Measuring the Social Cost of Carbon under Uncertainty

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Why do climate activists (and others) hate economists?

- Because we support climate policies that are too weak. We are short-termist, as the markets that we defend.
  - Does utilitarianism impose short-termism?
  - What is the optimal degree of long-termism? Choice of the discount rate?
- Why do we discount the future? Under certainty (Ramsey):
  - Because we are inequality-averse and we believe in growth.
  - With a growth rate of 2%, it is socially desirable to discount everything at a rate of 4%.
- But LT growth is deeply uncertain. Our DEU model provides arguments for smaller discount rate.
- What discount rate should be used to estimate the carbon price?
  - What is the social cost of carbon under this deeply uncertain future?

Social Cost of Carbon in the U.S. for 2020

$$\underbrace{52\$/tCO_2}_{\substack{\text{Obama}\\ \text{DR=3\%}}} \rightarrow \underbrace{1\$/tCO_2}_{\substack{\text{Trump}\\ \text{DR=7\%}}} \rightarrow \underbrace{52\$/tCO_2}_{\substack{\text{Biden}\\ \text{DR=3\%}}} \rightarrow \underbrace{190\$/tCO_2}_{\substack{\text{EPA (2022)}\\ \text{DR=2\%}}}$$

Social preferences: Utilitarianism

- Preferences under the veil of ignorance.
- Independence axiom: If one prefers X over Y, one also prefers X with probability p over Y with probability p.
- This implies the Discounted Expected Utility model:

$$V_0 = \sum_{t=0}^{T} e^{-\delta t} E_0[U(C_t)]$$

- The concavity of U represents risk and inequality aversions, which are equivalent under the veil of ignorance.
- Constant Relative Risk/Inequality Aversion: $U(C_t) = \frac{C_t^{1-\gamma}}{1-\gamma}$.

Pricing formula for future benefits

- Consider an uncertain payoff B_t in t years.
- Definition of the present value PV of B_t:

$$U(C_0 - PV) + e^{-\delta t} E_0 U(C_t + B_t) = U(C_0) + e^{-\delta t} E_0 U(C_t)$$

$$PV = \underbrace{e^{-\delta t} \frac{E_0[B_t U'(C_t)]}{U'(C_0) E_0[B_t]}}_{= \exp(-\rho_t t)} E_0[B_t]$$

The Ramsey rule in a risk-free economy

- Suppose $C_t = C_0 \exp(gt)$. Then, equation (1) implies the Ramsey rule:

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

- Why do we discount the future in a risk-free economy (beyond the immoral rate δ of preference for my generation)?
  - Because in a growing economy, investing for the future increases intergenerational inequalities;
  - In a growing economy, the discount rate is the minimum IRR that compensates for the welfare-deteriorating impact that investing generates on the generational distribution of consumption.

A model-free Ramsey rule

- Okun's leaky bucket experiment (reversed):
  - X consumes twice what Y consumes.
  - Okay to sacrifice up to 0.25 from Y to give 1 to X.

- Suppose that consumption doubles every 35 years.
- Conclusion: The PV of 1 in 35 years equals 0.25.
  - This means using a discount rate of 4%.

A model-free Ramsey rule

- Okun's leaky bucket experiment (reversed):
  - X consumes twice what Y consumes.
  - Okay to sacrifice up to 0.25 from Y to give 1 to X. $\Rightarrow \gamma = 2$
- Suppose that consumption doubles every 35 years. $\Rightarrow g = 2\%$
- Conclusion: The PV of 1 in 35 years equals 0.25.
  - This means using a discount rate of 4%$= \gamma g$.

The Stern Report Clash of 2007

$$r_f = \delta + \gamma g$$

Calibration	δ	γ	g	r_f	SCC
Nordhaus	1.5%	1.45	2.15%	4.62%	$\sim 20\$/tCO_2$
Stern	0.1%	1.00	1.30%	1.40%	$\sim 200\$/tCO_2$

My take on this debate

- Morale issue on the rate of pure preference for "us" (the present). Consensus at $\delta = 0$.
- Inequality aversion = risk aversion under the veil of ignorance. I take $\gamma = 2$.
- What about g? Long-term growth rates are deeply uncertain.
  - It makes little sense to build an answer to our sustainability concerns by assuming a large growth rate for the future.
  - What is the impact of long-term uncertainties on the estimation of the SCC?
- Most projects have uncertain LT impacts. The discount rate needs to be risk-adjusted.
  - I examine impacts having a constant income-elasticity: $B_t = \xi C_t^{\beta}$.

