Quantifying climate change Loss and Damage (consistent with a Social Cost of GHGs)

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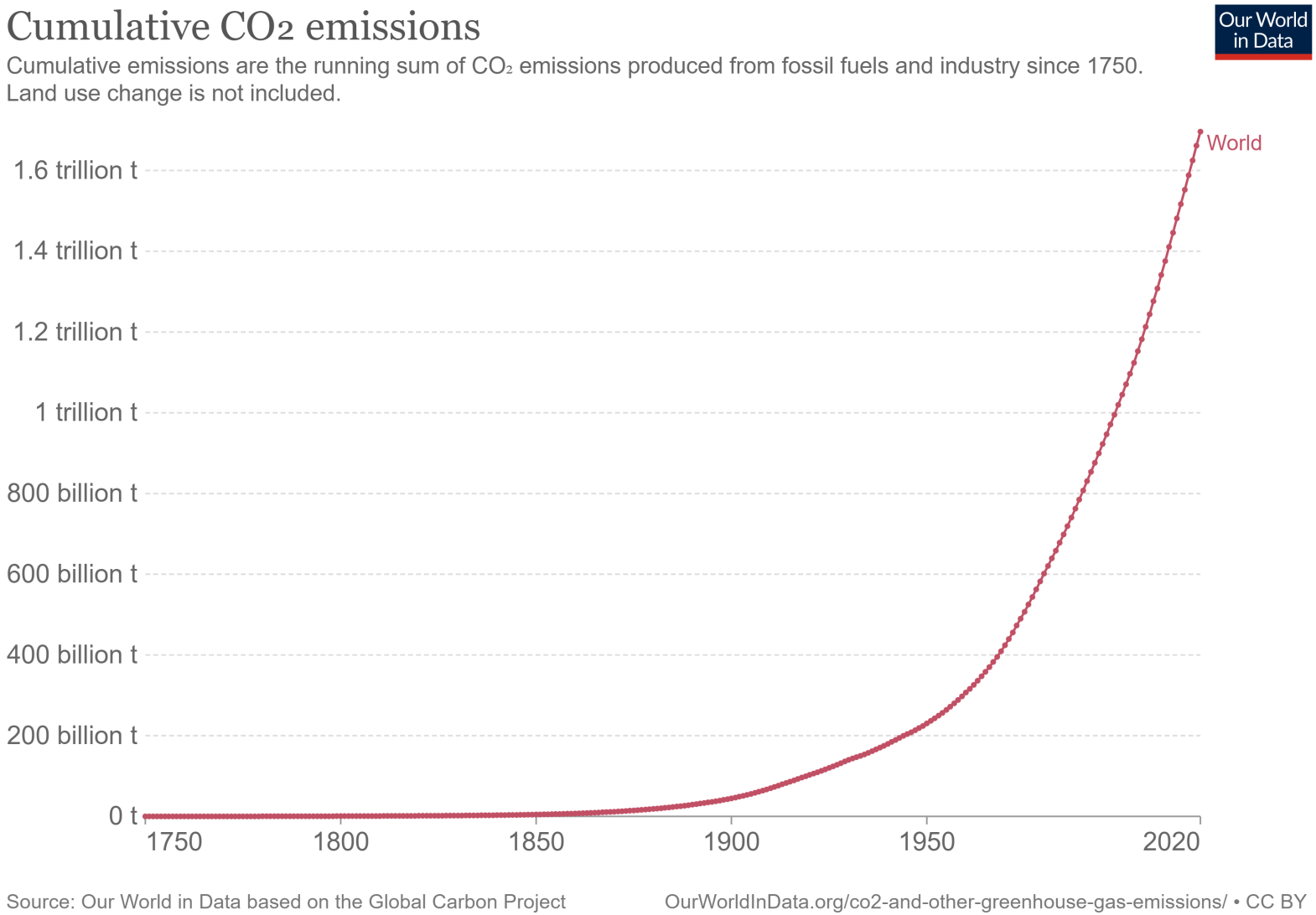
(Joint with Marshall Burke, Mustafa Zahid & Noah Diffenbaugh)

September 20, 2024 — Columbia U. & NY Fed

A historically missing market



Scale of the ongoing market failure

Current global emissions = **37B** tons CO2 per year

$231 per ton $\longrightarrow$ **$8.5T** in external costs worldwide

$=$ **8% of world GDP**

$\approx$ **GDP of Japan** (#3) + **Germany** (#4)

This talk

1. The problem of defining "Loss and Damage"
2. Our proposed solution
3. Demonstrate application using GDP-based damages

Bonus: Updated GDP growth estimates (reconciled with literature)

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Current international legal framework for GHG management

UN Framework Convention on Climate Change (UNFCC) - UN process for negotiating an agreement to limit dangerous climate change

Conference of the Parties (COP) - decision-making body of UNFCCC.

Kyoto Protocol - Treaty developed by COP entered into force in 2005 (currently 192 Parties).

Paris agreement - Legally binding treaty by COP entered into force 2016 (196 parties). Based on Nationally Determined Contributions (NDCs).

Article 8 $\rightarrow$ **"Loss & Damage"**

The World is negotiating over "Loss and Damage" from climate change

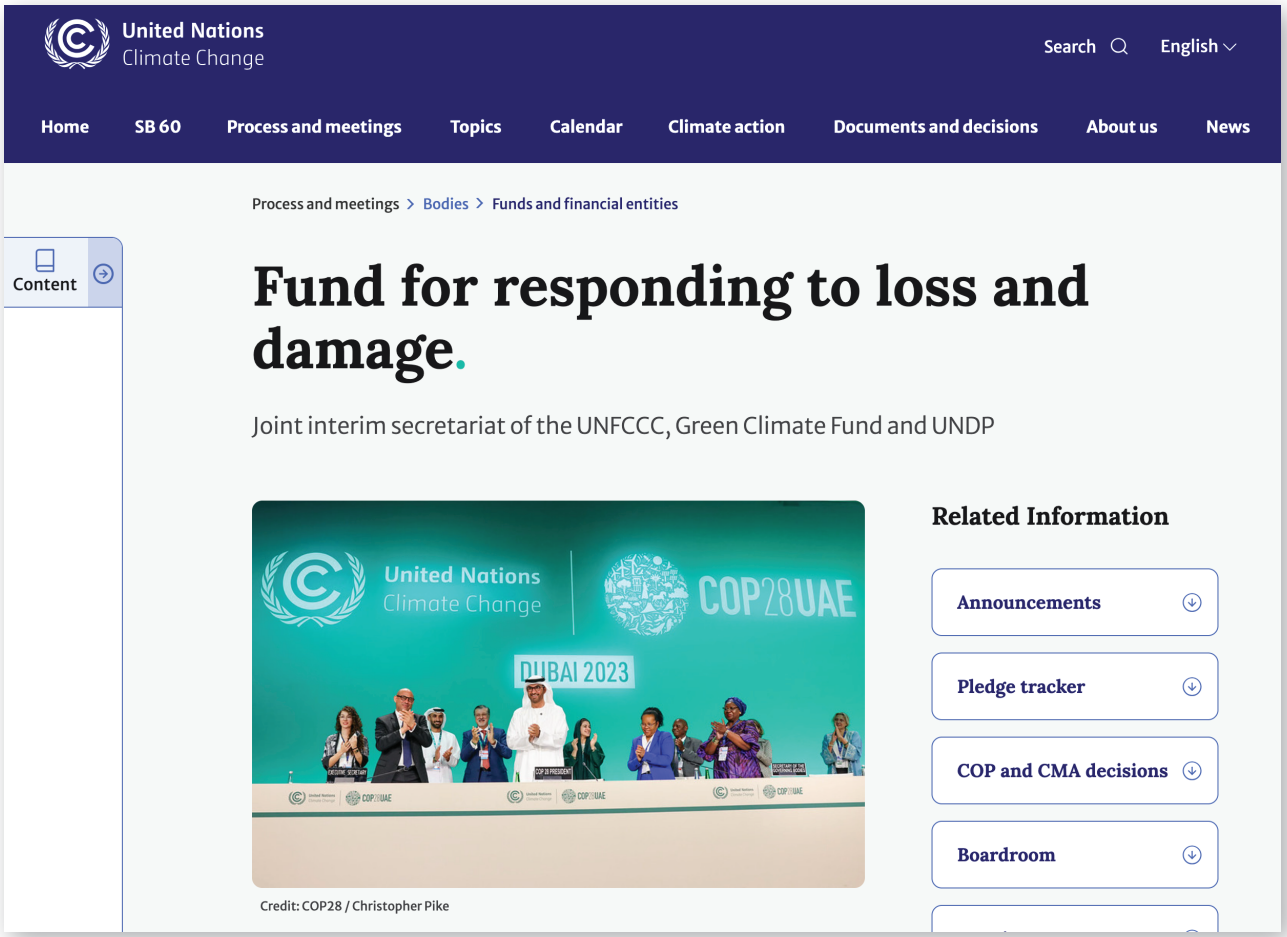
Article 8

1. Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage.

2. The Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts shall be subject to the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to this Agreement and may be enhanced and strengthened, as determined by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

3. Parties should enhance understanding, action and support, including through the Warsaw International Mechanism, as appropriate, on a cooperative and facilitative basis with respect to loss and damage associated with the adverse effects of climate change.

The World is negotiating over "Loss and Damage" from climate change



What is "Loss and Damage"?

https://unfccc.int/sites/default/files/resource/loss_and_damage_online_guide.pdf

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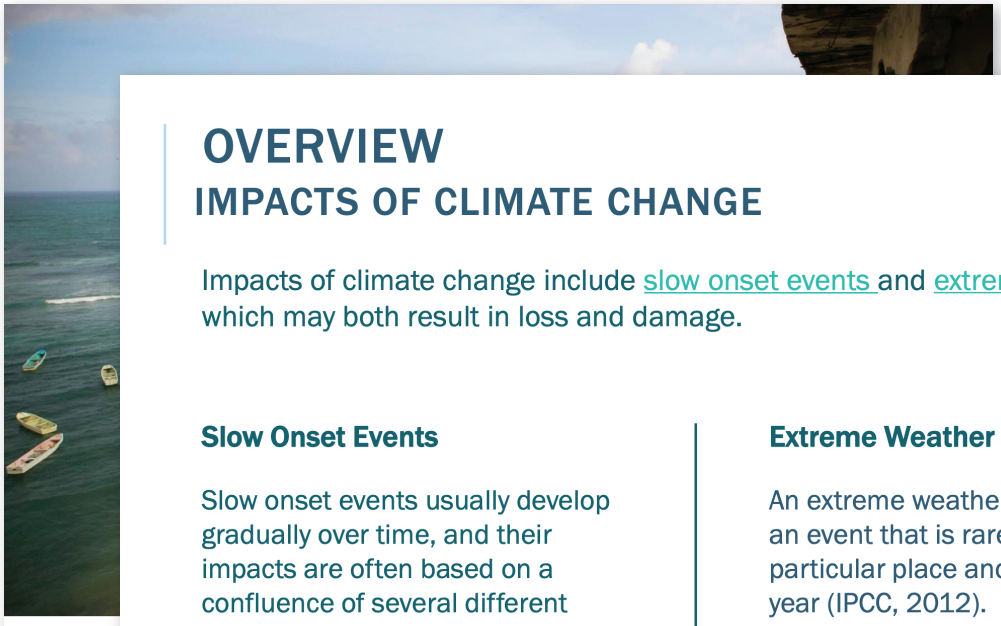


OVERVIEW

IMPACTS OF CLIMATE CHANGE

Impacts of climate change include slow onset events and extreme weather events which may both result in loss and damage.

Slow Onset Events

Slow onset events usually develop gradually over time, and their impacts are often based on a confluence of several different events (UNFCCC, 2012).

Extreme Weather Events

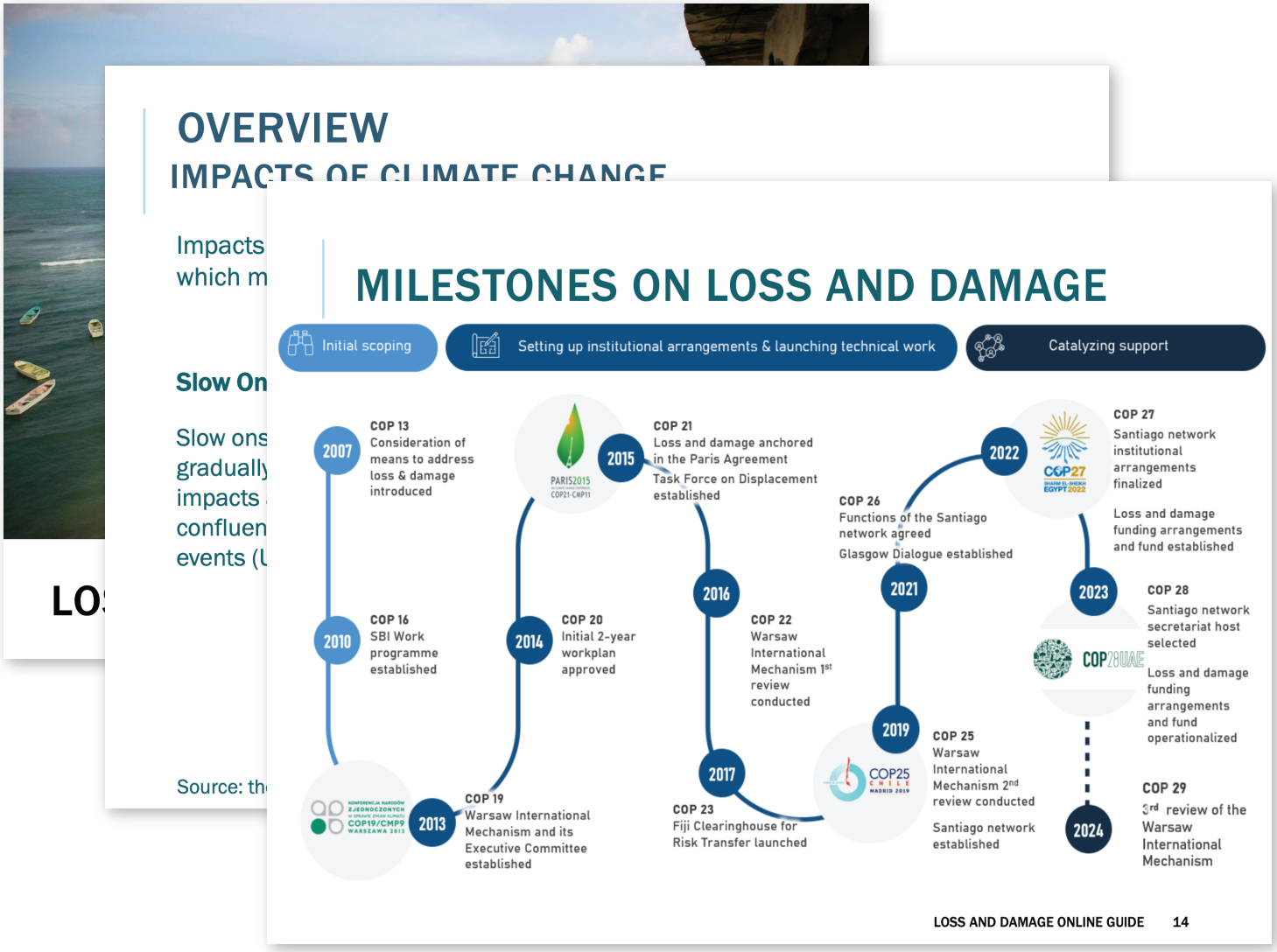
An extreme weather event is an event that is rare at a particular place and time of a year (IPCC, 2012).

