Regional Climates, Impacts, and strategic SRM

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AWEEE, June 27, 2016, Atoxa

Why modeling Climate Engineering?

Great Barrier Reef: 93% of reefs hit by coral bleaching

Comprehensive aerial survey reveals full extent of the devastation caused by abnormally warm ocean temperatures

Objectives

- Fast growing literature assessing the economic value of Solar Radiation Management (SRM) [(Bickel and Agrawal, 2011),Gramstad and Tjøtta (2010), Goes et al. (2011),Moreno-Cruz and Keith (2012), Emmerling and Tavoni (2014)]

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- Climate change: the biggest challenge is that of cooperation and free-riding
- Weitzman 2012: 'free driving' the low costs of SRM create incentives to unilateral geo-engineering
- Most of the assessment so far (including IAMs) at the global level

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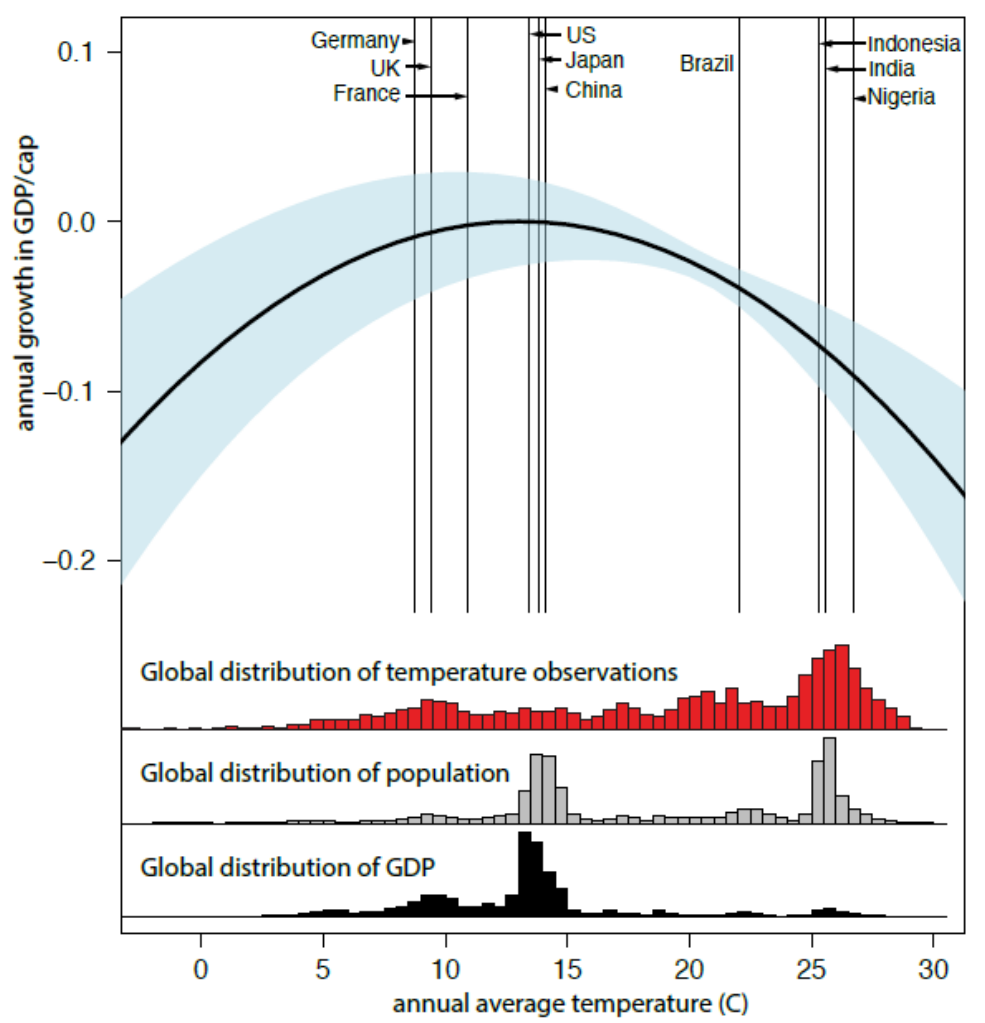
Aim of this work:

- Include region-specific climates and impacts in IAM
- Quantify strategic dimension of SRM

Outline

1. Regional climates
2. Growth impacts
3. SRM implementation
4. Cooperative vs. non-cooperative solution
5. Numerical results

