Climate policy under socio-economic scenario uncertainty

Laurent Drouet and Johannes Emmerling[1]

[1] Fondazione Eni Enrico Mattei (FEEM) and CMCC

IAMC Meeting, Nov 16th, 2015, Potsdam

Motivation

- Socioeconomic Drivers of the five SSPs
- Climate policies under very different baseline assumptions
- Policy costs or impacts under different GDP and population scenarios

Motivation

- Socioeconomic Drivers of the five SSPs
- Climate policies under very different baseline assumptions
- Policy costs or impacts under different GDP and population scenarios

- **Research questions**
  1. What is a robust and optimal climate policy under "baseline" uncertainty?
  2. How can policy costs and other measures be compared if different baselines are considered?
  3. How can scenario development exercises inform decisions under uncertainty taking into account the different "worlds" described

The Shared Socioeconomic Pathways (SSPs)

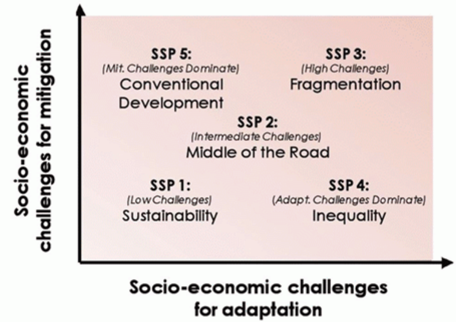
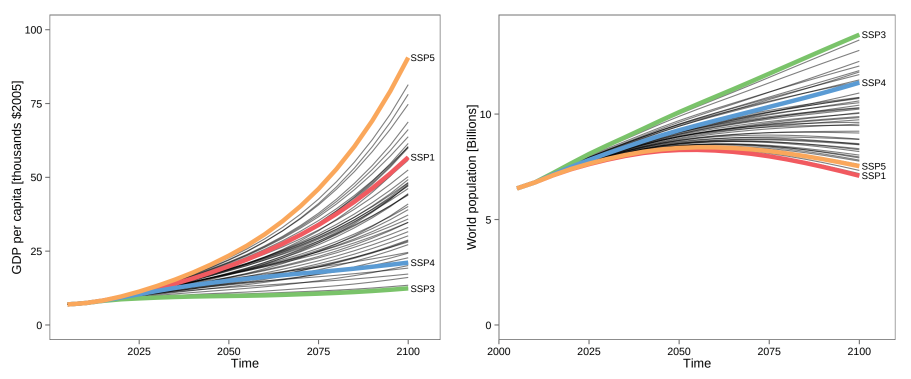


Figure 1. The Shared Socio-economic Pathways (SSPs) of the new IPCC-guided scenario set. Taken from O'Neill et al. (2012).

- Consider only different baseline assumptions about GDP and population (OECD/IIASA)!

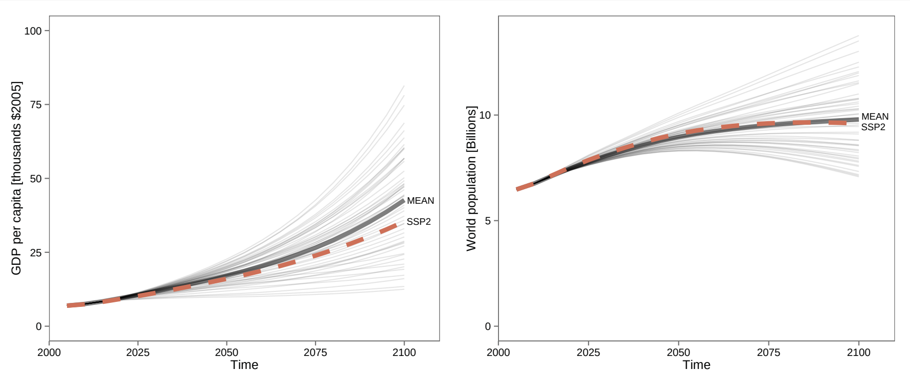
GDP and Population of the SSPs

Generate 50 baselines generated from the four extreme SSP baseline as a convex combination of population and GDP per capita



GDP and Population of the SSPs

Samples pathways and comparison to the SSP2 “Middle of the road”



Spatial Heterogeneity of Climate Change

- Additionally, running 100 carbon budgets (500-7000 $GtCO_2$) for each sampled pathway (5,000 runs in total)
- running the IAM WITCH for each scenario and policy ($CB_{2000-2100}$)

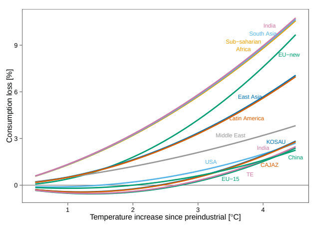
$$\max \sum_{t,r} w_{t,r} l_{t,r} \frac{(c_{t,r})^{1-\eta}}{1-\eta} \frac{1}{(1+\delta)^t} \ \textbf{s.t.} \sum_{t,r} emi(c_{t,r}) \leq CB$$

