The effect of climate thresholds on coalition formation

Kai Lessmann, Potsdam Institute on Climate Impact Research

Joint work with
Johannes Emmerling (FEEM),
Ulrike Kornek (MCC Berlin),
Valentina Bosetti (Universita Bocconi, FEEM),
Massimo Tavoni (FEEM)

Presented at AWEEE, the 7th Atlantic Workshop on Energy and Environmental Economics

Climate coalition analysis after the Paris Agreement

- Don't we *have* a large and ambitious climate coalition?
- Coalition analysis:
  - Investigates the incentives to contribute to an agreement
  - Often asking who would voluntary *sign an agreement*
- The Paris Agreement is signed (though it hasn't entered into force)
- But the Paris *Ambition Mechanism* begs the same questions:
  - Who will voluntarily be part of the group of countries to raise the ambition of NDCs?
  - What is the effect of supporting instruments (e.g. GCF, CBIT) or new insights into climate impacts on these incentives?

Literature: Climate change thresholds

- Lenton et al. (PNSA 2008): Tipping points from expert elicitation

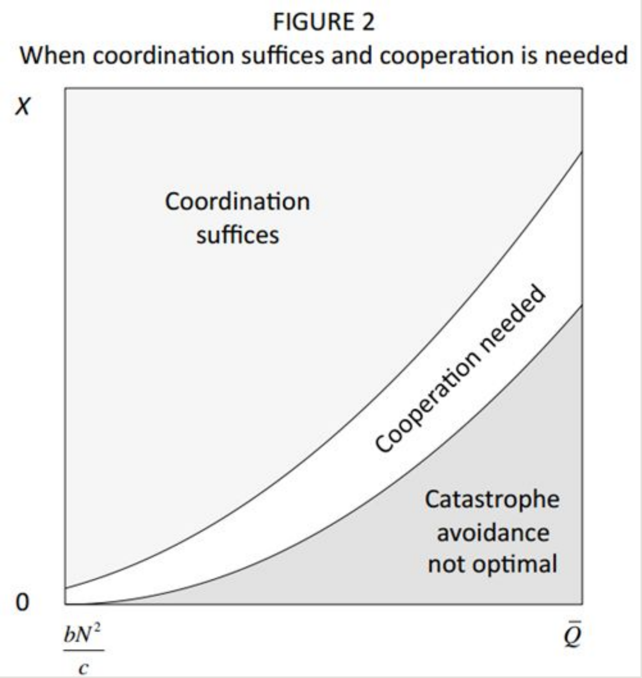
Tipping element	Feature of system, F(direction of change)	Control parameter(s), ρ	Critical value(s),† ρ_{crit}	Global warming†,‡	Transition timescale,† T	Key impacts
Arctic summer sea-ice	Areal extent (−)	Local ΔT_{air}, ocean heat transport	Unidentified§	+0.5–2°C	≈10 yr (rapid)	Amplified warming, ecosystem change
Greenland ice sheet (GIS)	Ice volume (−)	Local ΔT_{air}	+≈3°C	+1–2°C	>300 yr (slow)	Sea level +2–7 m
West Antarctic ice sheet (WAIS)	Ice volume (−)	Local ΔT_{air}, or less ΔT_{ocean}	+≈5–8°C	+3–5°C	>300 yr (slow)	Sea level +5 m
Atlantic thermohaline circulation (THC)	Overturning (−)	Freshwater input to N Atlantic	+0.1–0.5 Sv	+3–5°C	≈100 yr (gradual)	Regional cooling, sea level, ITCZ shift
El Niño–Southern Oscillation (ENSO)	Amplitude (+)	Thermocline depth, sharpness in EEP	Unidentified§	+3–6°C	≈100 yr (gradual)	Drought in SE Asia and elsewhere

- Cai, Lenton, Lontzek (NCC 2016): Stochastic modeling of thresholds
  - Eightfold increase in CO2 price from accounting for tipping points

Literature: Coalition formation

- Theoretical literature has established results with Linear or quasi-linear utility functions
  - Symmetric players, static setting
  - Coalition members internalize all coalition externalities, non-members do not
  - Stable coalition ≡ no incentive to leave/join
  - Very simple description of mitigation costs and benefits (Hoel, 1991; Carraro and Siniscalco, 1993; Barrett, 1994)

- Barrett (2013): *Approaching catastrophes*
  - Deterministic threshold coordination game
  - Uncertain threshold location coordination collapses



Source: Barrett (2013)

Research aim and design

- Study the impact of threshold impacts on cooperation and the stability of climate coalitions
  - Take into account
    - heterogeneity of players/regions
    - non-linearities
    - dynamics of the climate game
  - Study impact of real-world climate thresholds
- Use two numerically calibrated *Integrated Assessment Models* (IAM)
  - introduce threshold damages
  - study optimal and strategic behavior at the threshold
  - consider transfers and uncertainty

The numerical models

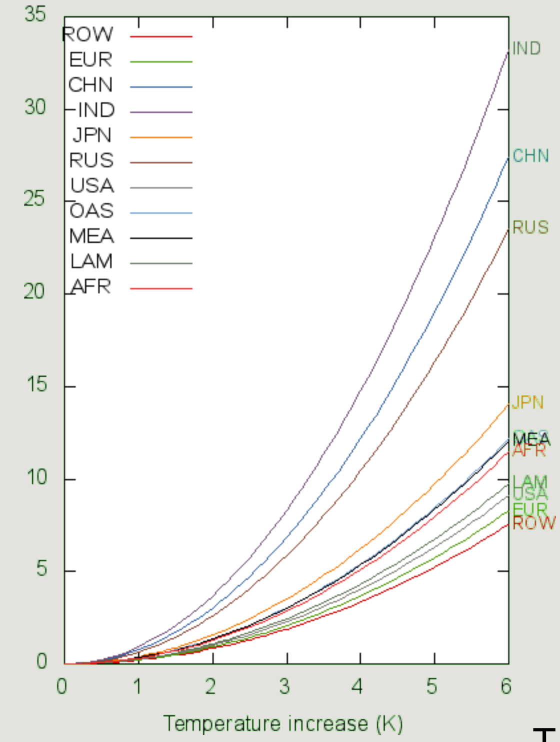
- *WITCH* (World Induced Technological Change Model)
  Bosetti et al. (2006, 2007, 2009)