Regional climates and impacts

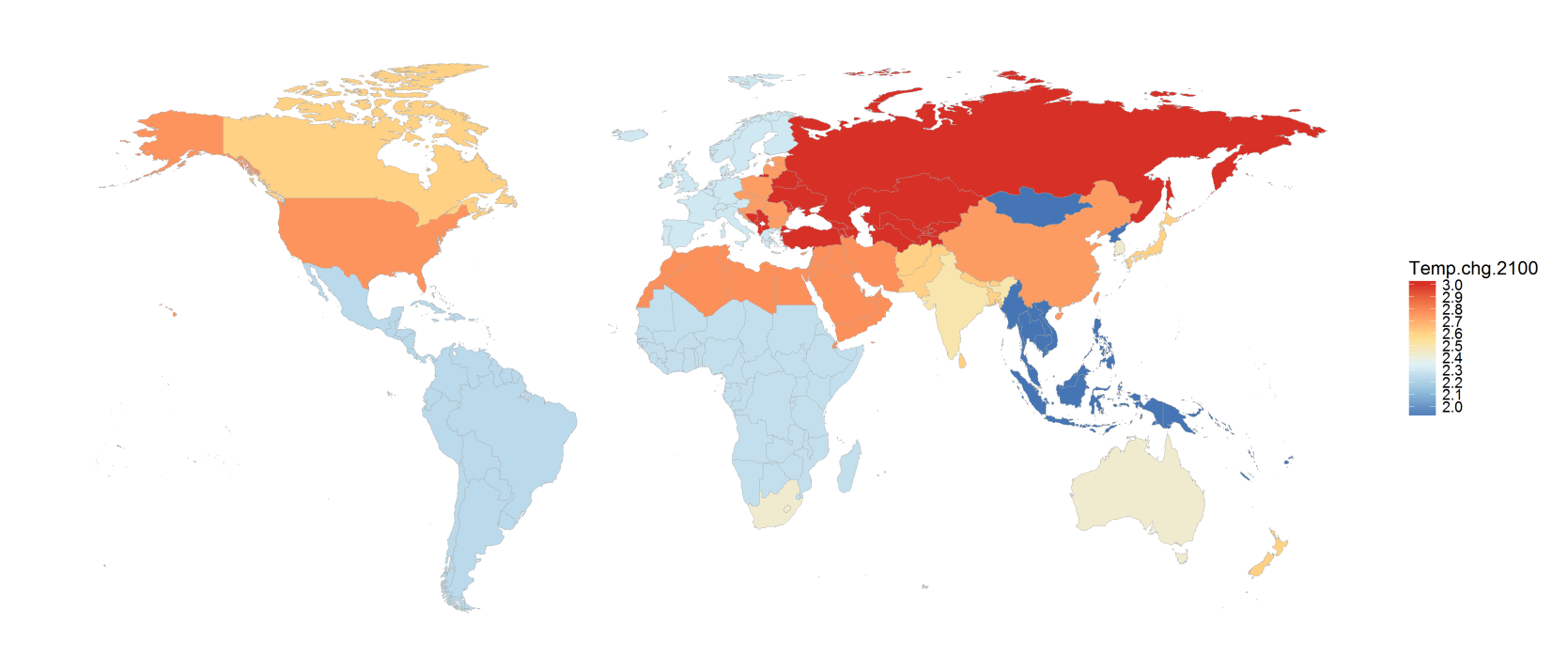


Burke et al. (2015)

Regional climates and impacts

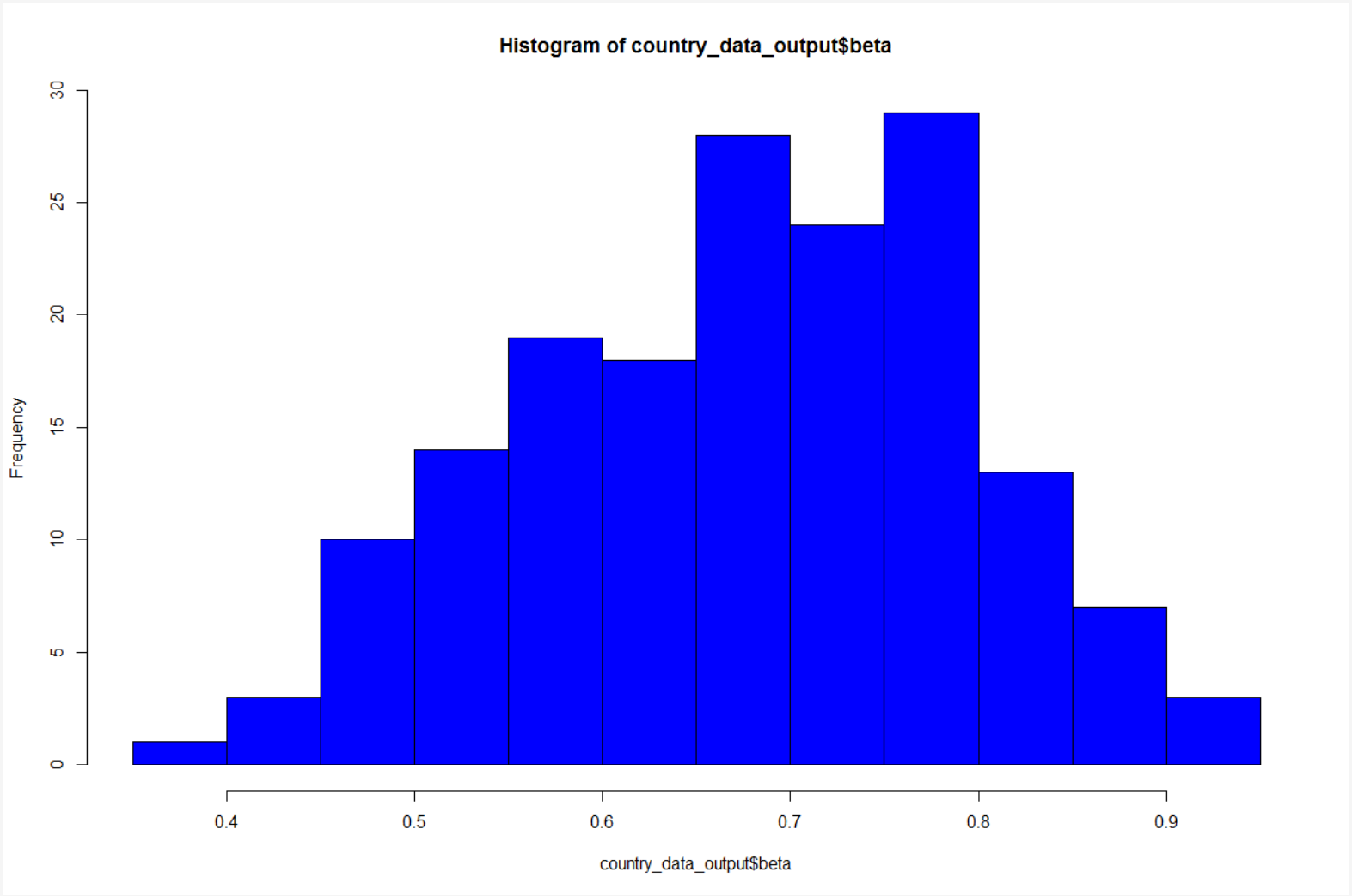
- CMIP5 database (Taylor et al., 2011), two RCPs, 26 models
- Population weighted data for $N = 169$ countries

