Week 02: Climate Adaptation

Barcelona School of Economics

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Climate Change and Climate Adaptation: Intro

- Most of our focus have been on the economic causes of climate change
  - Economic $\rightarrow$ CO_2 emissions $\rightarrow$ higher temperatures
- Economists integrate these climate impacts into their models
  - IAM $\rightarrow$ study CO_2-related policies (i.e, a narrow dimension of climate damage)
- Climate damages span along many dimensions (heatwaves, coastal flooding, ...)
  - And so do the related adaptation policies, their trade-offs, and frictions

<u>This class:</u> **how are we (or should be) adapting to climate damages?**

Climate Change and Climate Adaptation: Intro

- Adaptation approach looks from a different perspective: it takes **climate change as given**
- Complementary to mitigating policies whose aim is to reduce CO_2 emissions
  - Actually, sinergies with mitigation is an assessment criterion (more on that later)

- <u>Why is adaptation important?</u>
  - Intertemporal timespan of mitigating policies (e.g., pathway targets?)
  - Unequal and multidimensional aspects of climate damages (e.g., $\downarrow$ agric. yields?)
  - Link with UN's SDG that are not linked to $\downarrow CO_2$ (e.g., zero hunger, sustainable cities)

Getting started: what is Climate Adaptation?

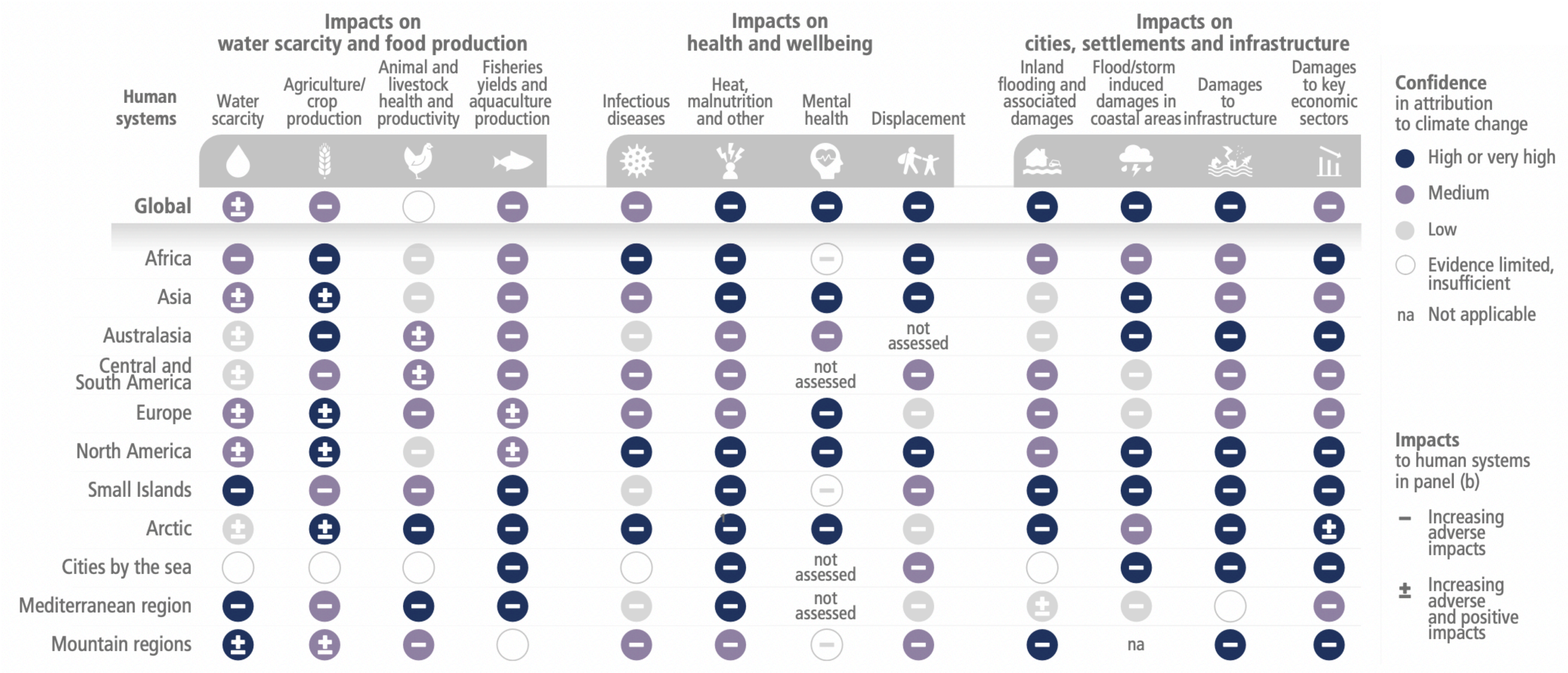
Climate Adaptation: Standards and Definitions

