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An experimental test of dual discounting for consumption and the environment

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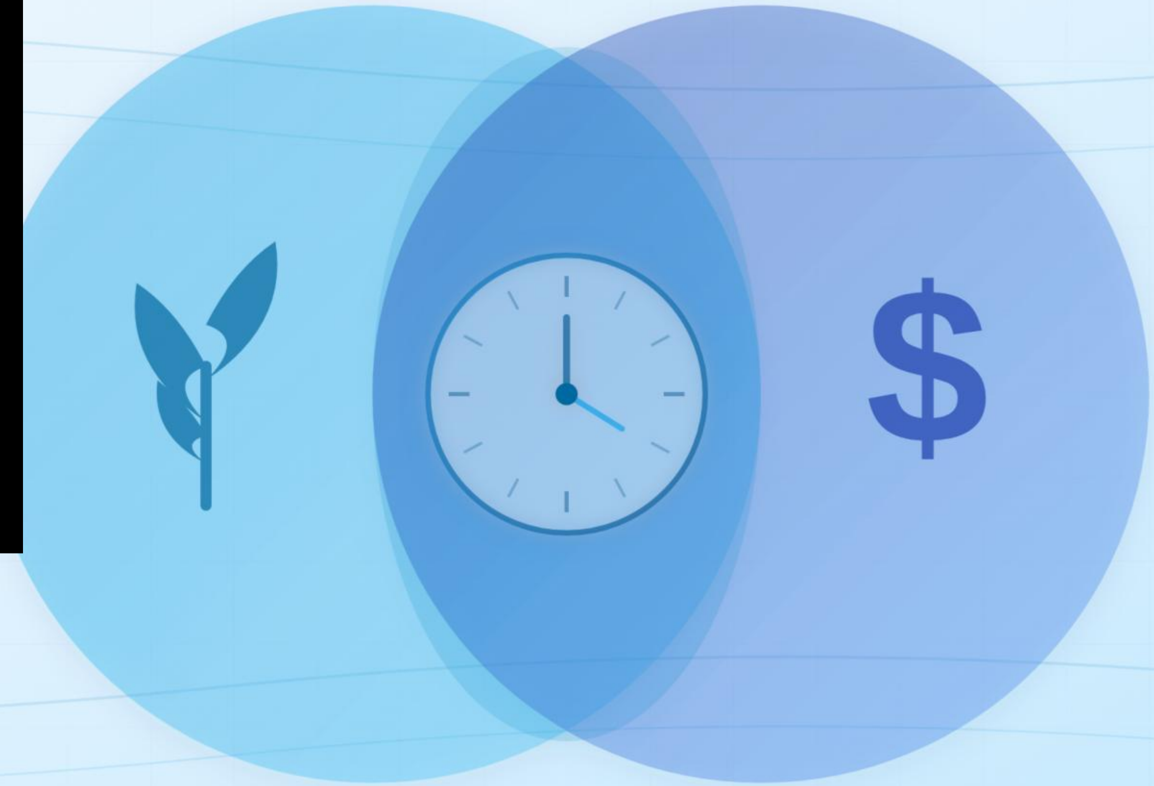
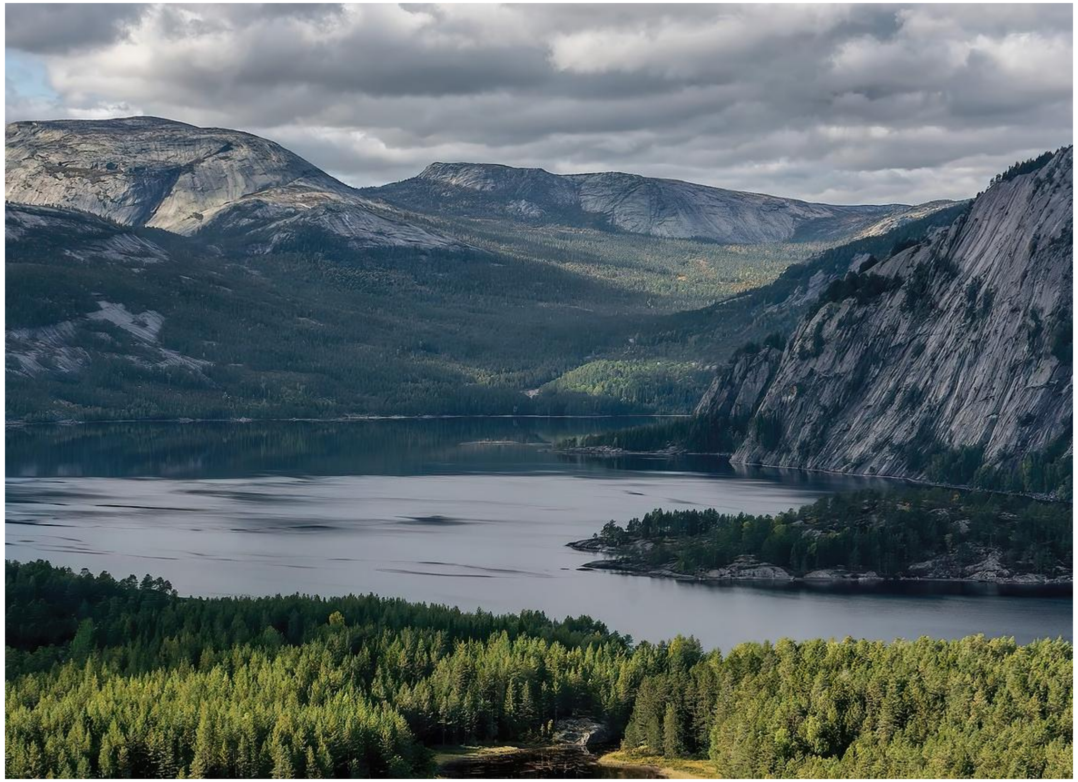


Are we moving towards an extreme future…?



