Robust selection of climate policies under current knowledge of uncertainties

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SEVENTH FRAMEWORK PROGRAMME

Fondazione Eni Enrico Mattei

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Motivations

Uncertainty is inherent to the climate change

- Incomplete understanding of climate change in many respects (Heal and Millner, 2013)
- Representing, analysing and reporting uncertainty for setting climate policy is required (IPCC)
- Large amount of models' outcomes are produced
  - Probabilistic version of models (Monte-Carlo, Stochastic programming, ADP)
  - Models intercomparison: climate model (CMIPs), Integrated assessment models (MIPs), impact models (ISI-MIP)

Motivations

Decision Making criteria

- **Decision making criteria** and **preferences over risks** have been shown to have an impact on the optimal abatment strategy (Dietz, Millner, Lemoine, Traeger, Ackerman, . . .)
- The maximisation of expected utility and CBA are difficult to apply under **deep uncertainty** (Kunreuter et al., 2013)
- **Variety of decision making criteria**, but no single one is dominating the others (Heal and Millner, 2013)

Research approach

Steps

1. Explore the space of future scenarios in an integrated assessment framework
2. Apply a set of decision rules on outcomes

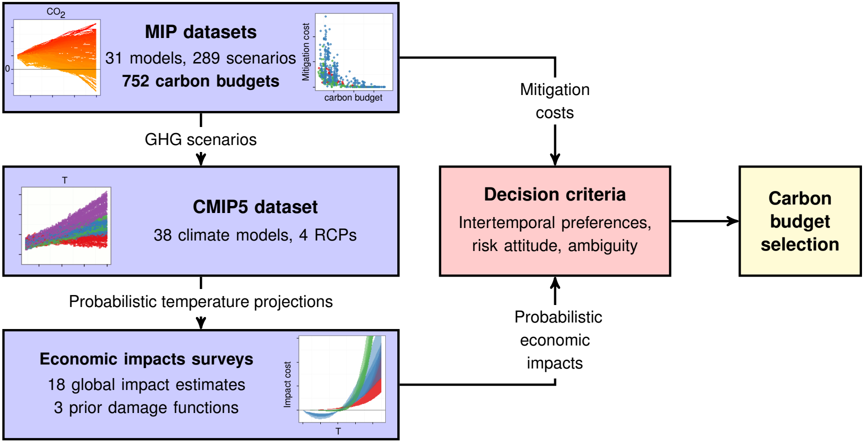
Capturing the current knowledge of uncertainty

- from a dataset of multi-model outcomes
- *from a probabilistic version of WITCH*

Climate policy is a carbon budget

- Cumulative CO_2 emissions (2000–2100)
- Robust indicator for the warming (Meinshausen, 2009)
- Associated climate targets (Steinacher et al., 2013)

Methodology



Model intercomparison projects (MIPs)

- 6 research projects:
  - EMF22, EMF27, **LIMITS**, AMPERE, ROSE, AME
- Policy scenarios run by many IAMs:
  - Common protocol
  - Characteristics: climate targets, technology options, tax levels, delay of action, type of cooperation
- Results database to be published

Dataset description

- Long-term policy assessment (until 2100)
- 31 versions of 10 models (including WITCH, TIMES, IMAGE, MESSAGE. . .)
- 164 policy scenarios
- 752 carbon budgets

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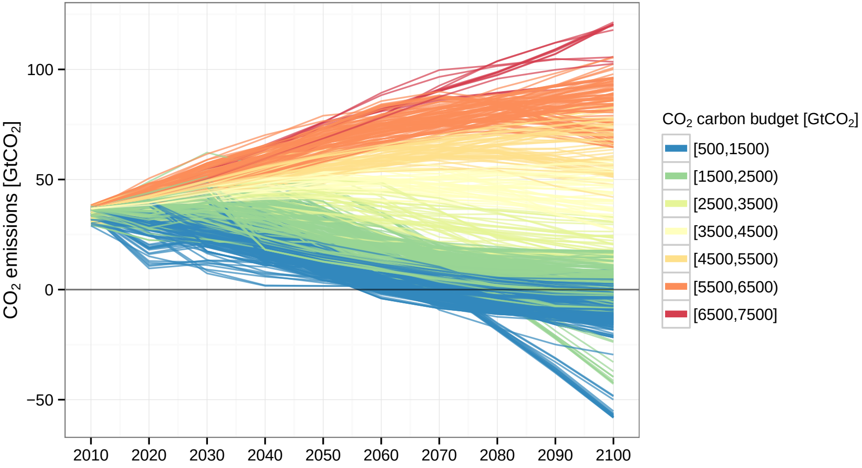
Emissions



