

# The Green New Deal Dilemma

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# Outline

- 1 Sustainability
- 2 Discounting
- 3 Climate policy

# The Green New Deal Dilemma

- Social priorities and environment priorities compete
- The benefits of preserving the environment will benefit future generations
- But social needs are urgent now, future generations will be more affluent
- Hence the imperative of taking account of inequalities in environmental policy

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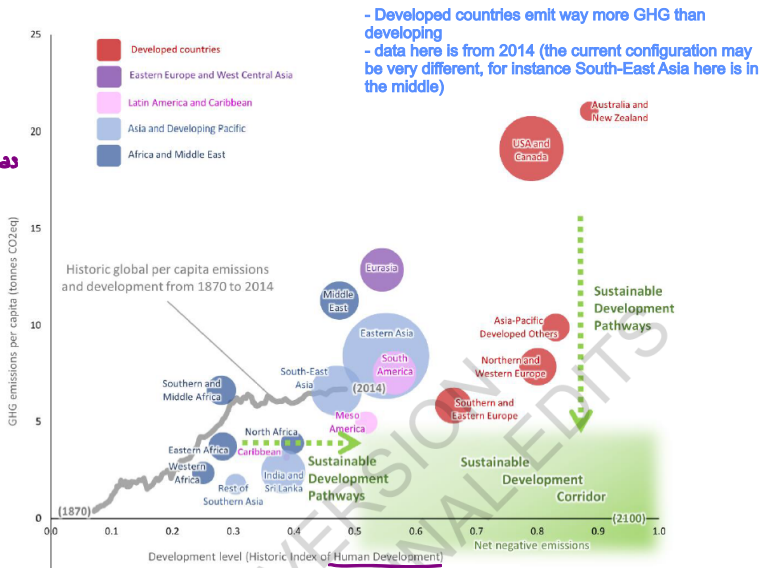
# Take away

- Sustainability cannot be assessed without building scenarios of the future, measures based on current statistics may be misleading
- Sustainability approaches should not eliminate our quest for progress
- One should not mix the assessment of sustainability with the assessment of current well-being

# Sustainable path

## IPCC AR6 WG3 Technical Summary

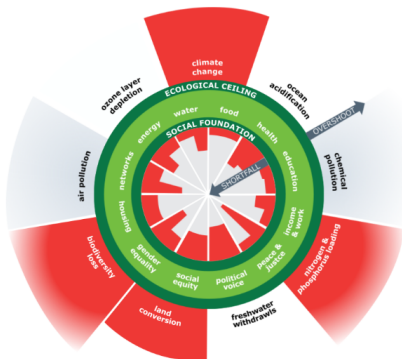
Green House Gas



# The doughnut

Between planetary boundaries and social needs

The Doughnut of social and planetary boundaries (2017)

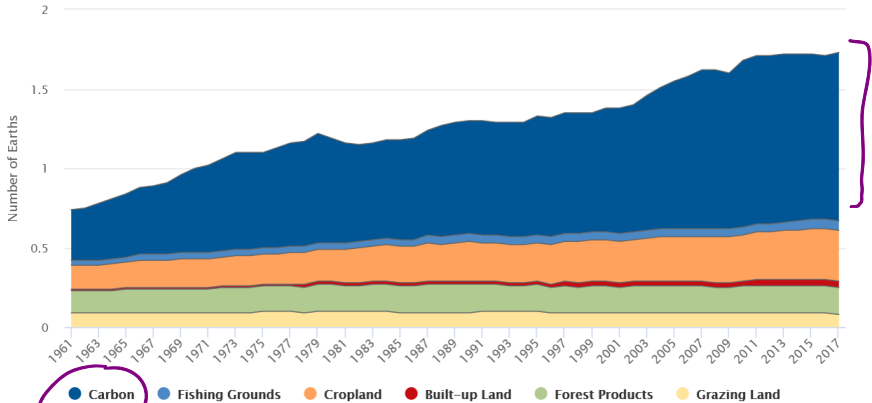


Approach initiated by Kate Raworth (2017). See an excellent critical review by E. Schokkaert <https://www.ejpe.org/journal/article/view/412/289>

# Ecological footprint

Surface needed to produce current production at current productivity, plus CO2 forest sink

World Ecological Footprint by Land Type





# Sustain what?

- **Eco-system** (strong sustainability): not plausible as ultimate value / too late Sustaining the ecosystem should be done SOONER
- **Needs satisfaction** (Brundtland Report, “development which meets the needs of current generations without compromising the ability of future generations to meet their own needs”): too modest
- **Welfare level** (most of sustainability literature): still too modest?
- **Growth** (Llavador et al. 2011): utopian?
  - Makes sense for finite horizon
  - Decoupling and recycling makes it possible (energy supply is enormous)
  - **Inequality reduction** can raise social welfare by up to 20x

**What to sustain?**

**SUSTAIN THE ECOSYSTEM:**

- Must be done soon, not as last resort

**SUSTAIN THE SATISFACTION OF NEED OF CURRENT GENERATIONS**

- do so without compromising future generations

**SUSTAIN WELFARE LEVELS**

- welfare analysis is the main focus of the literature
- not big enough scope?

**SUSTAIN GROWTH**

- reduce inequality --> possible way to implement growth in a sustainable way

## Basic welfare analysis of sustainable paths

$t=0,1,\dots,T$  represents EACH  
GENERATION

- Sequence of collective well-being  $W_0, W_1, \dots$  total welfare
- Every generation  $t$  makes decisions described by a vector  $S_t$  strategy refers to:  
- A actions  
- K stock of capital
- Set  $P(S_0)$  of possible paths  $(W_0, W_1, \dots)$  set that maps strategy to welfare
- A path  $(W_0, W_1, \dots)$  sustains the level  $W_0$  until  $T$  if for all  $t = 1, \dots, T$ ,  $W_t \geq W_0$  (adaptation to growth easy)
- Present actions  $S_0$  are sustainable with respect to level  $W_0$  until  $T$  if there is a path in  $P(S_0)$  which sustains the level  $W_0$  until  $T$ .
- Criterion:  $W_0 \leq V_1$ , where  
 $V_1 = \max_{(W_0, W_1, \dots) \in P(S_0)} \min \{W_0, W_1, \dots\}$

**SUSTAINABILITY DEFINITION CRITERIA: CURRENT WELFARE BEING LESS THAN OR EQUAL TO THE MAXIMUM SUSTAINABLE LEVEL.**

Condition for a non decreasing future path of welfare (Fleurbaey, 2015).