Source: the IPCC glossary, Technical paper on Slow Onset Events

LOSS AND DAMAGE ONLINE GUIDE 3

https://unfccc.int/sites/default/files/resource/loss_and_damage_online_guide.pdf

What is "Loss and Damage"?



https://unfccc.int/sites/default/files/resource/loss_and_damage_online_guide.pdf

What is "Loss and Damage"?

OVERVIEW

IMPACTS OF CLIMATE CHANGE

Impacts
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gradually
impacts
confluen
events (U

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Source: th

MILESTONES ON LOSS AND DAMAGE

Initial scoping

2007 — COP 13
Consideration
means to addr
loss & damage
introduced

2010 — COP 16
SBI Work
programme
established

2013 — COP19/CMP9 WARSZAWA 2013

LOSS AND DAMAGE UNDER THE UNFCCC PROCESS

Warsaw International Mechanism

Executive Committee

Santiago network

Loss and damage fund and funding arrangements

LOSS AND DAMAGE ONLINE GUIDE 6

https://unfccc.int/sites/default/files/resource/loss_and_damage_online_guide.pdf

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What Is "Loss and Damage" from Climate Change? 8 Key Questions, Answered

February 26, 2024 By **Preety Bhandari**, **Nate Warszawski**, **Deirdre Cogan** and **Rhys Gerholdt**
Cover Image by: Cheryl Ramalho

Explainer

Topic **Climate**

More on

1) What Is Loss and Damage?

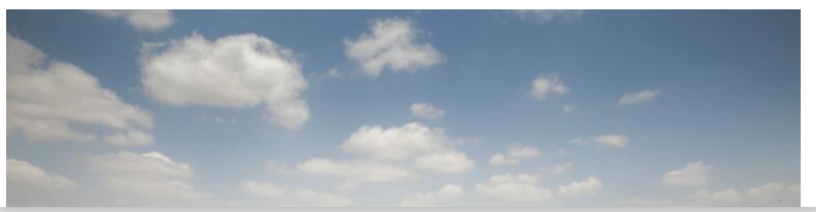
"Loss and damage" is a general term used in UN climate negotiations to refer to the consequences of climate change that go beyond what people can adapt to; for example, the loss of coastal heritage sites due to rising sea levels or the loss of homes and lives during extreme floods. This also includes situations where adaptation options exist, but a community doesn't have the resources to access or utilize them.

To date, there is no official definition of loss and damage under the UN.

Loss and damage is harming and will continue to harm vulnerable communities the most, meaning that addressing the issue is an urgent matter of climate justice. But the subject has historically been fraught with contention both inside and outside of UN climate negotiations. In particular, countries have struggled to reach agreement on how much money developed countries should supply to address loss and damage in developing nations, which have contributed the least to the climate crisis but are often hit hardest by its impacts.

2) What Counts as Loss and Damage?

Loss and damage can result from extreme weather events like cyclones, droughts and heatwaves, as well as from slow-onset changes such as sea level rise, desertification, glacial retreat, land degradation, ocean acidification and salinization. In some cases, damages may permanently alter places; for example, rising seas encroaching on low-lying islands, or drought shrinking water supplies and turning once-productive farmland into barren land.



https://www.wri.org/insights/loss-damage-climate-change

State of play

Treaties are essentially contracts between countries.

Terms of a contract are only legally binding insofar as a common understanding of their definition can be established.

"Loss and Damage" is now a legal object but lacks an actionable definition.

nature climate change

Article | Published: 25 September 2017

A typology of loss and damage perspectives

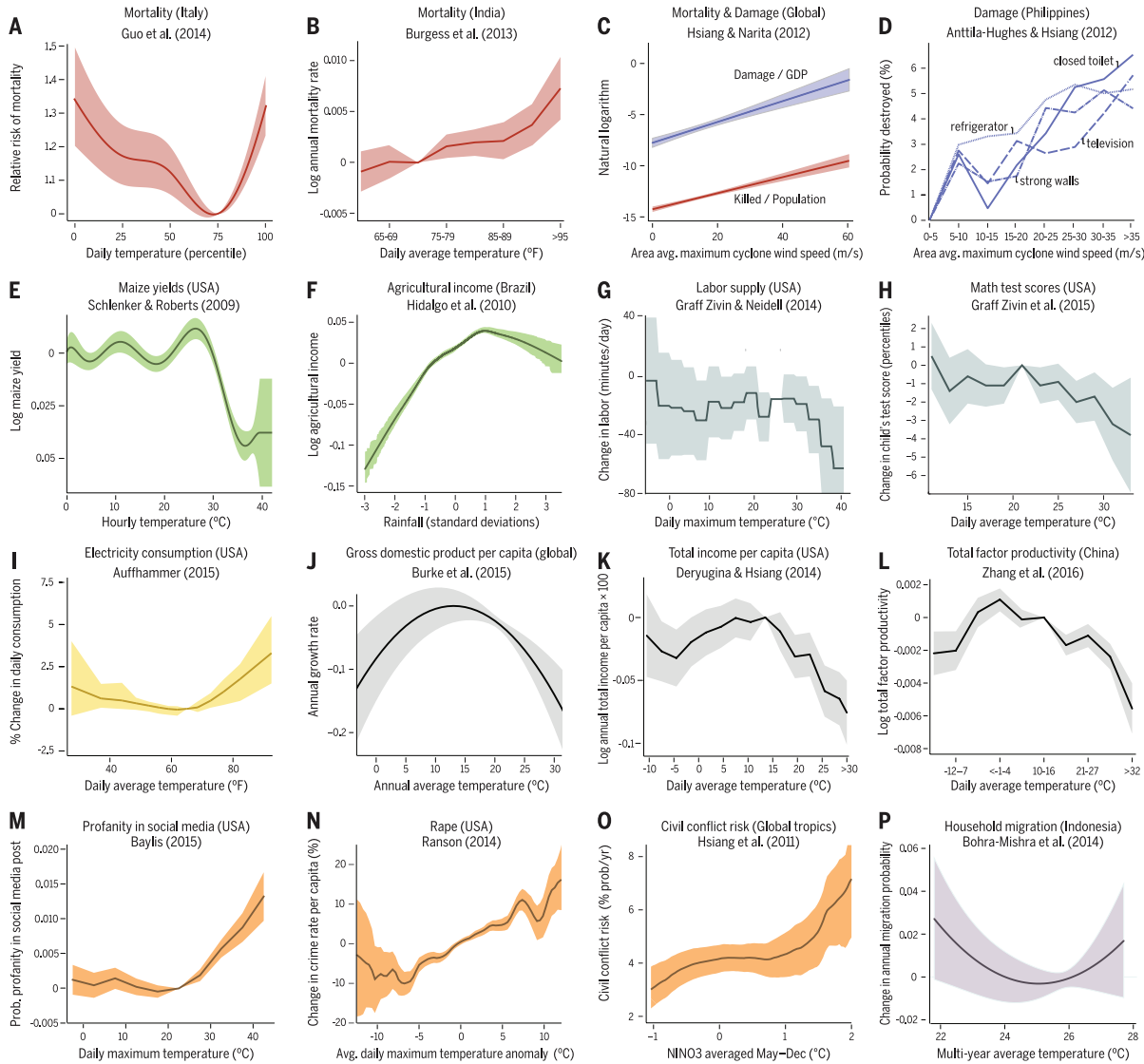
Emily Boyd, Rachel A. James, Richard G. Jones, Hannah R. Young & Friederike E. L. Otto

Nature Climate Change **7**, 723–729 (2017) | Cite this article

Abstract

Loss and Damage (L&D) has been the subject of contentious debate in international climate policy for several decades. Recently, formal mechanisms on L&D have been established, but arguably through unclear language. This ambiguity is politically important, but researchers and practitioners require clearer understandings of L&D. Here we report on the first in-depth empirical study of actor perspectives, including interviews with 38 key stakeholders in research, practice, and policy. We find points of agreement and also important distinctions in terms of: the relationship between L&D and adaptation, the emphasis on avoiding versus addressing L&D, the relevance of anthropogenic climate change, and the role of justice. A typology of four perspectives is identified, with different implications for research priorities and actions to address L&D. This typology enables improved understanding of existing perspectives and so has potential to facilitate more transparent discussion of the options available to address L&D.

...but we know a lot about quantifying damages!



Carleton & Hsiang (*Science*, 2016)

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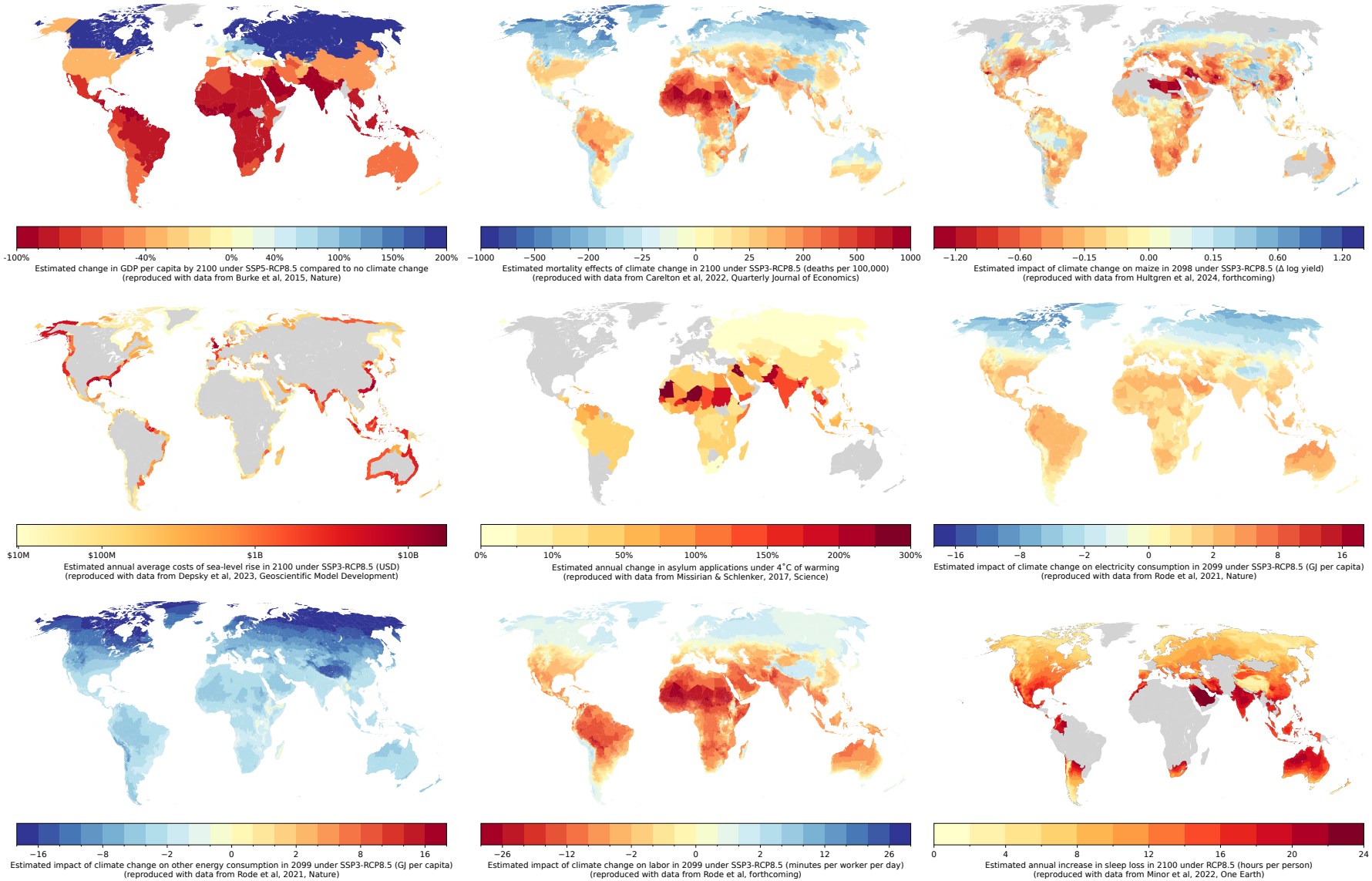

Hsiang (*Annual Review of Econ*, Forthcoming)