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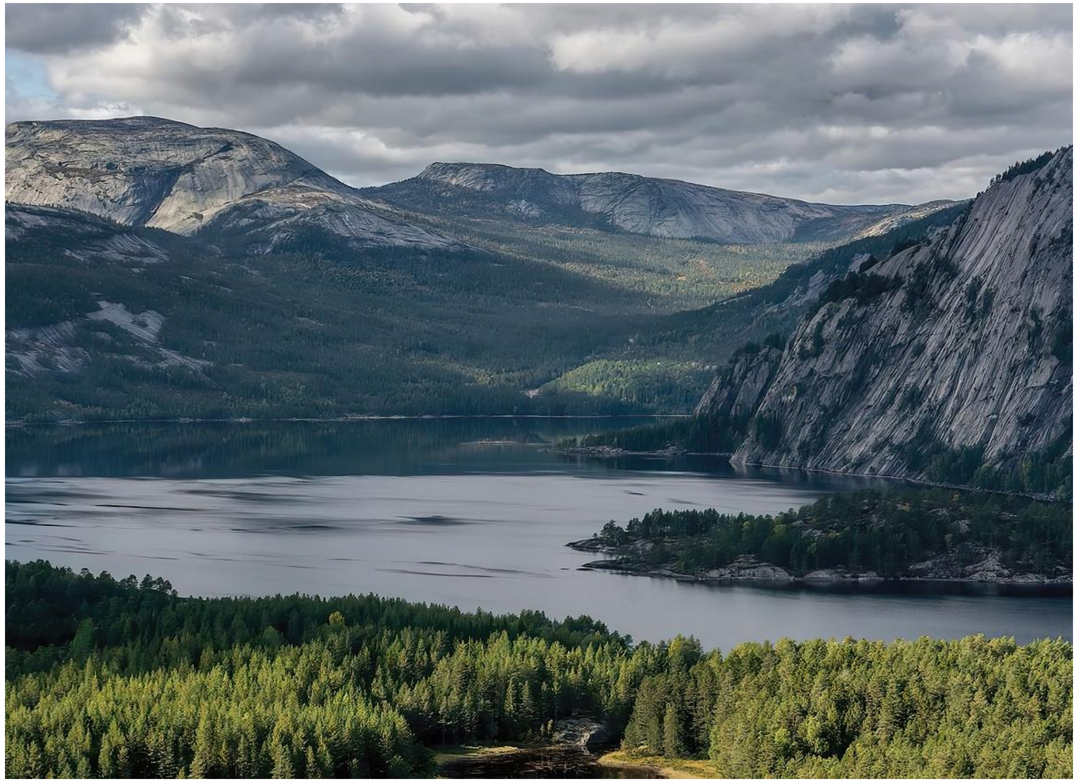

Conventional Ramsey rule(1):

$$CRR = r = \delta + \eta g$$

… or towards a more balanced future?

… or towards a more balanced future?

Dual discount rates[2,3]:

$$SDR_C = \delta + \eta_{CC} g_C + \eta_{CE} g_E$$
$$SDR_E = \delta + \eta_{EE} g_E + \eta_{EC} g_C$$

- δ is the pure rate of time preference (PRTP)
- g_C and g_E are the real growth rates p.a.
- η_{CC} and η_{EE} are simple marginal utility elasticities (inequality aversion)
- η_{CE} and η_{EC} are cross marginal utility elasticities (substitutability)

Social planner decisions in the lab

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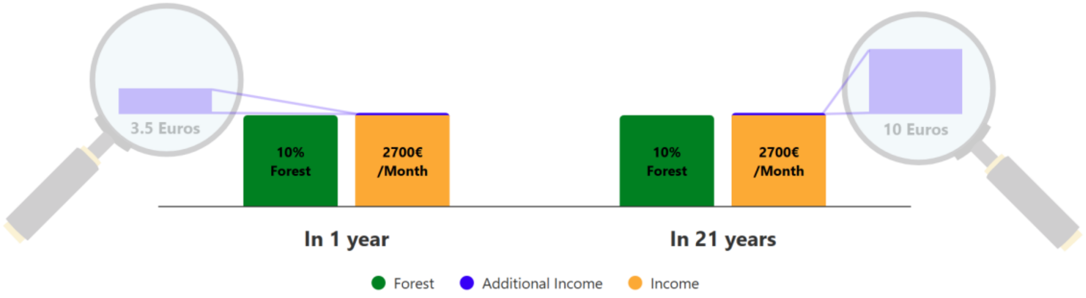

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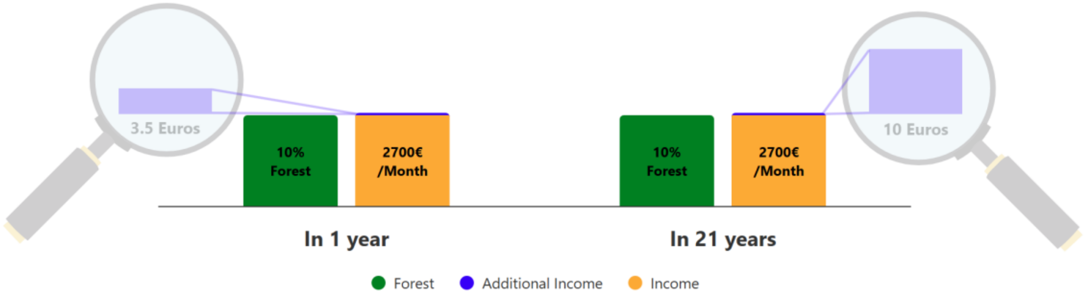

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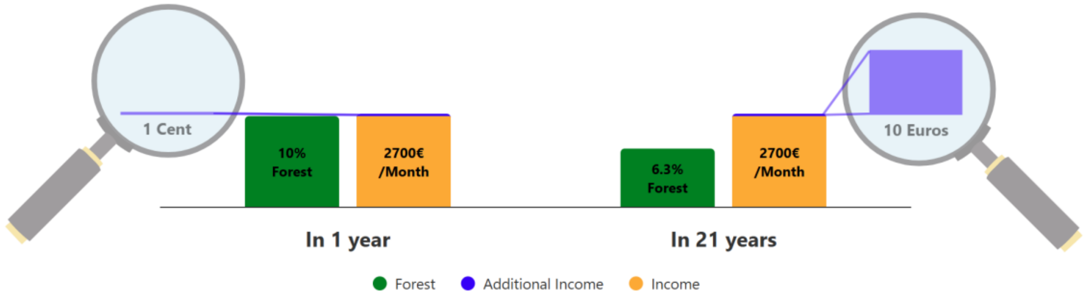