# A taxonomy of si

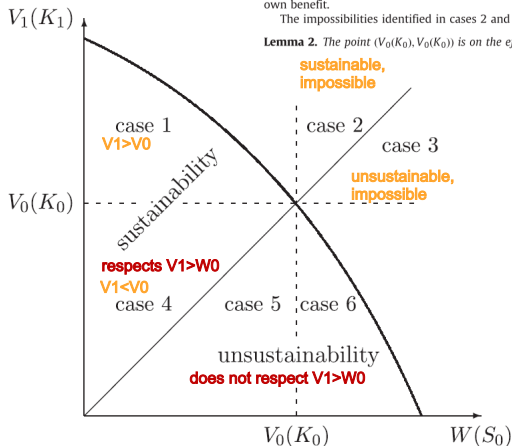
## Mapping out sustainability configurations

The results of the previous subsection allow us to identify the following configurations (equality cases are ignored, and simplified notations are adopted): (Table 1)

Intuitively, one can judge case 1 as a case of good (but not necessarily optimal) management, whereas case 4 achieves sustainability in a dubious way, because the present generation hurts itself more than it hurts the possibilities of future generations.<sup>17</sup> Case 5 is a case of very bad management, as the future is harmed even more than the present generation. Case 6 suggests a selfish management in which the present generation deprives future generations from possibilities for its own benefit.

The impossibilities identified in cases 2 and 3 are due to the following observation.

**Lemma 2.** The point  $(V_0(K_0), V_0(K_0))$  is on the efficiency frontier<sup>18</sup> for the pair  $(W(S_0), V_1(T(S_0)))$ .



### Sustainability configurations.

- Case 1:  $W_0 < V_0 < V_1$  sustainable
- Case 2:  $V_0 < W_0 < V_1$  impossible
- Case 3:  $V_0 < V_1 < W_0$  impossible
- Case 4:  $W_0 < V_1 < V_0$  sustainable
- Case 5:  $V_1 < W_0 < V_0$  unsustainable
- Case 6:  $V_1 < V_0 < W_0$  unsustainable

- “Ability” of future generations: what does that include? Political feasibility?
- Collective responsibility of future generations?
- Under uncertainty, does probable feasibility include innovation and learning?
- So: One should check intergenerational equity in a broader sense

## Making sustainability a component of intergenerational welfare

- Take  $F(W_0, W_1, \dots)$  such that  $F(w, \dots, w) = w$  (equally-distributed equivalent)  $F(W_0, W_1, \dots)$  be an intergenerational welfare function that evaluates each generation independently from the others
- Decomposition:

$$F(W_0, \dots, W_T) = W_0 + \underbrace{F(W_0, V_1, \dots, V_1) - W_0}_{\text{sustain-ability}} \\ + \underbrace{F(W_0, \dots, W_T) - F(W_0, V_1, \dots, V_1)}_{\text{sustain-actuality}}$$

- This can be adapted to expected values under uncertainty
- The worrisome case is when sustainability is achieved but not sustainactuality

# An alternative approach

Arrow et al. (2010), Dasgupta and Mäler (2000)

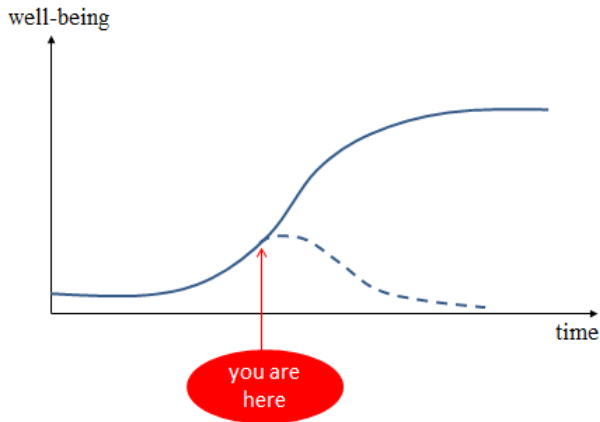
- The present generation's actions  $S_0$  are sustainable if

$$F(W_0, W_1, \dots) \leq F(W_1, W_2, \dots)$$

- This makes sense only with a stationary criterion and an infinite horizon
- It requires determining how  $F(W_1, W_2, \dots)$  depends on  $S_0$  (the first approach needs a prediction of the future realization only for sustainactuality, not for sustainability)
- Compatible with sure decline in  $W_t$  in the future (Asheim 2007)

# Deeper doubts

- Should we really sustain anything (level or growth)?
- Suppose the best path for life on Earth is a transition to an era of greater well-being: sustaining growth is asking for too much, sustaining level for too little





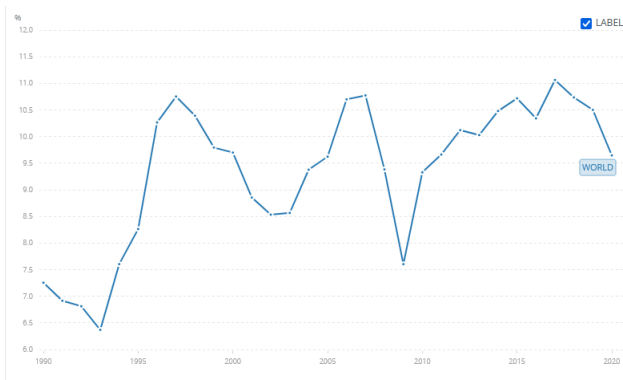
- Basic idea: write  $V_1(S_0)$
- Compare  $V_1(S_0)$  to  $V_0(S_{-1})$ : is there a link with sustainability ( $W_0 \leq V_1(S_0)$ )?
- It is not possible to have  $V_0(S_{-1}) < W_0, V_1(S_0)$
- Therefore:  $V_0(S_{-1}) < V_1(S_0)$  implies  $W_0 \leq V_0(S_{-1})$ , hence  $W_0 \leq V_1(S_0)$
- $V_1 - V_0 > 0$  is a sufficient, not a necessary condition for sustainability ( $V_1 - V_0 \geq 0$  is not sufficient)

- But achieving sustainability with  $V_1 - V_0 < 0$  looks bad (destroying the future while spoiling the present)
- So,  $V_1 - V_0 > 0$  is a reasonable condition
- Accounting prices for components of  $S_0$  are derived from

$$\sum_k \frac{\partial V_1}{\partial S_{0k}} (S_{0k} - S_{-1k}) > 0$$

# Inclusive wealth

## Adjusted net savings (world) - World Bank



net national savings plus education expenditure and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage

# Can one avoid predicting the future?

- If  $S_0$  is a single capital good (and no technical progress), checking  $S_0 < S_1$  is enough
- Multiple goods and technical progress complicate the picture considerably
- Question: What do we gain by computing  $\sum_k \frac{\partial V_1}{\partial S_{0k}} (S_{0k} - S_{-1k})$  rather than  $V_1$  directly?
- It is actually harder: counterfactual scenarios around values of  $S_0$  are needed, in order to compute derivatives
- In contrast, computing  $V_1(S_0)$  involves only looking at actual value of  $S_0$
- Looking for scenarios? Check the Shared Socioeconomic Pathways (Rao et al. 2019, Riahi et al. 2017)