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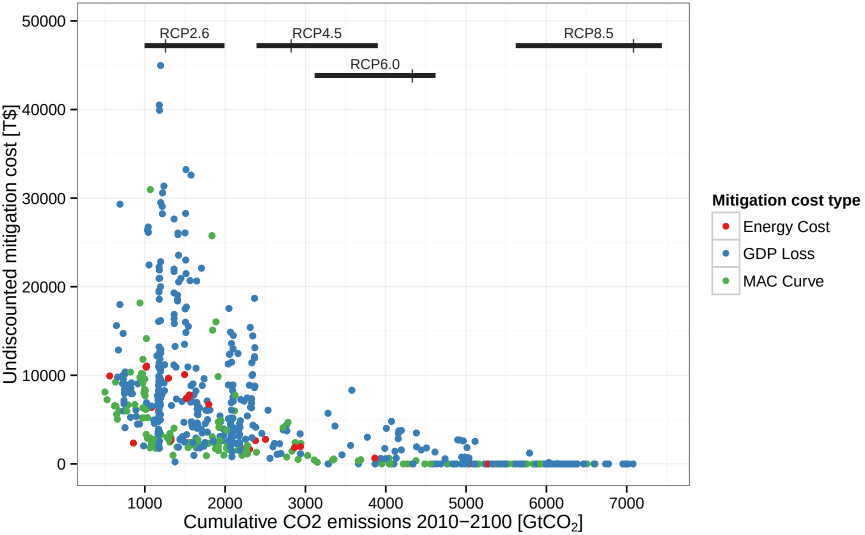
Mitigation costs versus carbon budgets



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CMIP5 emulator

SNEASY (Urban and Keller, 2010) is a simple Earth System Model composed of

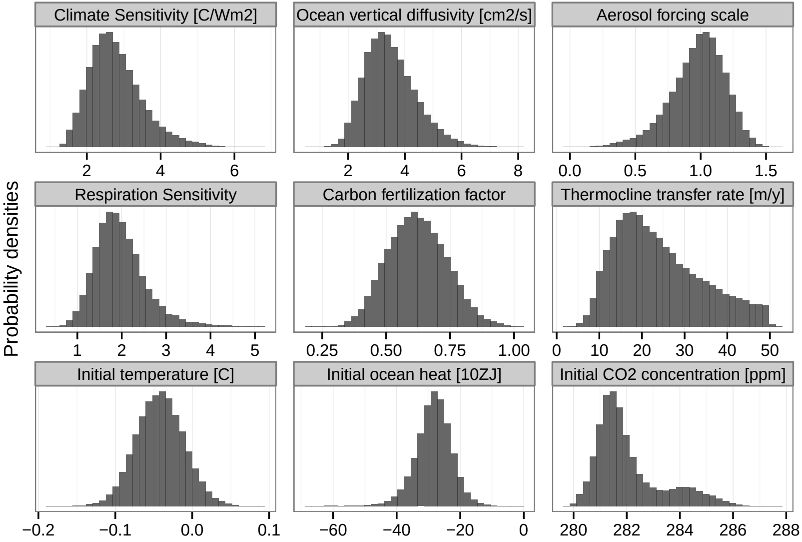
- a climate module based on DOECLIM,
- a carbon-cycle model, including feedbacks from CO_2 concentration and temperature,