Spatial Heterogeneity of Climate Change

- Additionally, running 100 carbon budgets (500-7000$GtCO_2$) for each sampled pathway (5,000 runs in total)
- running the IAM WITCH for each scenario and policy ($CB_{2000-2100}$)

$$\max \sum_{t,r} w_{t,r} l_{t,r} \frac{(c_{t,r})^{1-\eta}}{1-\eta} \frac{1}{(1+\delta)^t} \textbf{ s.t.} \sum_{t,r} emi(c_{t,r}) \leq CB$$

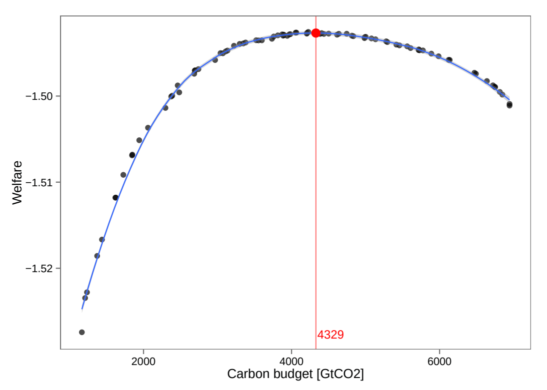
- Including damages from climate change (CLIMCOST damage function)



$$\Longrightarrow W(CB; Y, L)$$

Example of the optimal climate policy

Value function for the baseline $(\alpha_1, \alpha_3, \alpha_4, \alpha_5) = (0, 0, 1/9, 8/9)$



Decision framework

Deterministic case:

$$\forall\{Y,L\} : CB^*_{DET}(Y,L) = \underset{CB}{\operatorname{argmax}}\, W(Y,L,CB) \tag{1}$$

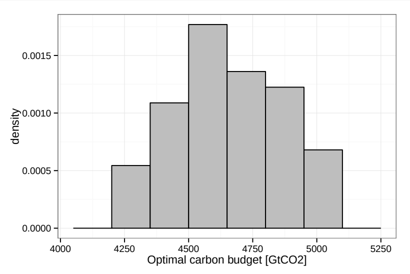
Under uncertainty: expected utility

$$CB^*_{EU} = \underset{CB}{\operatorname{argmax}}\, E_0 W(\widetilde{Y},\widetilde{L},CB) \tag{2}$$

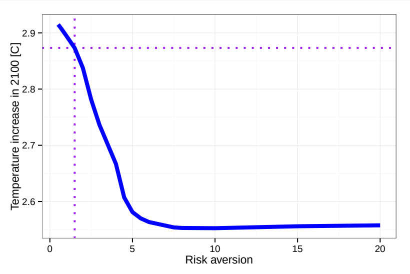
Disentangled Epstein-Zin SWF (relative risk acersion $\rho \neq \eta$)

$$CB^*_{DIS} = \underset{CB}{\operatorname{argmax}}\, E_0 \frac{1}{1-\rho}\left(\left\{(1-\eta)W(CB;\widetilde{Y},\widetilde{L})+1\right\}^{\frac{1-\rho}{1-\eta}} - 1\right) \tag{3}$$

Decision framework



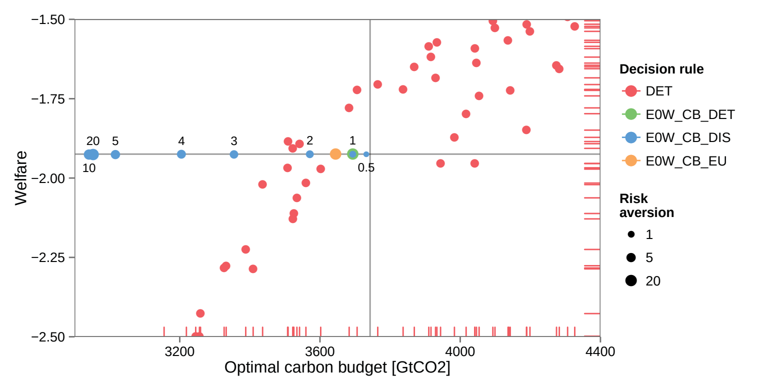
Optimal deterministic CB



The effect of risk aversion

Decision framework - results

- Optimal carbon budgets for all decision rules



Policy cost measures

- (discounted) Policy/damage cost measure:

$$PC = E \frac{\sum_{t=0}^{T} l_t (c_t^{pol} - c_t^{bau}) \frac{1}{(1+r)^t}}{\sum_{t=0}^{T} l_t c_t^{bau} \frac{1}{(1+r)^t}}$$

- Baseline GDP and population important, choice of discount rate matters.