$$\Delta T_{it} = \alpha_i^* + \beta_i F_t$$



Regional climates and impacts

- estimated $\hat{\beta}_i$ across countries: $(R^2 = 0.80 - 0.95)$



IAM Implementation

WITCH - energy-economy-climate model

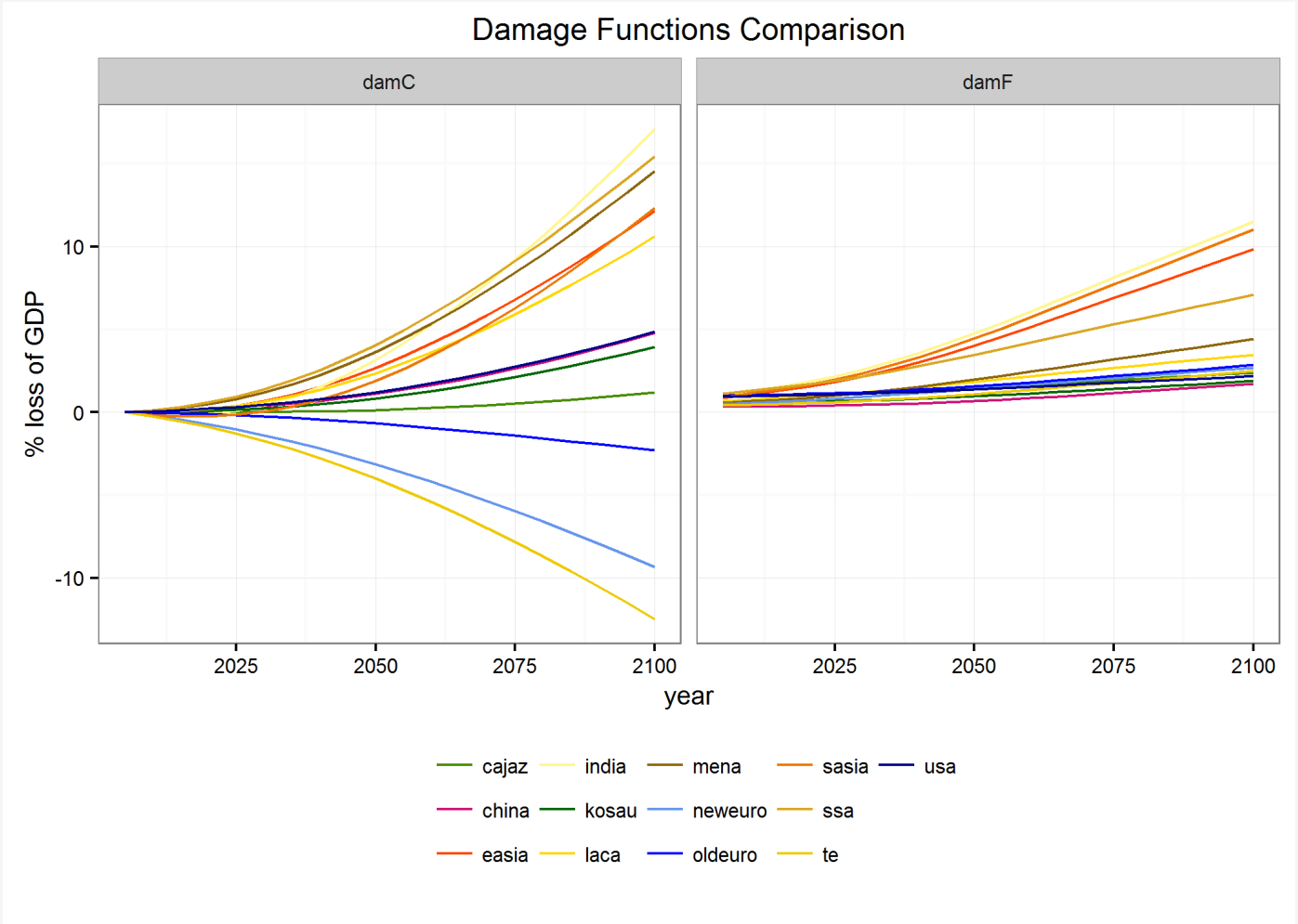
- global model, 13 regions
- Optimal growth model with bottom-up energy sector
- solution concepts:
  - Open-loop Nash solution (non-cooperative)
  - full global cooperation (Utilitarian)
- Cost benefit Analysis (CBA)

