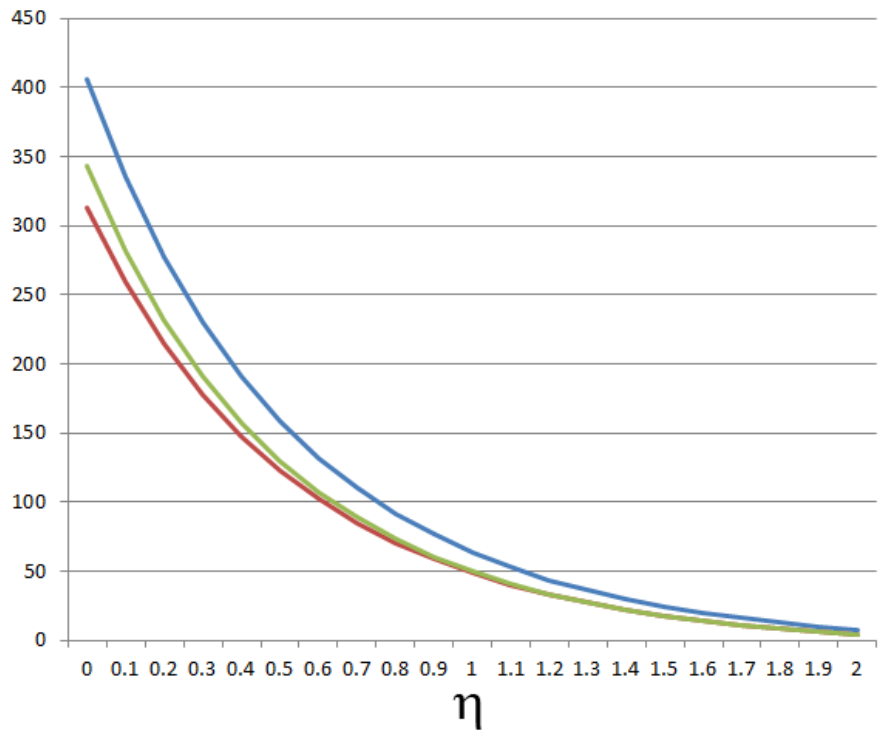
FUND model

- IAM focussing on impacts and evaluation of climate change
- rather complex damage module (energy, weather related events, health, biodiversity, migration)
- 16 regions
- GDP and Population scenario based on EMF14 Stand. Scen.
- SCC as optimal carbon tax/permit price

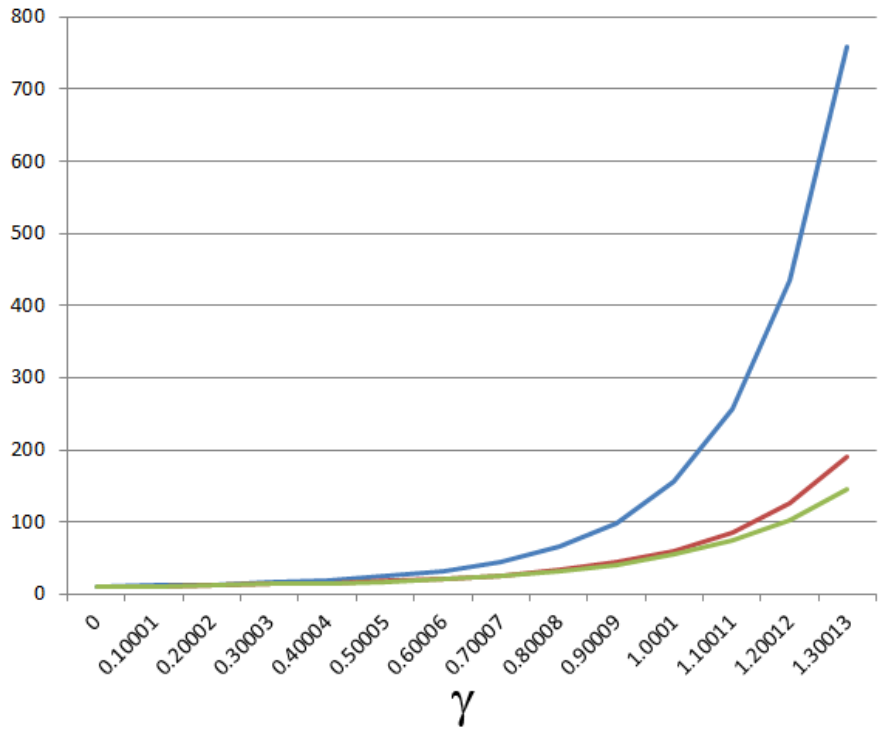
- Optimal Policy and Welfare optimization $\Longrightarrow$future work!