  - Full scale *Integrated Assessment Model* (IAM)
    Heavily contributed to AR5 scenario database
  - Multi-region growth model, 13 world regions
  - Detailed GHG mitigation options: multi-gas, energy sectors

- *MICA* (Model of International Climate Agreements)
  Lessmann et al. (2009, 2011, 2013)

  - Stylized IAM (think Nordhaus's RICE)
  - Multi-region growth model, 11 world regions
  - CO2 mitigation function calibrated to REMIND-R

Threshold implementation



- Regional, aggregate damage functions (percent of GDP)

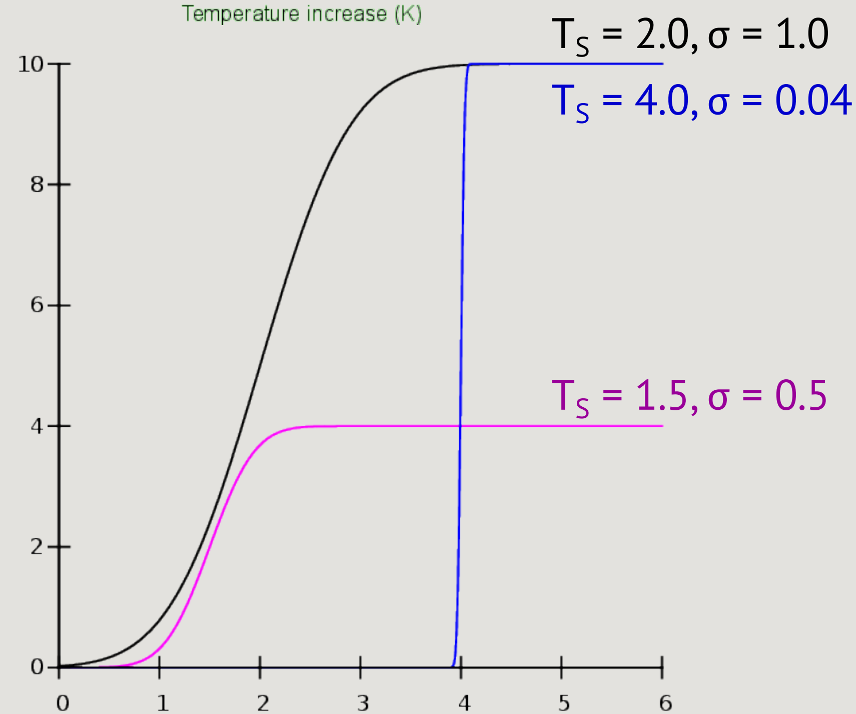
$$\Omega_i = \theta_{1i} T + \theta_{2i} (T)^{\theta_3}$$

  - T = temperature
  - θ_{ji} = parameter

- Thresholds: “smooth step”

$$\Omega_i = \theta_{1i} T + \theta_{2i} (T)^{\theta_3} + d * erf\left(\frac{T - T_S}{\sigma}\right)$$

  - *erf* = “error function”, cumulative distribution function of normal distribution
  - T_S, d, σ = location, level, and “sharpness” of threshold
  - Standard values: d = 4%, σ = 0.04 (Cai et al. 2016: 5-15% long term, total of 38% with 1.89% expected value)