Normative CCAPM

- Suppose that C_t follows a geometric Brownian process with trend μ and volatility σ.
- In this case, equation (1) yields the Consumption-based Capital Asset Pricing Model (CCAPM).
  - Linear risk-adjustment to the β:

$$\rho_t = r_f + \beta\pi$$

  - Extended Ramsey rule:

$$r_f = \delta + \gamma\mu - 0.5\gamma^2\sigma^2$$

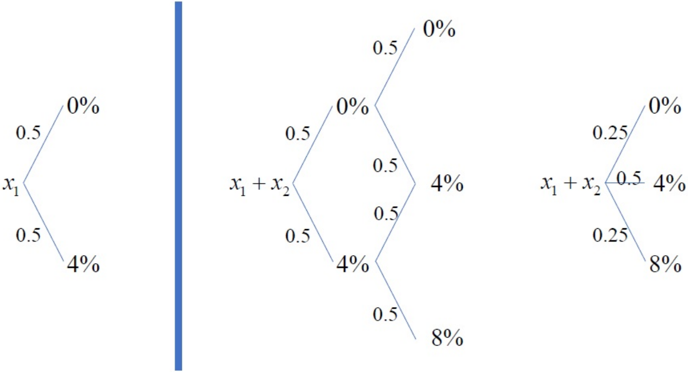
  - Aggregate risk premium:

$$\pi = \gamma\sigma^2$$

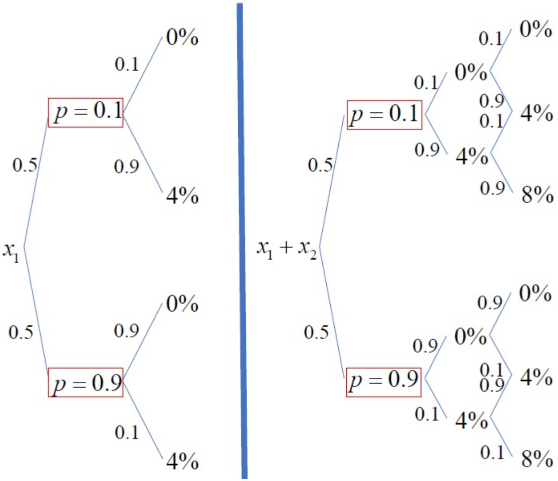
My take on the normative CCAPM

- The macro uncertainty reduces the risk-free rate r_f: Precautionary investment motive (U' convex).
- A valuation bonus should be given to actions that hedge the macro risk ($\beta < 0$).
  - Adaptation to climate change, strategic oil reserve, hospitals,...
- But this CCAPM yields the standard asset pricing puzzles.
  - $\sigma \sim 3\% \Rightarrow \sigma^2 \sim 0.1\%$: Negligible impact of risk.
  - Too large risk-free rate;
  - Too small aggregate risk premium.
- LT uncertainties are much deeper than those described by a Brownian process.
  - Recent literature: Barro, Weitzman, Gollier,...

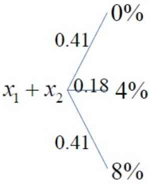
Parametric uncertainty: A simple illustration



A simple illustration

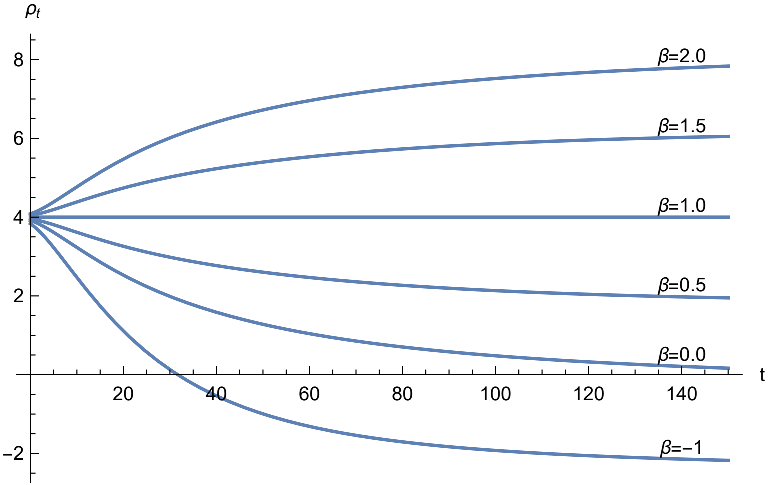


A bad news in the first period also forces us to revise our expectations downwards.