Inputs

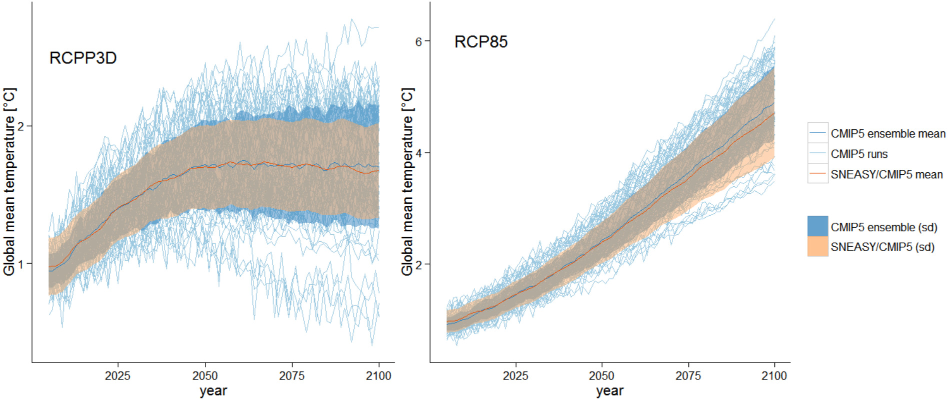
- CO_2 emissions,
- non-CO_2 radiative forcing components

We estimate the geophysical parameters from the CMIP5 temperature projections using a Bayesian inversion technique based on Monte-Carlo Markov Chain (MCMC).

Climate: posterior marginal distributions

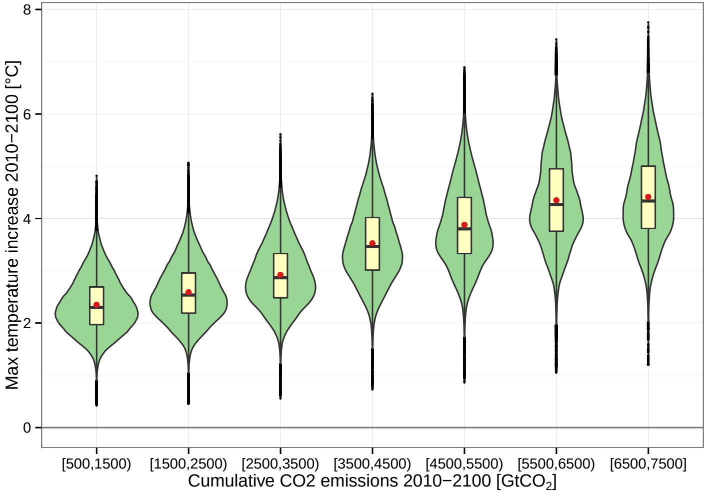


Climate: Temperature projections



Temperature projections from RCPP3D, RCP45, RCP60, RCP85

Climate: temperature distributions



Economic impacts

Tol (2009, 2013) review estimates of *global* economic impact of climate change from 16 studies:

- Mean estimates: Nordhaus(1994a), Frankhauser(1995), Tol(1995), Nordhaus and Young(1996), Mendelshon et al. (2000), Nordhaus and Boyer (2000), Maddison(2003), Rehdanz and Maddison (2005), Nordhaus (2008), Maddison and Rehdanz (2011), Bosello et al. (2012)
- Skewed distribution: Nordhaus(1994b), Plambeck and Hope(1996), Hope(2006)
- Normal distribution: Tol (2002), Nordhaus (2006)

- Impact estimates only for low warming (<3°C)
- We build 3 prior damage functions

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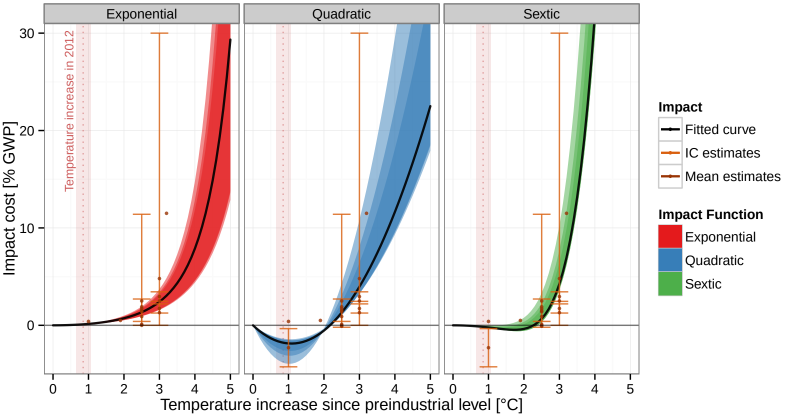
Prior damage functions