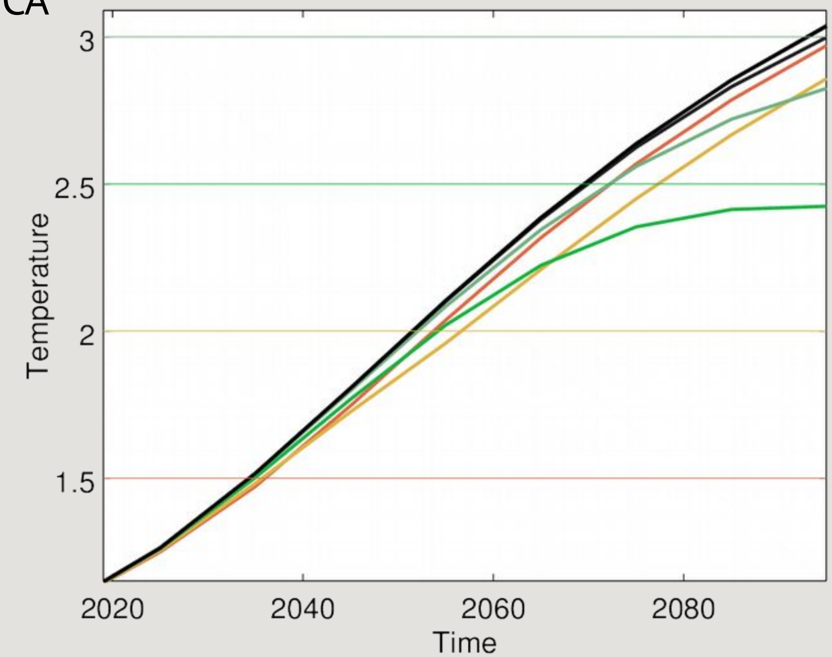


Potsdam Institute for Climate Impact Research

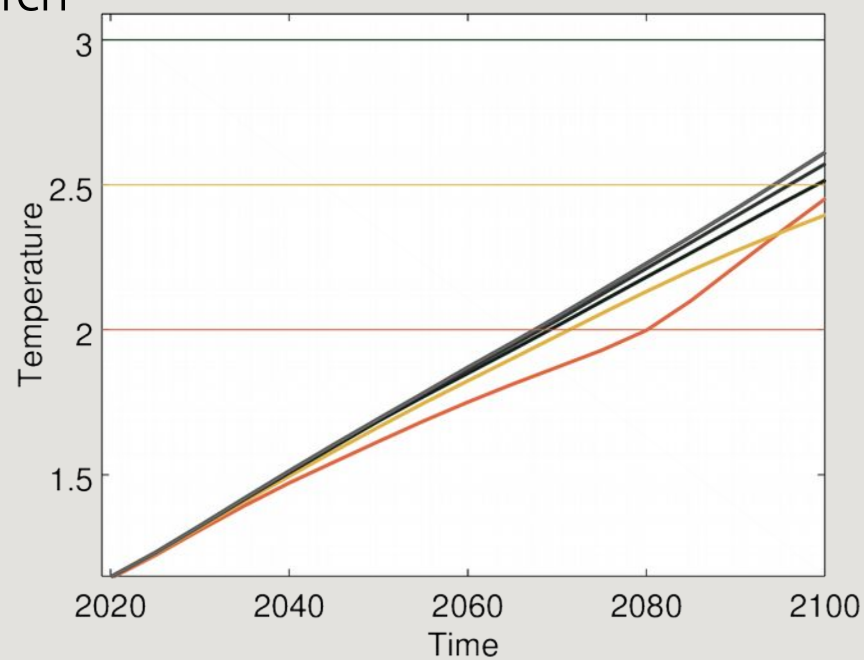
Threshold strategies

- Grand coalition
  = socially optimal
- Strategic behavior

MICA

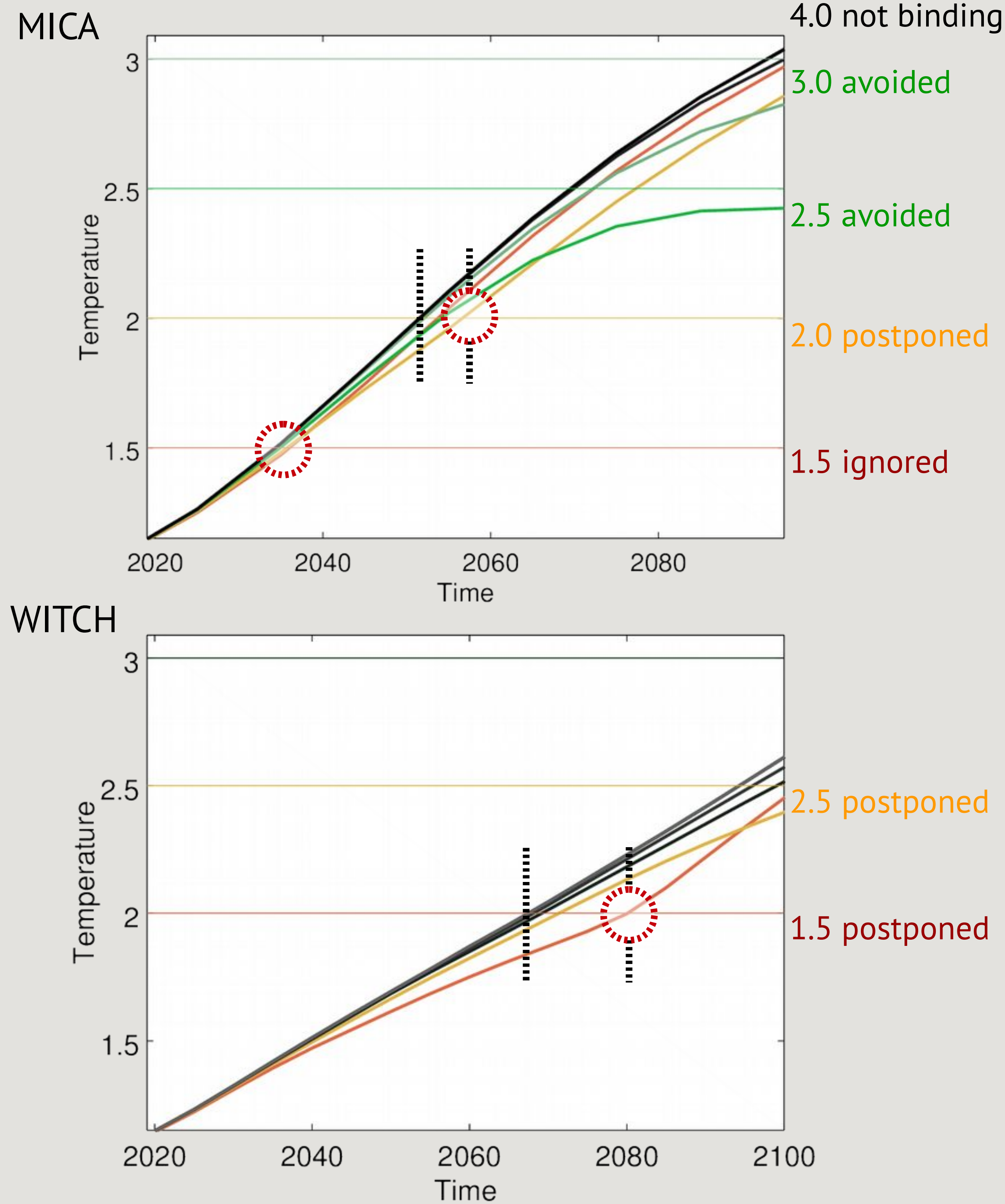


WITCH