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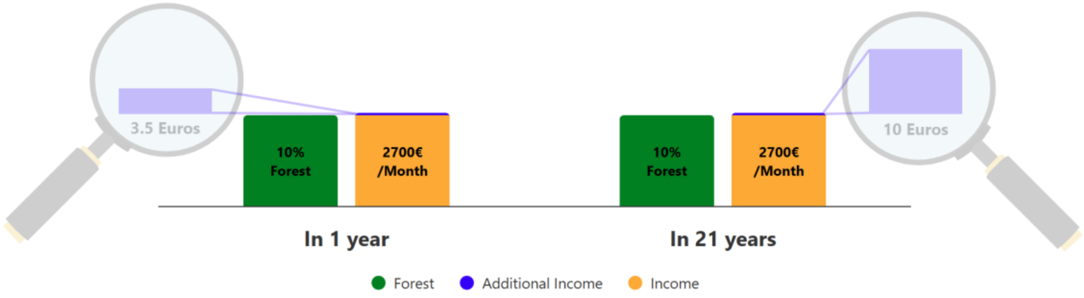

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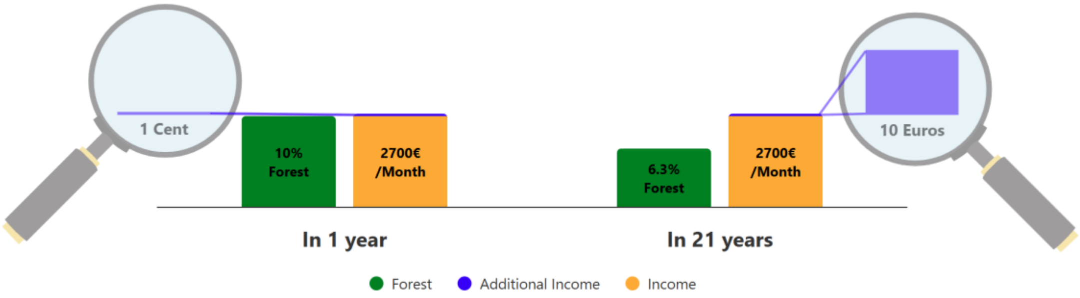

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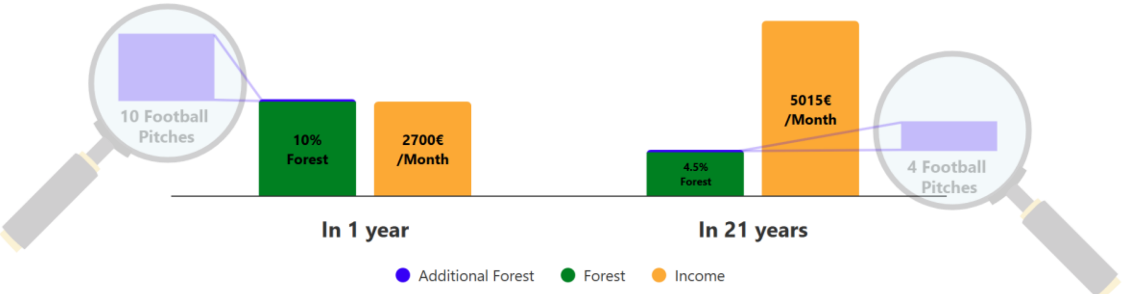
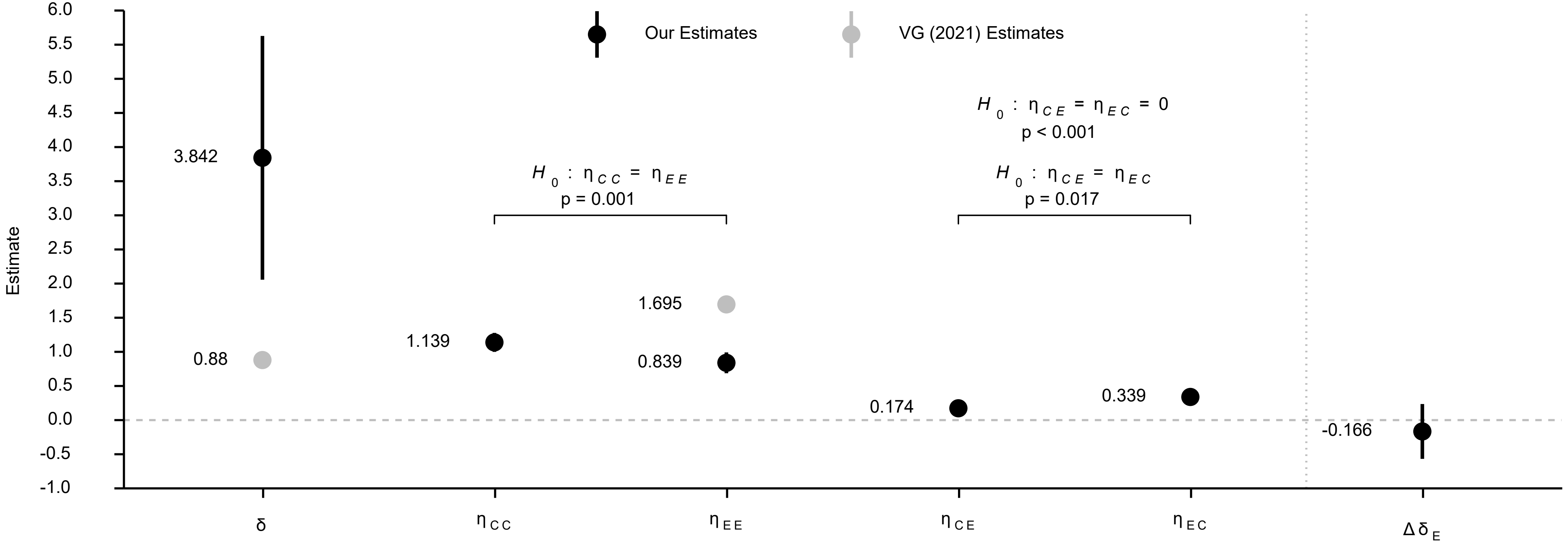