1. Exponential: $I(T) = \exp(\beta T^2) - 1$ (Weitzmann, 2010)
2. Quadratic: $I(T) = \beta_1 T + \beta_2 T^2$ (Tol, 2009)
3. Sextic: $I(T) = \beta_1 T^2 + \beta_2 T^6$ (Weitzmann, 2012)

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Utility function

Discounted GWP loss:

$$U(c;s) = \sum_{t \in T} \frac{1}{(1+r(t))^{(t-t_0)}} Y_M(c,t;s)\,(1 - I(c,t;s))$$

- c: carbon budgets
- s: states of the world
- $t \in \{2010, 2020, \ldots, 2100\}$
- $Y_M(c,t;s)$: GWP including mitigation costs
- $I(c,t;s)$: Economic impacts

Ramsey's rule

$r(t) = \rho + \eta \dot{g}(t)$,
ρ is the pure rate of time preference, η is the risk aversion and $\dot{g}(t)$ is the average growth rate since t_0.

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Set of decision rules

Expected Utility-based rules		
Subjective EU	$\max_{c \in \mathcal{C}} \mathbf{E}(U(c;s))$	Savage (1954)
Maxmin EU	$\max_{c \in \mathcal{C}} (\min_{\pi \in \Pi} \mathbf{E}(U(c;s)))$	Gilboa & S. (1989)
α-Maxmin EU	$\max_{c \in \mathcal{C}} (\alpha \min_{\pi \in \Pi} \mathbf{E}(U(c;s)) + (1-\alpha) \max_{\pi \in \Pi} \mathbf{E}(U(c;s)))$	GMM (2004)
Non-probabilistic rules		
Maxmin	$\max_{c \in \mathcal{C}} (\min_{s \in \mathcal{S}} U(c;s))$	Wald (1945)
α-Maxmin	$\max_{c \in \mathcal{C}} (\alpha \min_{s \in \mathcal{S}} U(c;s) + (1-\alpha) \max_{s \in \mathcal{S}} U(c;s))$	Arrow & H. (1972)
Minimax Regret	$\min_{c \in \mathcal{C}} (\max_{s \in \mathcal{S}} [(\max_{c' \in \mathcal{C}} U(c';s)) - U(c;s))])$	Savage (1951)

- Ambiguity: Subjective EU (neutral) versus Maxmin EU (full)
- α-rule: pessimistic versus optimistic decision maker
- max $\approx$ 99.9%

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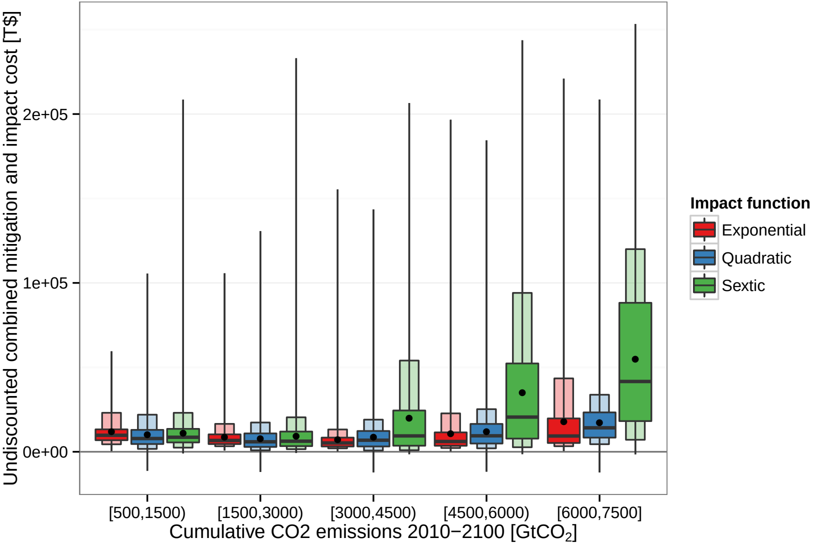
Undiscounted loss versus carbon budgets