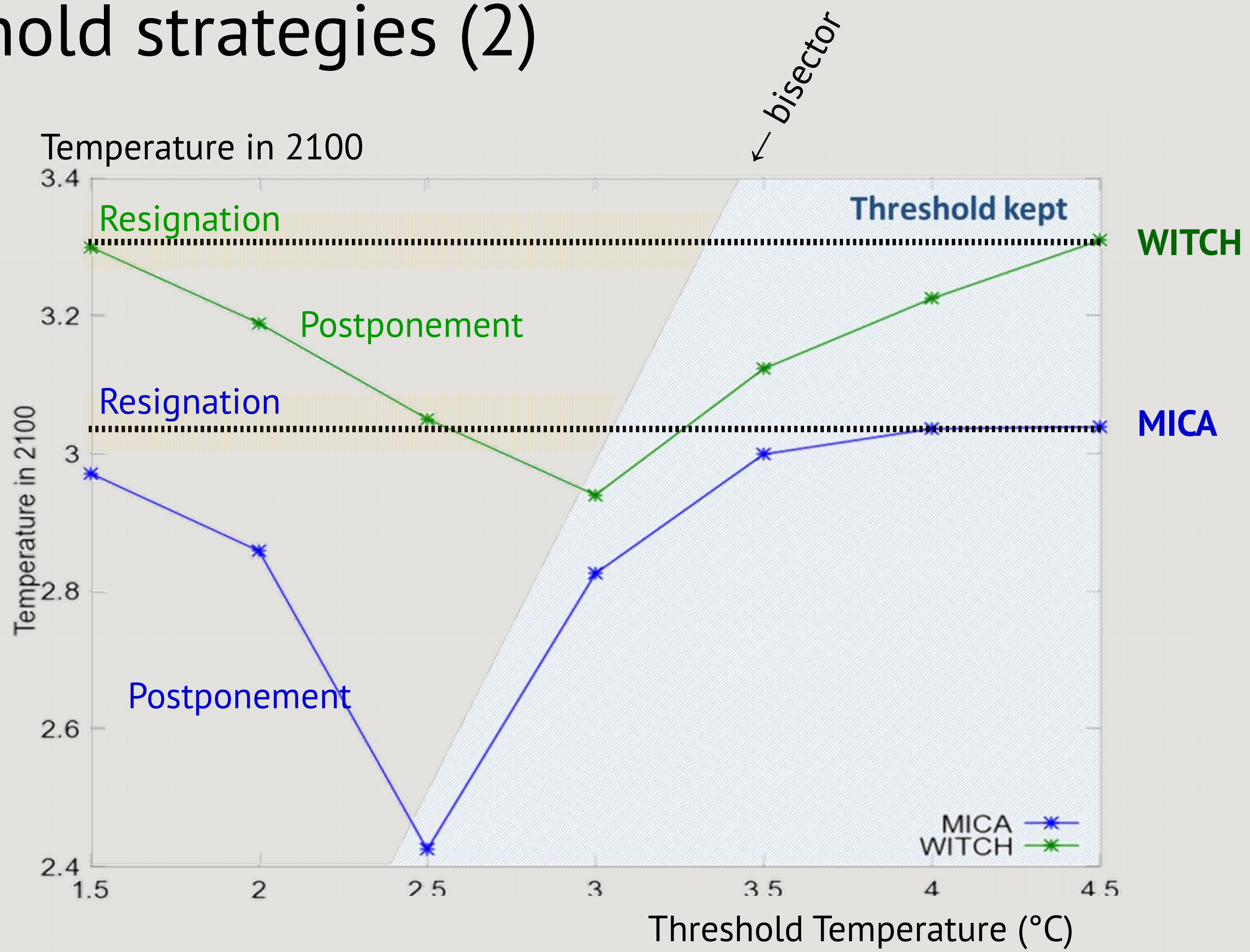


Threshold strategies

- Grand coalition
  = socially optimal
- Strategic behavior
  - **Avoidance** success
  - **Postponement** of exceeding the threshold
  - **Resignation** ignore the inevitable



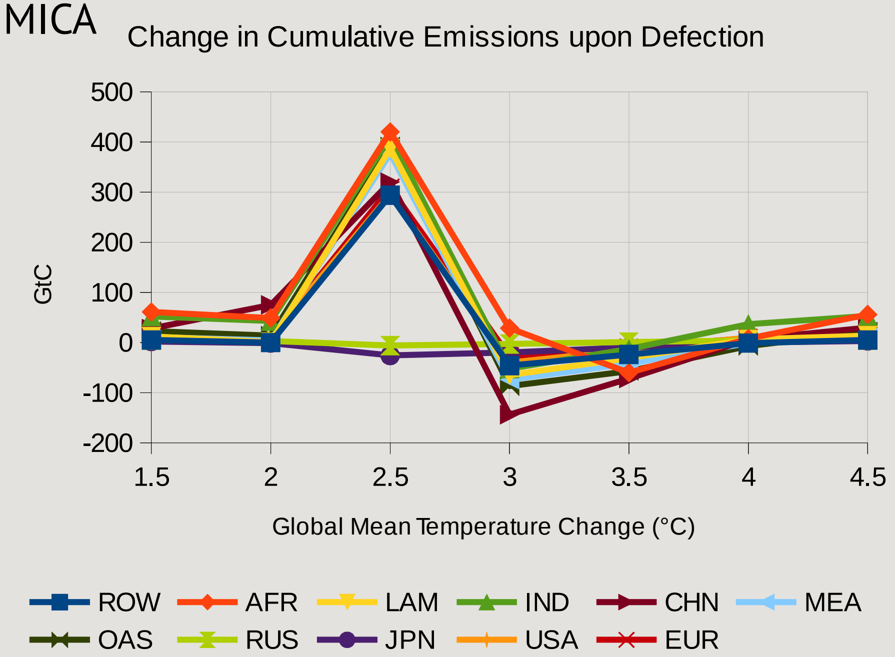
Threshold strategies (2)