# Ecological footprint revisited

Simplified version of what is in Fleurbaey 2015

- A relevant ecological footprint can be found by solving this equation for  $\lambda$

$$W_0 = V_1(\lambda K_0^n, K_0^h)$$

where  $S_0 = (K_0^n, K_0^h)$  depicts natural and human-made capital

- $\lambda \leq 1$  if and only if  $W_0 \leq V_1$
- Like genuine savings, this involves computing counterfactuals, and far away from  $S_0$
- But errors in the estimate may not matter much

# Greening income statistics?

- Green GDP = GDP - capital depreciation
- Comparing consumption to green GDP is another way to check sustainability
- But green GDP itself is not a relevant index: it depicts neither the current situation nor the future prospects
- One should keep two questions separate: 1) How well off is the present generation? 2) How well does it prepare for the future?
- Weitzman 1976: green GDP ("net national product") may represent intergenerational social welfare (more precisely, the equivalent level of constant consumption)

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# Take away

- Discounting is not dirty, it is a necessity because a \$ has different value depending on the social priority of different people at different times
- There is a simple formula to understand the value of the “social discount rate”
- In the long-run, only the poorest (present and future) stakeholders of contemplated programs matter for the evaluation

- Discounting is a central tool in intertemporal economic analysis.
- The difficulty is that we have to compare current costs/benefits with future (long-run and uncertain) costs/benefits.
- The question of how to price the future is of course crucial for energy policy, and policies dealing with the climate change issue.
- Example: the social cost of carbon.

# Discounting and net present value

- A key tool of evaluate policies/projects is to compute their Present Value (PV).
- If the policy/project  $P$  generates (net) flows  $F_t$  , its NPV is:

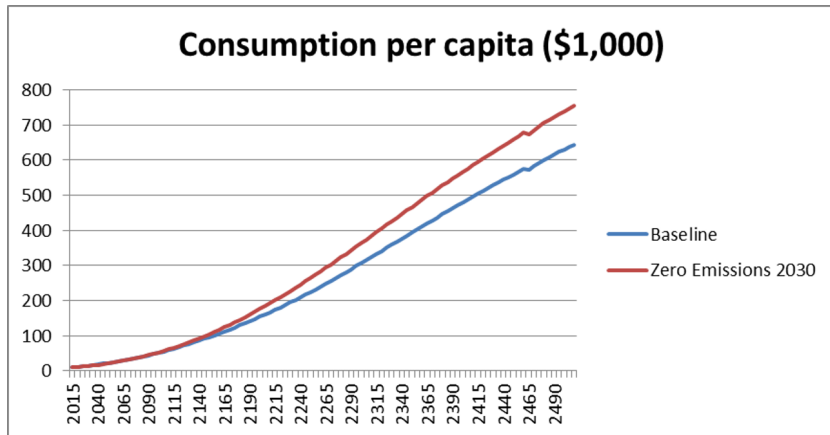
$$NPV(P) = \sum_{t=0}^T e^{-\rho_t t} F_t$$

where  $\rho_t$  is the discount rate: we put less weight on future costs/benefits.

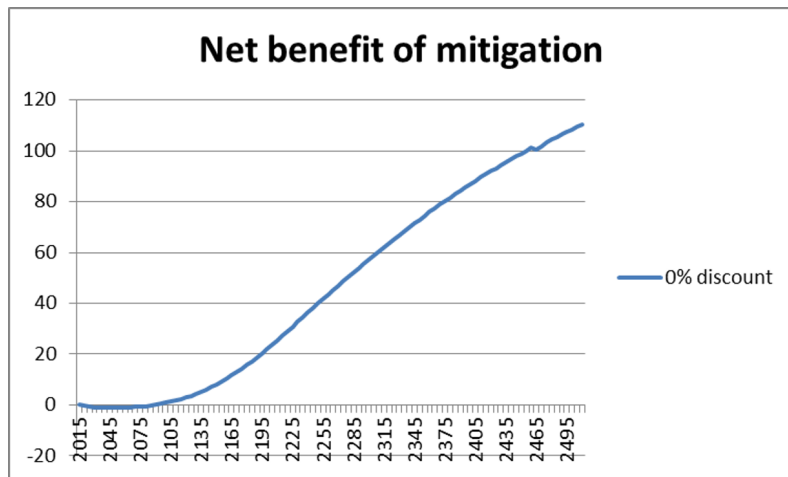
- Another formula is  $\sum_{t=0}^T \left( \frac{1}{1+\rho_t} \right)^t F_t$
- If the NPV is positive, the project/policy improves on the status quo (but may not be the best).

# Illustration

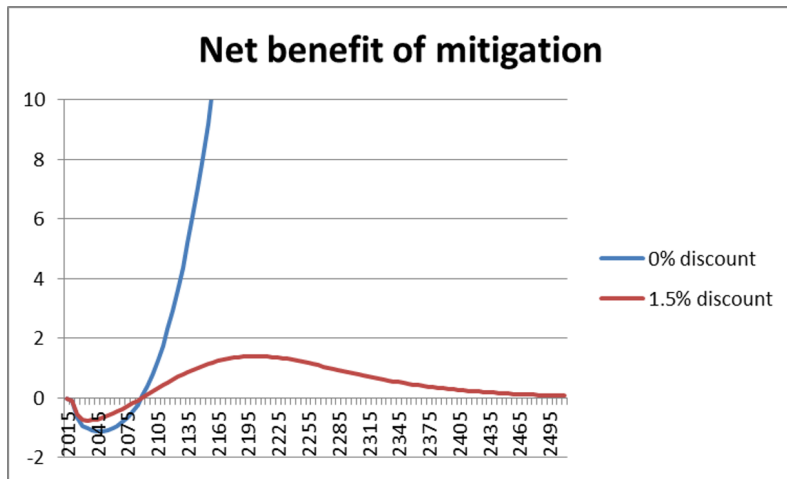
BAU vs. decarbonizing in 2030 (from DICE2016)