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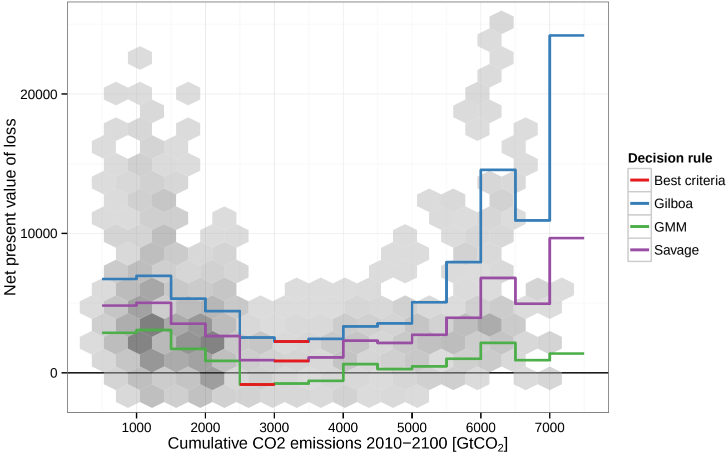
Carbon budget selection: EU rules



ρ = 3%, η = 1, bin size = 500 $GtCO_2$

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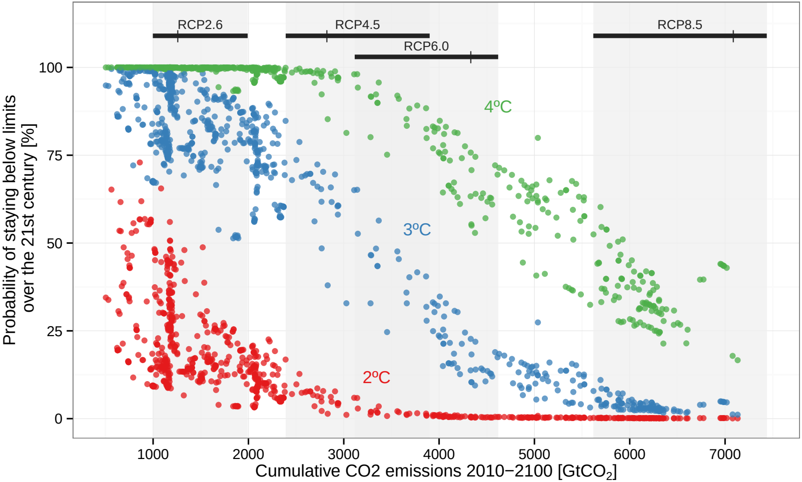
Temperature limits



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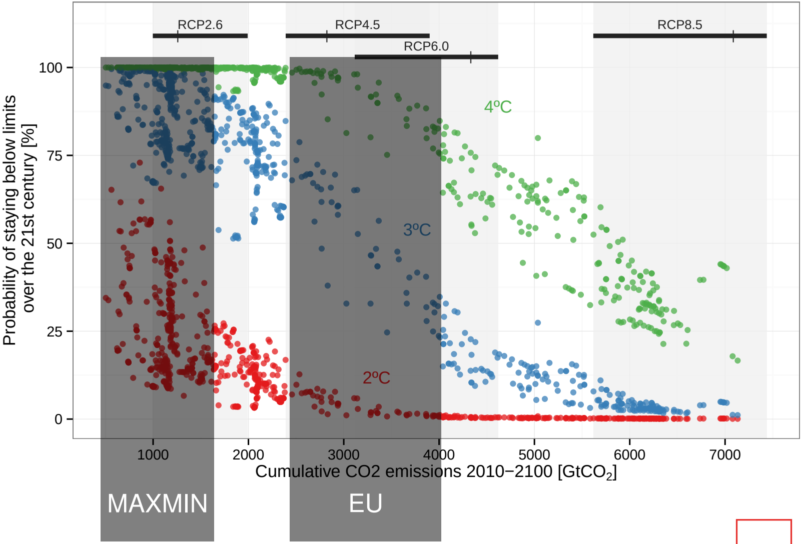

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Conclusions

1. Uncertainty very significant, especially on the damage
2. Quadratic damage function unsuited for climate policy recommendations
3. DM criteria matter for optimal carbon budget, as much as or even more than discounting
4. Only Maxmin and minmax regret yield policies consistent with 2℃
5. Ambiguity aversion doesn't seem to matter too much

- Smoother response with the probabilistic version of WITCH

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Thanks!

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