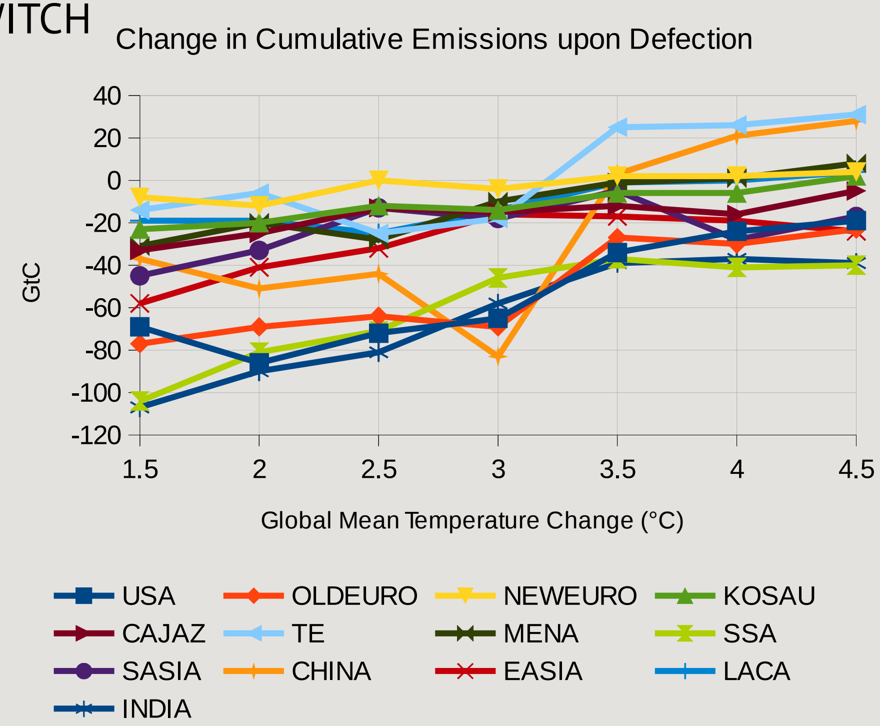
Resignation	Postponement	T_S critical	Avoidance	Regular free-riding
Avoidance infeasible	Avoidance infeasible or too costly			Threshold not binding

