Investment Policy for Time-Inconsistent Discounters

Bård Harstad

Northwestern/Oslo

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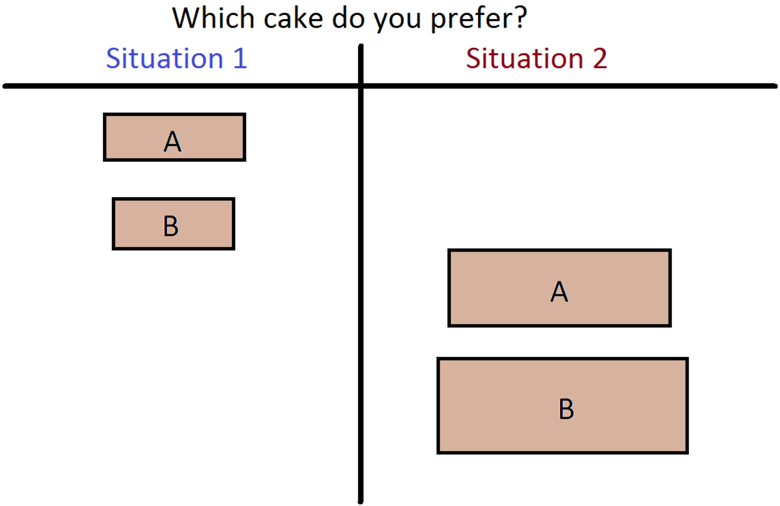
Like cake?



Public investments/policies with long-term consequences

- Education, child-care
- Research, academic research ("grunnforskning")
- Infrastructure (roads, bridges, tunnels...)
- Extraction of exhaustible/renewable resources
- Conservation, preservation of nature/species
- Pollution, emissions, recycling-programs
- **How should we evaluate such projects?**

The standard approach

- Rae, Jevons, Senior, Bohm-Bawerk: Multiple conflicting psychological factors
- Ramsey (1928):

$$\max \sum_{t=0}^{\infty} D(t) u\left(c_t\right).$$

- Samuelson (1937):

$$D\left(t\right) = \delta^t = \left(\frac{1}{1+r}\right)^t \approx e^{-rt}.$$

- Koopman's (1960) axiomatic foundation: period-independence, impatience, stationarity, continuity, sensitivity...
- The discount-rate for consumption becomes:

$$\begin{aligned} \rho &\approx \delta + \omega \dot{c} \\ &\approx 1 + 2 \cdot 4 = 7\%, \text{ where} \\ \omega &\equiv -\frac{u''\left(c_0\right)}{u'\left(c_0\right)} c_0. \end{aligned}$$

The standard approach: Norway

- **NOU 1997, 27**:109-110: "En slik konklusjon vil tilsynelatende føre til at få miljøprosjekter eller andre prosjekter med svært langsiktige virkninger blir gjennomført. Det er imidlertid flere forhold som tilsier at [dette] neppe vil gi et slikt resultat"
  - "Dersom senere generasjoner blir rikere enn oss, vil den relative prisen på miljøgoder tendere til å gå opp. Dette følger av at miljøgoder i de fleste tilfeller trolig har høy inntektselastisitet, samtidig som tilbudet vanskelig kan økes. I tillegg vil økt knapphet på miljøgoder føre til at kalkulasjonsprisene går opp"
- Matemathically, given $u(c_t, e_t)$, the discount-rate for the e-good is:

$$\begin{aligned}
\rho &\approx \delta + \omega_e \dot{e} + \omega_{e,c} \dot{c} < \delta \approx 1\% \text{ if} \\
\dot{e} &< 0 \text{ and} \\
\omega_{e,c} &\equiv -\frac{u_{ec}(c_0, e_0)}{u_e(c_0, e_0)} c_0 < 0.
\end{aligned}$$

- "En slik økning i relativ pris bør håndteres gjennom kalkulasjonsprisene..."

The standard approach: Multiple weaknesses

- Samuelson careful: not suggesting realism or normative
- Koopman's axioms are *very* strong
  1. Period-independence: In reality, rising paths often preferred
  2. We are required to be impatient
  3. We are required to have stationary preferences

Impatience: *Normative* justifications?