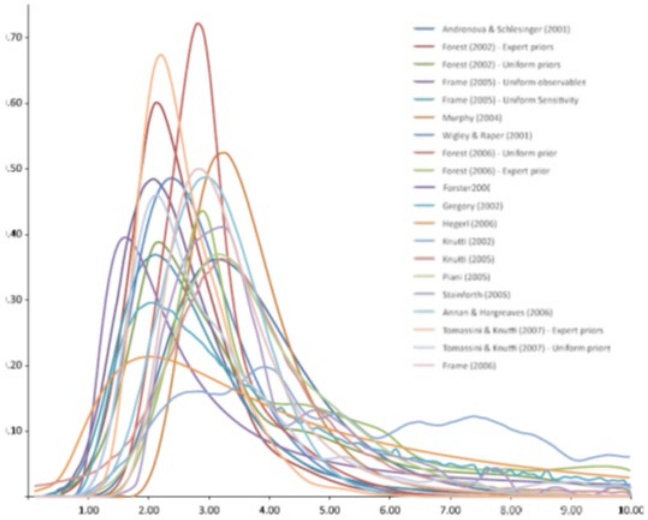


Uncertain trend and LT uncertainty

- Parametric uncertainty generates an increasing term structure of risk on future consumption.
- Example with $\mu \sim (1\%, 1/2; 3\%, 1/2)$ and $\sigma = 3.6\%$.



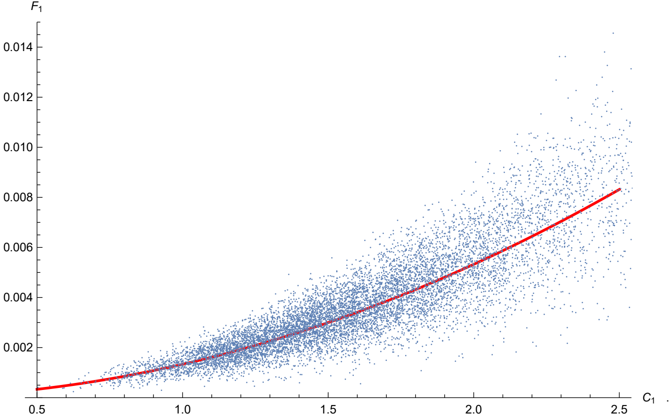
Uncertain climate sensitivity



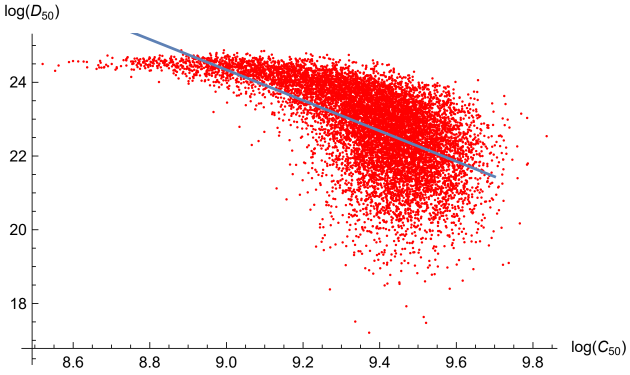
Climate beta

- What is the beta of investments whose aim is to reduce emission of CO_2?
- Two opposite stories:
  - $\beta < 0$: A larger climate sensitivity raises the marginal damages and reduces consumption.
  - $\beta = 1$: Climate damages are proportional to wealth and consumption.
- The combination of these two effects suggests that the climate beta is less than 1. By how much?
- More research is needed on this key topic.

Monte-Carlo simulation of DICE (Dietz, Gollier and Kessler, 2017)



- Estimated $\beta_{50} \sim 0.7$.



- Estimated $\beta_{50} \sim -3.5$.

Conclusion

- More research needs to be done on the risk characteristics of climate change. A climate beta close to zero is "likely".
- Deep uncertainties and the plausibility of a persistent macro-catastrophe suggests using a discount rate around 1-2%.
- Using EPA recent estimates, a value around 200 $\$/tCO_2$ seems reasonable.
- Given the remaining complexities of this CBA, a cost-efficiency approach should be considered.