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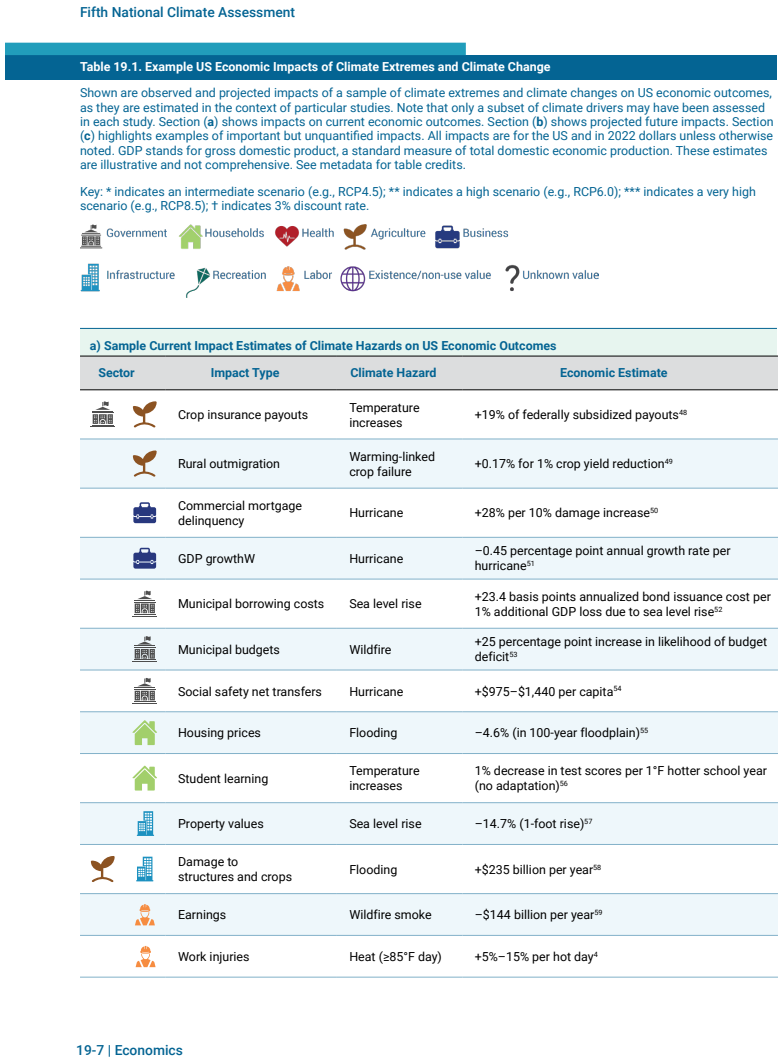

Fifth National Climate Assessment

Table 19.1. Example US Economic Impacts of Climate Extremes and Climate Change

Shown are observed and projected impacts of a sample of climate extremes and climate changes on US economic outcomes, as they are estimated in the context of particular studies. Note that only a subset of climate drivers may have been assessed in each study. Section (**a**) shows impacts on current economic outcomes. Section (**b**) shows projected future impacts. Section (**c**) highlights examples of important but unquantified impacts. All impacts are for the US and in 2022 dollars unless otherwise noted. GDP stands for gross domestic product, a standard measure of total domestic economic production. These estimates are illustrative and not comprehensive. See metadata for table credits.

Key: * indicates an intermediate scenario (e.g., RCP4.5); ** indicates a high scenario (e.g., RCP6.0); *** indicates a very high scenario (e.g., RCP8.5); † indicates 3% discount rate.

Government · Households · Health · Agriculture · Business · Infrastructure · Recreation · Labor · Existence/non-use value · ? Unknown value

a) Sample Current Impact Estimates of Climate Hazards on US Economic Outcomes

Sector	Impact Type	Climate Hazard	Economic Estimate
Government, Agriculture	Crop insurance payouts	Temperature increases	+19% of federally subsidized payouts[48]
Agriculture	Rural outmigration	Warming-linked crop failure	+0.17% for 1% crop yield reduction[49]
Business	Commercial mortgage delinquency	Hurricane	+28% per 10% damage increase[50]
Business	GDP growthW	Hurricane	−0.45 percentage point annual growth rate per hurricane[51]
Government	Municipal borrowing costs	Sea level rise	+23.4 basis points annualized bond issuance cost per 1% additional GDP loss due to sea level rise[52]
Government	Municipal budgets	Wildfire	+25 percentage point increase in likelihood of budget deficit[53]
Government	Social safety net transfers	Hurricane	+$975–$1,440 per capita[54]
Households	Housing prices	Flooding	−4.6% (in 100-year floodplain)[55]
Households	Student learning	Temperature increases	1% decrease in test scores per 1°F hotter school year (no adaptation)[56]
Infrastructure	Property values	Sea level rise	−14.7% (1-foot rise)[57]
Agriculture, Infrastructure	Damage to structures and crops	Flooding	+$235 billion per year[58]
Labor	Earnings	Wildfire smoke	−$144 billion per year[59]
Labor	Work injuries	Heat (≥85°F day)	+5%–15% per hot day[4]

19-7 | Economics

Hsiang, Greenhill, et al (*National Climate Assessment*, 2023)

...but we know a lot about quantifying damages!

Report on the Social Cost of Greenhouse Gases:

Estimates Incorporating Recent Scientific Advances

November 2023

National Center for Environmental Economics
Office of Policy

Climate Change Division
Office of Air and Radiation

U.S. Environmental Protection Agency
Washington, DC 20460

Perspective

We already have all the tools needed to give structure and definition to the concept of Loss & Damage from climate change.

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Economists and modern analytical tools should be at the center of any effort to quantify Loss & Damage.

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Economists and modern analytical tools should be at the center of any effort to quantify Loss & Damage.

$\rightarrow$ Requires economists engage with this international policy process.

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Bonus: Updated GDP growth estimates (reconciled with literature)

One approach: Basically a missing market for waste

Loss and Damage is analogous to debt from unpaid bills for garbage collection.

What would have X needed to have paid in order for others to be willing to accept the burden of X's GHG emissions?

Use the Social Cost of GHGs (SC-GHG) as a guiding framework

Social Cost of GHGs (SC-GHG) - the net present value of all future total global harm that results from the emission of a marginal ton of GHGs today (or in future).

$\rightarrow$ A yardstick for measuring the benefits of any GHG mitigation policy.

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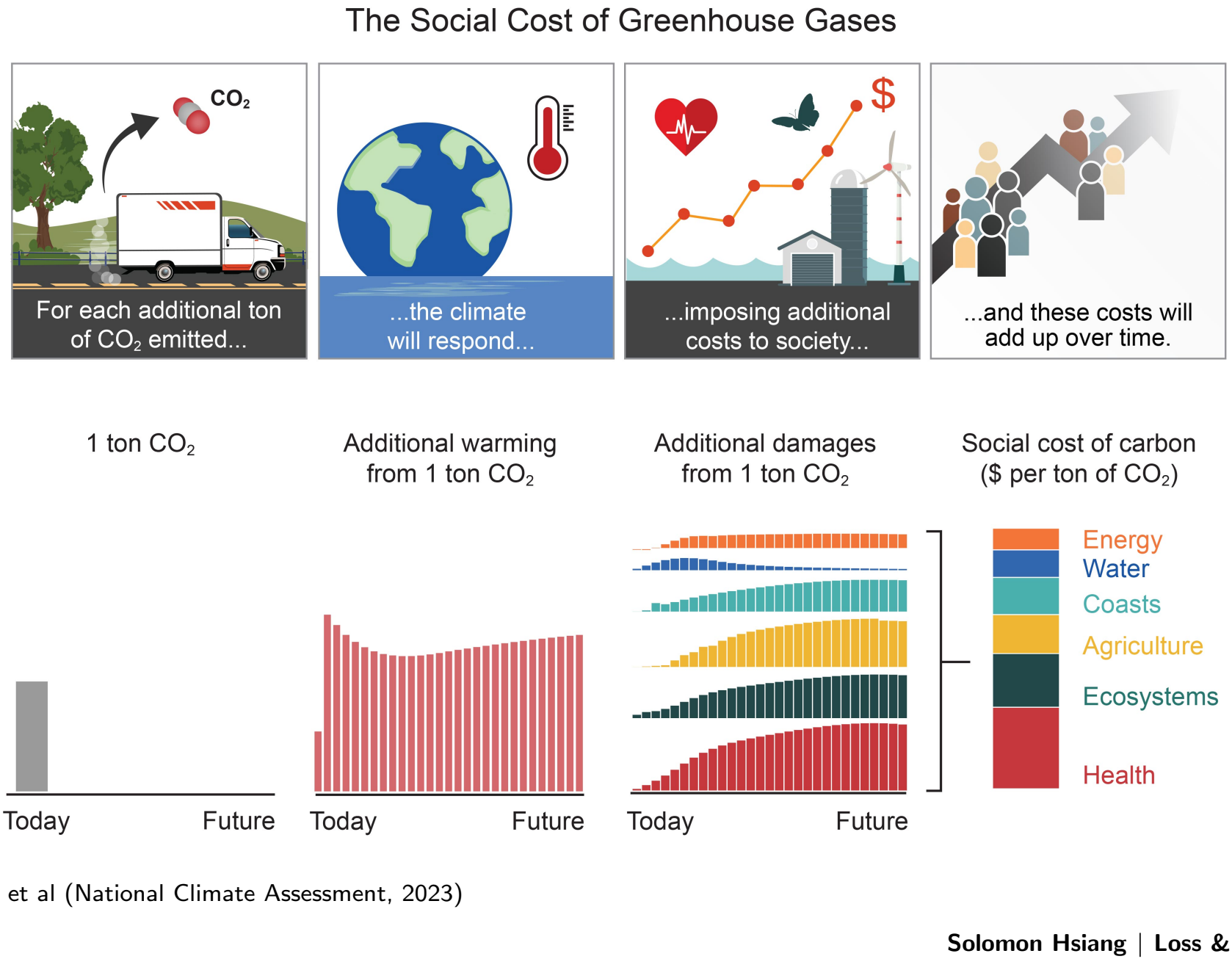
$\rightarrow$ A yardstick for measuring the benefits of any GHG mitigation policy.

Question: Can we define a similar yardstick to quantify the harm from emitting one ton of GHGs in the past?

$\rightarrow$ Would provide a foundation for practically quantifying L & D.

The Social Cost of GHGs



Hsiang et al (National Climate Assessment, 2023)

The Social Cost of GHGs

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2. Aid harmonization of legal interpretations in current and future legal cases worldwide on liability & accountability.

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3. Needed to align financial incentives in any situation where payments for past and future damages are institutionalized.

    - e.g. if cheaper to pay for damage from past emissions relative to future, incentivizes emitters to delay financial settlement as long as possible to maximize emissions that are categorized as historical

The proposed definition (in words)

We propose:

L&D be computed as the net present value of economic and non-economic impacts attributable to the emissions of greenhouse gases through their impact on the climate, net of any adaptation that was undertaken.

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Hypothetically, compensation for L&D would then be a payment schedule that reimburses all individuals for the damages (or benefits) that they have experienced or will experience from climate change, paid for by the individuals that caused these impacts via emissions.

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Note: consistent with Article 8 of the Paris Agreement, that these damage estimates do not necessarily equal what is "owed" by one entity to another, as that is a moral and legal question beyond the scope of this analysis.

The proposed definition (in concept)

		historical		**future**		**future**
Loss		damages		damages		damages
and	=	from	+	from	+	from
damage		**historical**		**historical**		**future**
		emissions		emissions		emissions

The proposed definition (in math)

Impact of marginal emissions on outcome, via a change in the climate is:

$$\Delta Y(\Delta emissions) = Y(climate(emissions)) - Y(climate(emissions - 1ton))$$

Resulting in cumulative damage to i from a marginal emission:

$$D_{i,t_e,t_s,t_1,t_2}(\Delta emissions_{t_e}) = \sum_{t=t_1}^{t_2} (1+r)^{-(t-t_s)} \cdot \Delta Y_{it}(\Delta emissions_{t_e})$$

For a time interval $t_1 \rightarrow t_2$ and context defined by:

t_0: time when first accountable for emissions
t_e: time of emissions
t_s: time when "accounts are settled"
r: discount rate