Results

Discounting ($\rho = 1.5\%, \gamma = 0.5$)



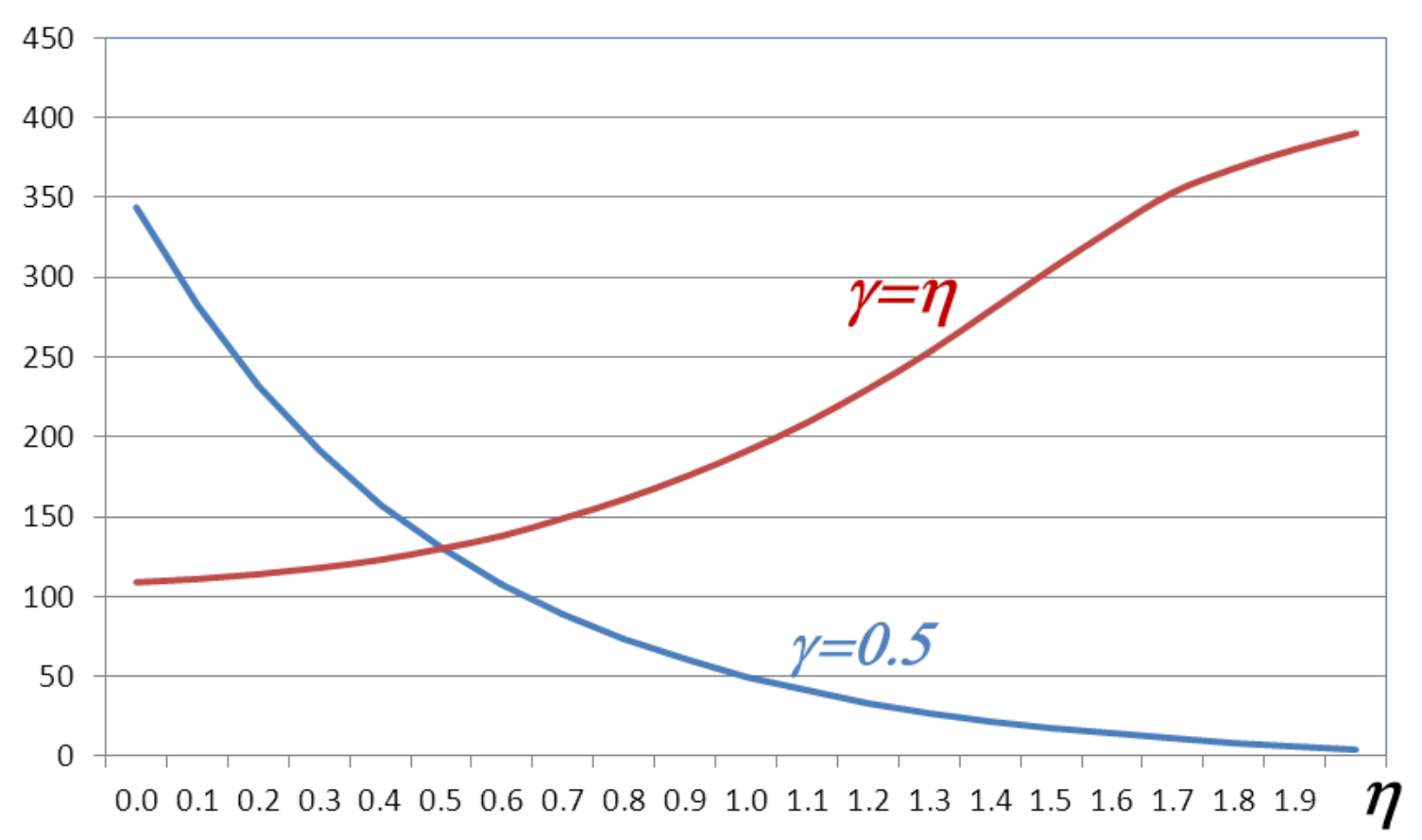
Equity weighting ($\rho = 1.5\%, \eta = 1.5$)