Coalition reaction around thresholds

MICA

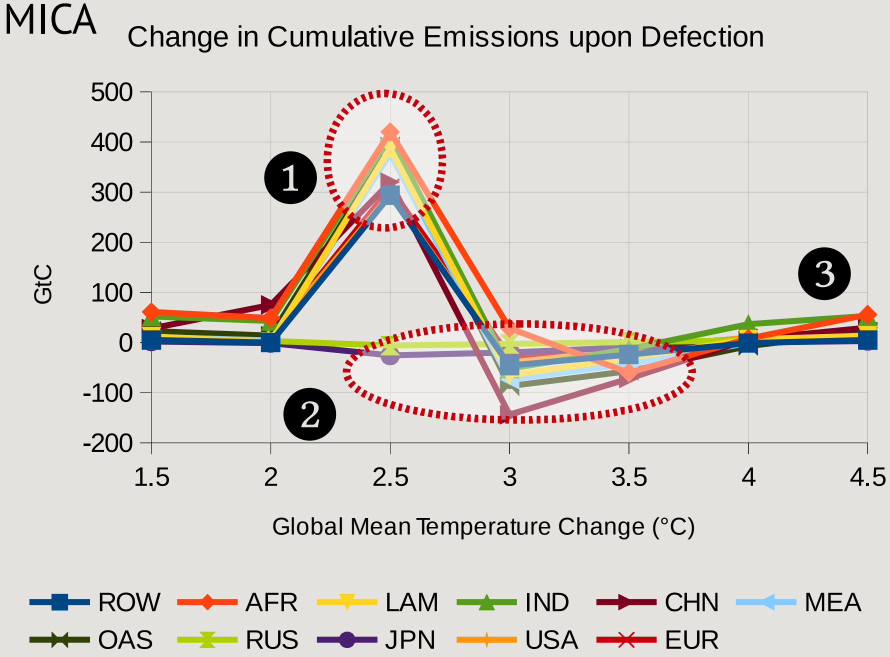


WITCH

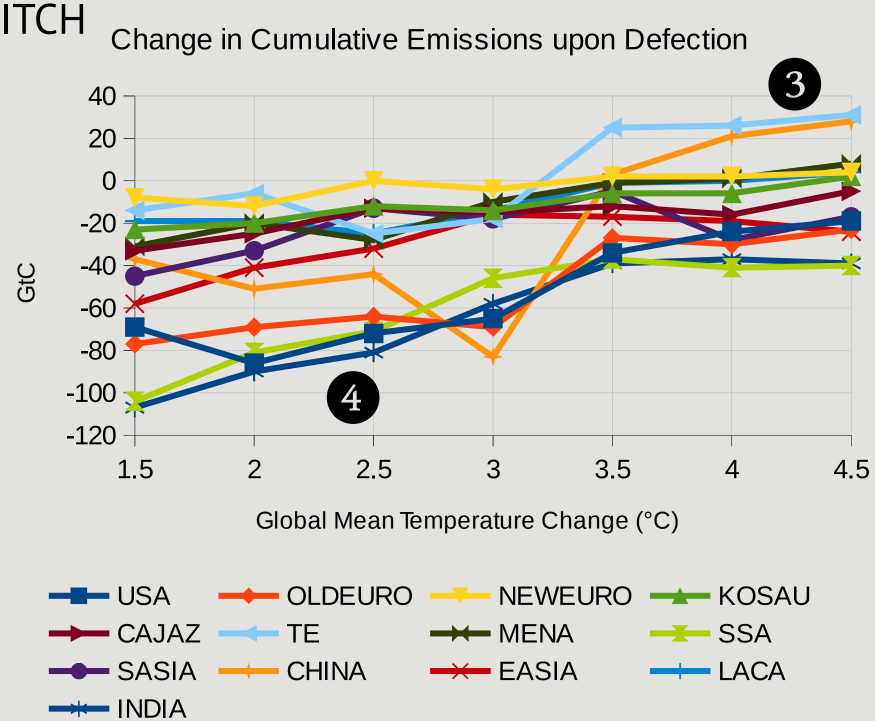


Coalition reaction around thresholds

MICA



WITCH



(1) Abandon threshold

which was previously avoided

(2) Counteract defection

to *still* keep below the threshold

(3) Reduced abatement incentive

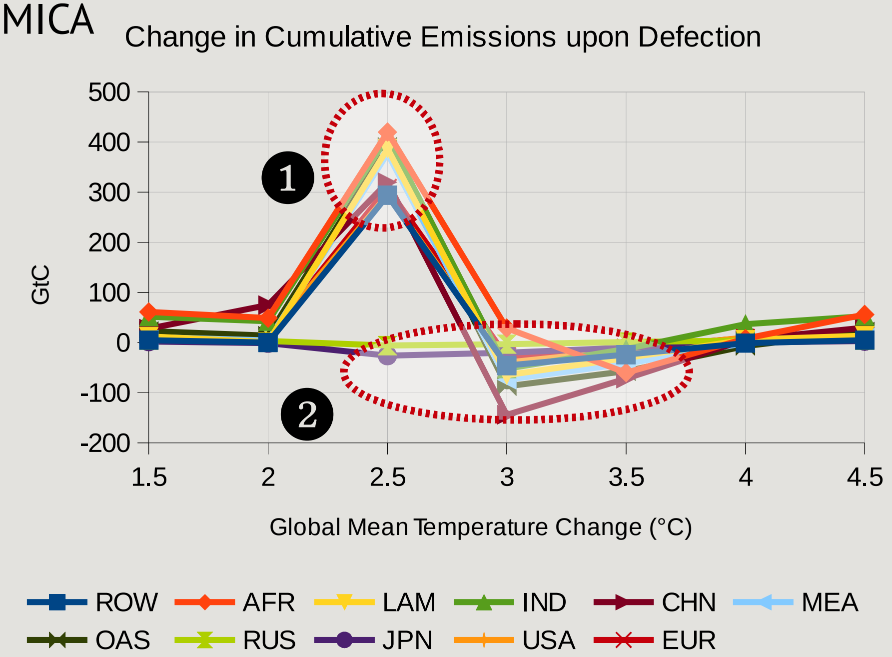
due to smaller coalition size and
non-binding threshold level