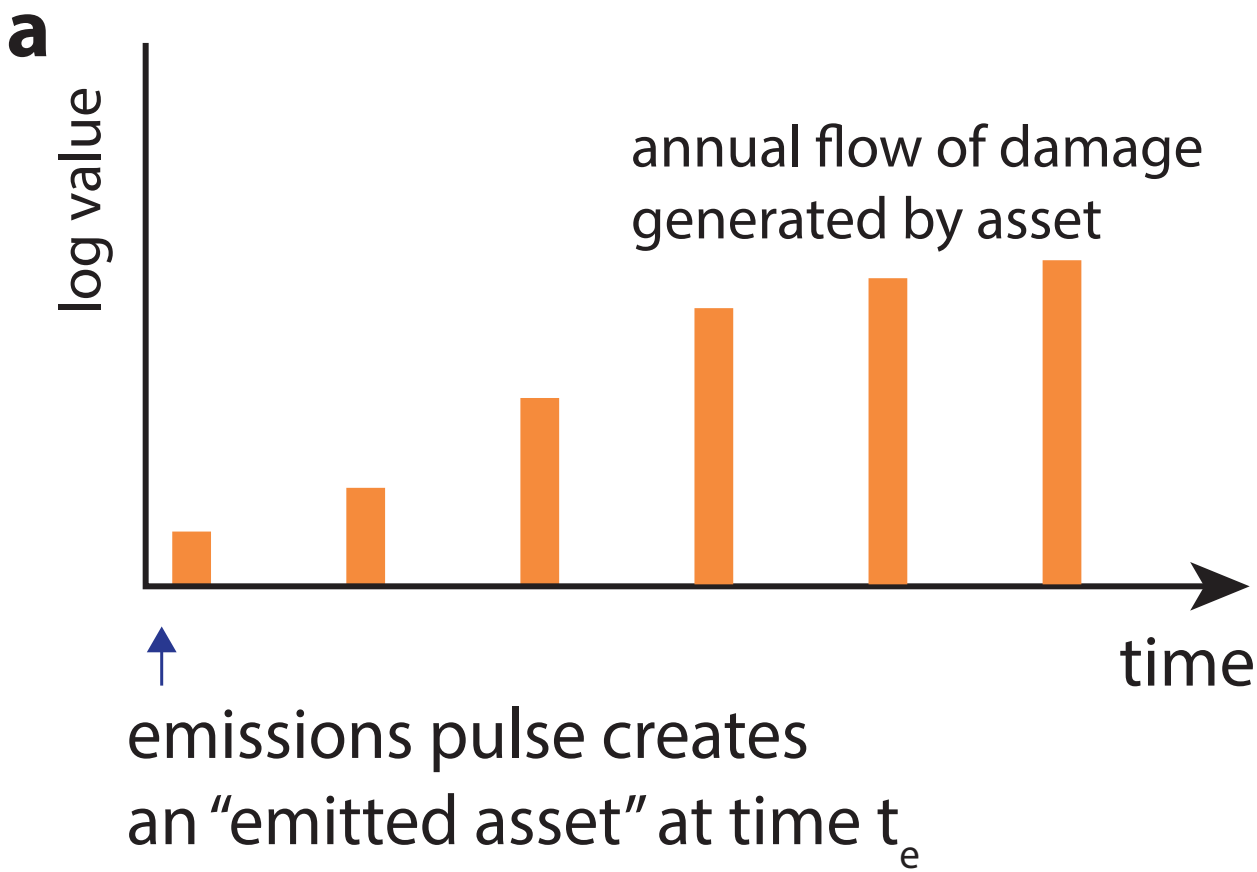
Timing

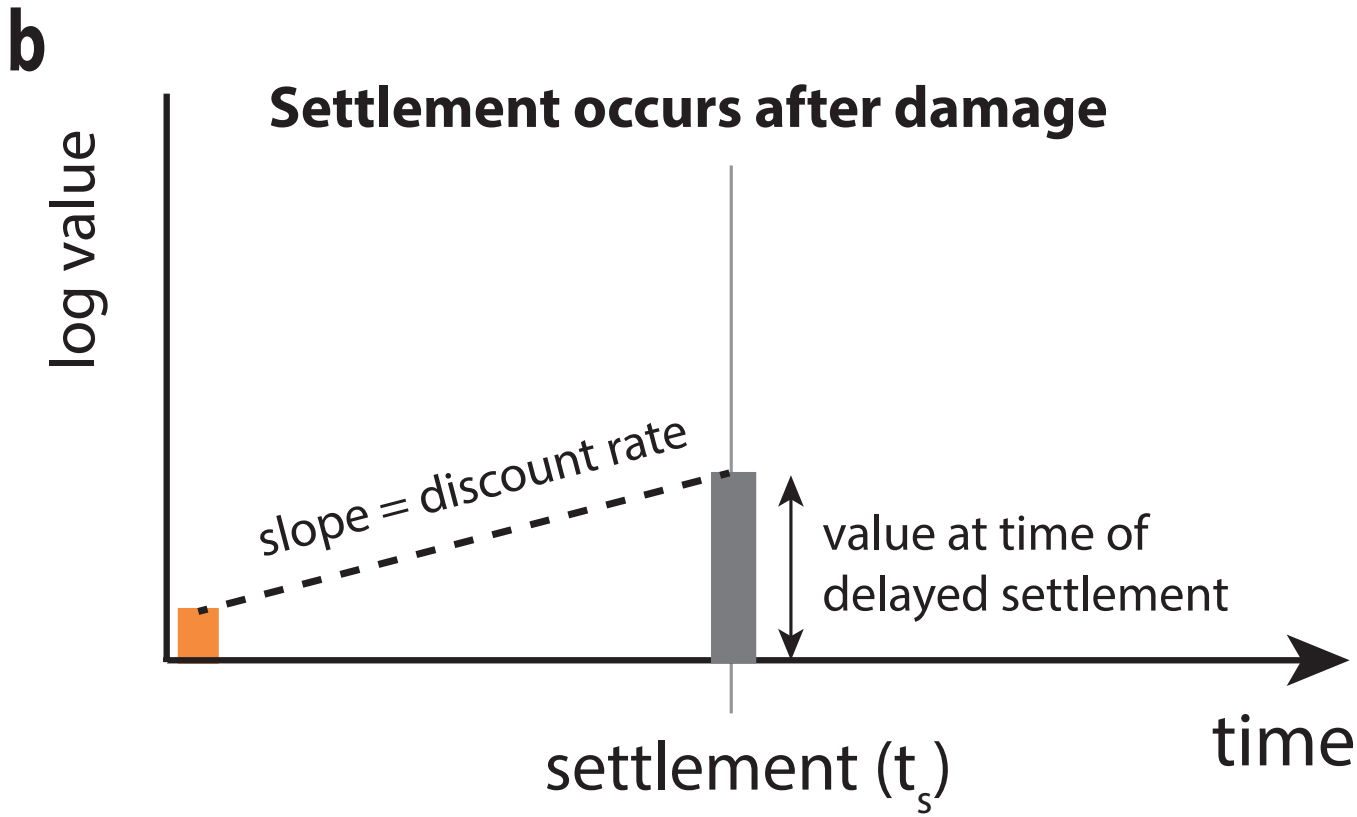
$$t_0 \longrightarrow t_e \longrightarrow t_s$$

t_0: time when first accountable for emissions

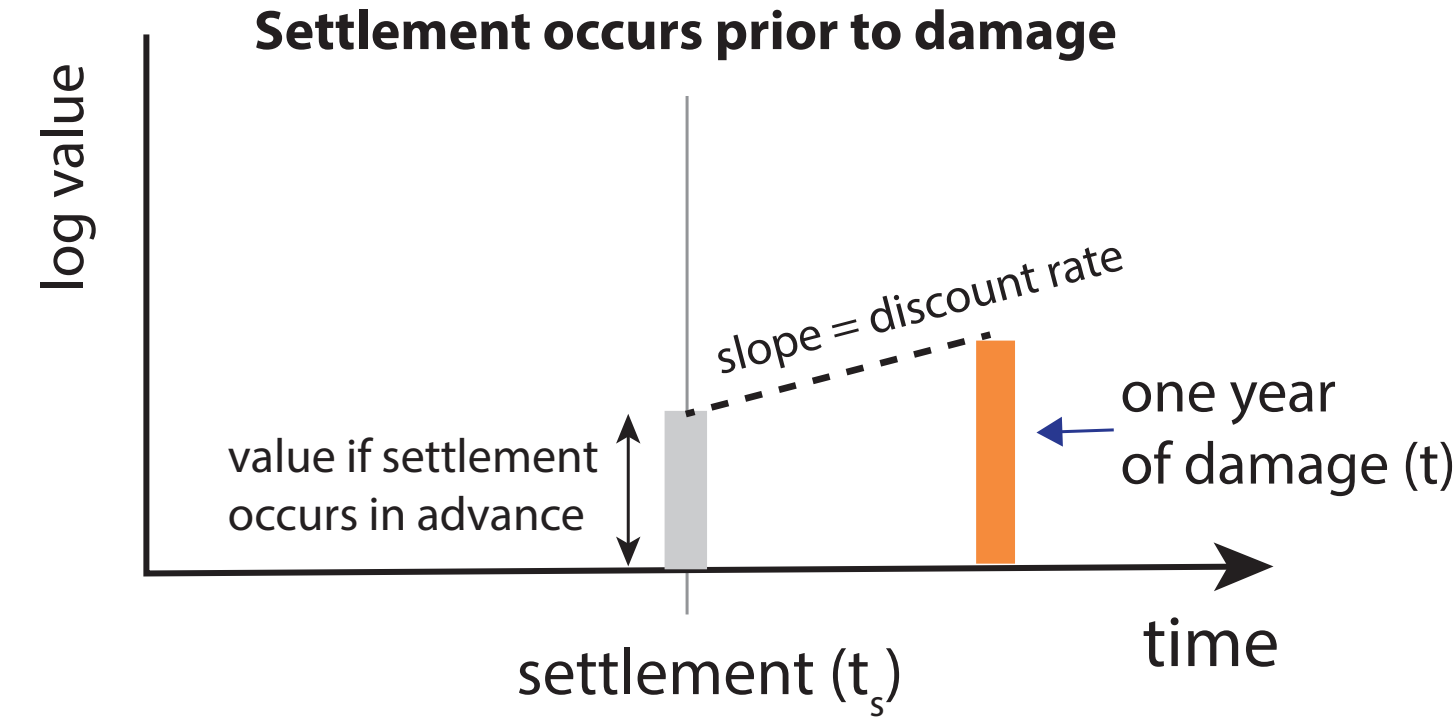
t_e: time of emissions

t_s: time when "accounts are settled"


a
log value
annual flow of damage
generated by asset
time
emissions pulse creates
an “emitted asset” at time t_e

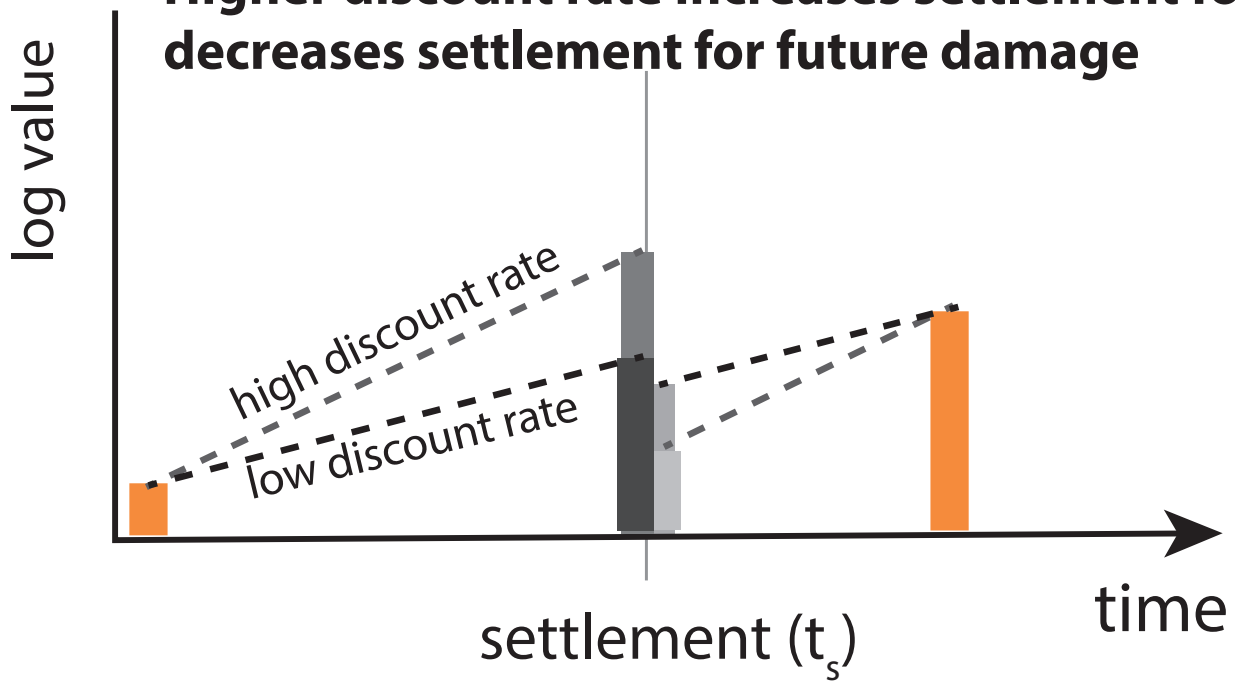

b
Settlement occurs after damage
log value
slope = discount rate
value at time of
delayed settlement
settlement (t_s)
time

c

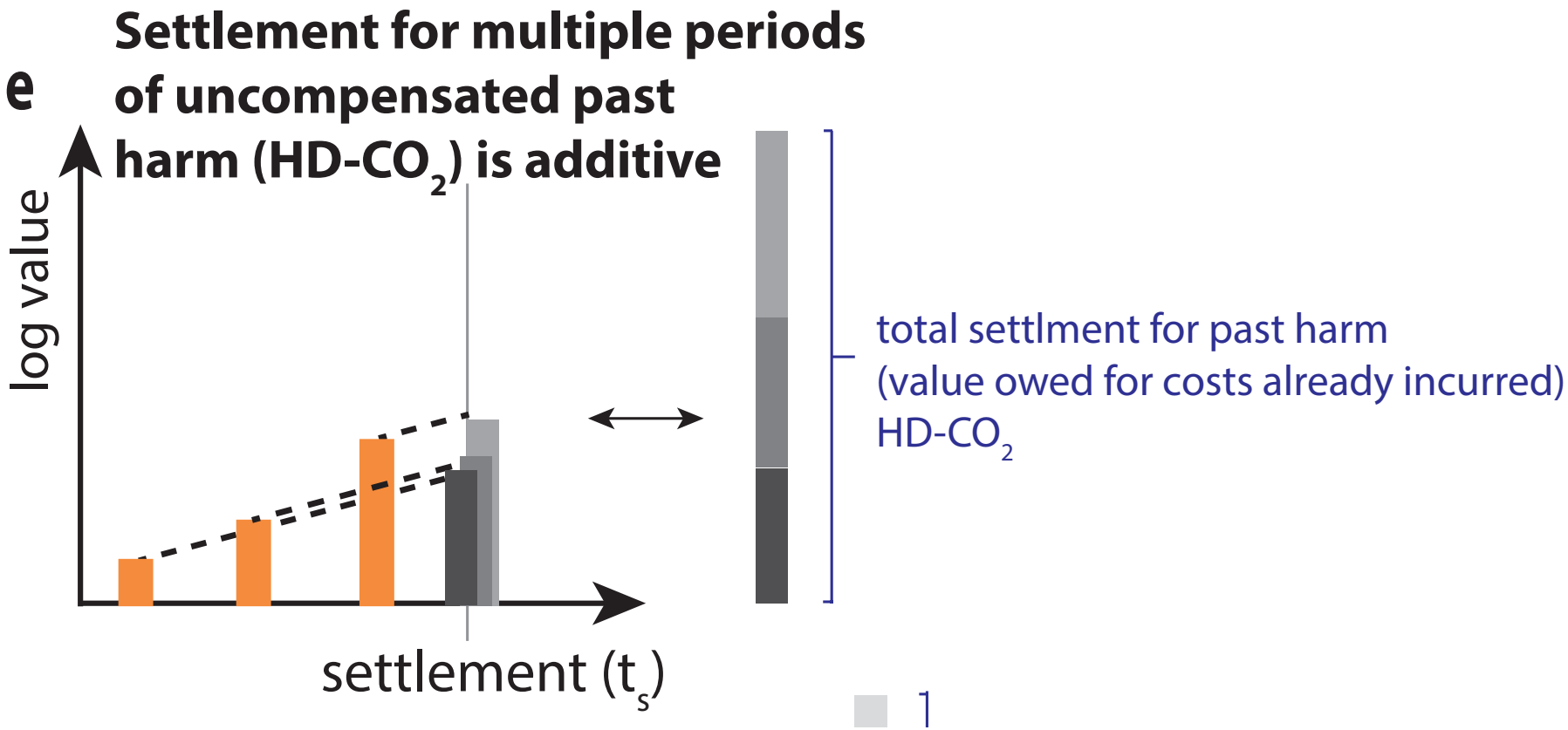

Settlement occurs prior to damage
log value
slope = discount rate
value if settlement
occurs in advance
one year
of damage (t)
time
settlement (t_s)