$$SDR_E = \delta + \eta_{EE} g_E + \eta_{EC} g_C$$

Weak substitutes

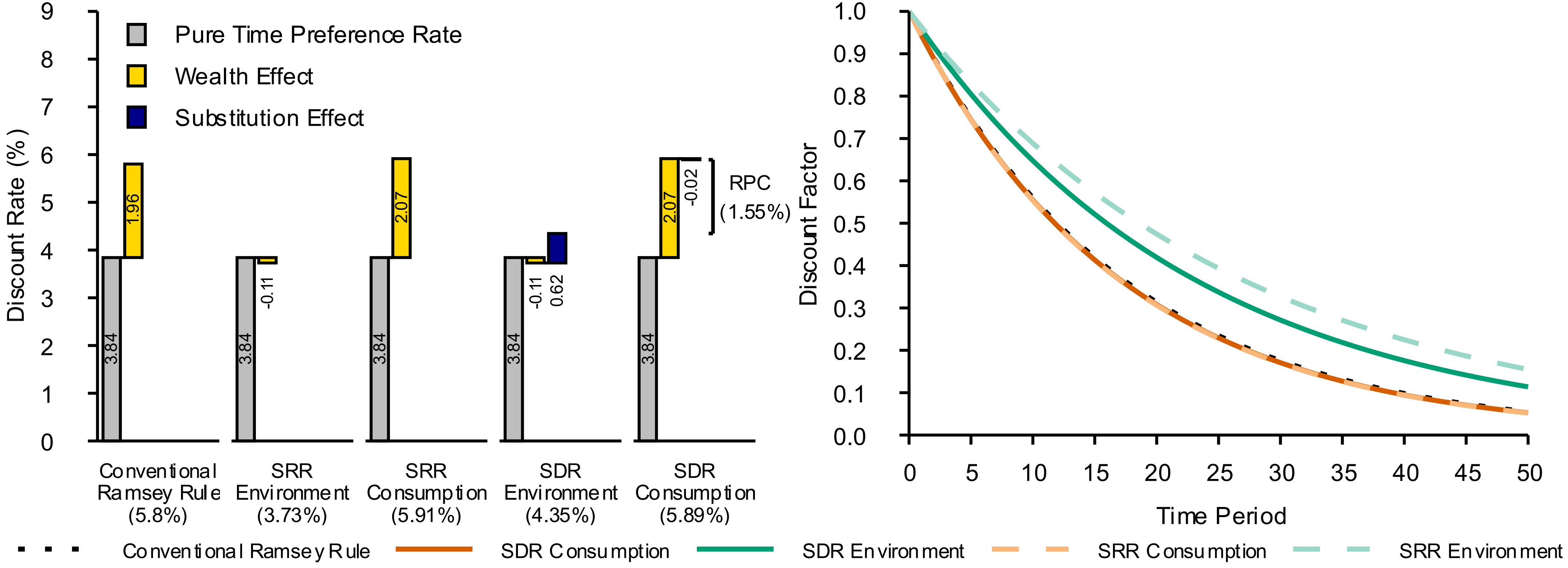
$$SDR_C = 3.84 + 1.14 \times g_C + 0.17 \times g_E$$
$$SDR_E = 3.84 + 0.84 \times g_E + 0.34 \times g_C$$

$$\rightarrow \sigma = 1.32$$



Lower environmental discount rate

Assuming[4] $g_C = 1.82$ and $g_E = -0.135$



Conclusion

Current practices might be misaligned with social preferences:

- Market consumption and non-market environment judged to be weak substitutes
  - Providies rationale for use of dual discount rates
- Environmental discount rate should be 1.55 percentage points lower than consumption rate
  - Using the simple Ramsey rule is erroneous primarily concerning the environment

Going forward:

- Alternative discounting frameworks should be considered
  - We find strong loss aversion and non-constant elasticities; often unaccomodated by models

References

(1): Ramsey, F. P. (1928). A mathematical theory of saving. *The Economic Journal* 38 (152),543–559.

(2): Weikard, H.-P. and X. Zhu (2005). Discounting and environmental quality: When should dual rates be used? *Economic Modelling* 22 (5), 868–878.