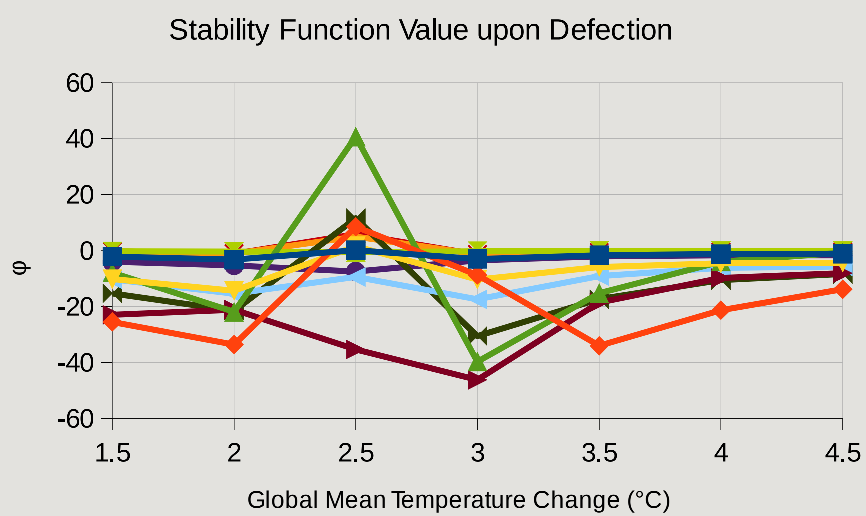
(4) Counteracting defection

to still ***postpone*** exceeding the threshold

Defector incentives around thresholds

MICA

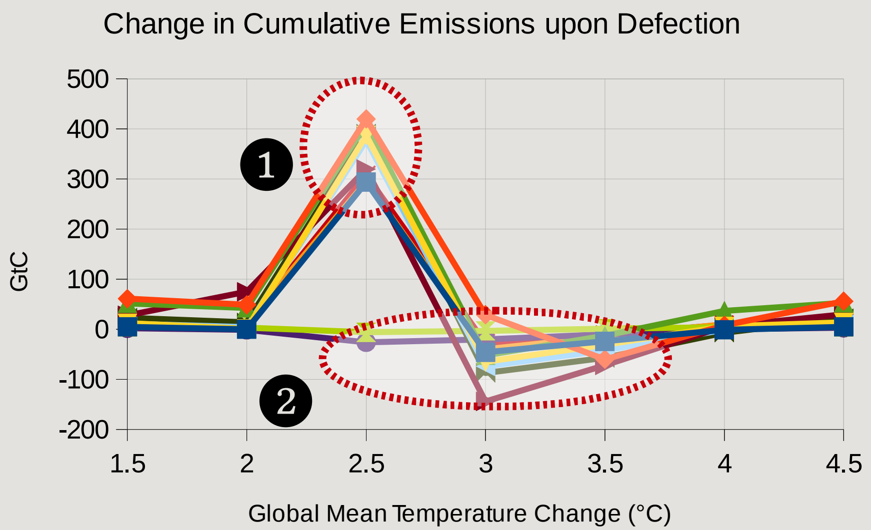


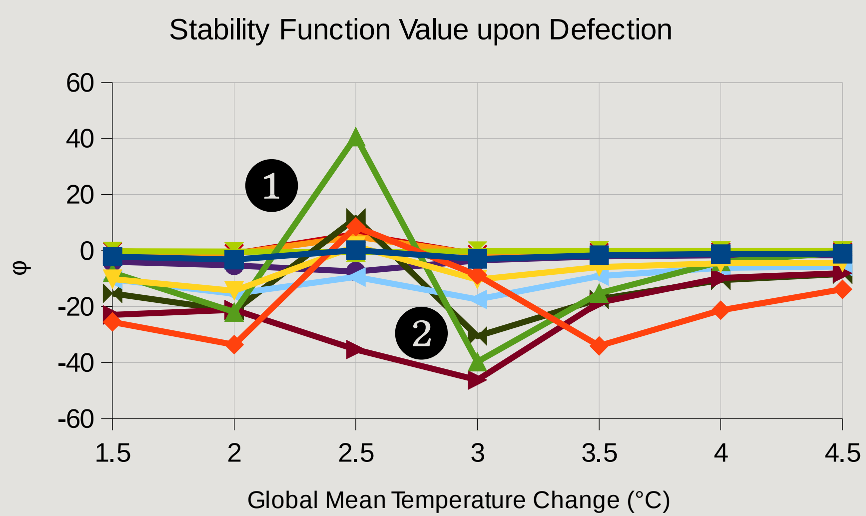


(1) Abandon threshold
which was previously avoided

(2) Counteract defection
to *still* keep below the threshold

Defector incentives around thresholds





(1) Abandon threshold
which was previously avoided

- Stability value *skyrockets*
→ defection unattractive

(2) Counteract defection
to *still* keep below the threshold

- Stability value *plummets*
→ defection very attractive

- Critical role for *pivotal* regions

Stable Grand Coalitions in threshold vicinity

- "Optimal" transfers among coalition members
  (OPTS → *Carraro, Eyckman, Finus 2006*, NTU implementation → *Kornek, Lessmann, Tulkens 2015*)

Threshold level (addition damages)

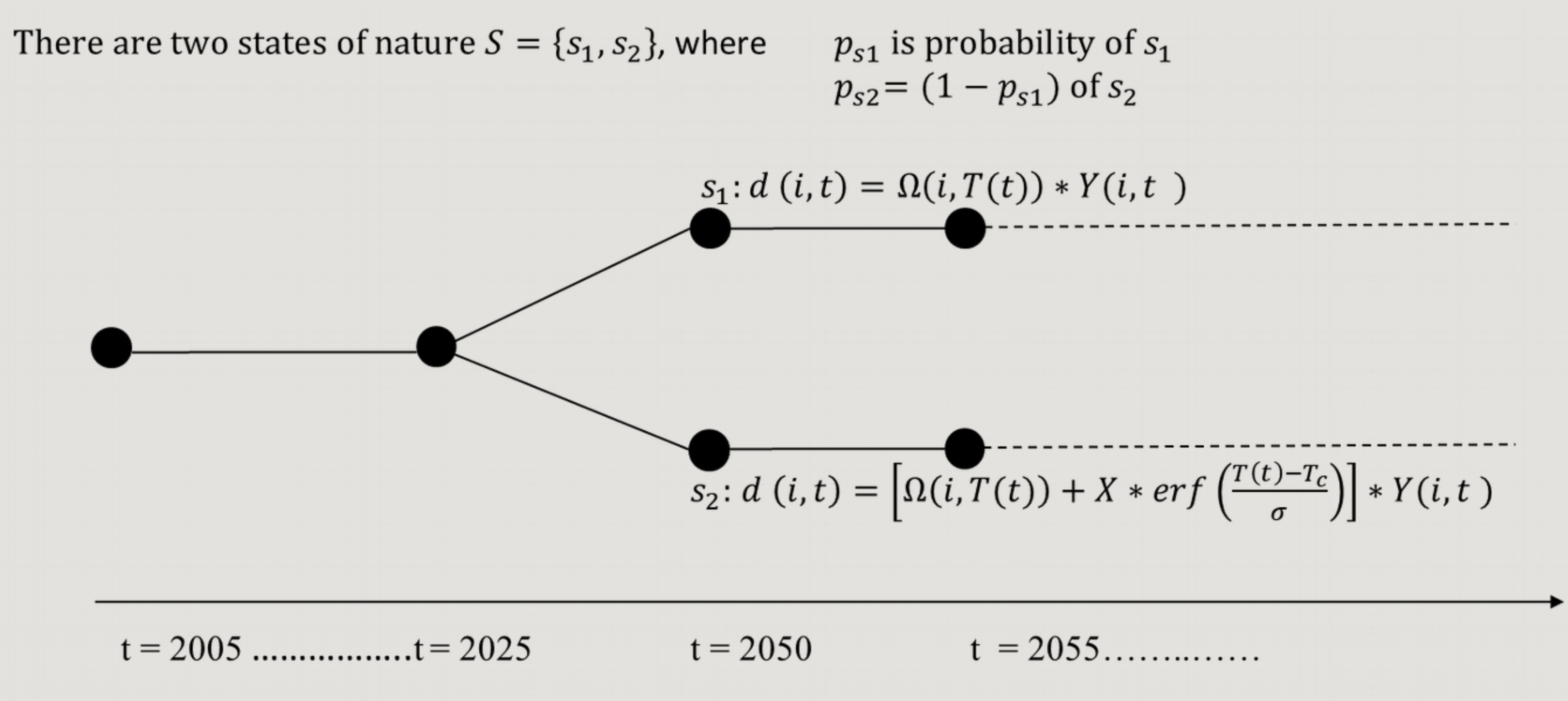
Threshold location (temperature)