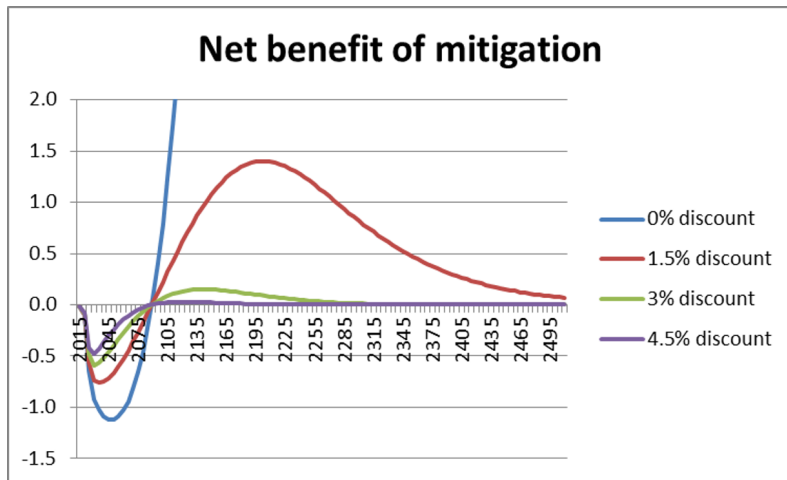
# Net costs and benefits (no discounting)



# With mild discounting



# With more standard discounting





# Discount rate and minimal return

- Consider a project costing  $c_0$  and yielding  $c_0 e^{Rt}$  (rate of return  $R$  per year:  $e^{Rt} \simeq (1 + R)^t$ ):

$$NPV = -c_0 + c_0 e^{(R - \rho_t)t}$$

- This is positive if and only if

$$e^{(R - \rho_t)t} > 1 \Leftrightarrow R > \rho_t$$

# The social cost of carbon

- The social cost of carbon (SCC) is just a particular application of the NPV concept.
- The SCC is the NPV of all future damages ( $D_t$ ) related to the emission of an extra ton of CO<sub>2</sub> in the atmosphere:

$$SCC_0 = \sum_{t=0}^T e^{-\rho_t t} D_t$$

- The SCC can also be computed for a future period—and is likely to increase

# The SCC depends crucially on the discount rate

EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances (Sept. 2022)

*Table 3.1.1: Social Cost of Carbon (SC-CO<sub>2</sub>) by Damage Module, 2020-2080 (in 2020 dollars per metric ton of CO<sub>2</sub>)*

Emission Year	Near-Term Ramsey Discount Rate and Damage Module								
	2.5%			2.0%			1.5%		
	DSCIM	GIVE	Meta-Analysis	DSCIM	GIVE	Meta-Analysis	DSCIM	GIVE	Meta-Analysis
2020	110	120	120	190	190	200	330	310	370
2030	140	150	150	230	220	240	390	350	420
2040	170	170	170	280	250	270	440	390	460
2050	210	200	200	330	290	310	500	430	520
2060	250	220	230	370	310	350	550	470	570
2070	280	240	250	410	340	380	600	490	610
2080	320	260	280	450	360	410	640	510	650

# Justifying discounting: the social discount rate (SDR)

- Consider a small change to a consumption path, from  $C_t, t = 0, \dots, T$  to  $C_t + F_t, t = 0, \dots, T$
- Is that a good change? Let us invoke a SWF social welfare function  $W(U_t(C_t), t = 0, \dots, T)$

$$dW \simeq \sum_{t=0}^T \frac{\partial W}{\partial U_t} \frac{\partial U_t}{\partial C_t} F_t = \sum_{t=0}^T \beta_t F_t$$

where  $\beta_t$  is the marginal social value of money for “generation”  $t$

- Let us write it in terms of current consumption (\$):

$$\frac{dW}{\beta_0} = \sum_{t=0}^T e^{-\ln \frac{\beta_0}{\beta_t}} F_t$$

justifying  $\rho_t = \frac{1}{t} \ln \frac{\beta_0}{\beta_t}$

# Interpreting the result

- $\ln \frac{\beta_0}{\beta_t}$  is the relative priority (in percentage) of  $C_0$  over  $C_t$
- Why should  $C_0$  have any priority over  $C_t$ ?
  - pure time preference
  - uncertainty about the future
  - the future is expected to be richer

# The Ramsey formula

CRRA constant relative risk aversion function

- Consider the CRRA function  $U(C) = \frac{C^{1-\eta}}{1-\eta}$  and the discounted utilitarian function  $W = \sum_{t=0}^T e^{-\delta t} U(C_t)$
- Then

$$\beta_t = e^{-\delta t} C_t^{-\eta}$$

$$\ln \frac{\beta_0}{\beta_t} = -\eta \ln C_0 + \delta t + \eta \ln C_t$$

$$\text{Ramsey formula: } \rho_t = \delta + \eta \frac{1}{t} \ln \frac{C_t}{C_0}$$

- $\delta$  may capture pure time preference, as well as the risk of extinction ( $e^{-\delta t} \simeq (1 - \delta)^t$  : probability of still existing in  $t$  if the extinction risk at each period is  $\delta$ )
- $\frac{1}{t} \ln \frac{C_t}{C_0}$  is the average growth rate per year between 0 and  $t$

# Why pure time preference is popular

- In an infinite horizon model, the sum  $\sum_{t=0}^{\infty} U(C_t)$  is generally not defined
- Exception (Ramsey):  $U$  tends to zero from below as  $C_t \rightarrow +\infty$  (zero is the “bliss” utility)
- Koopmans (1960) offered axiomatization of discounted utilitarianism  $\sum_{t=0}^{\infty} e^{-\delta t} U(C_t)$  (assuming bounded  $U$ —if  $U$  grows at rate greater than  $\delta$ , this sum is again not defined)

# A fundamental problem with infinite horizon

- Anonymity and Strong Pareto are incompatible

$$\mathbf{x} = (1, 0, 1, 0, 1, 0, \dots)$$

$$\mathbf{x}' = (1, 1, 0, 1, 0, 1, \dots)$$

$$\mathbf{x}'' = (1, 1, 1, 0, 1, 0, \dots)$$

Generally not understood.  
Specifically: what is meant  
with anonymity?