Definition according to IPCC (2022):

> *"Climate adaptation is the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial oportunities"*

- Climate harms/impacts are multidimensional, and so are adaptation margins
  - A/C or green cities for extreme heat in dense urban areas
  - Improved farming techniques (irrigation, machinery, and seeds) in rural economies
  - Migration from hazardous to safer areas
- Each of these solutions generates benefits, but potentially damages (e.g., A/C or migration)
  - This is particularly important due to the uneven spatial patterns of climate impacts!

Multidimensionality of climate impacts and adaptation



Adaptation versus *Maladaptation*

Definition according to IPCC (2022):

> *"Maladaptation is an adaptation action that increases the risk of adverse climate-related outcomes, including [...] more inequitable outcomes or dimished welfare."*

- Usually, it is a consequence of intertemporal trade-offs. Think of sea walls (Hsiao, 2023):
  - Short-term protection against flooding
  - Lock-ins and higher long-term vulnerability
- Often, it is a relative concept. Who benefits (and who does not) from adaptive actions?
- This is an important aspect to have in mind when designing (adaptative) policies!
  - Example: moral hazard following post-disaster aid (Fried, 2022)

Some facts on Global Adaptation (Gaps)

Global Adaptation to Climate Change

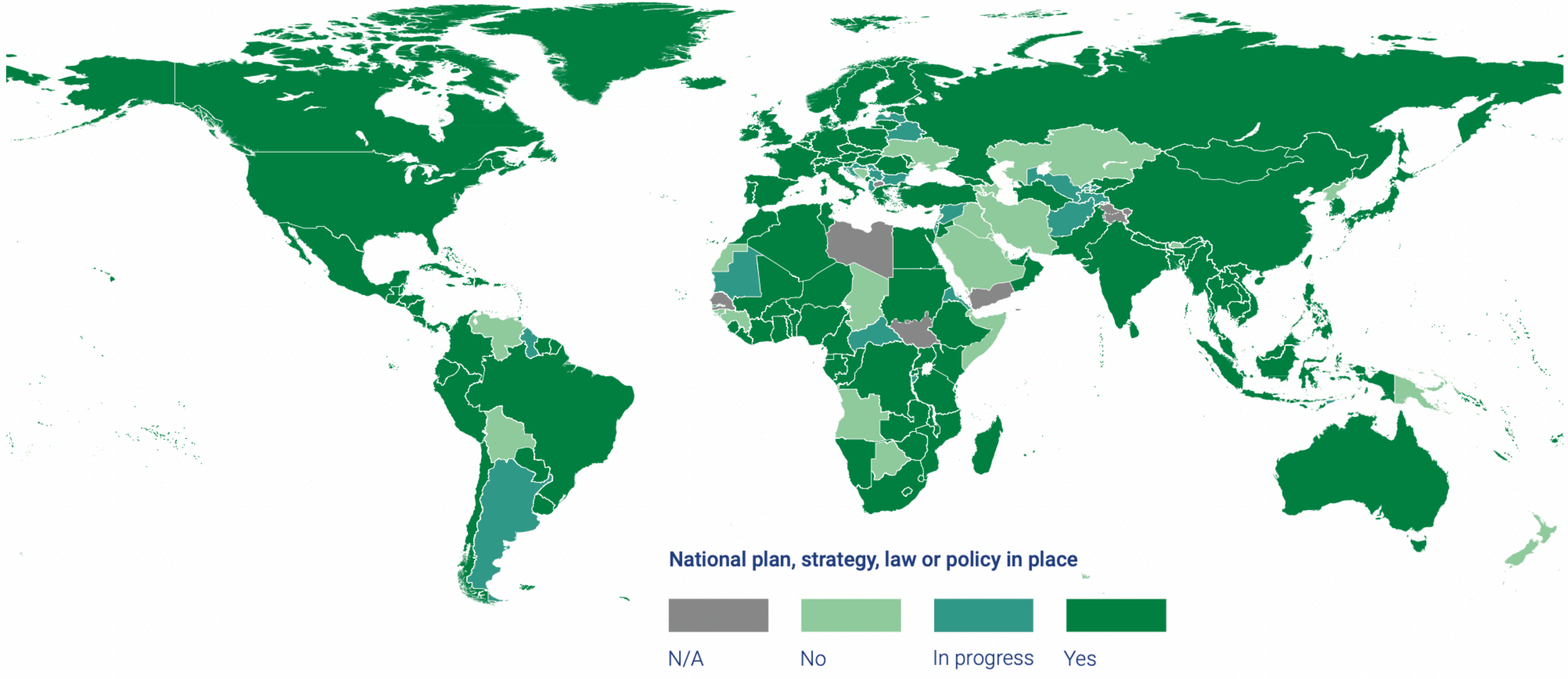
UN's Convention on Climate Change (Paris Agreement, 2015):