$T_S \setminus d$	3%	3.5%	4%	4.5%
2.3	0	0	0	0
2.4	0	0	0	0
2.5	***1***	***1***	***1***	0
2.6	0	0	0	0
2.7	0	0	0	0

- Threat of threshold successfully encourages cooperation
- "Knife edge" result: sensitive to threshold location and level

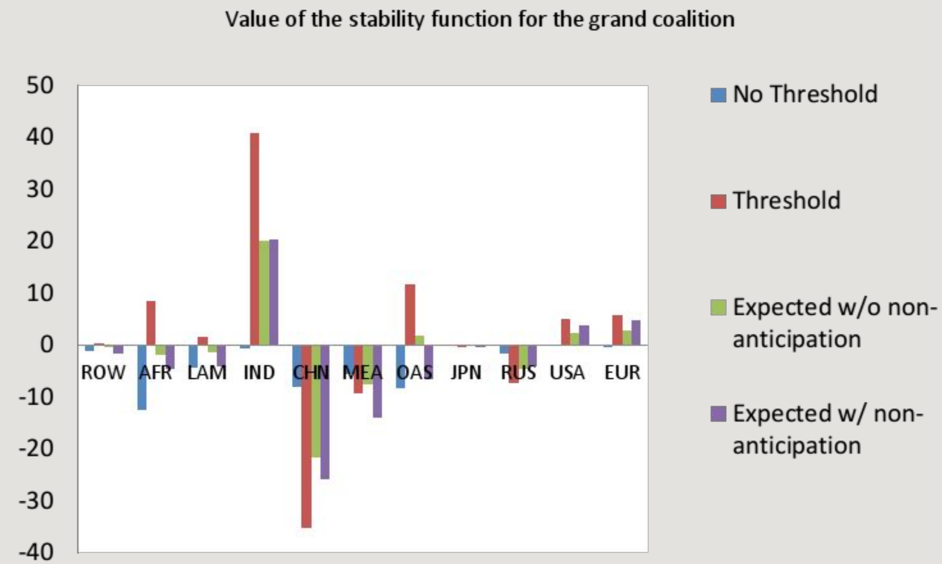
Uncertainty: Implementation

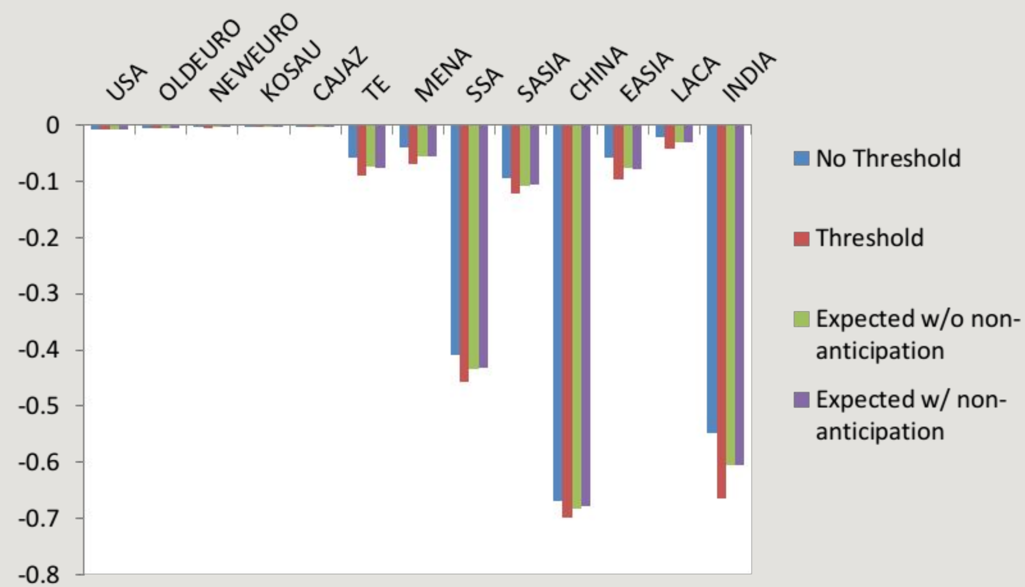
- Uncertainty about threshold location
  - Reduces beneficial effect of thresholds on cooperation (Barrett 2013)
  - *Is there still scope for more cooperation?*



Stochastic climate thresholds: Results

- Incentive to stay in the Grand Coalition
- Results
  - Stochastic threshold raise stability function by less
  - Learning improves stability value
- Transfers may stabilize





Conclusions and outlook

- In a nutshell
  - “At the threshold” *pivotal* regions matter
    - Whether coalitions *counteract defection* or *abandon the threshold*
    - Whether free-riding costs *skyrocket* or *plummet*
  - Whether climate change thresholds enhance cooperation depends
    - On threshold location
    - Regional characteristics
  - Uncertainty about threshold location partially undermines threshold benefits
- Outlook
  - Ongoing work: *Non-cooperative* equilibrium to keep the threshold
  - Application to tipping point empirics/science (cf. Lenton et al. 2008)

Thank you for your attention!

Thanks to my coauthors

Johannes Emmerling

Ulrike Kornek

Valentina Bosetti

Massimo Tavoni