- Standard utilitarianism requires $\delta = 0$
- Ramsey (1928): "how much of its income should a nation save? ...it is assumed that we do not discount later enjoyments in comparison with earlier ones, a practice which is ethically indefensible and arises merely from the weakness of the imagination"
- "a philosophical tradition, stretching from Ramsey 28 to Parfit 84, that has warned us against discounting future utilities without providing serious arguments" (Dasgupta, Barrett, and Maler, 1996).
- "Serious arguments"?
  1. Utilitarianism insensitive to distribution?
  2. Existence of solutions ("an unfair and absurd test" Phelps 1989)
  3. Risk of dying (Blackorby and Donaldson 1977)
- No convincing *normative* argument for $\delta > 0$

Impatience: *Empirical* foundation

- A *benevolent planner* would perhaps prefer $\delta = 0$
  - But she has no power in the real world :(
- Today's individuals *do* discount
  - Politicians are individuals - they *do* discount
  - Politicians are accountable/elected by individuals: they *should* and *must* discount
- As an economist: I must help them out!

Stationarity: Lack of *empirical* foundation

- But with this motivation, we need to understand "time preferences"
- Stationarity is technically convenient, but lacks both theoretical and empirical foundations
- **Intuitively:** The difference between t and $t+1$ vanishes as t grows (Strotz 1955). Human senses compares relative differences (this is not "irrational")
- **Empirically:** Individuals are not consistent over time: Eisenhauer and Ventura (2006), Angeletos et al, O'Donoghue and Rabin (1999): hyperbolic individuals will show exactly the low IRA participation we observe
- **Experimentally:** Viscusi and Huber (2006), Kirby and Marakovic (1995), Benhabib, Bisin and Schollter (2010), Ainslie (1992), Kirby and Herrnstein (1995), Thaler
- **Neuroscience:** McClure et al (2009), McLure et al (2004)
- **Governments:** In practice, policymakers have begun applying lower discount rates to long-term, intergenerational projects (Bazerlon and Smetters 1999)

Stationarity: Lack of *theoretical* foundation

- Thoughtful parents, Arrow (1973), Dasgupta (1974), Barro and Becker (1989):

$$w_t = u\left(c_t\right) + \delta w_{t+1}$$

- Recursively,

$$w_t = \sum_{\tau=t}^{\infty} \delta^{\tau-t} u\left(c_t\right)$$

- But suppose:

$$w_t = u\left(c_t\right) + \delta_1 w_{t+1} + \delta_2 w_{t+2} + \ldots$$

- Then, the effective discount rate decreases in t (Saez-Marti and Weibull, 2005 - and Harstad 1999)

Actual time preferences: What are they?

- A variety of estimates, but exponential discounting rejected.

$$w_t = \sum_{\tau=t}^{\infty} \left(\sqcap_{s=t}^{\tau} \delta_{s-t} \right) u_\tau \left(c_\tau \right)$$

- Hyperbolic discounting:

$$D\left(t\right) = \frac{1}{1+kt},\ k > 0.$$

- Phelps and Pollak (1968) argued for "imperfect altruism", where $\beta < 1$:

$$w_t = u\left(c_t\right) + \beta \sum_{\tau=t+1}^{\infty} \delta^{\tau-t} u\left(c_\tau\right).$$

- Laibson (1994 - 2030) etc adopts this function also to within-lifetime choices. Many names: (β, δ)-discounting, quasi-geometric discounting, quasi-exponential discounting, quasi-hyperbolic discounting, hyperbolic discounting

Consequences for project evaluation

- Discount benefits/costs at t at a lower rate if t is large
- With hyperbolic discounting, implement project if:

$$\begin{aligned} \Delta u_0 + \frac{1}{1+kt}\Delta u_t &> 0 \Rightarrow \\ \frac{1}{1+\overline{r}} &= \sqrt[t]{\frac{1}{1+kt}} \\ &\rightarrow 1 \text{ as } t \rightarrow \infty. \end{aligned}$$

- With (β, δ)-discounting, implement project if:

$$\begin{aligned} \Delta u_0 + \beta\delta^t \Delta u_t &> 0 \Rightarrow \\ \frac{1}{1+\overline{r}} &= \delta\sqrt[t]{\beta} \text{ or} \\ &\rightarrow \delta \text{ as } t \rightarrow \infty. \end{aligned}$$