> *"All countries must engage in adaptation planning processes and the implementation of actions […]" (art. 7.9)*

- Since then, UN's Environmental Programme (UNEP) has monitored the global progress
  - Summarised in the Adaptation Gap Reports (AGR)

- Next: three (summarised) facts from AGR 2020 (Neufeldt et al., 2020)

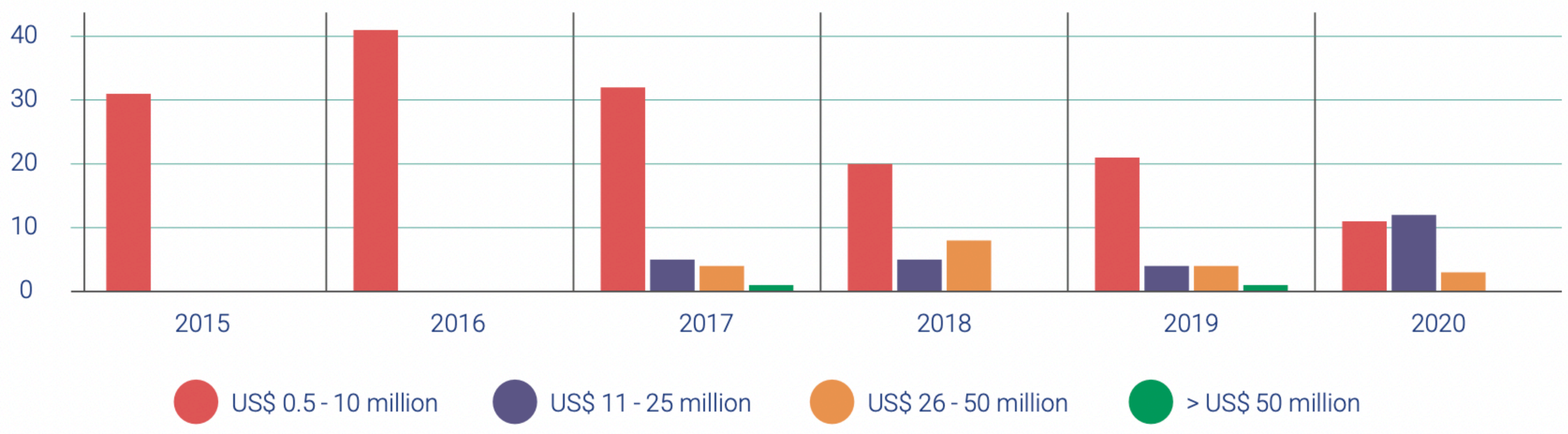
Fact 1: adaptation planning has been widely accepted...