Policy cost measures

- (discounted) Policy/damage cost measure:

$$PC = E \frac{\sum_{t=0}^{T} l_t (c_t^{pol} - c_t^{bau}) \frac{1}{(1+r)^t}}{\sum_{t=0}^{T} l_t c_t^{bau} \frac{1}{(1+r)^t}}$$

- Baseline GDP and population important, choice of discount rate matters.
- One way to avoid the dependence of different future growth scenarios is the use of a Balanced Growth Equivalent (Mirrlees, 1972):

$$CEBGE = \left[\frac{EW(1-\eta)}{\sum_{t=0}^{T} El_t \frac{(1+g)^{(1-\eta)t}}{(1+\delta)^t} dt} \right]^{\frac{1}{1-\eta}} \Longrightarrow \Delta CEBGE \equiv \frac{CEBGE^{pol}}{CEBGE^{bau}} - 1$$

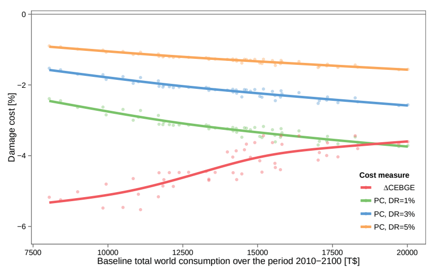
- Properties:
  - independent of the assumed growth rate g
  - welfare-based compatible with the IAM framework
  - Collapses to PC for $\eta = 0$ and $\delta = r$

Policy cost measures across different baselines

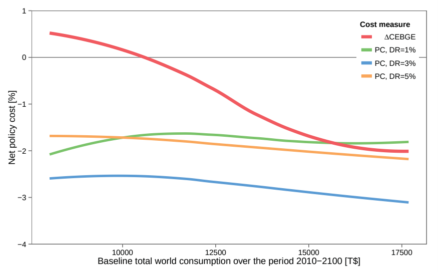
- Example: Compare the different policy/damage cost measures for impacts from climate change and a two degree target (with impacts!) across different baselines summarized by total global GDP

Policy cost measures across different baselines

- Example: Compare the different policy/damage cost measures for impacts from climate change and a two degree target (with impacts!) across different baselines summarized by total global GDP



(a) Damage costs of climate change

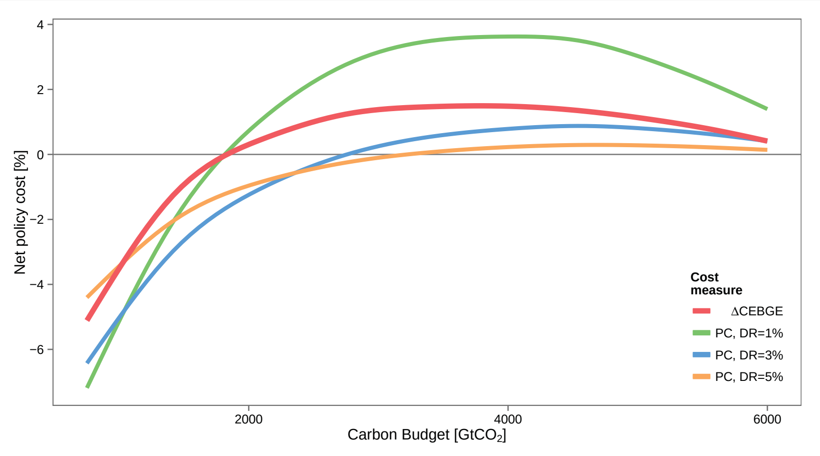


(b) Policy costs of a two-degree target

- According to the CEBGE, higher baselines lead to lower damage costs, but higher mitigation costs

Optimal climate policy and cost measures

- Compare the different measures of net policy costs (mitigation costs and impacts) across the range of policies/carbon budgets considered:



Results

- Comparison of different expected policy cost measures:

Decision criterion	CB	$\Delta CEBGE$	$PC_{r=0\%}$	$PC_{r=1\%}$	$PC_{r=3\%}$
$E_0 W(CB^*_{DET}(\widetilde{Y},\widetilde{L});\widetilde{Y},\widetilde{L})$	varying	-0.58%	-6.7%	-5.2%	-2.7%
$E_0 W(CB^*_{EU};\widetilde{Y},\widetilde{L})$	3645	-0.63%	-6.7%	-5.2%	-2.8%
$E_0 W(CB^*_{DIS};\widetilde{Y},\widetilde{L})$, $\rho = 20$	2953	-0.75%	-6.9%	-5.7%	-3.2%

- Overall, total socioeconomic uncertainty increases the welfare costs from climate change by about 29% (based on the EVPI)
- Rather balanced evaluation based on the *CEBGE*, sensitive to discount rate for the PC measures.

Conclusion

- Socioeconomic baseline uncertainty plays an important role for the optimal climate policy
- Comparing policy/damage costs for different baseline is not trivial
- Impact costs seem higher in low baselines, policy costs of stringent policies for high baselines (like SSP5)
- The SSP provide a useful and broad framework for describing the substantial socioeconomic uncertainties
- Numerically, we find that baseline uncertainty increases the welfare cost from climate change by about one fourth

Conclusion

Thank you!