Consequences for stationarity

- Costly today? Better to postpone until tomorrow!
  - People save too little (subsidize saving: Krusell et al 2010)
  - Retire too early (Diamond and Koszegi 2003)
  - Reason for obesity (Scharff 2009)
  - Smoke too much (tax tobacco more: Gruber and Koszegi 2001, 2004)
  - Governments delay projects (moon-landing), etc
- Great plans for the future postponed

Consequences for commitment

- With time inconsistency, pre-commitment is beneficial:
  - Saving plans (costly to exit). Thaler and Benartzi's (2004) "Save More Tomorrrow" program (SMarT)
  - Annual gym-membership (DellaVigna and Malmendier 2006) or appointments with friends
  - Establish rules: No deficit (handlingsregelen)
  - Investments in technologies...

A simple model with technology

- Suppose $w_0 = \sum_{\tau=0}^{\infty} \left(\prod_{s=0}^{\tau} \delta_s\right) u_\tau\left(c_\tau\right)$, $\delta_1 < \delta_2 < ...$
- In period 1, the government pollutes e, causing harm $-e$ in period period 2:

$$u_e\left(e, a\right) = \delta_1$$

- In period 0, we would have preferred a smaller e, given by:

$$u_e\left(e, a\right) = \delta_2 > \delta_1$$

- Invest in technology a to influence future decision?
- Answer: If $u_{ea} = 0$, invest until:

$$c'\left(a\right) = \delta_1 u_a\left(e, a\right).$$

- More generally: Invest more in substitutes, less in complements:

$$\begin{aligned} c'\left(a\right) &= \delta_1\left[u_a + \frac{u_{ea}}{u_{ee}}\left(\delta_2 - \delta_1\right)\right] \\ &= u_a\left(e, a\right)\left[\delta_1 + \frac{u_{ea} u_e}{u_a u_{ee}}\left(\delta_2 - \delta_1\right)\right] \end{aligned}$$

Adjust the discount factor/rate?

- Discount factor:

$$
\begin{aligned}
c'(a) &= \delta_a u_a \text{ where} \\
\delta_a &= \delta_1 \left[1 + \frac{u_{ea} u_e}{u_a u_{ee}} \left(\frac{\delta_2}{\delta_1} - 1 \right) \right]
\end{aligned}
$$

- With quasi-hyperbolic discounting:

$$\delta_a = \beta\delta \left[1 + \frac{u_{ea} u_e}{u_a u_{ee}} \left(\frac{1}{\beta} - 1 \right) \right].$$

- With perfect substitutes, $u = u(g + R)$:

$$\delta_a = \delta > \beta\delta = \delta_1.$$

- With perfect complements (Cobb-Douglas):

$$\delta_a = \delta (2\beta - 1) < \beta\delta = \delta_1 < \delta = \delta_2.$$

Subsidize/tax private investments?

- With subsidy s (or tax, if $s < 0$) private invest until:

$$c'(a) = \delta_1 (1+s) u_a,$$

- The optimal s is:

$$s_a = \frac{u_{ea} u_e}{u_a u_{ee}} \left(\frac{\delta_2}{\delta_1} - 1 \right).$$

- With quasi-hyperbolic discounting:

$$s_a = \frac{u_{ea} u_e}{u_a u_{ee}} \left(\frac{1}{\beta} - 1 \right).$$

- For perfect substitutes, $u = u(e+a)$:

$$s_a = \frac{1}{\beta} - 1 > 0.$$

- For perfect complements (Cobb-Douglas):

$$s_a = 1 - \frac{1}{\beta} < 0.$$

Conclusions

1. Intuitively, empirically, and experimentally: Discount rates decline with the time horizon
2. This should be reflected in public CBA
3. Long-term benefits/costs should be discounted at a lower rate
4. Time inconsistency is a consequence and concern; not a critique
5. Pre-commitments are beneficial
6. Many public projects permit such commitments
    1. Investments in substitutes to future bads, or complements to future goods, should be subsidized or discounted at lower rates
    2. Investments in substitutes to future goods, or complements to future bads, should be taxed or discounted at higher rates