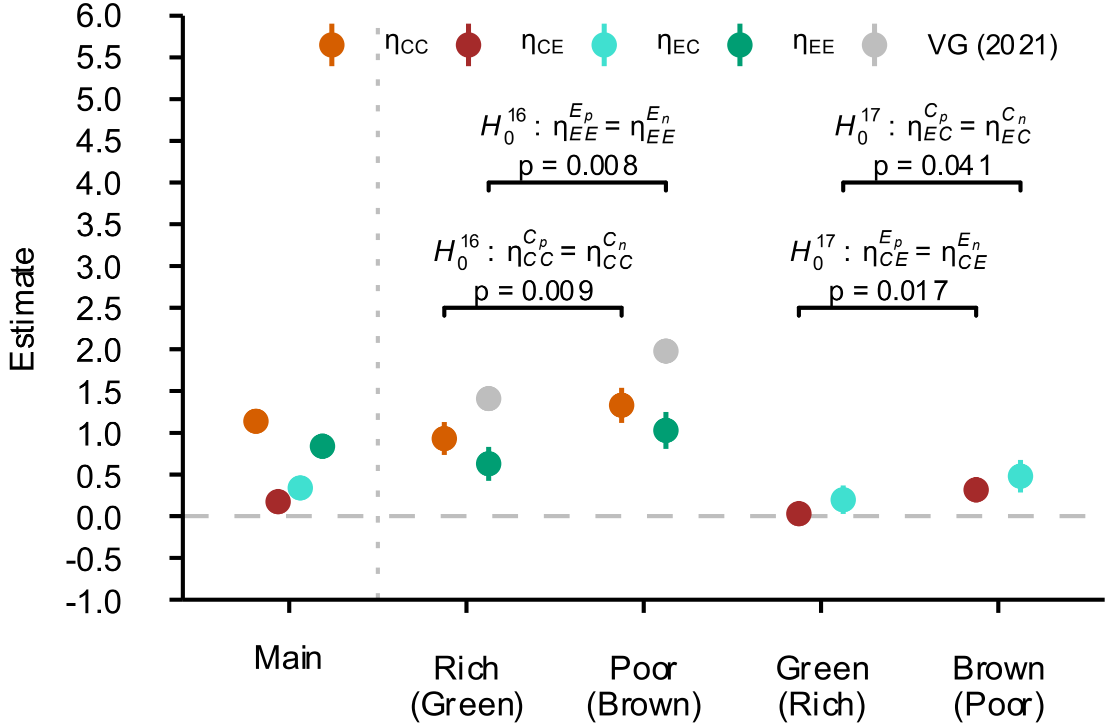
(3): Hoel, M. and T. Sterner (2007). Discounting and relative prices. *Climatic Change* 84 (3),265–280.

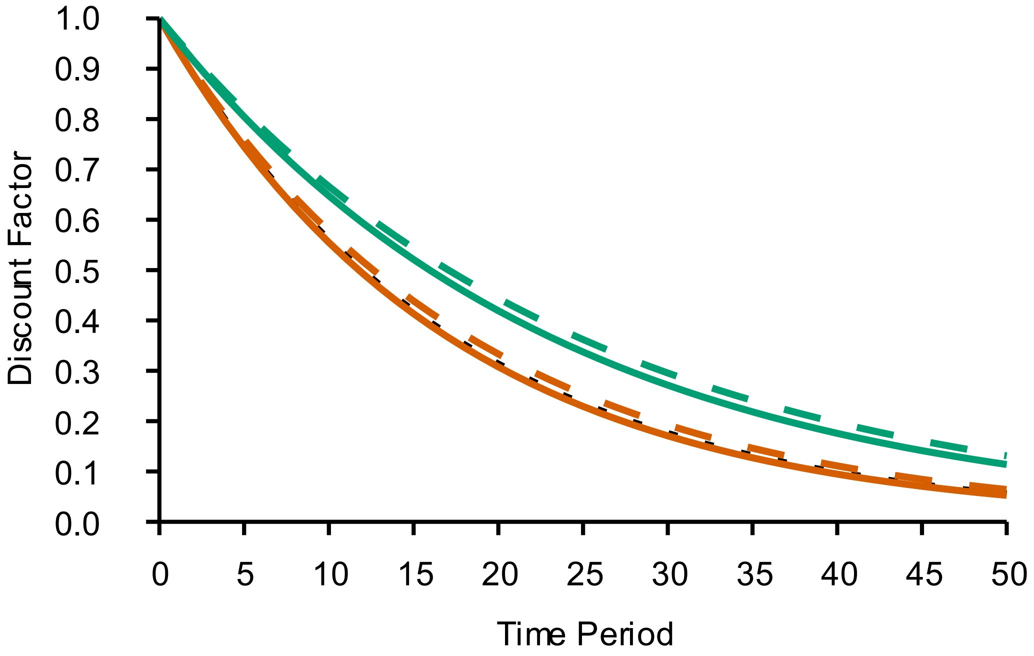
(4): Drupp, M. A., Z. M. Turk, B. Groom, and J. Heckenhahn (2025). Global evidence on the income elasticity of willingness to pay, relative price changes and public natural capital values. *Environmental and Resource Economics*, 1–40.

Appendix

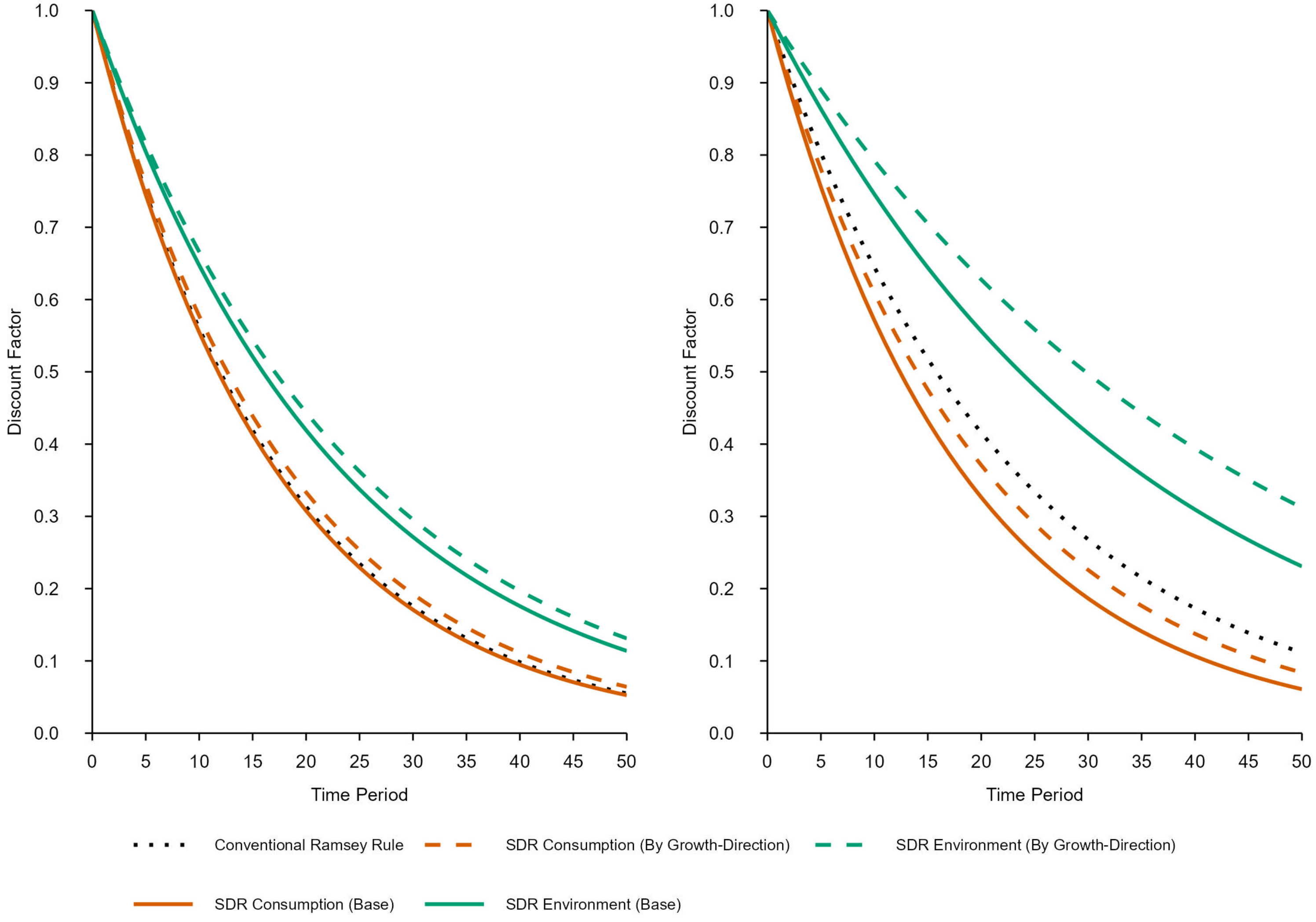
Loss inversion implies downward level-shift for both rates