d

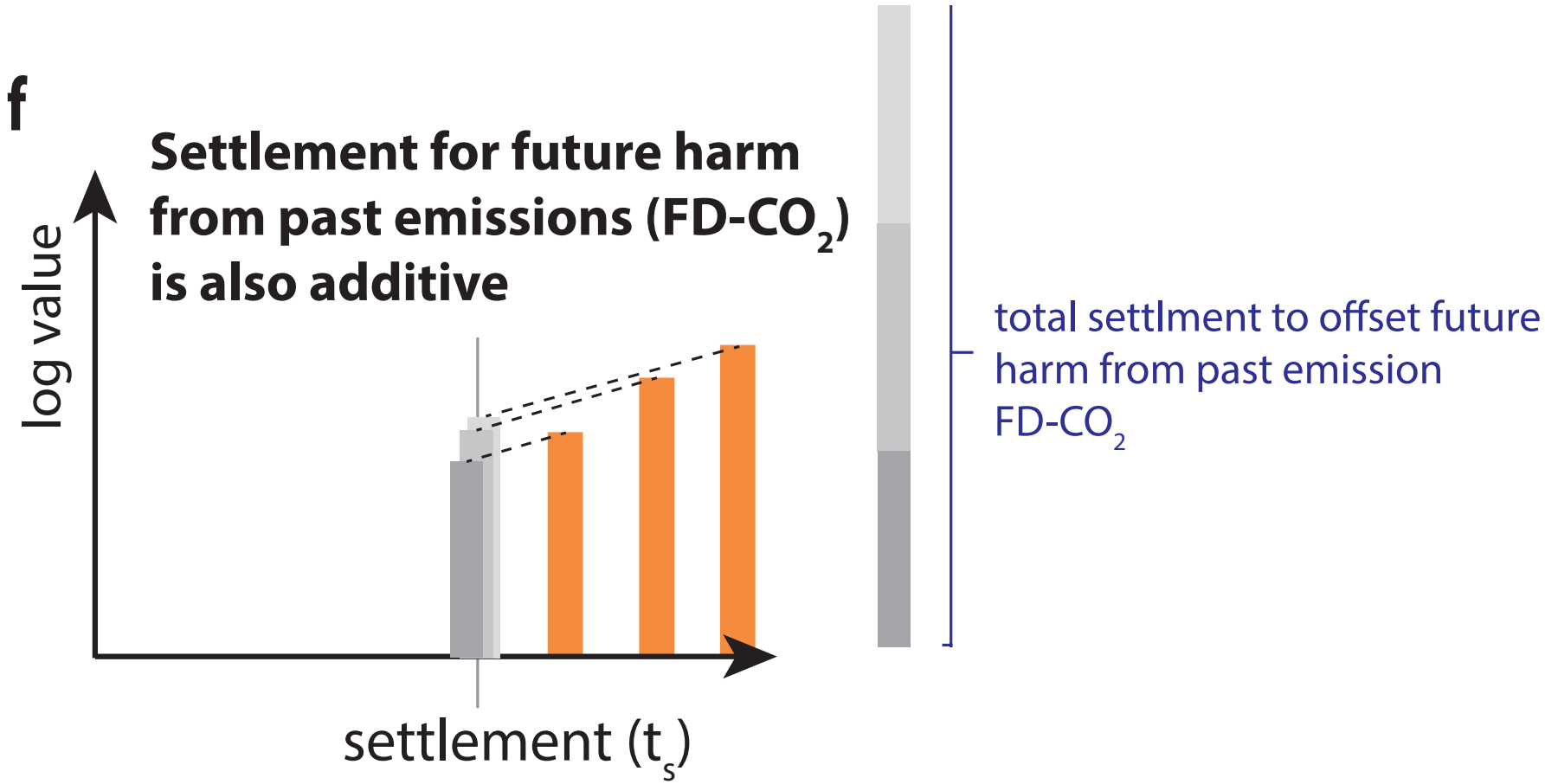
Higher discount rate increases settlement for past damage, decreases settlement for future damage



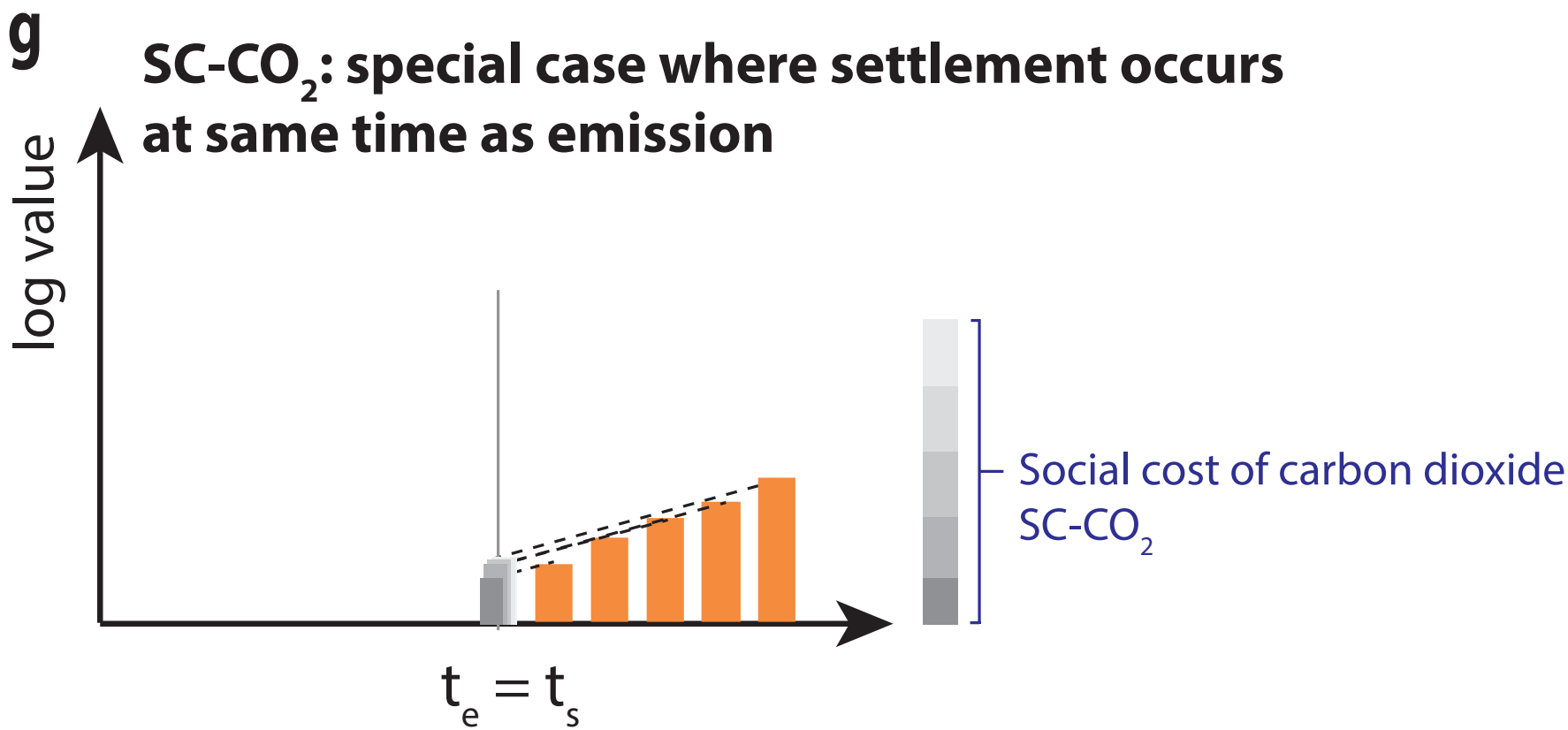
Historical Damage ("HD-CO2")

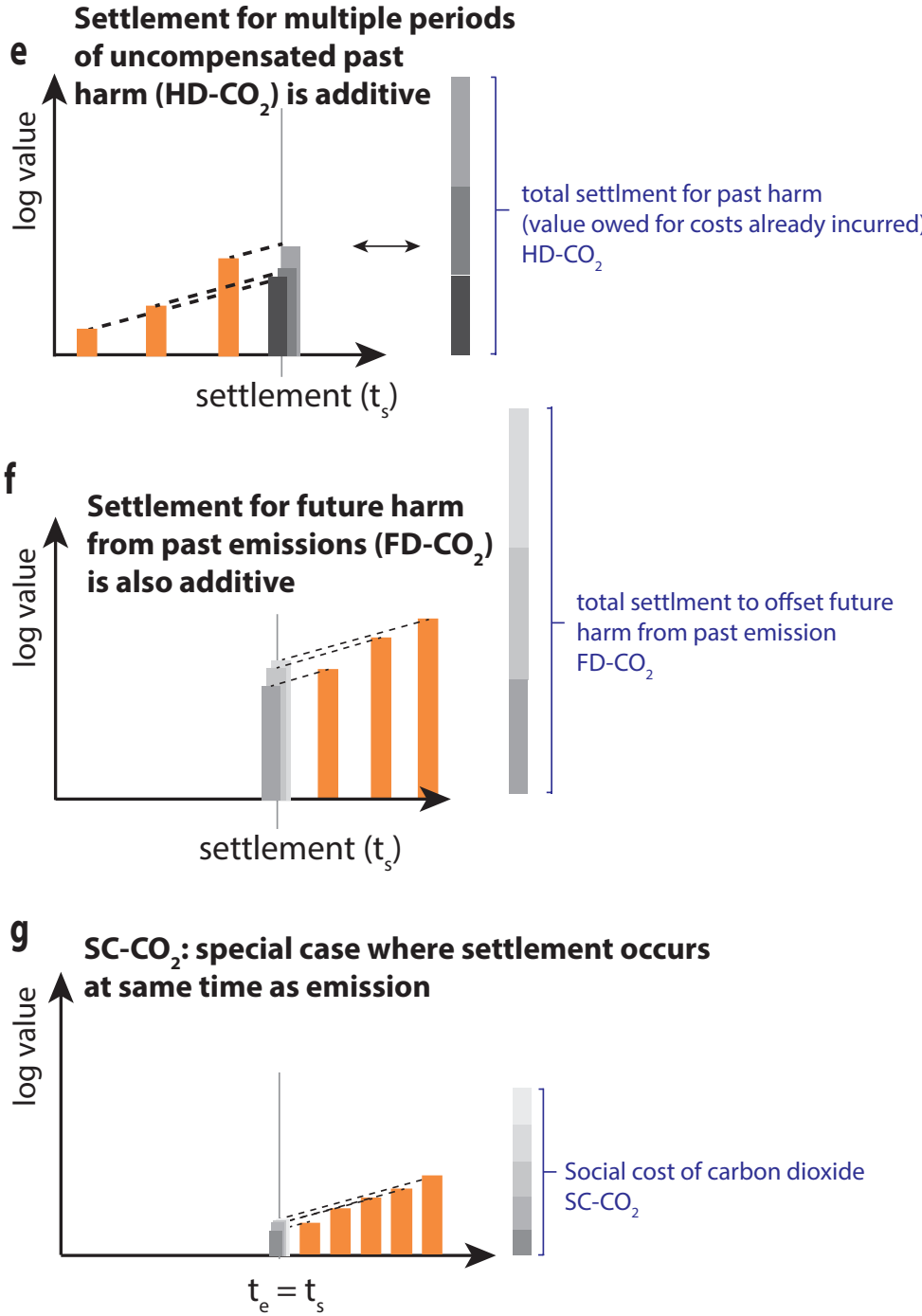


Future Damage ("FD-CO2")



Social Cost of Carbon ("SC-CO2")




e
Settlement for multiple periods of uncompensated past harm (HD-CO2) is additive
log value
settlement (ts)
total settlment for past harm
(value owed for costs already incurred)
HD-CO2
f
Settlement for future harm from past emissions (FD-CO2) is also additive
log value
settlement (ts)
total settlment to offset future harm from past emission
FD-CO2
g
SC-CO2: special case where settlement occurs at same time as emission
log value
te = ts
Social cost of carbon dioxide
SC-CO2

Historical damage from a marginal emission (HD-CO2)

$$HD\text{-}CO2_{t_e} = \sum_i \sum_{t=t_e}^{t_p} (1+r)^{-(t-t_p)} \cdot \Delta Y_{it}(\Delta emissions_{t_e \leq t_p})$$

Future damage from a historical marginal emission (FD-CO2)

$$FD\text{-}CO2_{t_e} = \sum_i \sum_{t=t_p}^{\infty} (1+r)^{-(t-t_p)} \cdot \Delta Y_{it}(\Delta emissions_{t_e \leq t_p})$$

Future damage from a current/future marginal emission (SC-CO2)

$$SC\text{-}CO2_{t_e} = \sum_i \sum_{t=t_e}^{\infty} (1+r)^{-(t-t_e)} \cdot \Delta Y_{it}(\Delta emissions_{t_e \geq t_p})$$

t_p: present time (assume $t_p = t_s$)

Three yardsticks to measure all harm from CO2 emissions

Total welfare loss for humanity from all emissions ever:

$$L_{t_0} = \sum_{t_e=t_0}^{\infty} global\_emissions_{t_e} \cdot (HD\text{-}CO2_{t_e} + FD\text{-}CO2_{t_e} + SC\text{-}CO2_{t_e})$$

