Tipping points in the climate system and the economics of climate change

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Motivation and aims

Tipping points in the climate system are one of the principal reasons for concern about climate change (e.g. IPCC AR5)

In spite of this, leading economic estimates of the cost of climate change EITHER ignore these tipping points OR represent them in a highly simplified way that is impossible to calibrate

But all is not lost: an emerging literature incorporates individual tipping points in IAMs (e.g. Nordhaus on the GIS in PNAS, 2019)

Our aim is to bring this literature closer to incorporation in leading economic estimates of climate costs, by

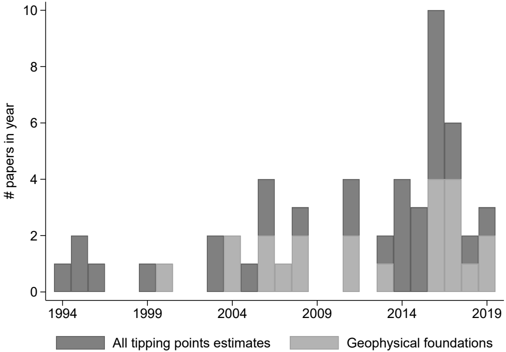
- Reviewing and synthesising this literature
- Building a meta/structural model capable of incorporating all the tipping points studied so far and estimating the overall contribution to the social cost of carbon

Broad search [yielding 53 articles, not all created equal]:

1. Study of a geophysical tipping point in relation to climate change
2. An economic valuation (i.e., not just a physical impact)

Realism in physical module [22 articles]:

3. Geophysical model of the tipping point coupled with an IAM. Only research with physical foundations, i.e.,



Models synthesised in this study

Tipping point	Papers	IAM	Model of TP	Uncertainty
Permafrost Carbon Feedback (PCF)	Kessler (2017, *Clim. Chge. Econ.*)	DICE	Process-based	Deterministic & MC
	Hope & Schaefer (2016, *Nat. Clim. Chge.*)	PAGE09	Process-based	MC
	Yumashev et al. (2019, *Nat. Comms.*)	PAGE-ICE	Process-based	MC
Ocean Methane Hydrates (OMH)	Ceronsky et al. (2011, unpublished)	FUND	Tipping event	Deterministic & MC
	Whiteman et al. (2013, *Nature*)	PAGE09	Tipping event	MC
Surface Albedo	Yumashev et al. (2019, *Nat. Comms.*)	PAGE-ICE	Process-based	MC
Amazon dieback	Cai et al. (2016, *Nat. Clim. Chge.*)	DSICE	Tipping event	Survival analysis
GIS disintegration	Nordhaus (2019, *PNAS*)	DICE	Process-based	Deterministic
WAIS disintegration	Diaz and Keller (2016, *AER P&P*)	DICE	Tipping event	Survival analysis
AMOC slowdown	Anthoff et al. (2016, *AER P&P*)	FUND	Tipping event	Deterministic
Indian summer monsoon variability	Belaia (2017, unpublished)	RICE	Process-based	Stochastic

Towards a new consensus estimate for climate impacts that includes tipping points

Naive addition of these tipping points yields an increase in economic impacts of climate change of 73.6% of baseline estimate.

However, this comparison is wildly inconsistent

- Differences in economic modules and damage functions
- Incompatible climate modules
- Different economic metrics (marginal vs. total damages)
- Different emissions scenarios
- ...

$\Longrightarrow$ Need for a consistent framework to advance the economics of climate change

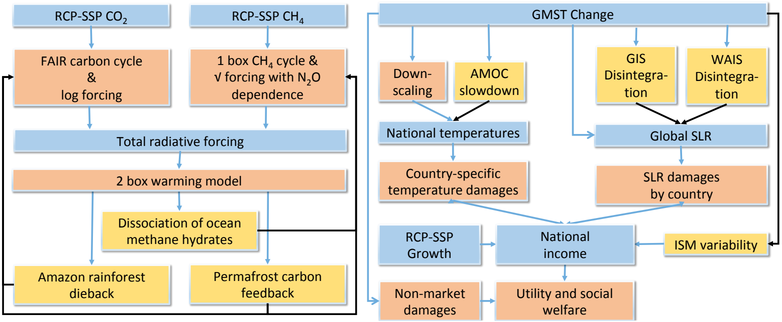
A meta/structural economic model of climate change including tipping points

We replicate the TP modules in each of these papers

Then we build a meta/structural model of emissions → temperatures → damages that can accommodate all TP.

General features of the structural model:

- Climate dynamics with explicit methane cycle
- National-level damages from climate econometrics lit.



Results: main specification

TP	SC-CO_2 (USD/tCO_2)	% increase due to TP
None	43.26	-
PCF	46.87	8.3
OMH	48.97	13.2
SAF	42.53	-1.7
Amazon	43.39	0.3
GIS	43.93	1.6
WAIS	44.62	3.2
AMOC	42.64	-1.4
ISM	43.82	1.3
All	54.35	25.6
$\sum$ 'main effects'	-	24.8

Note: RCP4.5/SSP2; Kessler main PCF; Whiteman et al. main OMH; IPSL AMOC

Additional tests

Scenario	W/o TP	With TP	% increase
PCF models (5)	49.07	51.71 - 56.95	5.4 - 16.1
OMH models (4)	49.07	50.14 - 74.54	2.2 - 51.9
AMOC models (4)	49.07	48.14 - 48.77	-6.0 - -0.6
RCP3-PD/2.6, SSP1	33.06	42.78	29.4
RCP4.5, SSP2	49.07	62.98	28.3
RCP6, SSP4	70.33	86.36	22.8
RCP8.5, SSP5	31.08	37.09	19.3
Least sensitive climate*	31.61	39.87	26.2
Most sensitive climate**	90.26	112.46	24.6
Pure levels damages	25.13	32.41	28.9
Pure growth damages $\approx$ Ricke et al. (2018)	2059.81	3513.08	70.6

* ACC2/GISS-E2-R, ** MESMO/HadGEM2-ES

Conclusions

We built a meta/structural model to integrate different climate TPs, in order to estimate the overall effect on the SC-CO_2

Our central estimate so far is a 28% increase in the SC-CO_2, within a range of 24-71% (this is an incomplete estimate of the uncertainty)

- The largest contributions to the SC-CO_2 come from the PCF and OMH dissociation; the former seems much better constrained than the latter
- GIS and WAIS have small positive effect on SC-CO_2
- AMOC slowdown reduces the SC-CO_2
- ISM effect is large enough to register in global SC-CO_2