- Anonymity and Weak Pareto are also incompatible

$$\mathbf{x} = \left(\frac{1}{3}, \frac{2}{3}, \frac{1}{4}, \frac{3}{4}, \frac{1}{5}, \frac{4}{5}, \dots\right)$$

$$\mathbf{x}' = \left(\frac{1}{4}, \frac{1}{3}, \frac{1}{5}, \frac{2}{3}, \frac{1}{6}, \frac{3}{4}, \dots\right)$$

- Even finite anonymity and Weak Pareto are only weakly compatible: social preferences exist but are not constructible



# How to deal with it?

- ① Consider a finite horizon and a finite population
- ② Take finite anonymity and accept incompleteness:
  - ① overtaking (strict preference): there is  $T_0$  such that for all  $T > T_0$ , greater  $\sum_{t=0}^T U(C_t)$
  - ② catching-up (weak preference): for all  $\varepsilon > 0$ , there is  $T_0$  such that for all  $T > T_0$ ,  $\sum_{t=0}^T U(C_t)$  is greater by at least  $-\varepsilon$
- ③ Weaken Pareto and possibly accept incompleteness:
  - ① greater  $\liminf_{T \rightarrow \infty} \sum_{t=0}^T U(C_t)$
  - ② rank-discounted utilitarianism (Zuber & Asheim 2012):  
 $\sum_{t=0}^{\infty} e^{-\delta t} U(C_{[t]})$ , where  $(C_{[t]})$  is re-ordered in increasing fashion (incomplete as not all streams can be reordered in this way; it satisfies Strong Pareto on the streams that can)

# Introducing risk

- States of the world  $s$
- Expected social welfare

$$dEW \simeq \sum_{t=0}^T \sum_s p_s \frac{\partial W_s}{\partial U_{st}} \frac{\partial U_{st}}{\partial C_{st}} F_{st} = \sum_{t=0}^T \sum_s p_s \beta_{st} F_{st}$$

- One has  $\sum_s p_s \beta_{st} F_{st} = (\sum_s p_s \beta_{st}) (\sum_s p_s F_{st}) + \text{Cov}(\beta_t, F_t) = E\beta_t E F_t + \text{Cov}(\beta_t, F_t)$
- The term  $\text{Cov}(\beta_t, F_t)$  is positive if benefits fall in high priority states (insurance-type project)

# The “beta” of the project

- One computes  $\rho_t$  by solving

$$e^{-\rho_t t} E F_t = \sum_s p_s \frac{\beta_{st}}{\beta_0} F_{st} = \frac{E \beta_t E F_t + \text{Cov}(\beta_t, F_t)}{\beta_0}$$

- This implies

$$e^{-\rho_t t} = \frac{E \beta_t E F_t + \text{Cov}(\beta_t, F_t)}{\beta_0 E F_t} = \frac{E \beta_t}{\beta_0} \left( 1 + \frac{\text{Cov}(\beta_t, F_t)}{E \beta_t E F_t} \right)$$

$$\begin{aligned} \rho_t &= -\frac{1}{t} \left( \ln \frac{E \beta_t}{\beta_0} + \ln \left( 1 + \frac{\text{Cov}(\beta_t, F_t)}{E \beta_t E F_t} \right) \right) \\ &\simeq -\frac{1}{t} \ln \frac{E \beta_t}{\beta_0} - \frac{1}{t} \frac{\text{Cov}(\beta_t, F_t)}{E \beta_t E F_t} \end{aligned}$$

# Introducing inequality and risk

Fleurbaey & Zuber (2013, 2015)

- One can compute a specific discount rate for a transfer from one person  $i$  in 0 to another person  $j$  in  $t$  and in a particular state of the world

$$\rho_{ijts} = \frac{1}{t} \ln \frac{\beta_{i0}}{\beta_{jts}}$$

- When evaluating a policy with many stakeholders, the SDR over the volume of investment is an average of such person-to-person-state rates, weighted by their relative shares in the costs/benefits

$$\begin{aligned} \rho_t &= \frac{1}{t} \ln \frac{\sum_i \beta_{i0} \sigma_{i0}}{\sum_s p_s \sum_j \beta_{jts} \sigma_{jts}} = \frac{1}{t} \ln \sum_i \frac{1}{\sum_s p_s \sum_j \frac{\beta_{jts} \sigma_{jts}}{\beta_{i0} \sigma_{i0}}} \\ &= \frac{1}{t} \ln \sum_i \frac{1}{\sum_s p_s \sum_j \frac{\sigma_{jts}}{\sigma_{i0}} e^{-\rho_{ijts} t}} \end{aligned}$$

# Long-run SDR under inequality and risk

- Formula

$$\rho_t = \frac{1}{t} \ln \sum_i \frac{1}{\sum_s p_s \sum_j \frac{\sigma_{jts}}{\sigma_{i0}} e^{-\rho_{ijts} t}}$$

When  $t \rightarrow \infty$ , the expected value  $\sum_s p_s \sum_j \frac{\sigma_{jts}}{\sigma_{i0}} e^{-\rho_{ijts} t}$  is dominated by  $\min_{j,s} \rho_{ijts}$ , i.e., by  $\max_{j,s} \beta_{jts} / \beta_{i0}$ : the worst-case scenario for the worst-off in the future

- And the term  $\sum_i e^{\min_{j,s} \rho_{ijts} t}$  is dominated by  $\max_i \min_{j,s} \rho_{ijts}$ , i.e., by  $\max_i \min_{j,s} \beta_{i0} / \beta_{jts}$ : the worst-off in the present
- Simple lesson: in the long run, the SDR only depends on the worst: poorest people now and in the future, in the worst state of the world
- The shares and probabilities do not matter—they only affect the speed of convergence to the long-run SDR

# The discounting debate

Positive/descriptive vs. normative/prescriptive (Arrow et al. 1995, Posner and Weisbach 2007, Stern 2014)

- Normative: rely on a SWF
- Positive: rely on market interest rates—which ones: Treasury bonds or NASDAQ?
- Arguments of the positive school:
  - opportunity cost: the market interest rate is the normal rate of return of investments, and using another threshold to select investments will lead either to rejecting good projects (if the SDR is too high) or accepting bad projects (if low SDR, one should rather invest on the market)
  - market rates reflect the population preferences "democratic argument"

**SPOILER: both arguments for using market interest rates are wrong.**

# The opportunity cost argument is wrong

- If the growth path is socially optimal,

$$\frac{\beta_0}{\beta_t} = e^{Rt}$$

and the two methods coincide

- If the growth path is not optimal, the market may reject socially good projects ( $R$  is too high, under-accumulation) or accept socially bad projects ( $R$  is too low, over-accumulation)
- Whatever the SDR, a project that dominates another (better flow at all periods) is never rejected. So the argument that, if the SDR is too low, it will accept projects dominated by investments at the market rate is logically invalid: confusion between acceptable project and best project

# The democratic argument is dubious

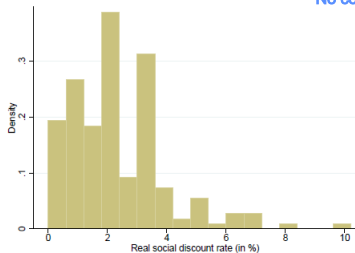
- The market rate is likely to reflect intra-generational preferences
- For long-term policies, one needs social inter-generational preferences: the market rate is unlikely to be aligned with reasonable inter-generational preferences
- The market rate is fine and “democratic” if the growth path is socially optimal and reflects inter-generational altruism
  - if the growth path is not socially optimal or the market rate does not reflect inter-generational altruism, then one needs to assess the gap between the chosen SWF and altruism
  - key reason why the market rate is unlikely to reflect inter-generational altruism: collective action problem. People may want to save the Planet through their investment, but cannot do so alone, and thus only invest in their family wealth