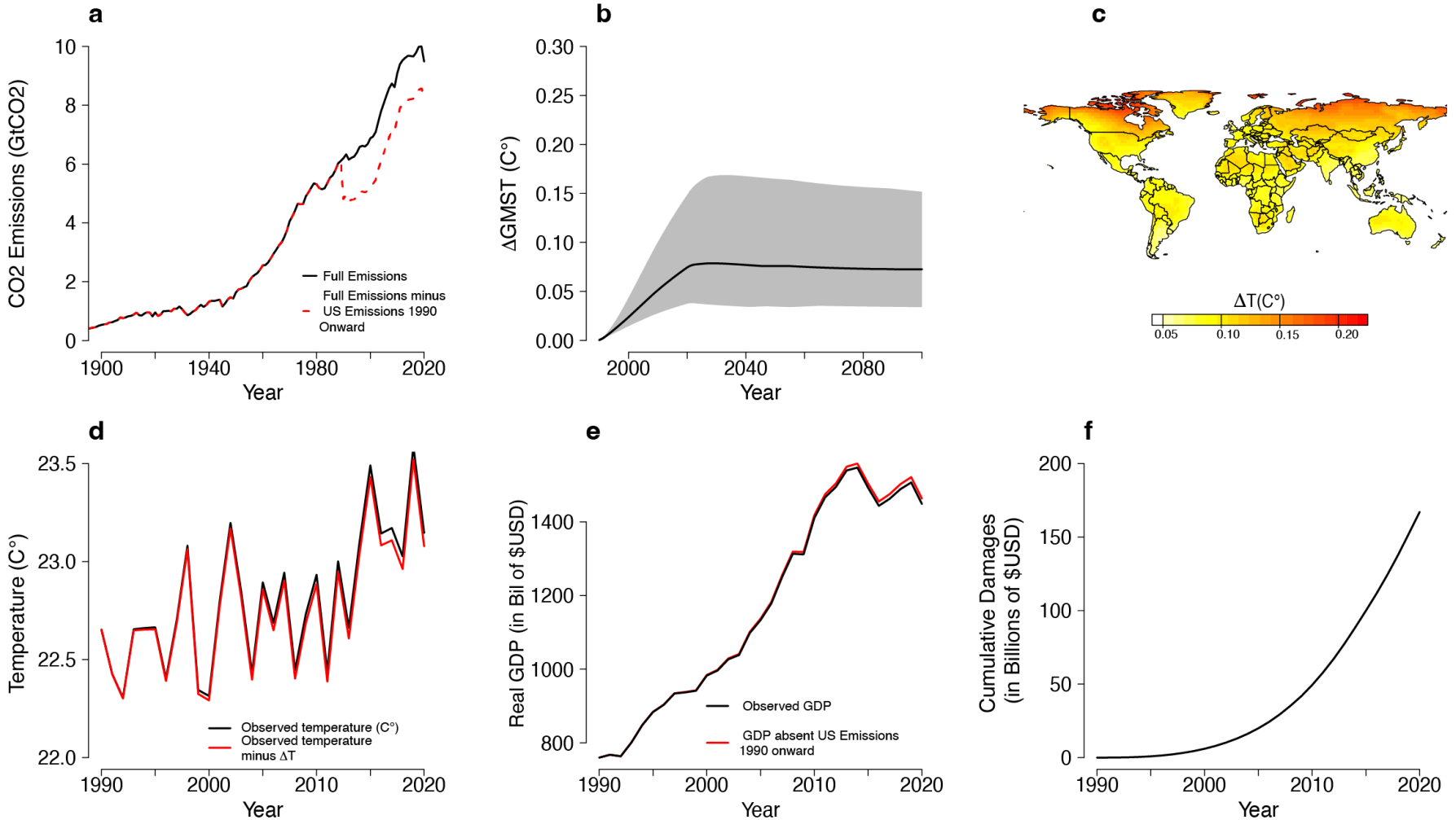
HD-CO2: Historical damage, historical emissions
FD-CO2: Future damage, historical emissions
SC-CO2: Future damage, current/future emissions

Bilateral L&D from emitter $j \rightarrow i$ starting at t_0

$$L_{j\rightarrow i,t_0} = \sum_{t_e=t_0}^{t_p} \Bigg(\underbrace{HD\text{-}CO_{2,i,t_e}}_{\text{past harm to i}} + \underbrace{FD\text{-}CO_{2,i,t_e}}_{\text{future harm to i}} \Bigg) \cdot \underbrace{E_{j,t_e}}_{\text{past emissions from j}} +$$

$$\sum_{t_e=t_p}^{\infty} \underbrace{SC\text{-}CO_{2,i,t_e}}_{\text{future harm to i}} \cdot \underbrace{E_{j,t_e}}_{\text{future emissions from j}}$$

Example: Historical damages from USA → Brazil



Interesting Legal Question 1: Selecting a discount rate?

Table 2 Calibration of the discount rate based on the Ramsey equation (Equation 3)

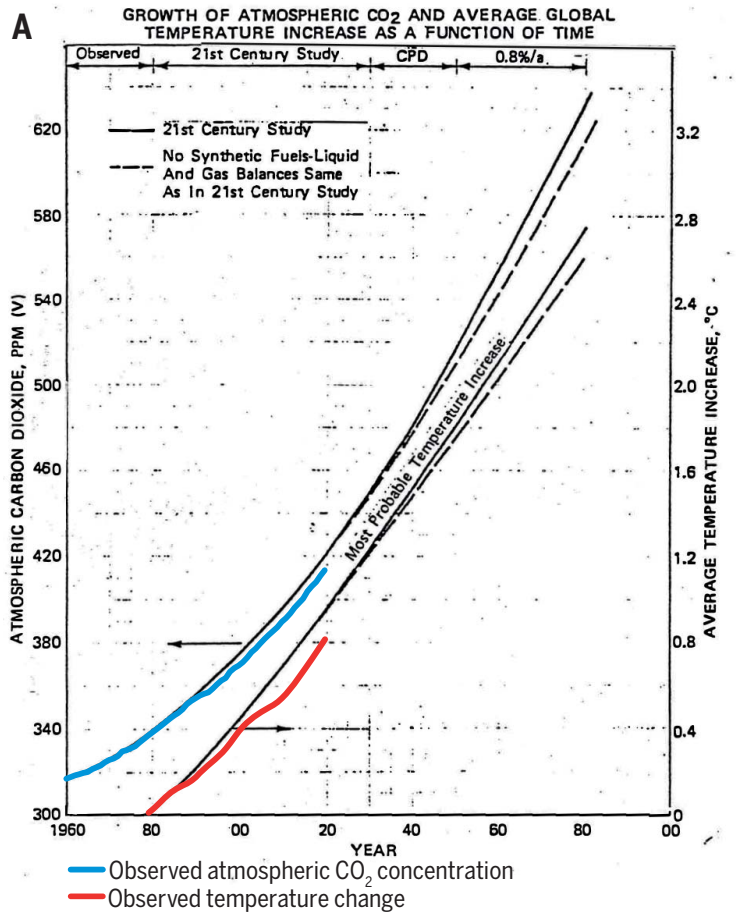
Author	Inequality aversion γ	Growth rate G	Discount rate γg
Stern (1977)	2		
Cline (1992)	1.5	1%	1.5%
IPCC (1995)	1.5–2	1.6–8%	2.4–16%
Arrow (1999)	2	2%	4%
HM Treasury (2003)	1	2%	2%
Lebègue (2005)	2	2%	4%
Arrow (2007)	2–3		
Dasgupta (2007)	2–4		
Stern (2007)	1	1.3%	1.3%
Weitzman (2007a)	2	2%	4%
Nordhaus (2008)	2	2%	4%
Pindyck (2013)	1–3		

Some of the authors add a rate of impatience δ to the Ramsey rule so that the last column is only a partial representation of what these authors recommend for the discount rate. Blank cells denote that data were not given.

Gollier & Hammit (Annual Rev of Res Econ, 2014)

Interesting Legal Question 2: When is t_0?

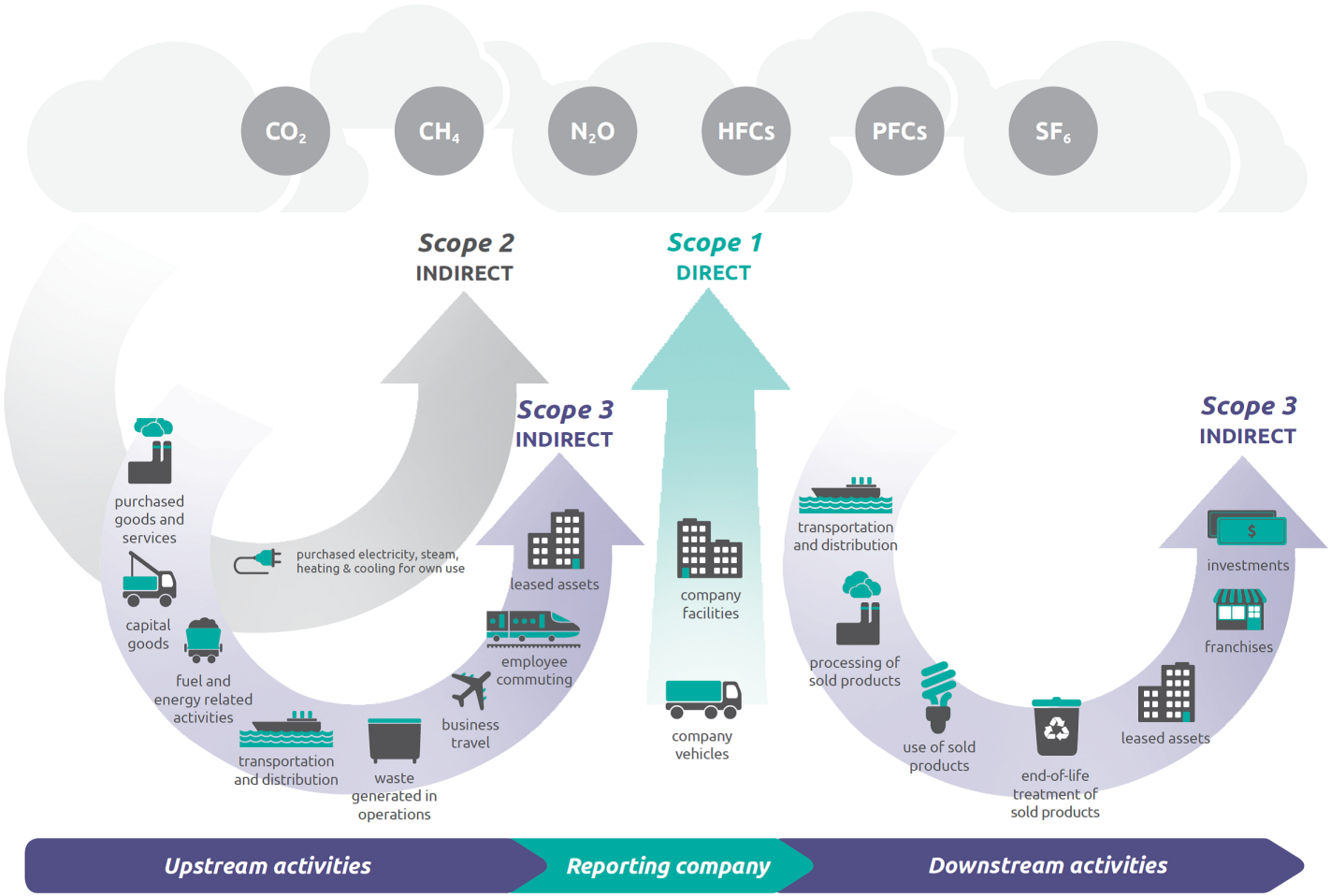
i.e. what is the date for when to start holding emitters accountable?



"Proprietary" 1982 Exxon-modeled projections.

Supran, Rahmstorf, Oreskes (Science, 2023)

Interesting Legal Question 3: Use consumption or production based emissions?