Growth vs. level impacts

- Burke et al. (2015): $GDPpc_{it} = GDPpc_{it-1}(1 + g_{it} + \delta_{it})$ where δ_{it} is the impact on the growth rate of per capita GDP in each country
- $\delta_{it} = g(T_{it}) - g(T_{i0})$ (quadratic specification for $g(T) = 0.0127\,T - 0.0005\,T^2$)
- "Standard" damage function: $Y_{net,it} = \frac{Y_{gross,it}}{\Omega_{it}}$, $\Omega_{it} = 1 + f(\Delta T)$
- one can show that the Ω_{it}-Formulation can still be used based on δ_{it} with

$$\Omega_{it} = \Omega_{it-1} \frac{1}{1 + \delta_{it}}$$

Results - comparison of damage functions

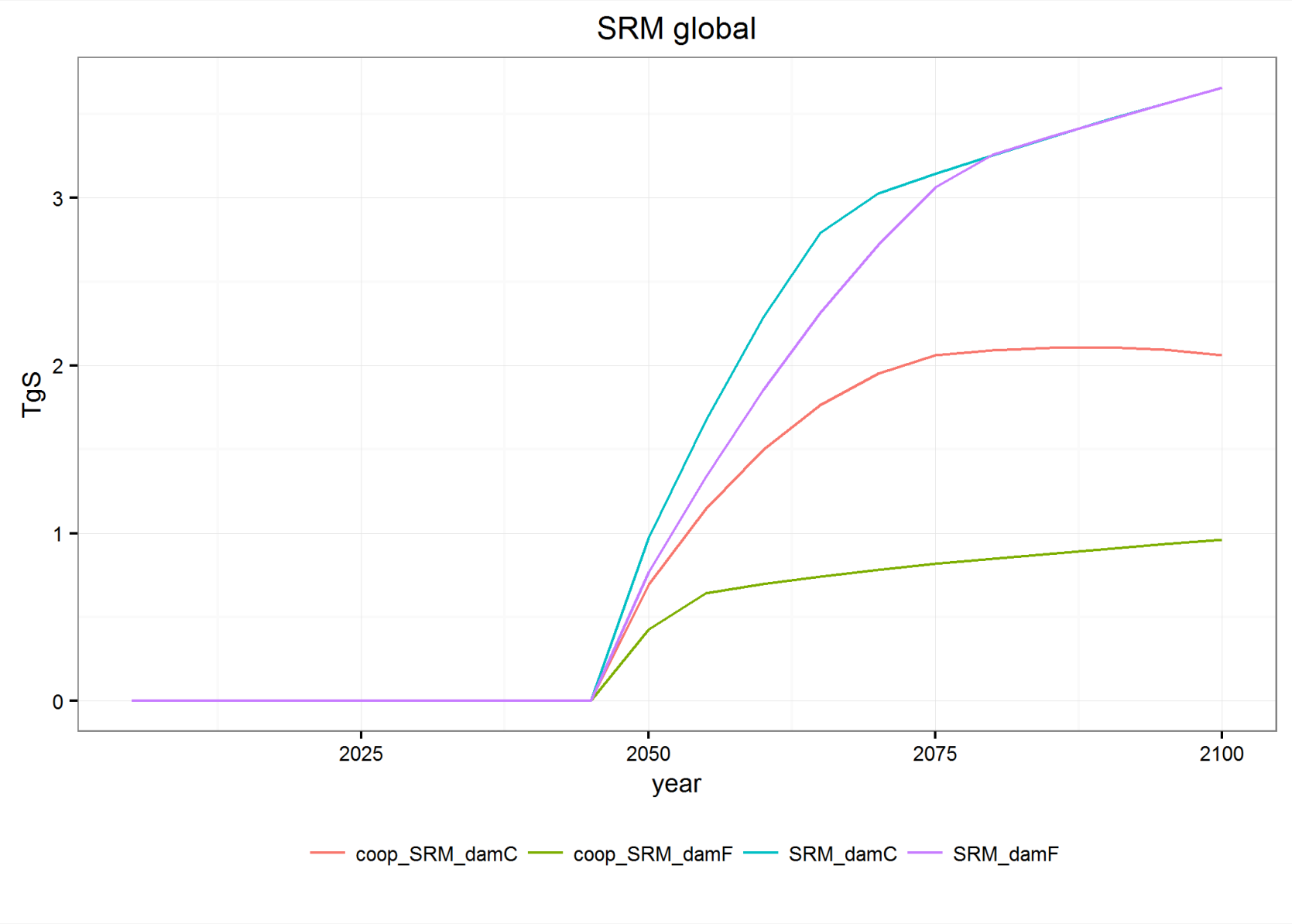


SRM module in WITCH

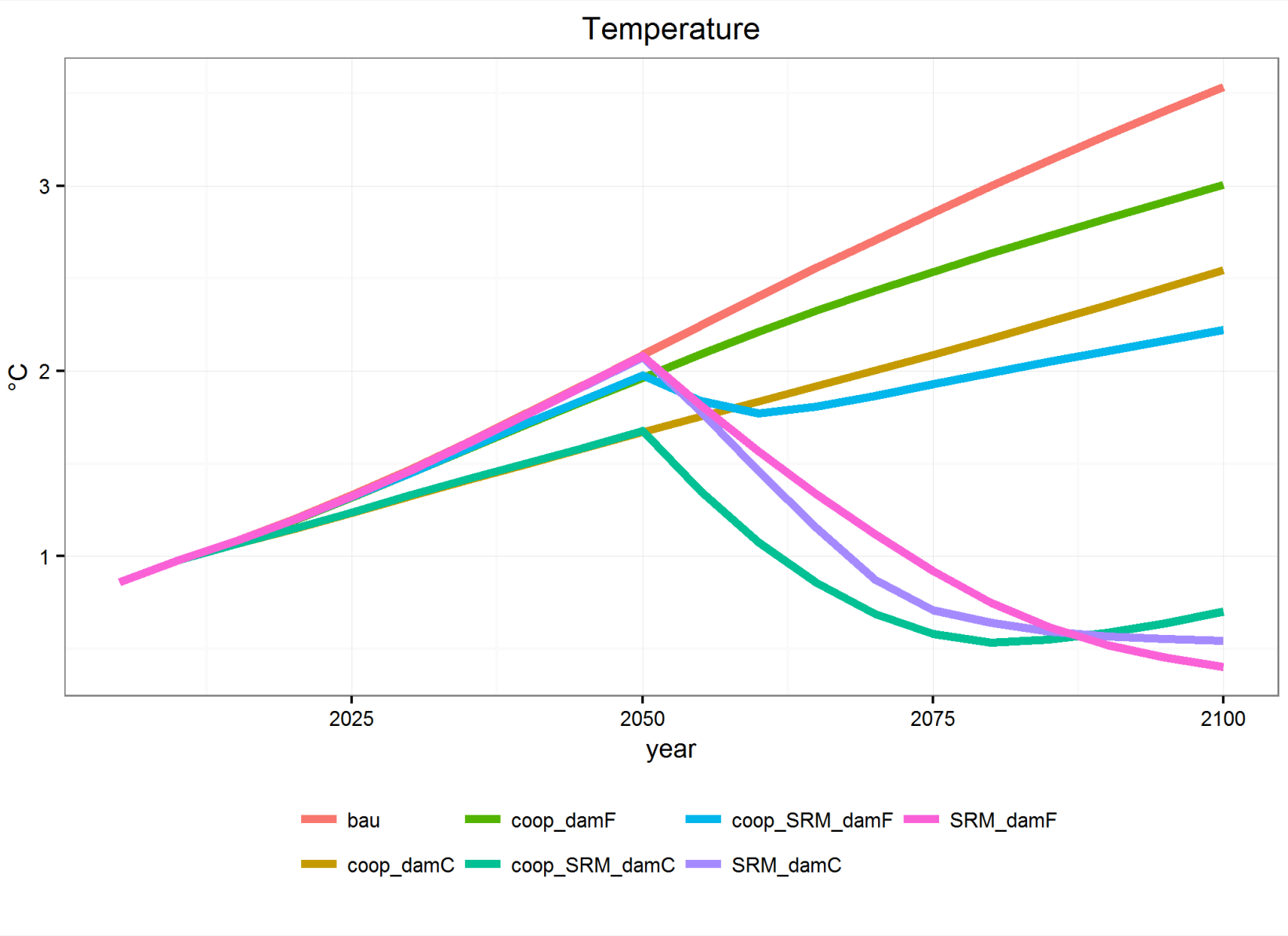
Solar Radiation Management (SRM) via Stratospheric sulfate aerosols injection