regional weights disaggregated non-constant damages

Results

- Standard SCC vs. disentangled discount rate and equity weights



Results

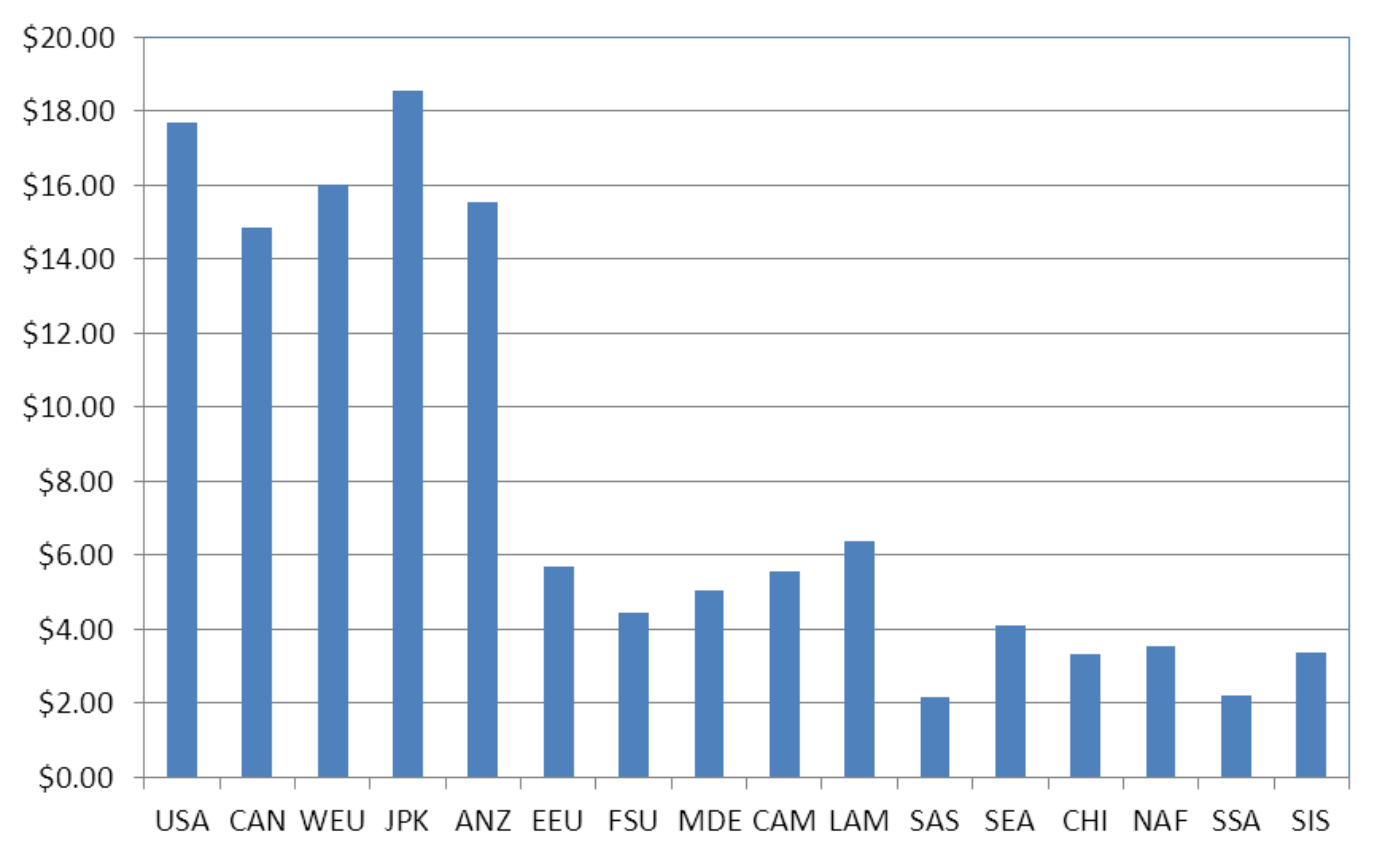
- Using the FUND model to compute the Social Cost of Carbon in $\$/tC$ ($\eta = 1.5, \rho = 1.5\%$):

type of equity weights	$\gamma = 1.5$	$\gamma = 0.5$
no equity weighting ($\gamma = 0$)	10.2\$	10.2\$
regional equity weights	304.7\$	17.7\$
individual equity weights	2479\$	24.5\$
constant relative impacts ($\alpha = 1$)	458.1\$	17.8\$

- Standard regional equity weights imply a higher SCC
- Considering inequality within regions, the SCC increases; non-constant impacts reduce the effect
- Effect of equity weighting is significantly lower if the discount rate is left unchanged

Results

- Equity weighted SCC estimates according to region ($\rho = 1.5\%, \eta = 1.5, \gamma = 0.5, \alpha = 1$)



Conclusion

- The welfare specification has a dramatic impact on the optimal climate policy
- Social preferences in different dimensions typically do not coincide, in particular $\gamma < \eta$
- Equity weightys increase the SCC, but the effect is reduced if disentangled from the discount rate, and thus lower than previous estimates
- The spatial resolution of models matters and finer resolution seems to increase the SCC

Conclusion

Thank you!