The discounting controversy

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Our responsibilities towards the future generations

- Do we do enough for the future ?
- Universal policy applications:
  - Capital accumulation, infrastructure
  - Pension liabilities, public debt
  - R&D, scientific research
  - Environment, natural resources, climate change
- This is a difficult question, mainly because of the uncertainties surrounding our collective destiny.
- At the end of the day, in a decentralized economy, everything relies on how we price the future.

Social Cost of Carbon in the U.S.

Social Cost of CO_2, 2015-2050 [a] (in 2007 Dollars per metric ton CO_2)

Source: Technical Support Document (PDF, 21 pp, 1 MB): Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015)

	Discount Rate and Statistic			
Year	**5% Average**	**3% Average**	**2.5% Average**	**3% 95th percentile**
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

a The SC-CO_2 values are dollar-year and emissions-year specific.

Why do we discount the future?

- Positive arguments:
  - People are impatient. Rate of pure preference for the present δ.
  - There is an opportunity cost to capital.
  - If we would perform all actions whose current cost is smaller than the unweighted sum of future benefits, nothing would remain for consumption today.
- Normative arguments:
  - These future generations will be wealthier than us anyway.
  - Investing for the future is risky, and future generations are risk-averse.

The positive approach to discounting: Opportunity cost of capital

- Arbitrage argument: Reallocating capital from a productive sector of the economy to fighting climate change should be beneficial to future generations.
- The discount rate for a green project should be equal to the expected rate of return of a traded asset with the same risk and duration profile.
  - What is the expected rate of returns for different risk profiles?
  - What is the risk profile of climate mitigation?

Historical returns: Real annualized 20-year bond returns (in %)

	2000-2014	1965-2014	1900-2014
Canada	6.0	4.0	2.2
China	3.0		
France	6.6	5.9	0.2
Germany	7.5	4.9	-1.4
Japan	3.9	4.4	-0.9
United Kingdom	3.6	3.2	1.6
United States	6.0	3.4	2.0
World	5.5	4.3	1.9

Source: Elroy Dimson, Paul Marsh and Mike Staunton, Credit Suisse Global Investment Returns Sourcebook 2015

Historical returns: Real annualized equity returns (in %)

	2000-2014	1965-2014	1900-2014
Canada	4.2	4.8	5.8
China	3.0		
France	0.6	5.2	3.2
Germany	1.5	5.0	3.2
Japan	0.1	4.4	4.1
United Kingdom	1.0	6.2	5.3
United States	2.4	3.4	6.5
World	1.8	5.3	5.2

Source: Elroy Dimson, Paul Marsh and Mike Staunton, Credit Suisse Global Investment Returns Sourcebook 2015

Critiques to the positive approach

- Are asset prices right?
- Efficiency issues:
  - Future generations cannot trade $\rightarrow$ OLG models.
  - The competitive equilibrium may not be efficient.
- Equity issues:
  - May our individualistic impatience drive our collective attitude towards the future?
  - Even if efficient, the equilibrium may be socially undesirable because of large intertemporal inequalities.
- Observability issue:
  - No risk free asset with large maturities.

The normative approach under uncertainty: Related literature

- Public and environmental economics
  - Ramsey (1928): Solve the optimal saving/investment problem under certainty.
  - Weitzman (2001): Gamma discounting under uncertainty.
  - Stern Review (2007): No consensus on the discount rate.
- Asset pricing theory
  - Consumption-based CAPM: Lucas (1978), Rubinstein, Breeden, Hansen,...
  - Long-run risk: Bansal and Yaron (2004), ...
  - Parameter uncertainty: Veronesi (2000), ...
- Giglio, Maggiori and Stroebel (2015): The discount rate observed on real estate markets for 100_{+}-year maturities is 2.6%.