EPA (2024)

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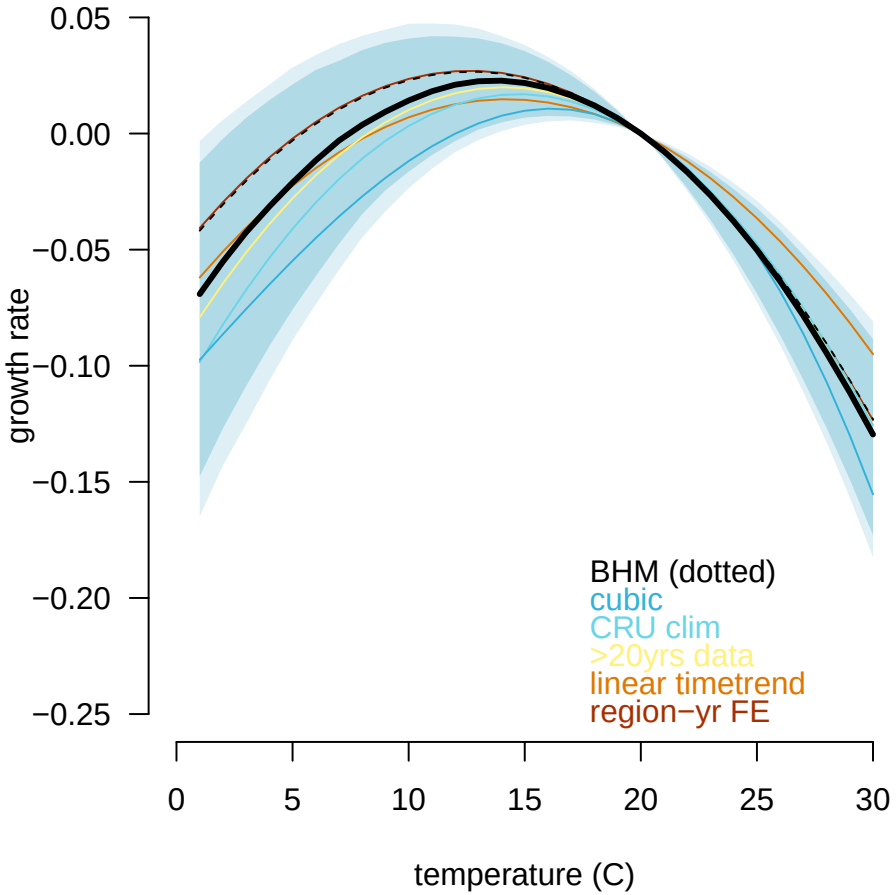
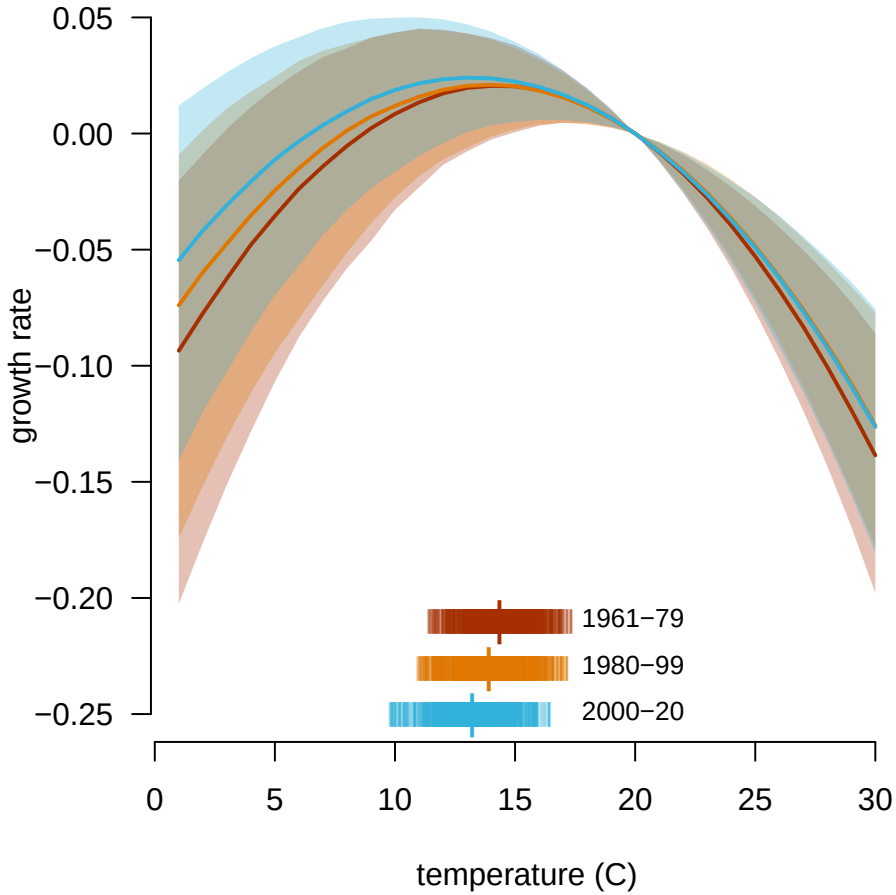
Bonus: Updated GDP growth estimates (reconciled with literature)

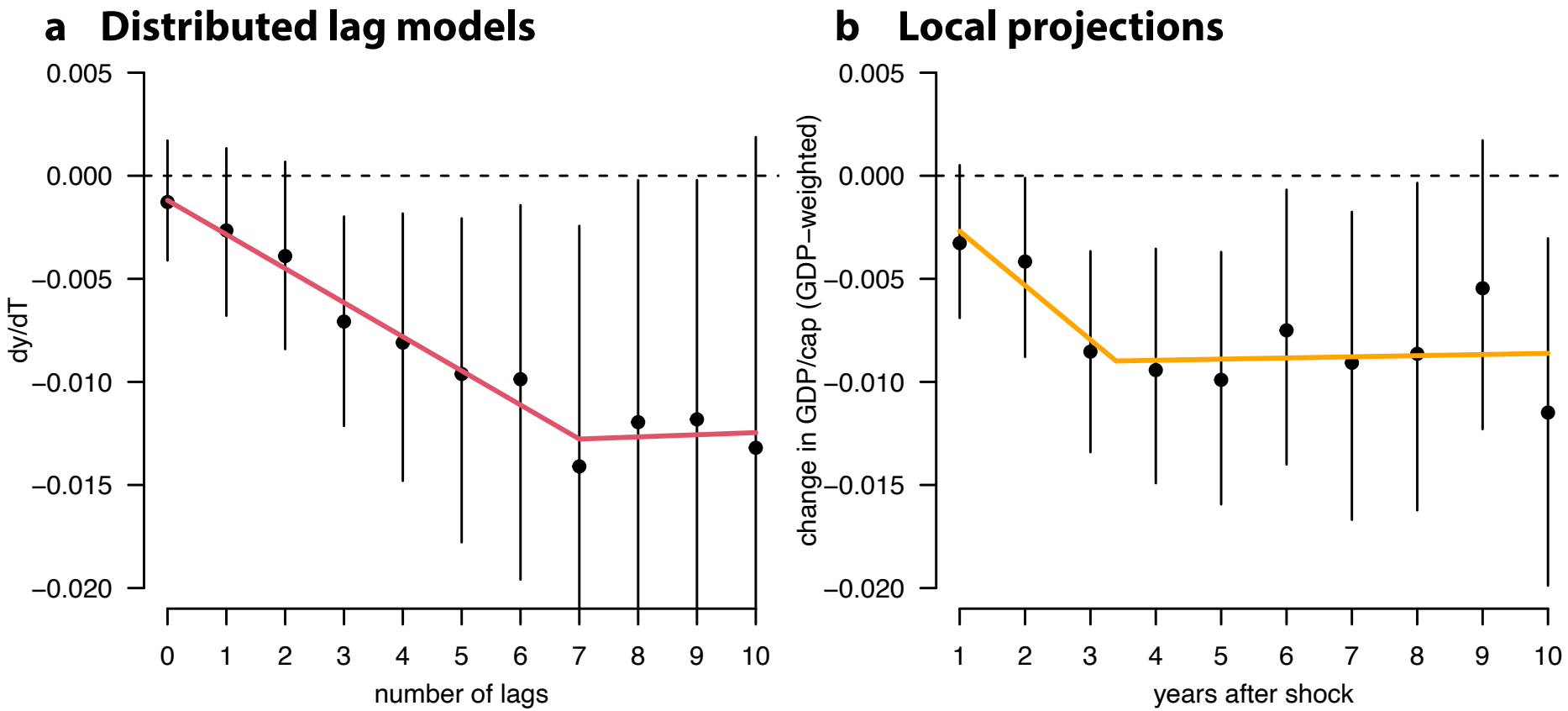
Demonstrate application with GDP impacts



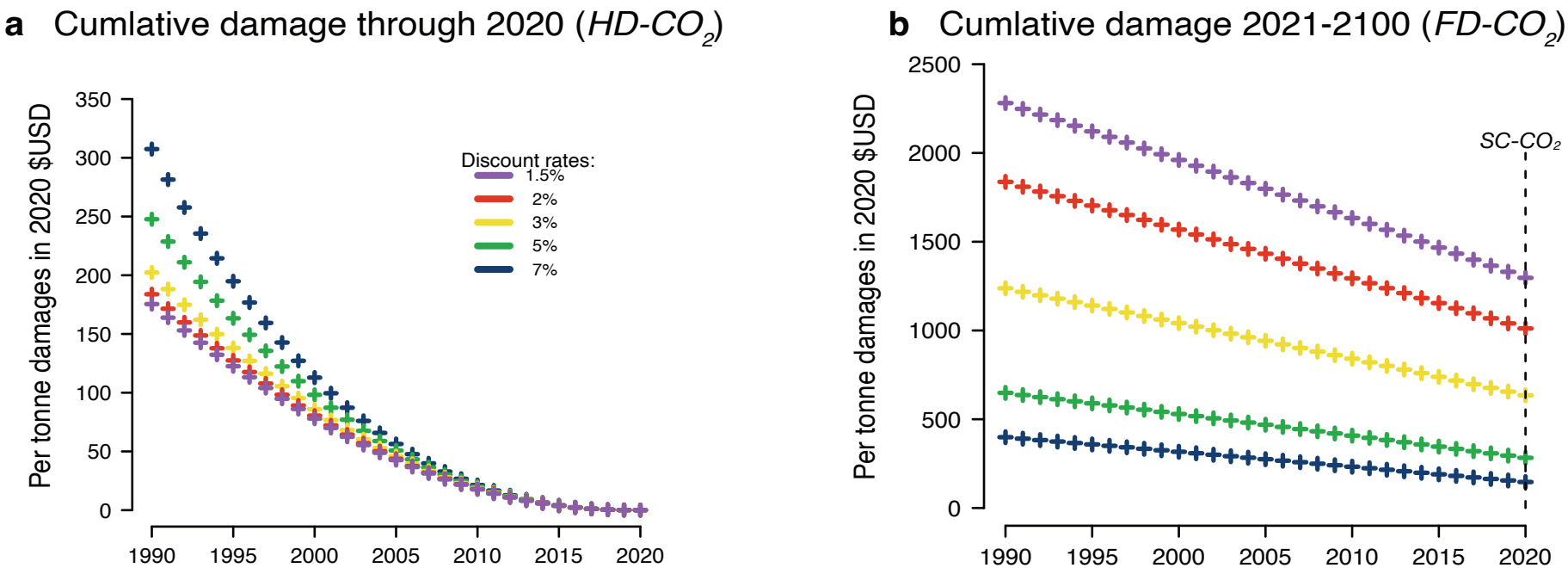


Full update of Burke, Hsiang, Miguel (Nature, 2015) [BHM] addressing all testable concerns raised in literature.

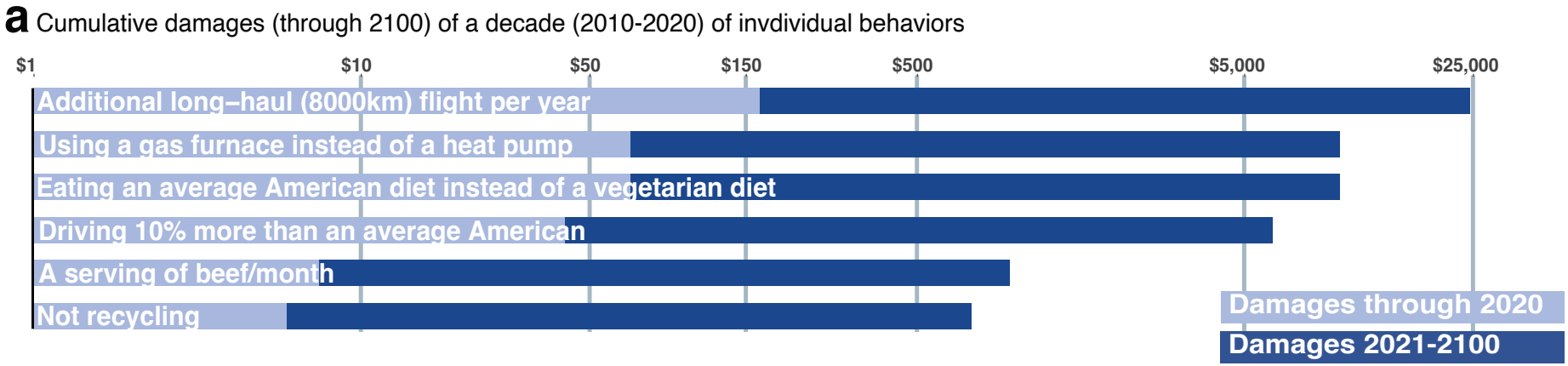
Technical aside: here, use 5 years of lags (no recovery at 10 years)



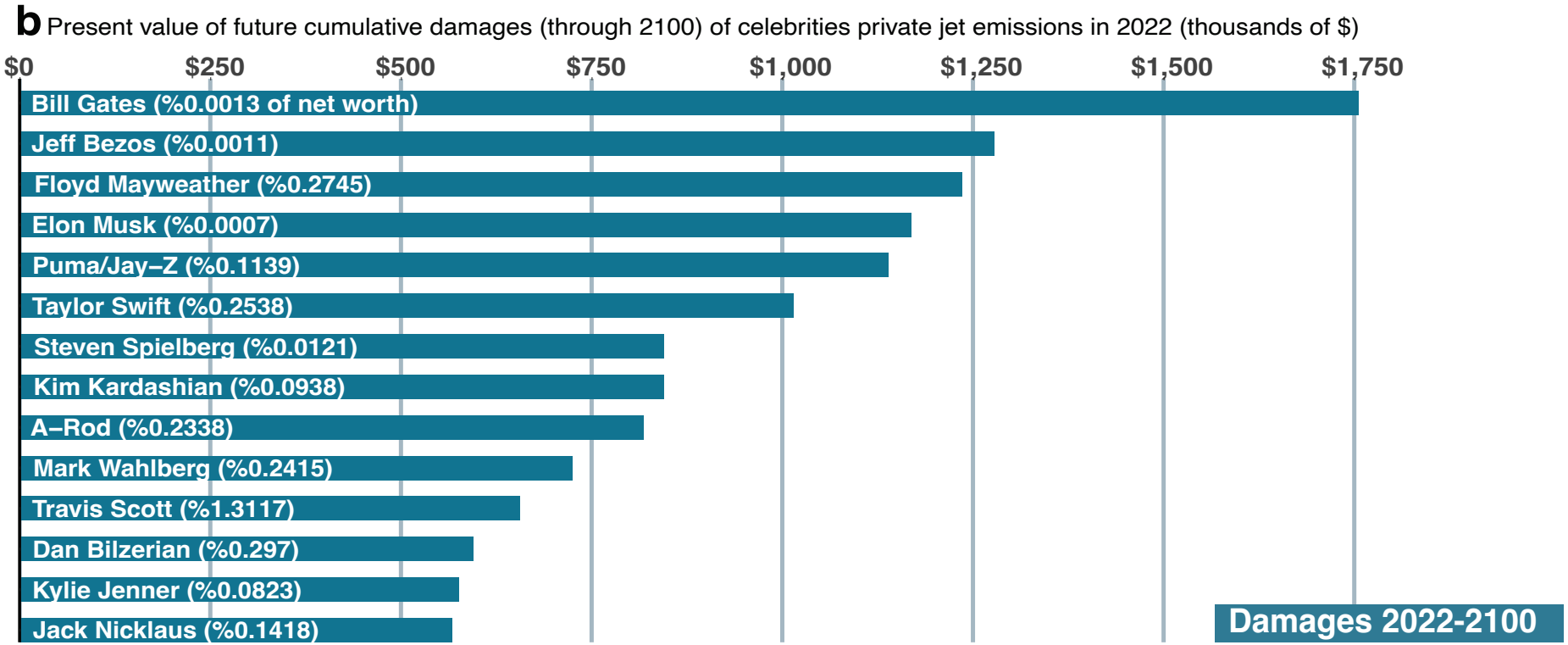
Historical & future damage from historical marginal emissions



