Carbon pricing and stress discounting

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Roadmap

CO2 emission and Cost-Benefit analysis

Net Present Value of future costs and benefits, taking into account project's impact on CO2 emission ?

Basic example : an investment today that modifies future CO2 emission by a volume Δ_t at times $t > 0$
$\rightarrow \Delta_t > 0$ for a new highway inducing more pollution
$\rightarrow \Delta_t < 0$ for a new renewable energy production unit instead of a fossil-fuel based one

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We consider here only projects with marginal impacts on consumption.

Let's assume 1 ton of CO2 emitted at time T as a negative (marginal) impact MD_t^T on consumption at time $t \geq T$ ($MD_t^T = 0$ for $t < T$).

Marginal impact on the utility of the representative consumer at time t:

$$u(C_t + MD_t^T) \simeq u(C_t) + u'(C_t) \times MD_t^T$$

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For a simple project reducing emissions by Δ at time T ($\Delta_t = \Delta$ for $t = T$ and 0 otherwise),

$$\text{CO2 impact on project's } NPV_0 = \frac{E[\Sigma_{t=0}^{\infty} e^{-\delta t} u'(C_t) \times \Delta \times MD_t^T]}{u'(C_0)}$$

When $\Delta = 1tCO2$ and $T = 0$, this is today's social cost of carbon.

CO2 emission and Cost-Benefit analysis

Public administrations choose an official social cost of carbon SCC_t link

$= \textit{monetary equivalent at } t \textit{ of damages induced by 1tCO2 emitted at } t$

... and an official "social discount rate" r_t (cf. next slides) in order to get the NPV impact: Jump back

$$\text{CO2 impact on project's NPV} = \Sigma_{t=0}^{\infty} e^{-r_t} SCC_t \times \Delta_t \qquad (1)$$

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$$\text{CO2 impact on project's NPV} = \Sigma_{t=0}^{\infty} e^{-r_t} SCC_t \times \Delta_t \qquad (1)$$

but SCC_t and r_t often not the result of mutually consistent evaluations:

Illustration: what is the optimal speed of CO2 emissions reduction ?

- France (2019): Political decision on a carbon budget $\Rightarrow \tilde{g} > 10\%$ and $r = 3.2\% \Rightarrow$ procrastination
- US (2022): Joint evaluation of the two parameters $\Rightarrow \tilde{g} \simeq 1.2\%$ and r between 1.5% and 2.5% $\Rightarrow$ action brought forward

Even when the two parameters are consistently defined, the formula 1 is not correct when Δ_t is uncertain !

Roadmap

Social value of a marginal investment project

Classical approach used to compute the net present value of a project yielding net benefits B_t at time t : discount the expected benefit :

$$PV = \sum_{t=0}^{+\infty} E\left[B_t\right] e^{-r_t t}$$

As seen before, when the project has marginal impacts on consumption, this should be also

$$PV = \frac{1}{u'(C_0)} \sum_{t=0}^{+\infty} e^{-\delta t} E\left[B_t u'(C_t)\right]$$

Thus, the social discount rate to be used is

$$r_t = \delta - t^{-1} \log\left(\frac{E\left[B_t u'(C_t)\right]}{u'(C_0) E B_t}\right)$$

The social discount rate

The risk-free rate is given, under specific assumptions*, by the extended Ramsey rule:

$$r_f = \underbrace{\delta + \gamma\mu}_{\text{time preference and wealth effect}} - \underbrace{0.5\gamma^2\sigma^2}_{\text{precautionary effect}}$$

(* constant relative risk aversion γ, consumption follows a geometric brownian motion with trend μ and volatility σ)

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The risk premium. Consumption-based asset pricing model by Rubinstein (1976), Lucas (1978) and Breeden (1979):

$$r = r_f + \beta \times \phi$$

- ϕ: systematic risk premium
- β: consumption beta, defined as the elasticity of the net social benefit of the project to a change in aggregate consumption

Interpreting β

- $\beta >> 0$ means that the project gains value in times of growth, and helps to reinforce macroeconomic risk (transportation).
- $\beta < 0$ means that the project has an insurance value (hospitals, nuclear wastes deep repository) $\rightarrow$ high value when everything goes wrong.
- Consider a motorway project
  - Economic benefits have a positive income elasticity
  - Negative externalities are proportional to both the road traffic and the marginal carbon damage ("Climate β")

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β is complex to set.

- UK (2021) : $r = 3.5\%$
- France (Guesnerie 2021): $r = 1,2\% + \beta * 2\% = 3,2\%$ until 2070.
  In the absence of existing sectorial estimations, β is supposed equal to 1.

Roadmap

Methodology (1)

→ *Cherbonnier F., Gollier C. and Pommeret A. (2023), "Stress Discounting", mimeo.*

Basic principle of asset valuation:

- An asset's value is equal to the expectation of its contingent NPV over the multiple states of nature that characterize this asset;
- For each state of nature, one just need to use the Ramsey rule to discount the flow of net benefits under certainty;
- This approach gives the exact value if one takes into account all possible states of nature.

Claim: a good approximation can be obtained by reducing the uncertainty to a few discrete numbers of state of nature

Methodology (2)

→ As an illustration, we consider the most simple way to do that, with only two states of nature : a "business as usual" scenario and a "stressed scenario" (Barro type catastrophe).

$$PV = (1-\pi)\sum_{t=1}^{T} e^{-r^b t} B_t^b + \pi \Delta \sum_{t=1}^{T} e^{-r^s t} B_t^s$$

B_t^b and B_t^s are all future gross flows associated with the project and occurring between $t = 1$ and $t = T$ in the BAU scenario and the stress scenario, respectively.