- linear cost function, 10 billion USD/TgS (Robock et al., 2009)
- Radiative Forcing of $-1.75 \frac{W}{m^2 \, TgS}$ (Gramstad and Tjøtta, 2010)
- stratospheric residence time: 2 years
- Impacts from SRM: $0.03 \times \frac{1.75 \frac{W/m^2}{TgS} \times \sum_n SRM(t,n)}{3.5}$% of GDP (Goes et al., 2011)
- Impacts from abrupt temperature change: $0.01 \times \left(\frac{\Delta T_t}{0.35} \right)^4$ (Lempert et al., 2000)
- Available from 2050 onwards

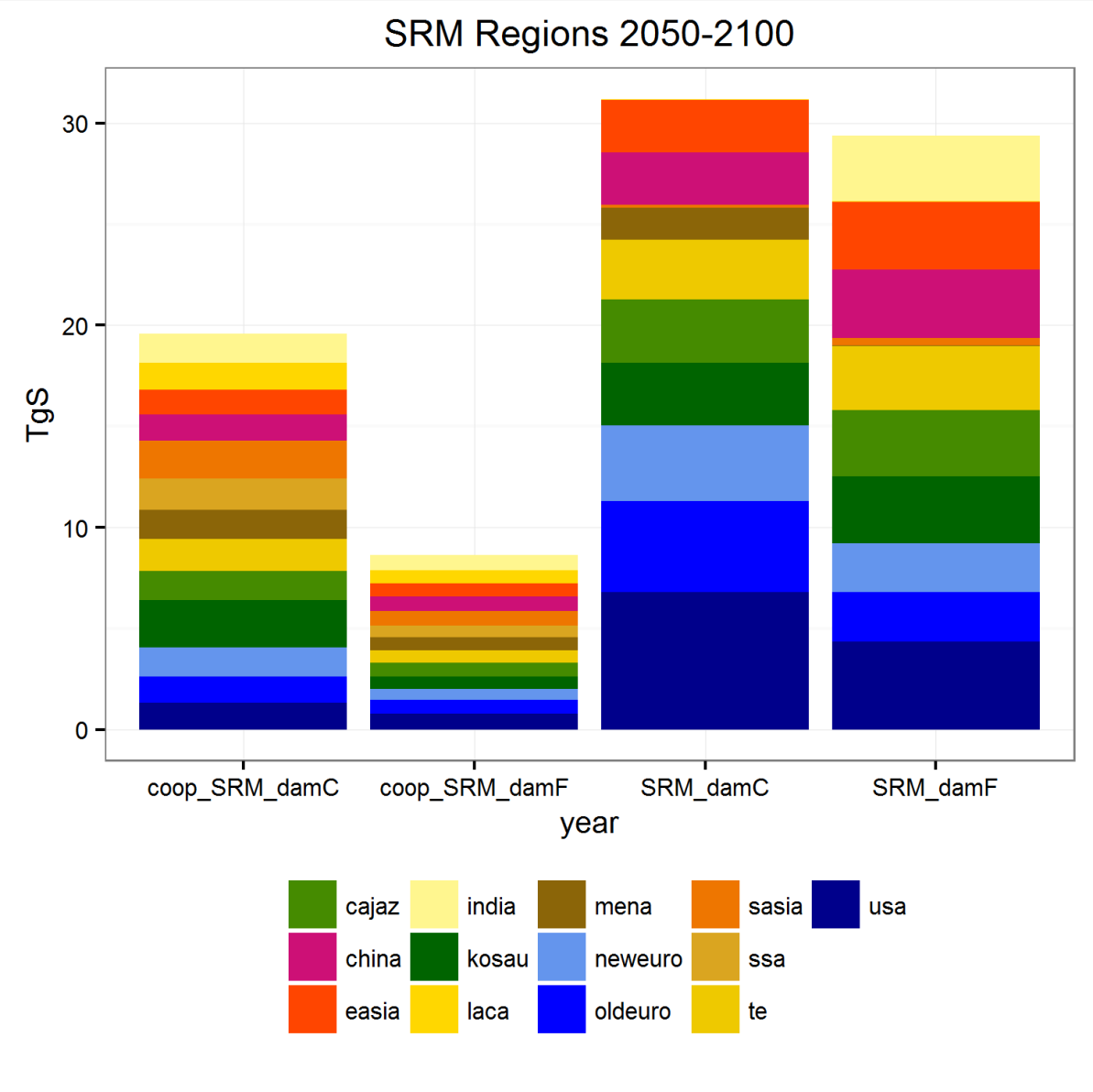
Cooperative vs non cooperative Global SRM