Welfare and discounting

- Consider a marginal investment that reallocate consumption over time: Cashflow $(F_0, F_1, ...)$.
- When does it increase intertemporal/intergenerational welfare?

$$V_0 = E_0 \int_0 e^{-\delta t} U(C_t) dt$$

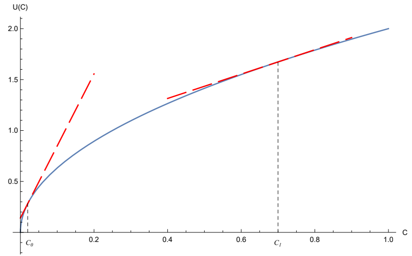
- It does increase V_0 iff the present value of the flow of expected benefits $(EF_0, EF_1, ...)$ is positive.
- Socially desirable discount rates:

$$\rho_t = \delta - \frac{1}{t} \log \left(\frac{EF_t U'(C_t)}{U'(C_0) EF_t} \right)$$

- Calibration: U, δ, and joint distribution of (C_t, F_t).

Inequality aversion is central

- Inequality aversion $\gamma \geq 0$.
- In a growing economy, investing raises intergenerational inequalities.
- The discount rate is the minimum rate of return of the project that compensates for this adverse effect.



Ramsey (1928) rule

- Suppose that
  - the relative aversion γ is constant.
  - the growth rate of consumption is a constant g: $C_t = C_0 \exp(gt)$.
  - the cash-flow is certain.
- Then,

$$\rho_t = \delta + \gamma g.$$

- The discount rate equals the product of inequality aversion by the growth rate of consumption.

Measure of inequality aversion

- Consider an economy with 2 social groups of equal size, A and B. Each agent in group A is 2 times wealthier than in group B.
- We can transfer wealth from A to B. What is the maximum sacrifice of A that Society should accept for B to get one more dollar ?

inequality aversion	sacrifice of the rich
0.0	\$ 1.00
0.5	\$ 1.41
1.0	\$ 2.00
2.0	\$ 4.00
4.0	\$ 16.00

Measure of inequality aversion: Experts' view

author	inequality aversion	growth rate	discount rate
Stern (1977)	2		
Cline (1992)	1.5	1%	1.5%
IPCC (1995)	1.5-2	1.6%-8%	2.4% - 16%
Arrow (1995)	2	2%	4%
UK: Green Book (2003)	1	2%	2%
Stern (2007)	1	1.3%	1.3%
Arrow (2007)	2-3		
Dasgupta (2007)	2-4		
Weitzman (2007)	2	2%	4%
Nordhaus (2008)	2	2%	4%

Precautionary motive to invest safely

- Precautionary behavior: we save more when our future becomes more uncertain.
- At the collective level, this is done by reducing the discount rate.
- By how much?
- Suppose that consumption follows a geometric Brownian process with trend μ and volatility σ.
- Extended Ramsey rule:

$$r_{ft} = \delta + \gamma\mu - \frac{1}{2}\gamma^2\sigma^2$$

- Historically, the precautionary term is small ($\simeq$ 0.1....0.3%).
- Risk-free rate puzzle: Large risk-free discount rate.
- The term structure of riskfree discount rates is flat.

CCAPM risk premium and market short-termism

- Suppose that
  - consumption follows a geometric Brownian process with trend μ and volatility σ;
  - the income-elasticity of the net benefit of the project is a constant β.

$$\Rightarrow \rho_t = r_{ft} + \beta\gamma\sigma^2$$

- The aggregate risk premia ($\pi_t = \gamma\sigma^2$) are small ($\simeq 0.1....0.3\%$) and are the same for all maturities.
- For risky investments, markets have been extremely short-termist during the last century.

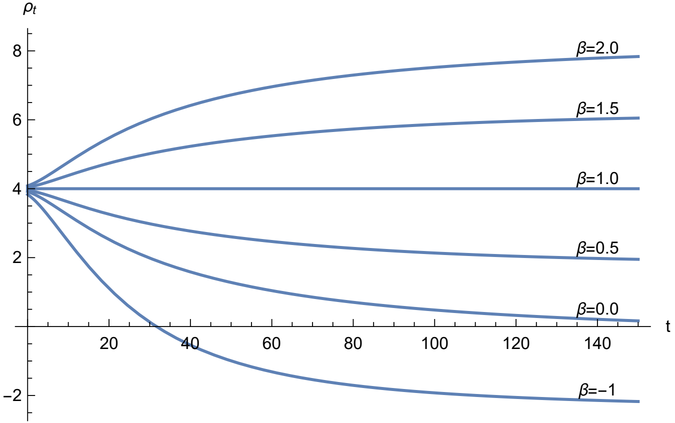
Filling the gap between the positive and normative approaches

- Empowering risk in the normative model.