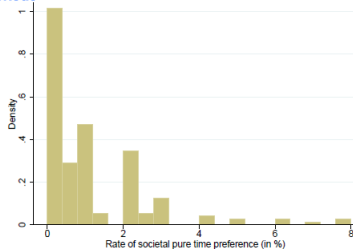
# Survey among experts

Drupp et al. (2018)

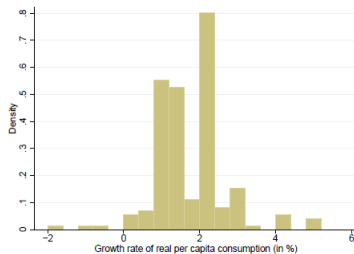
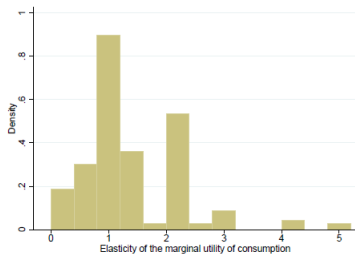
No consensus



(a)



(b)



- IPCC (AR5, WG3): “a relative consensus emerges in favour of  $\delta = 0$  and  $\eta$  between 1 and 3, although they are prescriptive parameters.”

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# Outline

- 1 Sustainability
- 2 Discounting
- 3 Climate policy**

# Take away

- Integrated assessment models provide scenarios and carbon pricing insights
- Inequality between generations should not hide inequalities within generations, which are relevant (recall discounting in the presence of inequalities)
- Co-benefits in air pollution and social redistribution alter carbon abatement recommendations
- Population scenarios and national social policies may interfere with global carbon policy

# Integrated assessment models

- Integrated Assessment Models (IAMs) are numerical models of the climate and the economy used to study the interactions between the two systems.
- Such models have been important to shape climate policy: in the US, regulatory rules regarding the Social Cost of Carbon are based on such models.

# Different types of models

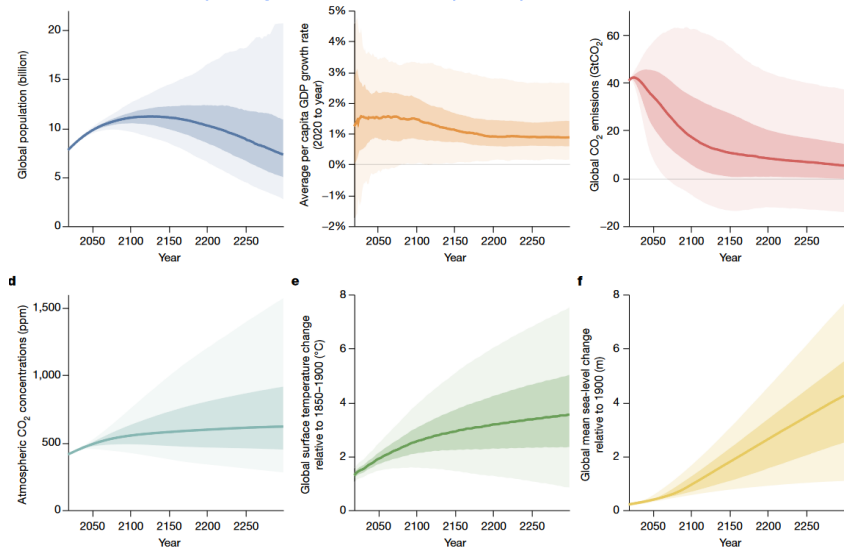
Why RICE and NICE versus the others?

- Cost-benefit analysis IAMs (CBA IAMs): few sectors, simplified models, used for optimization and cost-benefit analysis.
  - Numerical models: PAGE (Hope et al., 1993); DICE (Nordhaus, 1994); RICE, (Nordhaus and Yang, 1996); FUND (Tol, 1997); NICE (Budolfson et al., 2015); GIVE (Rennert et al. 2022)
  - Models with closed form solutions: Golosov, Hassler, Krusell, Tsyvinski (2014); Traeger (2021).
- Detailed-process IAMs (DP-IAMs) used to perform cost-effectiveness analysis given a trajectory fixed in climate agreements (e.g.: ReMiND; WITCH, IMACLIM).

# Long-term scenarios

Example (Rennert et al. 2022, GIVE model)

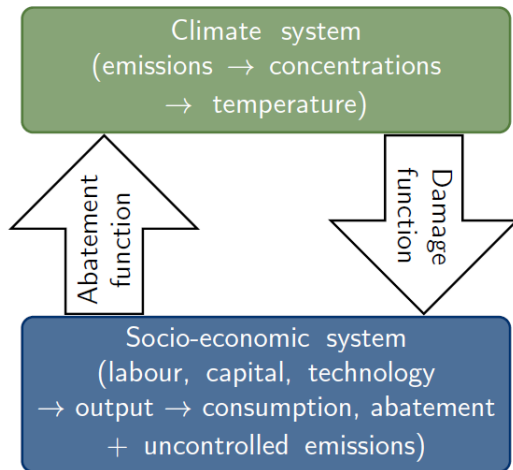
GIVE model is a cost benefit analysis integrates assessment model (CBA IAM)





# Structure of a CBA IAM

Stanton et al. (2009)



# How is policy designed with such a model?

- With CBA-IAMs:

social cost of carbon

- One technique takes a reference scenario and computes the SCC alongside the scenario—this is supposed to be indicative of the recommended carbon price (implemented through a tax or a cap-and-trade mechanism)
  - Beware: unless the path is optimal with respect to the social welfare function (SWF) used to compute the SCC, the optimal carbon tax differs from the SCC
- Model the abatement of GHG as a function of the carbon price, and compute the optimal carbon price over time in the model, maximizing the SWF

- With bottom-up models: cost-effectiveness analysis, for a given carbon budget or decarbonization path (i.e., how to distribute abatement effort across sectors and industries)

# Why does the SCC rise with time

- Hotelling rule for a depleted resource (arbitrage): its price should increase at the market interest rate—this assumes optimal accumulation path
- More direct reasons for the SCC to rise (no optimality assumed):

$$SCC_{T_0} = \sum_{t=T_0}^T e^{-\rho_t(t-T_0)} D_t$$

- The **damage curve is convex**: the later tons emitted generate more damage as they arrive in a warmer world. Thus the marginal damages  $D_t$  rise over time
- If there is uncertainty,  $\rho_t$  decreases in  $t$ , hence  $e^{-\rho_t(t-T_0)}$  goes up (with  $T_0$ , for any given  $t - T_0$ )