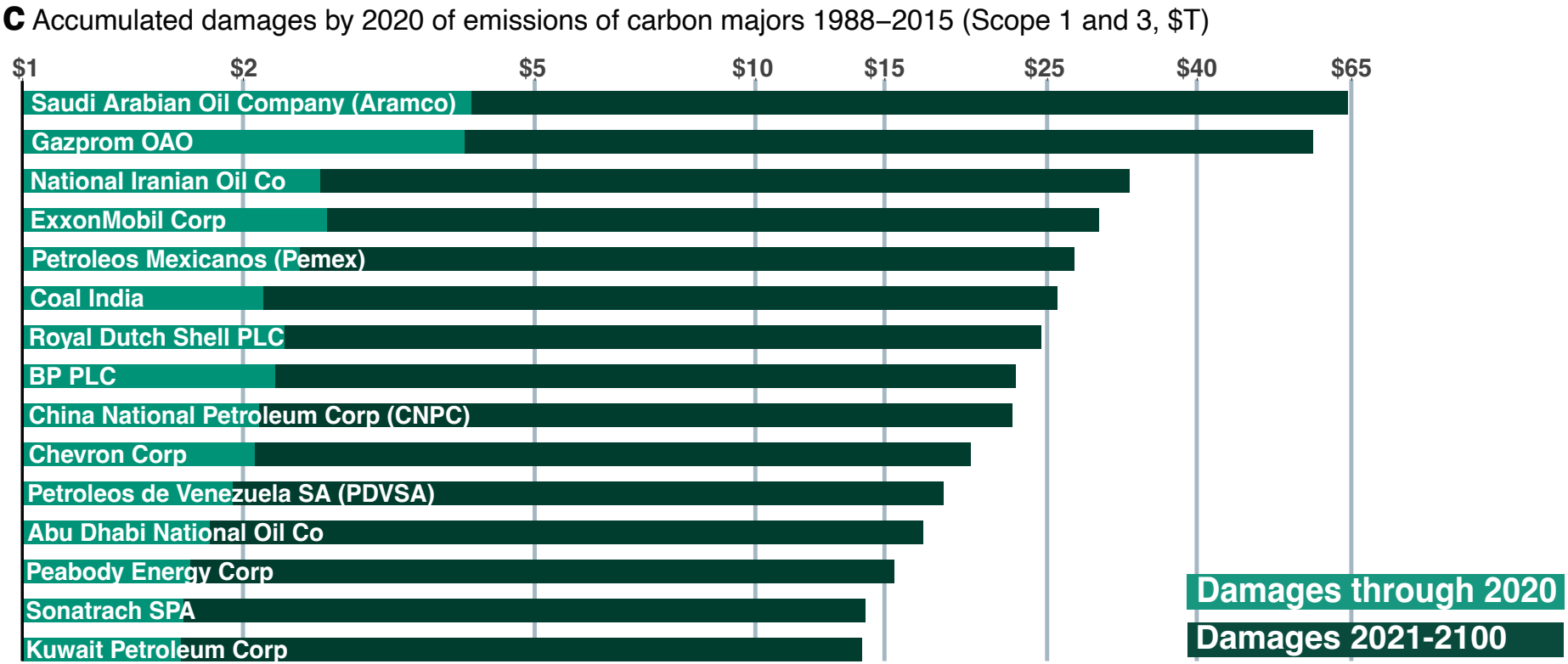
Application to behaviors



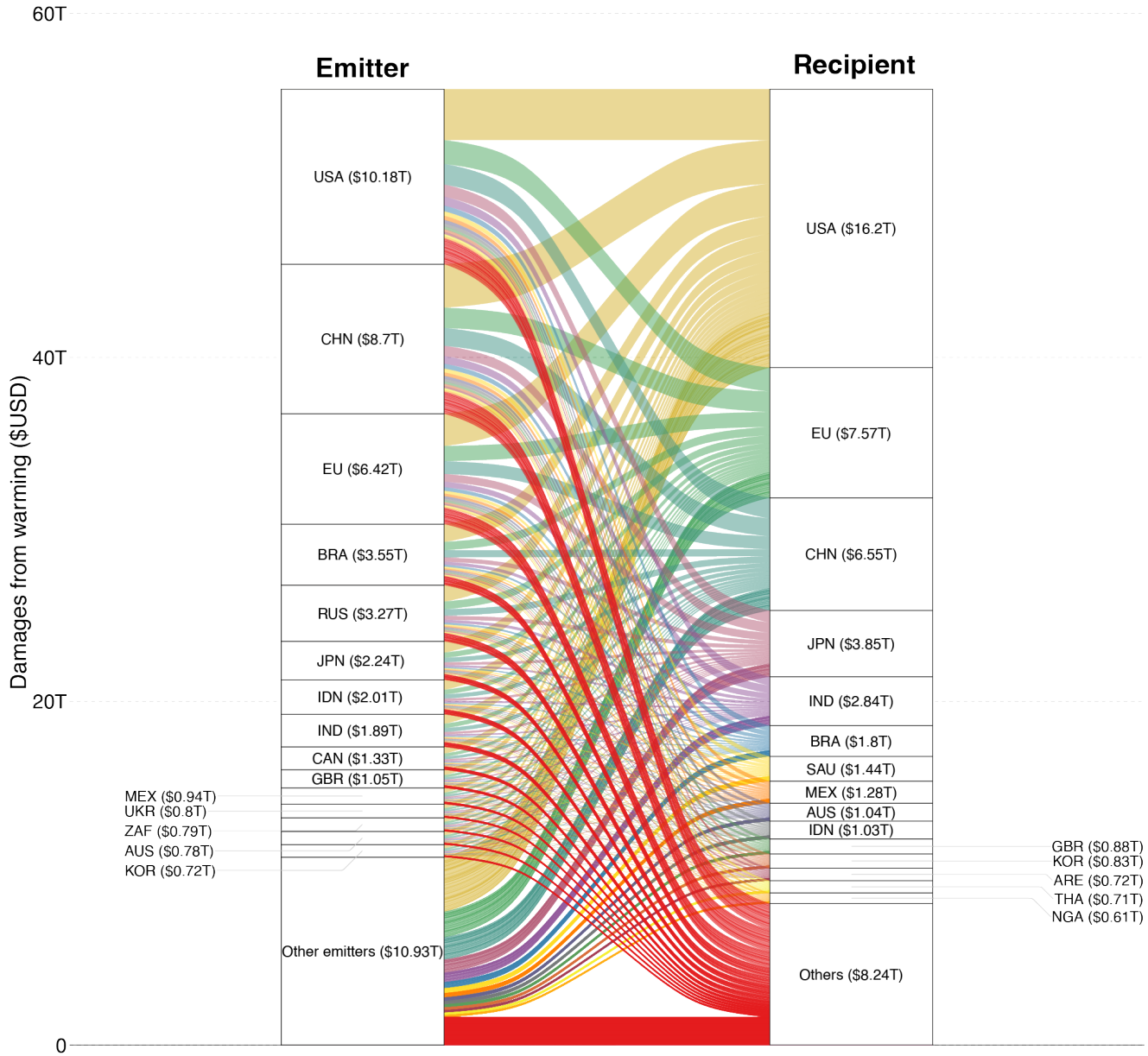
Application to individuals

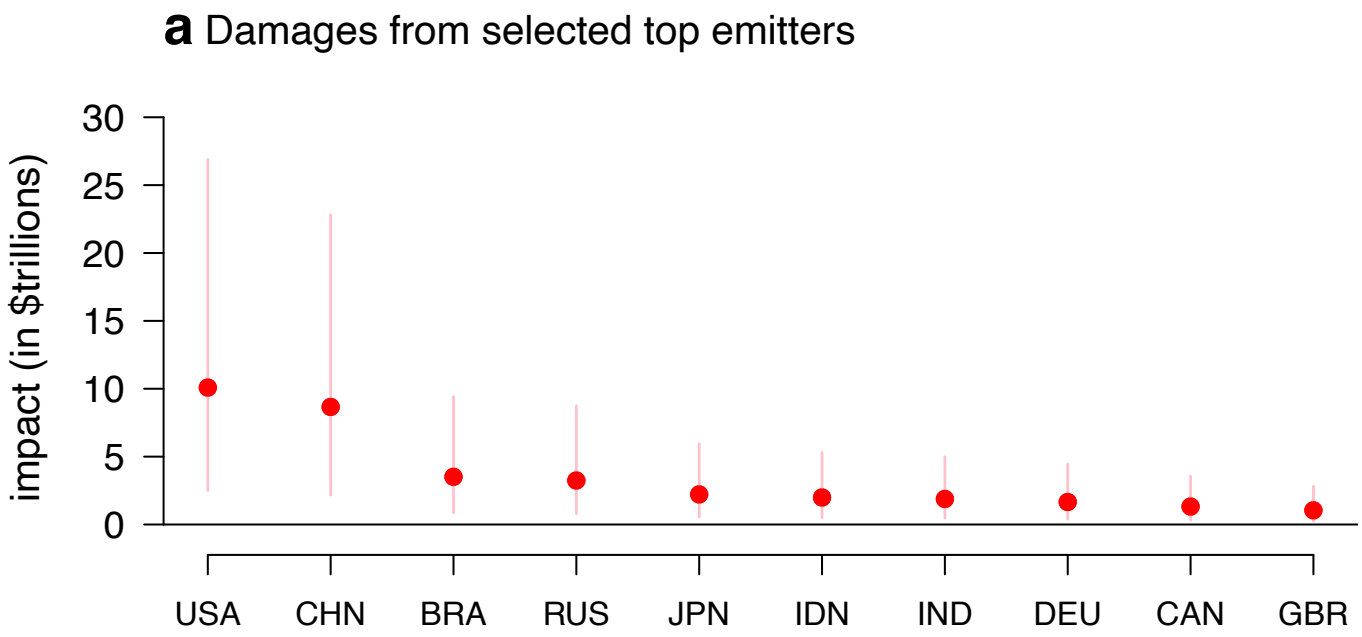


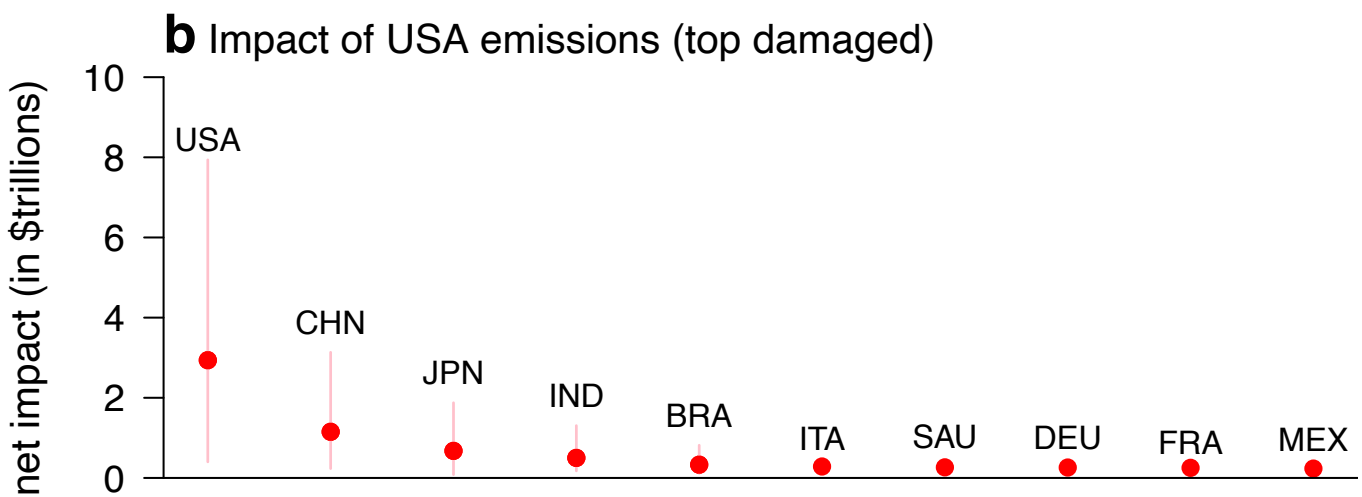
Application to firms



Application to countries




a Damages from selected top emitters
impact (in $trillions)
30
25
20
15
10
5
0
USA
CHN
BRA
RUS
JPN
IDN
IND
DEU
CAN
GBR


b Impact of USA emissions (top damaged)
net impact (in $trillions)
10
8
6
4
2
0
USA
CHN
JPN
IND
BRA
ITA
SAU
DEU
FRA
MEX

Conclusions 1

Economists should be involved with defining Loss & Damages.

It is straightforward to apply standard economic tools to formalize a quantitative measure of Loss and Damage.

This quantification can be fully consist with standard def of the SC-CO2.

Conclusions 2

We propose a framework for L&D that reduces to three marginal costs for each unit of emissions: HD-CO2, FD-CO2, SC-CO2

$\rightarrow$ SC-CO2 is a special case of L&D where accounts are "settled" at the time of emission.

For instance, we estimate that 1 ton of CO_2 emitted in 1990 caused \$180 in global cumulative discounted damages by 2020 [95% CI: \$40-530] and will cause an additional \$2000 in discounted damages through 2100 [\$500-5700] (2% annual discount rate).

Settling debts for past damages will not settle debts for past emissions.