Assuming[4] $g_C = 1.82$ and $g_E = -0.135$

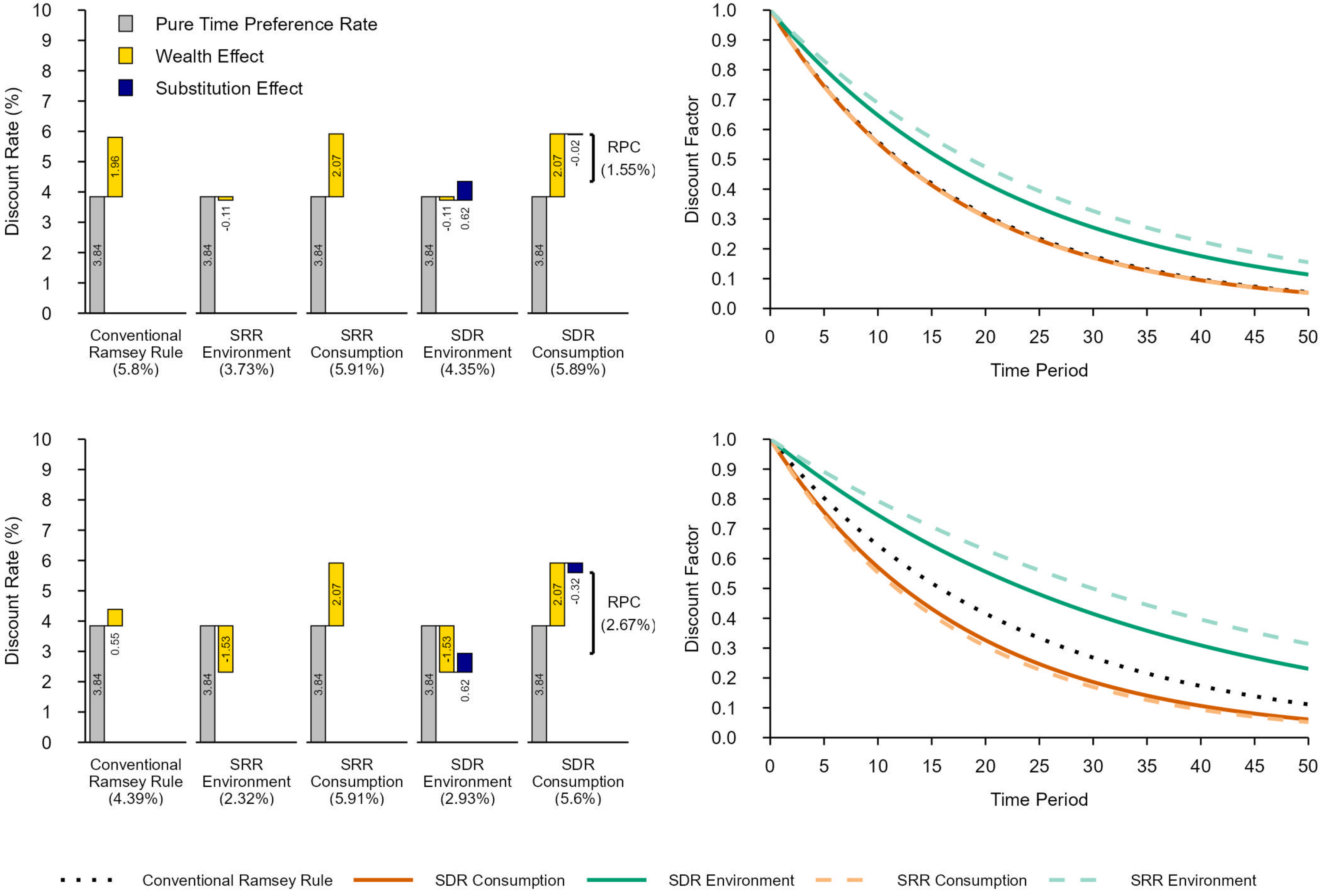




Loss inversion (incl. stronger degrowth scenario)



SDR decomposition (incl. stronger degrowth scenario)



Social discounting, and the environment

- **Social planner that maximizes a discounted-utilitarian social welfare function (SWF)** with standard properties:

$$W = \int_{t=0}^{\infty} U_t(\cdot) e^{-\delta t} dt$$

- **Classic Ramsey growth model (1928)** uses a composite consumption good C_t and a simple production function to arrive at the optimal savings rule between two periods („Ramsey rule“):

$$SDR_{C,t} = \delta + \eta_{CC} g_C$$

- $SDR_{C,t}$ denotes the optimal social discount rate (SDR), δ denotes the pure rate of time preference (PRTP), η_{CC} denotes the simple elasticity of marginal utility w.r.t. consumption, and g_C denotes the consumption growth rate

➢ **The rate of return** (left-side) of a project needs to be **equal to the difference in utility through consumption** (right-side) between the periods.

