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Weighting Emissions and Removals over Time: A Welfare-Equivalent CO_2 Weighting Rate

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Introduction

- Climate decisions often compare CO_2 profiles with different ***timing***: temporary storage, delayed releases, and mixed removals/emissions (e.g., biomass, electric vehicles).
- Common practice reduces these time-paths to one number via fixed-horizon physical metrics (e.g., GWP100) or an arbitrarily chosen discount rate.
- These choices can hide value judgements and mis-rank options when time preference, marginal damages, and carbon-cycle behaviour evolve over time.
- We propose a welfare-based approach of practical carbon metrics plus a transparent modelling framework to apply them.

Our Model

Configurable, modular python model to compute these metrics along the full impact chain:
Emissions/Removals → Temperature Change → Economic Damages → Social Welfare

We use:

- A **calibrated FaIR** climate model
- Official **SSP trajectories** for **climate** and **socioeconomics**
- **Ramsey-style discounting** with parameters from published surveys

Conclusions

- The damage function matters only in shape, not scale.
- Most confident range for weighting rate: 0.5-1% (bigger than 3% is only reached with extreme assumptions).
- Climate overshoot raises the weighting of emissions before the peak, as they contribute to damages during the temperature peak, when marginal damages are highest.
- These metrics apply across a wide range of contexts—from biomass and land-carbon dynamics to temporary storage, life-cycle assessment, and electric vehicles.

The Metrics

Notation

- t_0: base (valuation) year
- t: year
- $\mathrm{CSC}(t)[\mathrm{tCO_2}]$: carbon stock change (+ emission, - removal)
- $\mathrm{SCC}_{t_0}(t)$ [currency-equivalent at $t_0$per $\mathrm{tCO_2}$]: Present value welfare damages at t_0 from a marginal pulse in year t
- w(t) [1]: welfare weight relative to a tonne in t_0

Welfare Weights

Meaning: How welfare-relevant one tonne in year t is relative to one tonne in the base year t_0.

$$w(t) = \frac{SCC_{t_0}(t)}{SCC_{t_0}(t_0)}, \qquad [1]$$

Welfare-Equivalent CO_2 at t_0

Meaning: The amount of base-year CO_2 that would cause the same present-value welfare damages as the full emissions/removals profile.

$$\mathrm{we{-}CO_2}(t_0) = \sum_t CSC(t)\ w(t), \qquad [\mathrm{tCO_2}]$$

CO_2 Weighting Rate (continuous, discrete, forward)

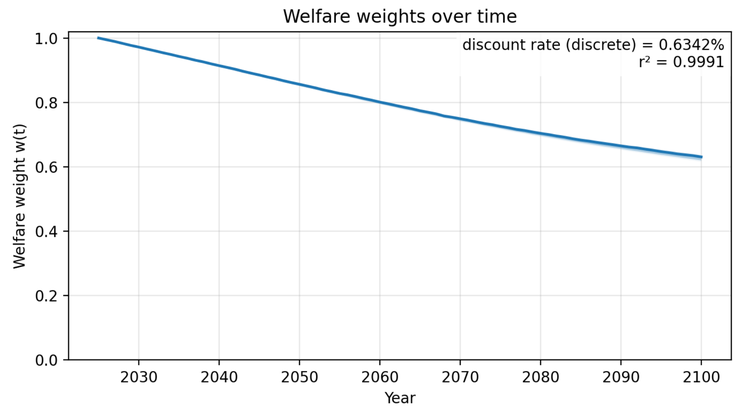
Meaning: The effective annual rate at which future tonnes are discounted relative to today.

$$\rho_{eff}(t) = -\frac{1}{t-t_0}\ln w(t), \qquad r_{eff}(t) = w(t)^{-1/(t-t_0)} - 1, \qquad f(t_1,t_2) = -\frac{1}{t_2-t_1}\ln\left(\frac{w(t_2)}{w(t_1)}\right).$$

Default Run

Assumptions

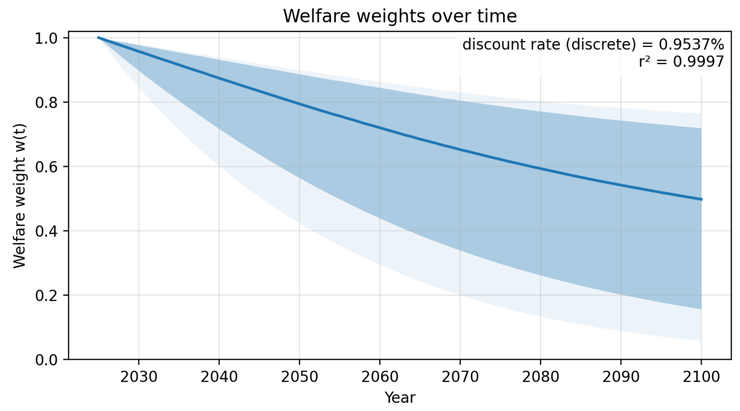
- SSP245
- Quadratic DICE damage function
- Rho= 0.5%, eta =1



Discounting

Assumptions

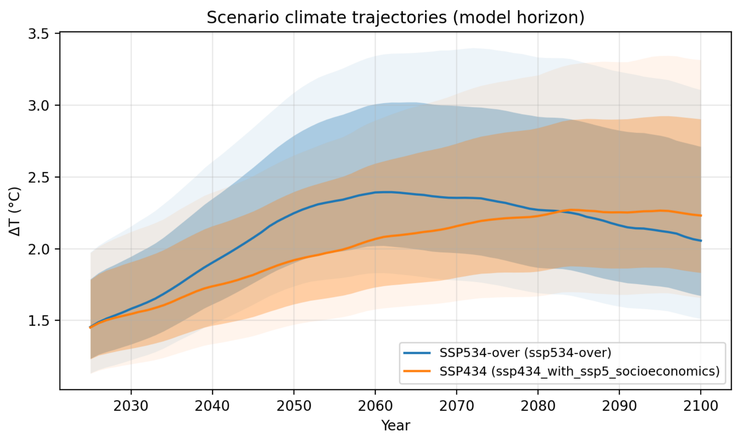
- SSP245
- Quadratic DICE damage function
- Full Discounting sample from Nesje et al. (2023)
- Dark area 66%
- Light area: 90%

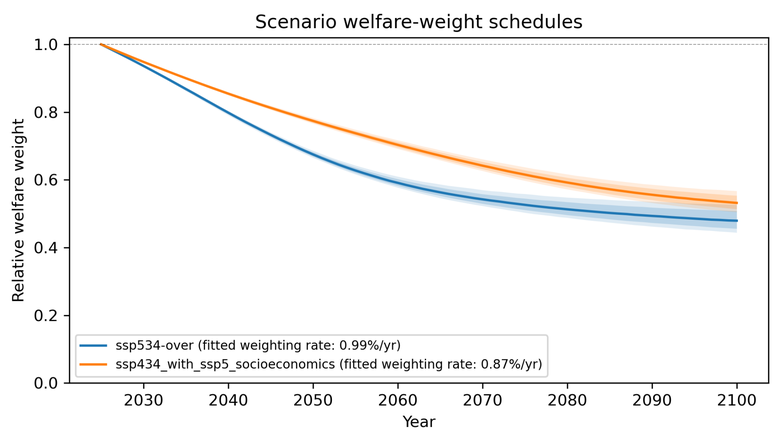


Climate Overshoot

Assumptions

- SSP534-over and SSP434
- Socioeconomics for SSP5
- Quadratic DICE damage function
- Rho= 0.5%, eta =1





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References
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