# Can we learn anything from IAMs?

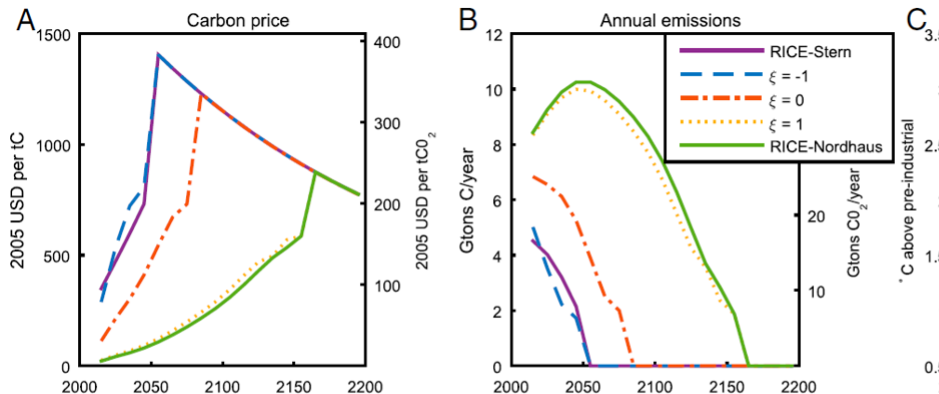
- Some people **argue** that we **cannot learn anything from IAMs** because of the inherent underlying uncertainties in the models. Even worse, IAMs may create a false sense of knowledge and precision (Pindyck, 2013).
- One of the key element of Pindyck's line of argument: **we do not know the "correct value" of the social discount rate.**
- But he misses the point that this is a normative debate.
- We should certainly be very cautious with the specific numbers obtained by IAMs, in particular the social cost of carbon. However, IAMs may be useful to identify key issues to build a more informed public discussion.

# Dealing with inequality

- CBA-IAMs optimize using a discounted utilitarian social welfare function—thus, they typically focused on intergenerational inequality
- Climate impacts are likely to disproportionately hurt the future poor (World Bank 2016; Hsiang et al. 2017).
- Social cost of carbon literature took inequalities into account using equity weights: Azar and Sterner (1996); Fankhauser et al. (1997); Pearce (2003); Anthoff et al. (2009).
- A specific issue: IAMs (in particular RICE) used to include Negishi weights, i.e. weights on the welfare of the different regions to bracket out inequality from climate policy design
- Until recently: no inequalities within (big) regions. And not much work on the differentiated impacts of climate change.

# Unequal impacts vs. the discounting debate

Dennig et al. (2015)

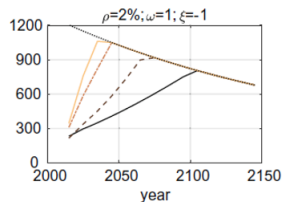
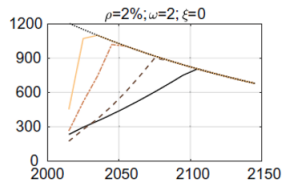
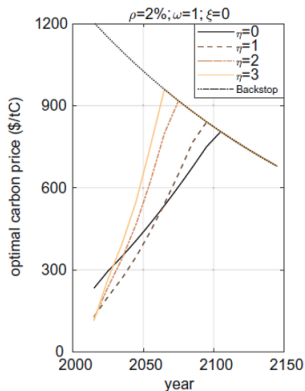
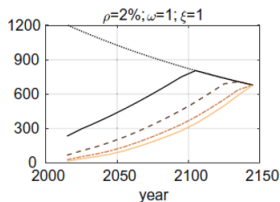
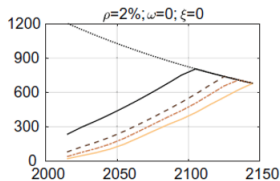


**Fig. 1.** The three panels plot model outcomes in NICE for different values of the income elasticity of damage:  $\xi = -1, 0, 1$ . The policies in our implementation of RICE for the (different) specific assumptions about discounting endorsed by Nordhaus are similar, as are RICE-Stern and  $\xi = -1$ . (A) Optimal policy (carbon price trajectories). The descending line eventually joins the trajectory of the maximum of the regional backstop prices. (B) The total emission rates for these policies. (C) The carbon concentration above pre-industrial levels.

# Can inequality aversion push mitigation?

Budolfson et al. (2017)

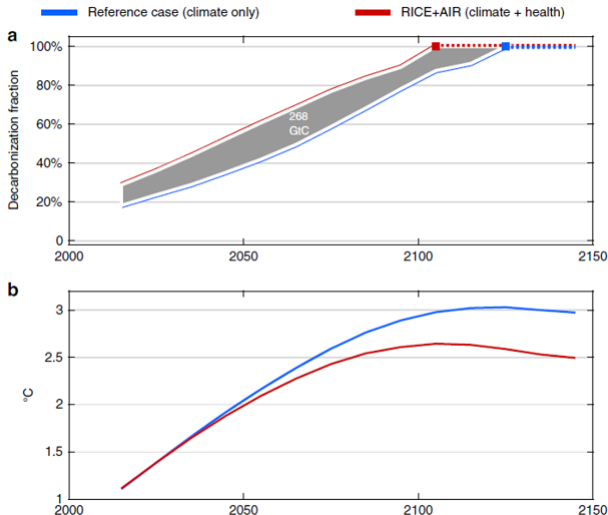
What is  $\omega$ ?



# Air pollution and health co-benefits

Scovronick et al. (2019)

Interpretation: when modeling decarbonization using "climate+health" you should **DECARBONIZE MORE** and keep C° **LOWER**.



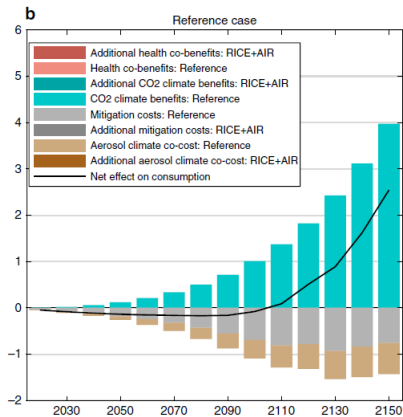
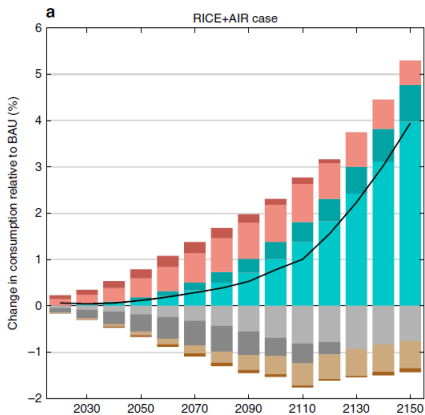