Fact 2: … yet, gaps in realism, quality, and implementation

Fact 3: limited allocated resources (finance gap) as the main obstacle

- Size of financed projects has increased over time
- However, there is a sizeable finance gap between developed and developing economies
- This is particularly important for policy design
    - Developing economies are the most exposed to future climate impacts



Climate Change Adaptation in Agriculture

Climate Effects and Adaptation in Agriculture

Agriculture has been at the spotlight: very sensitive to weather and climate changes

- It also brought many empirical methodological advances

Cross-sectional approach

Mendelsohn et al. (1994) proposed a "hedonic approach" for climate effects on agriculture

$$y_i = \alpha + \beta C_i + \gamma X_i + \epsilon_i,$$

- $y_i \equiv$ land prices (why?) in US county i. What is the *source of identifying variation*?
- C_i long-term climate characteristics (why?); $X_i \equiv$ controls (see Dell et al., 2014)
- β + future climate = small climate change effects in the US
- Schenkler et al. (2005) shows that adaptation as irrigation $\rightarrow$ negative bias (why?)
    - Estimates for drylands alone are sizeable and robust!

Climate Effects and Adaptation in Agriculture

Deschenes and Greenstone (2007) proposed a **weather shock (panel) approach**

$$y_{it} = \beta C_{it} + \gamma X_{it} + \mu_i + \theta_t + \epsilon_{it}$$

- μ_i and θ_t are county and time fixed effects, respectively, and $t \equiv$ year
    - What is the source of *identification variation*?
    - Why does β capture the effect of weather (and not climate) shocks?
- This framework inspired an immense literature on climate effects (see Kala et al., 2023)
- It was further extended to account for long-term (and/or general equilibrium) effects
    - Idea: use long-term (say, decadal) changes in C_i
    - Why does it help accounting for adaptation?

Climate Effects and Adaptation in Agriculture

This literature has also focused on (lack of) climate adaptation

- Burke and Emerick (2016): similar short- and long-term estimates = no adaptation

Other papers have study specific margins of adjustment:

- Land reallocation: switch to relativelly less affected sectors (e.g., livestock, resilient crops)
  - Hornbeck (2012): no evidence of reallocation as adaptation in the US (but of migration)
  - Costinot et al. (2016): general equilibrium effects in the globalized economy
- Irrigation:
  - Crucial for shock coping in India (Fishman, 2018; Taraz, 2017)
  - Related to long-run groundwater depletion in the US (Hornbeck and Keskin, 2014)

Climate Effects and Adaptation in Agriculture

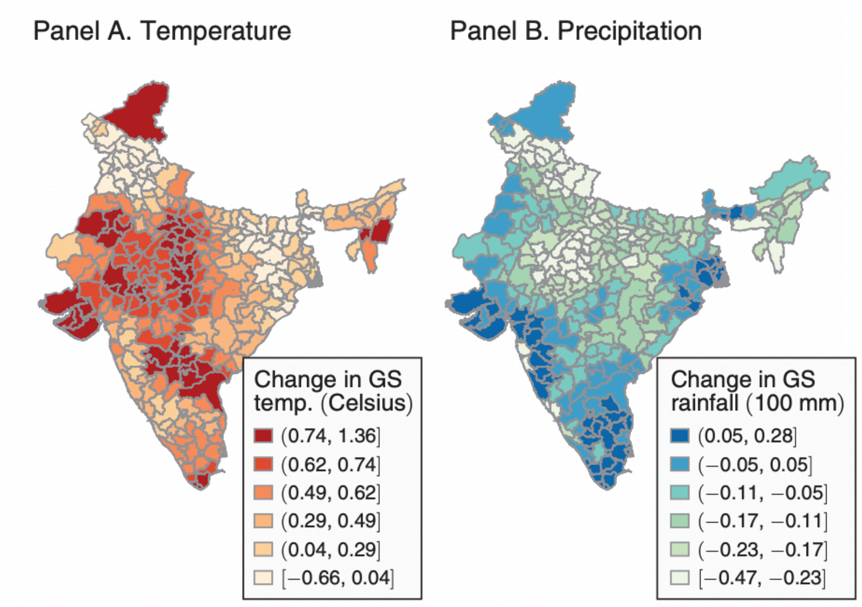
Other papers have study specific margins of adjustment:

- Better practices, tech. adoption and financial products (see Kala et al., 2023, Section III)
  - Limited evidence (information frictions and insufficient credit markets)
- Migration as adaptation (idea: last resort due to costly adaptation; Hornbeck, 2012)
  - Deschenes and Moretti (2009): attenuated mortality effects in the US
  - Cai et al. (2016): strong effects on international migration from agricultural countries
  - Groeger and Zylberberg (2016): urban migration as risk-coping in Vietnam
  - Liu et al. (2023): more agric. employment and less urbanization in Indian districts
  - Henderson et al. (2017): urbanization increased in SSA only in manufacturing cities (and not in market cities)

Climate Effects and Adaptation in Agriculture

Liu et al. (2023): demand-side effects of (long-term) climate shocks

- Higher temperatures, less agric. income
  - $\downarrow$ demand for non-agricultural goods
  - Climate change $\rightarrow$ obstacle for structural change!



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$$\Delta y_i = \beta \Delta T_i + \gamma \Delta P_i + \epsilon_i$$

- $\Delta T_i \equiv$ long-term temperature changes
- $\Delta P_i \equiv$ precipitation (control)

	Ag. labor share	Nonag. worker share
	(1)	(2)
T	0.3819	−0.1491
	(0.0995)	(0.0531)
	[0.2292]	[0.0621]
P	0.3256	0.0202
	(0.2236)	(0.1080)
	[0.4429]	[0.0777]
Region fixed effects	Y	Y
Observations	258	270

Climate Effects and Adaptation in Agriculture

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Stronger effects on developed D_i districts

$$\Delta y_i = \beta \Delta T_i + \alpha D_i \times \Delta T_i + \gamma \Delta P_i + \epsilon_i$$

Vulnerable districts drive the results!

	Ag. labor share		Nonag. worker share	
	(1)	(2)	(3)	(4)
Panel A. Road network density				
T	0.322	0.355	−0.104	−0.137
	(0.091)	(0.099)	(0.055)	(0.058)
	[0.108]	[0.118]	[0.054]	[0.052]
T × High road density	−0.320	−0.362	0.094	0.119
	(0.110)	(0.114)	(0.070)	(0.068)
	[0.125]	[0.128]	[0.068]	[0.062]
Region-year trends	Y	N	Y	N
Region-year fixed effects	N	Y	N	Y
P-value of sum, cluster	0.974	0.919	0.827	0.633
P-value of sum, Conley	0.978	0.929	0.860	0.665
Observations	1,458	1,458	1,458	1,458
Panel B. Bank credit per capita				
T	0.288	0.271	−0.147	−0.157
	(0.067)	(0.070)	(0.054)	(0.048)
	[0.083]	[0.082]	[0.066]	[0.062]
T × High bank credit	−0.210	−0.217	0.108	0.106
	(0.109)	(0.110)	(0.065)	(0.059)
	[0.108]	[0.111]	[0.072]	[0.066]

Climate Effects and Adaptation in Agriculture

Henderson et al. (2017): heterogeneous effects in SSA (using a similar empirical setting)

- Δ moisture $\rightarrow$ agricultural shock
    - Urbanization decreases, mostly in market cities
    - But less so for manufacturing and exporting cities
- What is the underlying mechanism?