Social discounting, and the environment

- With an **additional non-market environmental good *E_t*** the Ramsey equation extends to (Weikard & Zhu, 2005; Hoel and Sterner, 2007):

$$SDR_{C,t} = \delta + \eta_{CC} g_C + \eta_{CE} g_E$$

$$SDR_{E,t} = \delta + \eta_{EE} g_E + \eta_{EC} g_C$$

- Where η_{XY} denotes the **elasticity of marginal utility of good *X* w.r.t good *Y***
- Cross elasticities η_{CE} and η_{EC} have never been identified before
- If goods are **‚net' substitutes**, the cross elasticities are positive and if they are complements, they are negative
- **‚Gross' substitution** is measured through the **elasticity of substitution (EOS)** σ which can be shown to be equal to the inverse of $(\eta_{CC} - \eta_{EC})$ or $(\eta_{EE} - \eta_{CE})$
  - Substitutes if consuming one more, say *C*, decreases marginal utility of *C* and marginal utility of *E* similarly. If marginal utility of *E* increases relatively, than increasingly complementary

Social discounting, and the environment

Intuition on **'net' substitutability** (cross elasticities) and **'gross' substitutability** (EOS)

$$SDR_C = \delta + \eta_{CC} g_C + \eta_{CE} g_E$$
$$SDR_E = \delta + \eta_{EE} g_E + \eta_{EC} g_C$$

- How does consumption of, say, *C* change the marginal utility of *E?*
  - **No impact on marginal utility of *E*:** Utility is additively separable ($\eta_{EC} = 0$)
  - **It lowers marginal utility of *E*:** Goods are net substitutes ($\eta_{EC} > 0$)
    - Does it lower marginal utility of *E* to the same extent than the marginal utility of *C*?
      - Yes: Perfect (gross) substitutes: $(\eta_{CC} - \eta_{EC}) \to 0 \quad \Rightarrow \quad \sigma \to \infty$
      - No: Ratio of η_{EC} to η_{CC} indicates extent of net substitutability; gross substitutability ambigious (e.g. complements if $(\eta_{CC} - \eta_{EC}) > 1$)
  - **It increases marginal utility of *E*:** Goods are net complements ($\eta_{EC} < 0$)
    - Again, gross substitutability ambigious and gross complements if $(\eta_{CC} - \eta_{EC}) > 1$

Social discounting, and the environment

	Net substitutes	Net complements	Additively separable
Gross substitutes	$\eta_{EC} > 0$ $0 < (\eta_{CC} - \eta_{EC}) < 1$	$\eta_{EC} < 0$ $0 < (\eta_{CC} - \eta_{EC}) < 1$	$\eta_{EC} = 0$ $0 < \eta_{CC} < 1$
Gross complements	$\eta_{EC} > 0$ $(\eta_{CC} - \eta_{EC}) > 1$	$\eta_{EC} < 0$ $(\eta_{CC} - \eta_{EC}) > 1$	$\eta_{EC} = 0$ $\eta_{CC} > 1$
Perfect (gross) substitutes	$\eta_{EC} > 0$ $(\eta_{CC} - \eta_{EC}) \rightarrow 0$	–	$\eta_{EC} = 0$ $\eta_{CC} = 0$

*For case of good *E* regarding good *C* – switch indices for opposite interpretation (results are unchanged)

Idea

- The Ramsey equation (and its dual discounting extension) are rooted in **social planner preferences** – as these are difficult to observe in the real world, we use **hypothetical decision tasks** instead
- Participants are asked to **trade-off public project decisions** between present and future, **revealing their implied social discount rate** to us
- Through **different framings**, we can sequentially elicit all equation parameters

- To this end we present them with **graphical multiple price lists…**
  - We build upon a study by Venmans and Groom (2021) who partially elicited the parameters of the environmental social discount rate with this approach

Key Information

- **One of two environmental domains** per participants (forests or air quality)
- **Full factorial design**: no/positive/negative growth in one/both domains
  - Therefore 18 decision blocks in total (2x9) per participant
- **Randomized positive/negative growth rates for each domain** but only random across and not within participants (same positive/negative growth rate per domain across tasks)
- **441 student participants** from economic labs in Hamburg, Bremen & Exeter
- **7,879 total observations** (social discount rates)
- **Pre-registered with pre-analysis plan** at AEA RCT Registry (ID: AEARCTR-0015423)

Estimation

Main model:

$$SDR_{C/E;i} = \delta + \eta_{CC} g_{CC;i} + \eta_{EE} g_{EE;i} + \eta_{CE} g_{CE;i} + \eta_{EC} g_{EC;i} + \mathbf{Z_i}\theta + \epsilon_i$$

- where $\boldsymbol{Z_i}$ denotes a set of controls concerning complexity and comprehension for decision block i (Enke et al. 2025)

Relative price change (RPC) equation model:

$$\Delta SDR_i = \beta_\sigma (g_{C;i} - g_{E;i}) + \mathbf{Z_i}\theta + \epsilon_i$$

- where β_σ is the inverse of the elasticity of substitution σ

Relative price change equation and EOS

$$\Delta SDR = \beta_{\sigma}(g_C - g_E)$$

$\downarrow$

0.76 $\rightarrow$ $\sigma = 1.31$
(0.06)