# Cont'd

BAU = business as usual

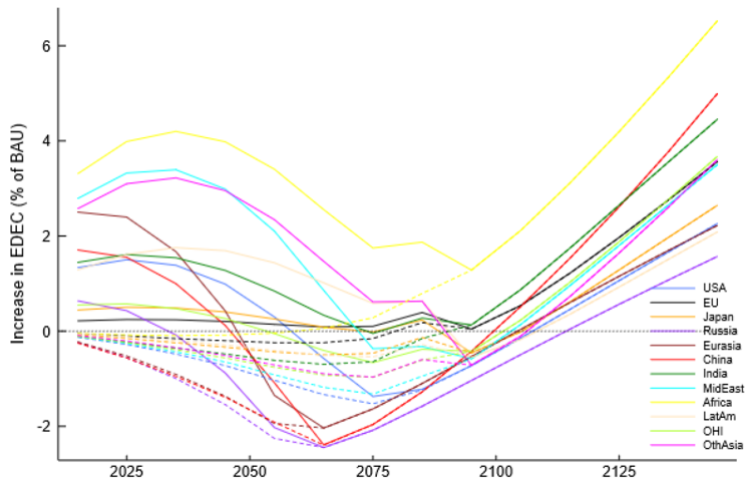
Benefits/costs can come from:

- just climate
- just health
- interaction of climate and health getting better/worse



# Tax recycling (uniform lump-sum)

Budolfson et al. (2021)



"The Green New Deal and Beyond: Ending the Climate Emergency While We Still Can" by Budolfson et al. (2021), tax recycling refers to a policy approach in which revenue generated from carbon pricing (such as a carbon tax) is used to fund investments in clean energy and other climate-friendly initiatives. This approach is called "recycling" because the revenue generated from the tax is reinvested back into the economy.

Tax recycling can help address the potential economic costs associated with carbon pricing, such as increased prices for fossil fuels and potential job losses in the fossil fuel industry. By investing in clean energy and other climate-friendly initiatives, tax recycling can help create new job opportunities and stimulate economic growth in other sectors. Additionally, by reducing greenhouse gas emissions, tax recycling can help prevent the potentially catastrophic economic and social costs associated with climate change.

EDEC stands for "Energy Demand Efficiency Credits".

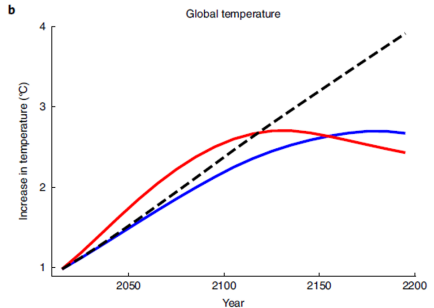
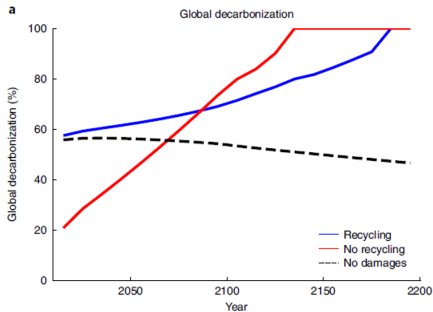
A graph of the increase in EDEC (% of BAU) over time would likely show the percentage by which energy demand efficiency credits (EDECs) increase compared to a business-as-usual (BAU) scenario over time.

If the percentage of EDECs is increasing over time, it suggests that more building owners and transportation providers are participating in the program and making energy efficiency improvements. This would result in lower energy consumption and emissions compared to a BAU scenario.

The rate of increase in EDECs over time could also provide information on the effectiveness of the policy. A steeper increase would indicate a more rapid uptake of the policy, while a slower increase may suggest that additional incentives or regulatory measures may be needed to encourage participation.

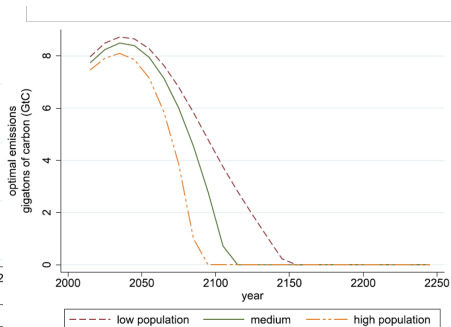
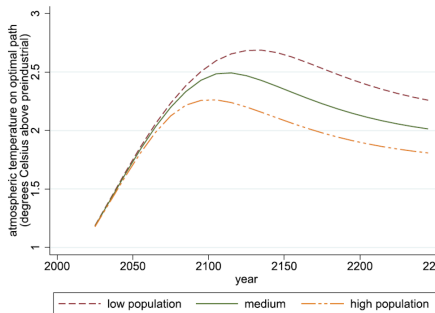
How do EDECs work?

- The basic principle behind EDECs is that energy users who reduce their energy consumption can earn credits that can be used to offset future energy use or sold to other energy users who need to meet energy efficiency targets. The amount of EDECs that a user can earn is typically based on the amount of energy that they save compared to a baseline level of energy use. For example, if a company reduces its energy consumption by 10% compared to the previous year, they may earn a certain number of EDECs based on the amount of energy that they saved.
- Once earned, EDECs can be used in a number of ways. For example, a company could use EDECs to offset their own energy consumption in the future, effectively reducing their energy costs. Alternatively, they could sell their EDECs to another company that needs to meet energy efficiency targets but has been unable to do so on their own. In this way, EDECs provide a financial incentive for energy users to become more energy-efficient, while also helping to create a market for energy savings that can benefit both energy users and the environment.



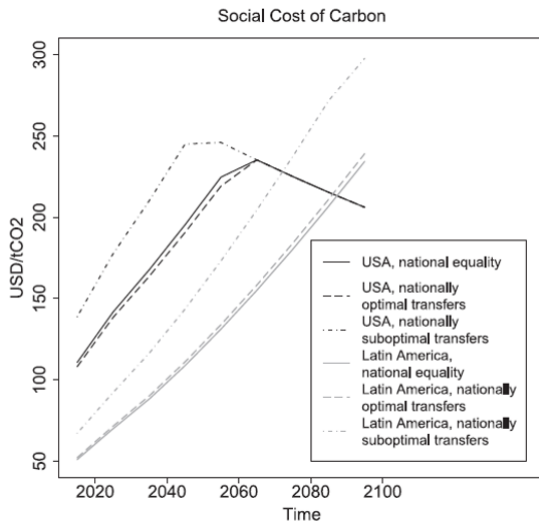
# Population scenarios

Budolfson et al. (2019)



# Suboptimal national distributions

Kornek et al. (2021)



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