- Calibration left to the evaluator
- For benchmarking purposes, we propose one in the paper that is consistent with the main characteristics of the yield curve

Benchmark comparisons: PV

The benchmark is provided by the complex discounting method that corresponds to the project analysts' view of the world: Martin's cumulants method (REStud 2013)

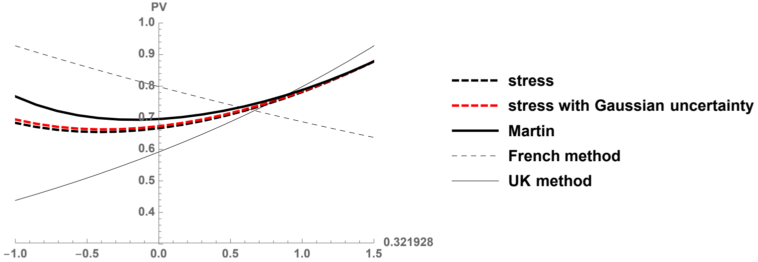


Figure: Present values obtained using different methods for a benefit at $t = 15$ years equal to c_t^{β}

Roadmap

Stress-discounting when climate matters

Need to consider two sources of uncertainty : climate and growth

Methodology:

Stress-discounting when climate matters

Need to consider two sources of uncertainty : climate and growth

Methodology:

- First step = choose a description of the economy (illustrative)

  → DICE slightly modified and enriched with the two main sources of uncertainty identified by Dietz et al. 2018 : climate sensitivity and total factor productivity

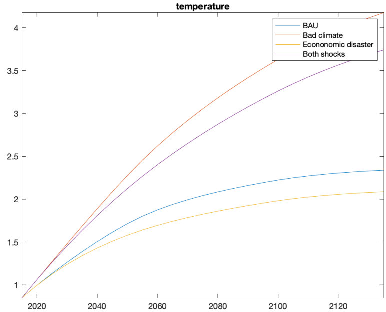
- Second step = 4 scenarios (good or bad news on economy & climate)

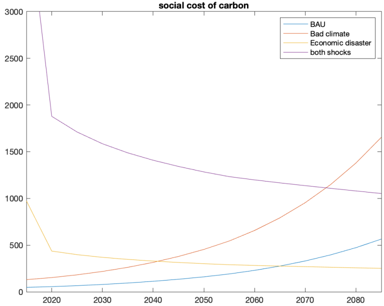
  → For each scenario (with certain growth and given climate sensitivity), compute social discount rate (Ramsey rule) and social cost of carbon

- Third step = check method's efficiency

  → Benchmark of the present value of the social cost of carbon : Stress discounting method vs. Montecarlo simulations

Choice of four scenarios





→ Climate sensitivity : either 2.6°C or 5.7°C

→ Economic growth : $g = 3.6\%$ or 43% drop of GDP followed by $g = -0.1\%$

We assume an initial drop of 43% in the bad economic scenario. The remaining parameters are chosen such that bad (resp. good) scenarios correspond to the mean of the 8% worst cases (resp. 92% best cases).

Illustration of the insurance value of a mitigation project

We consider a mitigation project that prevents the emission of 1 tCO_2 each year during 50 years

STRESS DISCOUNTING			
	probability	*Present value*	*contribution*
No negative shocks	*84,64%*	335	*283*
climate shock	*7,36%*	932	*69*
eco shock	*7,36%*	7322	*539*
both shocks	*0,64%*	31361	*201*
stress		1091	
BENCHMARK (Montecarlo Simulations)			
Exact value		1080	

→ Illustrates the insurance value of mitigation projects : about 75% of the project's value comes from catastrophic scenarios.

→ Biggest contribution from the economic shock (future generations will be very poor)

→ The contribution from the very low probability scenario (both catastrophic events) is very significant

Benchmark

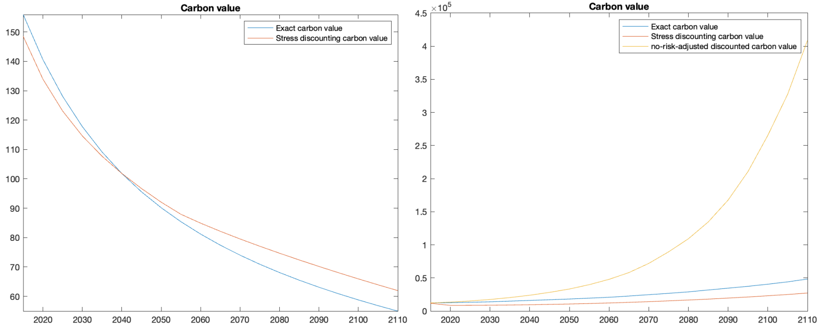


Figure: Present expected value of C_t^{β} tCO2 at t with $\beta = 0$ (left) or 1 (right)

→ Stress discounting gives in both case a relatively good approximation of the estimation based on Montecarlo simulations

→ When $\beta = 1$, using equation 1 to discount the social cost of carbon with the (non-risk adjusted) social discount rate strongly overestimates carbon value on long horizon link

Thanks

CO2 emission and Cost-Benefit analysis

The SSC_t reflects expected damages, and takes into account expected marginal utility at time t. It is a shadow price, given by

$$SCC_t = \frac{E[\Sigma_{\tau=t}^{\infty} e^{-\delta(\tau-t)} u'(C_\tau) MD_\tau^t]}{E[u'(C_t)]}$$

The expected damages at time 0 is

$$\frac{E[\Sigma_{\tau=t}^{\infty} e^{-\delta\tau} u'(C_\tau) MD_\tau^t]}{u'(C_0)}$$

so that the SSC_t must be discounted at the risk-free discounting rate

$$r_t = \delta - t^{-1} \log\left(\frac{E\left[u'(C_t)\right]}{u'(C_0)}\right)$$

Jump back