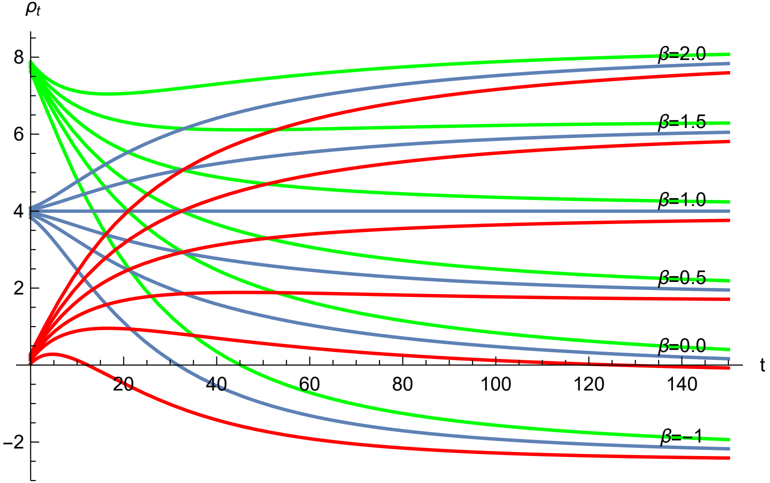
1. Literature on Long Run Risk (Bansal and Yaron (2004)).
   - Disentangle inequality aversion from risk aversion;
   - A slow-moving hidden variable (trend or volatility);
   - The persistence of shocks yields a decreasing r_{ft} and a decreasing π_t.
2. Literature on deep uncertainties and learning.
   - Magnifies the long-term risk.
   - Also implies the same term structures.
3. Literature on catastrophic events (Barro (2006)).

Application: Uncertain trend

- $\delta = 0$, $\gamma = 2$, $\sigma = 2\%$, and $\mu \sim (1\%, 1/2; 3\%, 1/2)$



Application 3, surimposing mean-reversion



Barro's model with a certain probability of catastrophes

- Barro (2006) observes 60 catastrophes over 3500 country-years. Best estimate of the probability of catastrophe: $p = 60/3500 = 1.7\%$.
- Following Martin (2013), let us consider a mixture of normal distribution: $g \sim N(h_1, 1-p; h_2, p)$.
  - $h_1 \sim N(\mu_1, \sigma_1^2)$ with $\mu_1 = 2.5\%$ and $\sigma_1 = 2\%$;
  - $h_2 \sim N(\mu_2, \sigma_2^2)$ with $\mu_2 = -39\%$ and $\sigma_2 = 25\%$;
- Assuming $\delta = 3\%$ and $\gamma = 4$ as in Barro (2006), we obtain $\forall t$
  - $r_{ft} = 0.2\%$;
  - $\pi_t(1) = 6.0\%$.

Extensions

- Environmental economics questions:
  - Discounting of environmental assets: Relative scarcity and evolution of relative prices.
  - Uncertain substitutability of ecological services.
  - Option values and discounting.
- Decision theory questions:
  - Disentangling risk aversion and aversion to fluctuations (and inequality aversion?): Epstein-Zin preferences, and alternative models.
  - Multivariable stochastic dominance orders and the role of autocorrelation of growth rates.
  - Time consistency, hyperbolic discounting, and the political economy of climate change.

Take-home messages

- CBA is about social welfare: $NPV > 0 \Leftrightarrow \Delta V_0 > 0$.
- Ethical justification of discounting (Ramsey rule): In a growing economy, investing raises intertemporal inequalities.
- Calibration requires agreeing on
  1. our collective degree of inequality aversion;
  2. our collective beliefs relative to long-term prosperity.
- We must favor projects that reduce the collective risk.
- There are arguments for using a smaller riskfree discount rates for longer maturities.