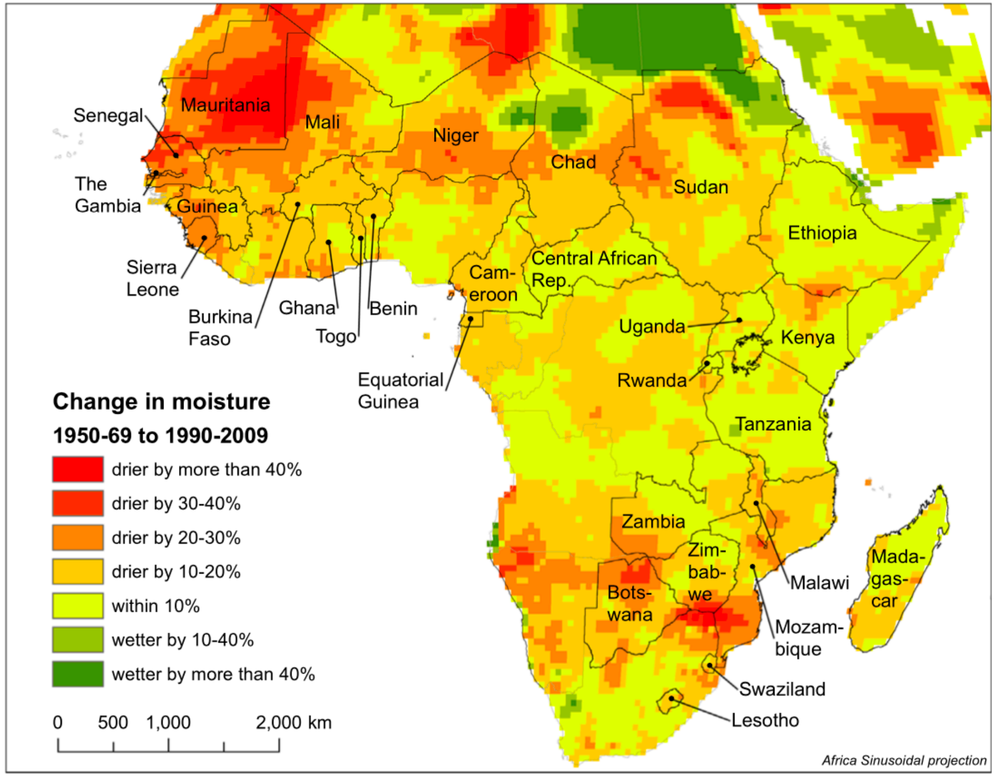

Fig. 2. Moisture in Africa 1950–69 to 1990–2009.

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Table 2
Effect of moisture on urbanization: heterogeneity by industrialization.

	(1)	(2)	(3)
Δmoisture	−0.0761	−1.064***	−1.164***
	(0.180)	(0.360)	(0.354)
Δmoisture × (9 – #modern industries)		0.116***	
		(0.0414)	
Δmoisture × (14 – #all industries)			0.0824***
			(0.0263)
(9 – #modern industries)/1000		−0.51	
		(1.22)	
(14 – #all industries)/1000			0.131
			(0.727)
Initial share urban/1000	−48.9***	−55.0***	−52.0***
	(5.53)	(8.79)	(8.15)
ln(distance to coast)/1000	1.43	1.55	1.47
	(1.89)	(1.87)	(1.89)

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  - Relates to structural transformation!

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Structural change as adaptation:

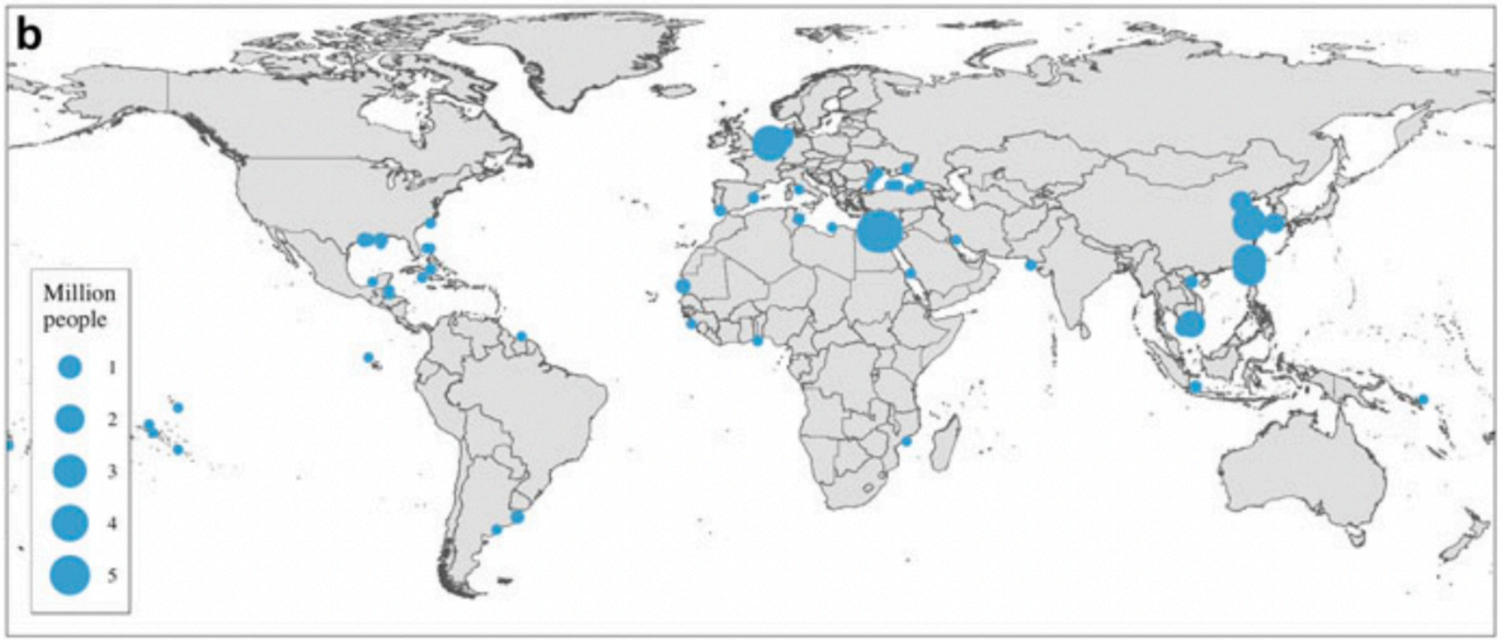
- Industrialization $\rightarrow$ lower vulnerability
- Economies need to meet subsistence
  - Trade barriers $\rightarrow$ importing food is limited (the "food problem")
- Ishan (2023): food problem exarcebates welfare losses in poor countries
  - Lower agric. productivity: more agricultural employment (why?)