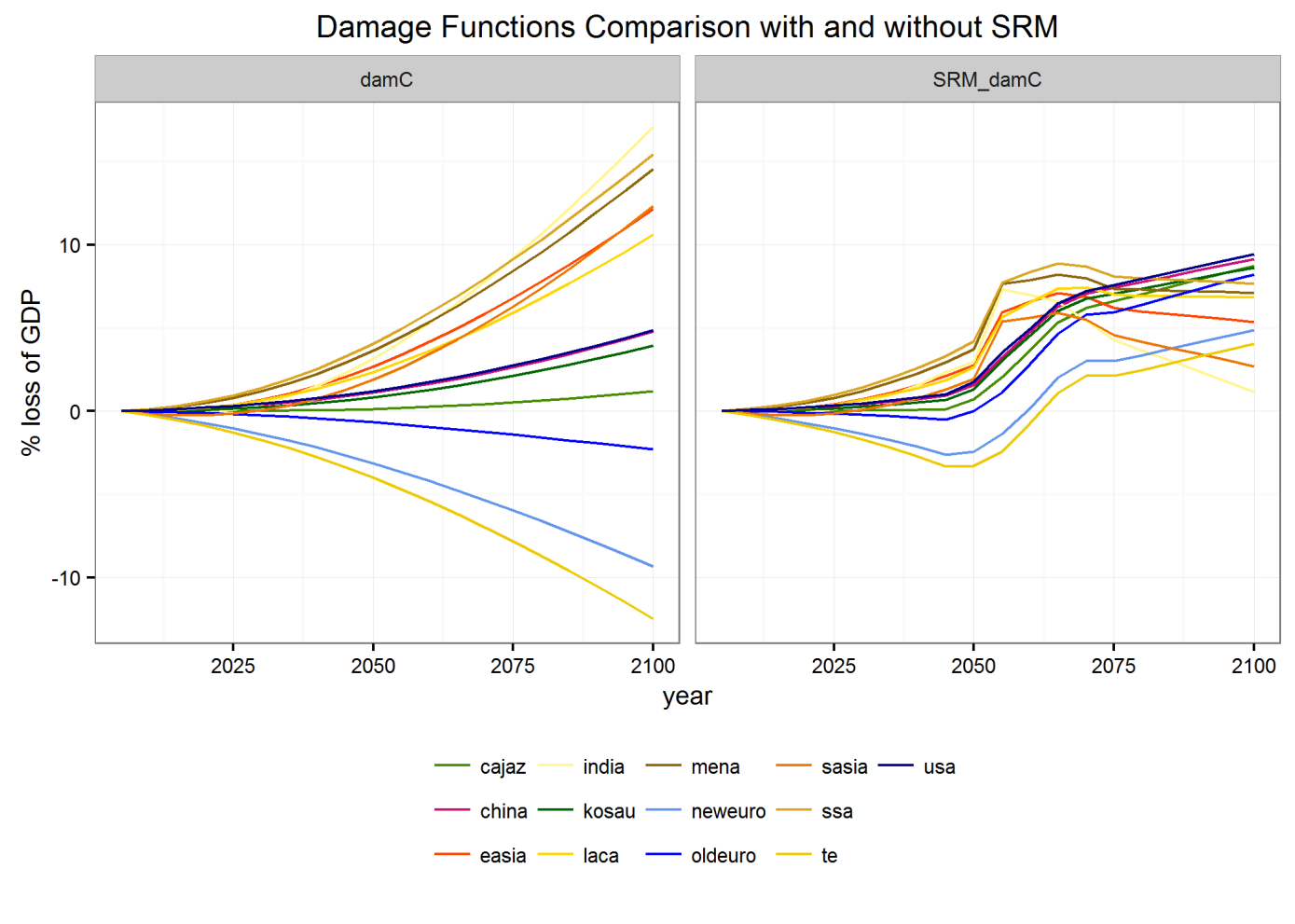
Temperature



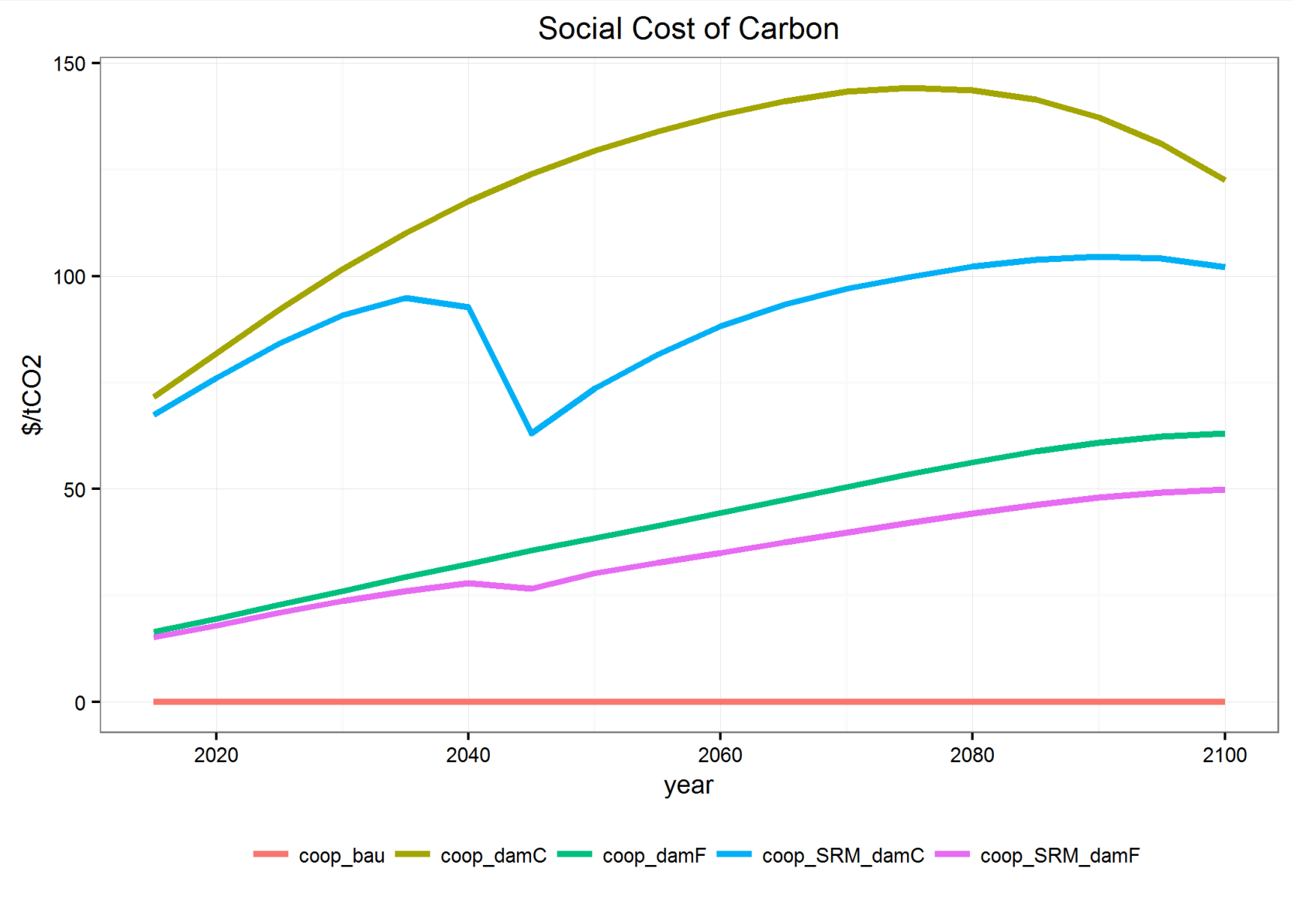
Regional shares of SRM



Results - damage wout SRM



Social Cost of Carbon (SCC)



Conclusions

- SRM as climate policy with region specific climate and growth impacts
- Cooperative vs. strategic non-cooperative implementation
- IAM supports large 'free driving effect':
  - temperature decrease due to SRM is three times larger in non cooperative case than in cooperative
- Regional contributions change

Bibliography

Bickel, J., Agrawal, S., 2011. Reexamining the economics of aerosol geoengineering.

Burke, M., Hsiang, S. M., Miguel, E., Oct. 2015. Global non-linear effect of temperature on economic production. Nature advance online publication.
URL http://www.nature.com/nature/journal/vaop/ncurrent/full/nature15725.html

Goes, M., Tuana, N., Keller, K., Apr. 2011. The economics (or lack thereof) of aerosol geoengineering. Climatic Change 109 (3-4), 719–744.
URL http://www.springerlink.com/index/10.1007/s10584-010-9961-z

Gramstad, K., Tjøtta, S., 2010. Climate engineering: cost benefit and beyond. MPRA Paper 27302, University Library of Munich, Germany.
URL http://ideas.repec.org/p/pra/mprapa/27302.html

Lempert, R., Schlesinger, M., Bankes, S., Andronova, N., 2000. The Impacts of Climate Variability on Near-Term Policy Choices and the Value of Information. Climatic Change 45 (1), 129–161.
URL http://dx.doi.org/10.1023/A%3A1005697118423

Moreno-Cruz, J. B., Keith, D. W., May 2012. Climate policy under uncertainty: a case for solar geoengineering. Climatic Change.
URL http://www.springerlink.com/index/10.1007/s10584-012-0487-4

Robock, A., Marquardt, A., Kravitz, B., Stenchikov, G., Oct. 2009. Benefits, risks, and costs of stratospheric geoengineering. Geophysical Research Letters 36 (19), L19703.
URL http://www.agu.org/pubs/crossref/2009/2009GL039209.shtml

Taylor, K. E., Stouffer, R. J., Meehl, G. A., Oct. 2011. An Overview of CMIP5 and the Experiment Design. Bulletin of the American Meteorological Society 93 (4), 485–498.
URL http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-11-00094.1