- **Consumption and environment are gross substitutes**, albeit to a limited extend (close to the Cobb-Douglas case of $\sigma = 1$)
- **The difference in the social discount rates** should therefore be 76% of the difference between the growth rates (compared to 0% assumed by simple Ramsey rule with one good)

Workhorse isoelastic utility model

We stick with the welfare function as before:

$$W = \int_{t=0}^{\infty} U_t(\cdot) e^{-\delta t} dt$$

But now we impose more structure by using the workhorse CES-CIES utility function:

$$U_t(C_t, E_t) = \frac{1}{1 - \frac{1}{\gamma}} \left[\alpha C_t^{\frac{\sigma - 1}{\sigma}} + (1 - \alpha) E_t^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{(1 - \frac{1}{\gamma})\sigma}{\sigma - 1}}$$

where σ denotes the constant elasticity of substititution (CES) and γ denotes the constant intertemporal elasticity of substitution (CIES)

Workhorse isoelastic utility model

Dual discount rates then become (Träger, 2011; Zhu et al. 2019):

$$SDR_{C,t} = \delta + \frac{1}{\gamma}\left[\lambda g_C + (1-\lambda)g_E\right] + \frac{1}{\sigma}(1-\lambda)\left[g_C - g_E\right]$$

$$SDR_{E,t} = \delta + \frac{1}{\gamma}\left[\lambda g_C + (1-\lambda)g_E\right] - \frac{1}{\sigma}\lambda\left[g_C - g_E\right]$$

where λ denotes the value share of the consumption good (non-intuitive interpretation)

- CES remain unchanged at 1.31
  - we can test if the EOS is actually constant and cannot reject this hypothesis
- CIES is 0.76 → aggregate consumption is complementary across time periods
  - we (narrowly) reject that the IEOS is constant
- CES-CIES model is internally consistent i.e. different ways of arriving at estimates lead to the same results

Scenario Description (Consumption Good)

Funding Scenario - Block 1 out of 9

Imagine the following "base case" *Funding Scenario:*

Your role: You work for the ministry of economic affairs in your state and have been allocated a fund to support the local population of a region in your state. When the fund is allocated to the region, it is distributed evenly across the population as a tax-free one-time payment to each individual.

The decision: The region that will be supported has already been selected and now you are given the task to decide on the timing of the funding: Either in 1 year or in 21 years. Assume that each member of the local population earns the respective average income and that they do not differ in any other aspect. The only difference between the region in 1 year and in 21 years is the size of the fund, which is reflected by the one-time payment that each individual receives.

All else is equal: In all other regards, the region in 1 year is identical to the same region in 21 years. In particular, the region is equally green, in the sense that it has the same percentage of forest cover. The average net income at both points in time is 2700 Euros/month. Euros are always expressed in Euros of 2025, as if there were no inflation.

There is therefore a trade-off between the amount of money received by each individual and the timing with which they receive the payment. In both cases, you make the decision today and the funds will be reserved right away. Once you made the decision, there is no doubt about the course of action. In particular, there is no political or economic uncertainty involved.

Scenario Description (Environmental Good – Forest)

Forest Scenario - Block 1 out of 9

Imagine the following "base case" _Forest Scenario:_

Your role: You work for the environmental agency of your country. A sand extraction company approaches you. They operate a number of extraction quarries in various forests of your country, which are a common source of sand. They want to stop operating one of its quarries temporarily, because they have to change their method of operation. For technical reasons (drainage) this transition from one method to another takes 5 years.

The decision: They propose to give access to the public on this site for recreational purposes during the transition (When the site is in operation, the public cannot access it for security reasons). The sand extraction company makes two proposals to you that require the same compensation payment: Either they temporarily stop the operations of a quarry in 1 year or in 21 years. The only difference is the size of the quarry made accessible.

Note: *The space made available only matters for recreational purposes. Due to its size, relative to the total forest cover, it does not affect aspects like pollution levels or biodiversity.*

All else is equal: During operations, the region in 1 year is identical to the same region in 21 years, in all regards. In particular, the region has the same economic performance, in the sense that the average income of the population is equal at both points in time. Assume that each member of the local population earns the respective average income and that they do not differ in any other aspect. The average net income of the region is 2700 Euros/month at both points in time. Euros are always expressed in Euros of 2025, as if there were no inflation.

There is therefore a trade-off between the quantity of forest that is made accessible and the timing. In both cases, the compensation payment to cease the operations will happen today. Once the contract is signed, there is no doubt about the course of the operations.

Scenario Description (Environmental Good – Air Quality)

Air Quality Scenario - Block 1 out of 9

Imagine the following "base case" *Air Quality Scenario:*

Your role: You work for the environmental agency of your country. A team of geologists informs you that a volcanic system in your country is continuously leaking gases which leads to increased air pollution in the local region. In fact, the gases released are very similar to the polluting gases from car traffic. They propose to seal the rifts in the terrain through which the gases are leaking. However, the sealing only persists for 5 years after which the gases will leak through the rifts again.

The decision: The geologists propose to seal the rifts either in 1 year or in 21 years and you have to decide on the timing. Sealing the rifts increases the air quality in the local region temporarily. Air quality is measured with an index, where a higher number resembles higher air quality. An air quality of 1000 is considered to be average. Due to environmental circumstances the effectiveness of sealing the rifts differs, depending on the timing. Therefore, the possible air quality improvement differs as well.

Note: Sealing only matters for air pollution. The volcano is inactive, poses no danger and sealing the rifts does not influence its activity.

All else is equal: The region surrounding the volcano in 1 year is identical to the same region in 21 years, in all regards. In particular, the region has the same economic performance, in the sense that the average income of the population is equal at both points in time. Assume that each member of the local population earns the respective average income and that they do not differ in any other aspect. The average net income of the region is 2700 Euros/month at both points in time. Euros are always expressed in Euros of 2025, as if there were no inflation.

There is therefore a trade-off between the amount of improvement in air quality and the timing. In both cases, the costs of sealing are the same and are paid today. Once the decision is made, there is no doubt about the course of action.