Adaptation to Coastal Flooding

Adaptation to Coastal Flooding

Coastal flooding: among the most concerning consequences of future climate change

- Balboni (2021): ~ 300 million living in locations <5 meters
- Adaptation: sea walls or reallocation? What is better, and for whom?



(picture: million people in locations <2.5 meters from Conte, 2023)

Adaptation to Coastal Flooding

Coastal flooding: physical damage to immobile capital (e.g., buldings, roads)

Tension between:

- Gradual increase of water levels
- Intertemporal allocation of (adaptative) investments

Moreover, moral hazard rising from

- High sunk costs of adaptative measures
- Existence of post-disaster aid

Who should move: capital, people, or none?

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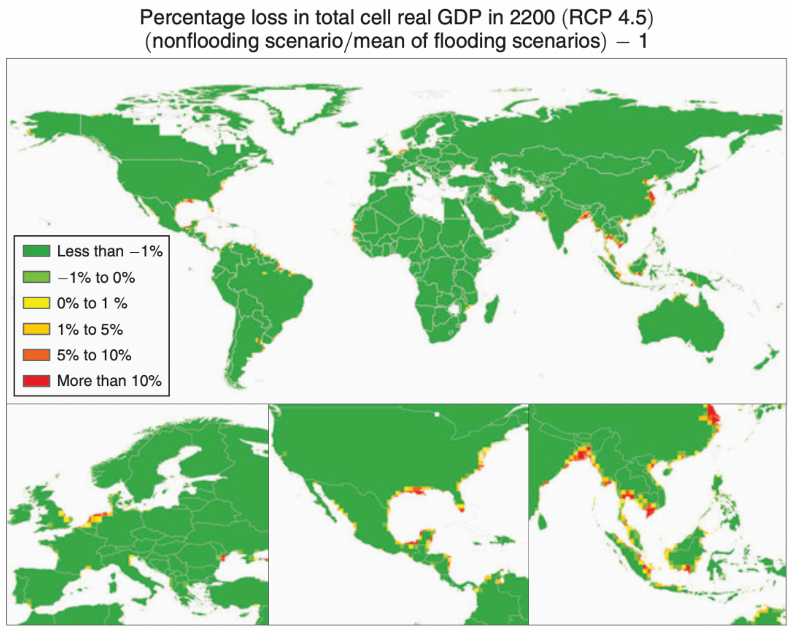
Who should move: capital, people, or none?

Desmet et al. (2021): dynamic effects of gradual coastal flooding.

- No (gradual) migration + investment adaptation: ↑ losses 40 times!



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Who should move: capital, people, or none?

Adapting to future coastal flooding needs investment in the present

It is an intergenerational transfer, subj. to:

- Political constrains (why?)
- Path-dependence/lock-in

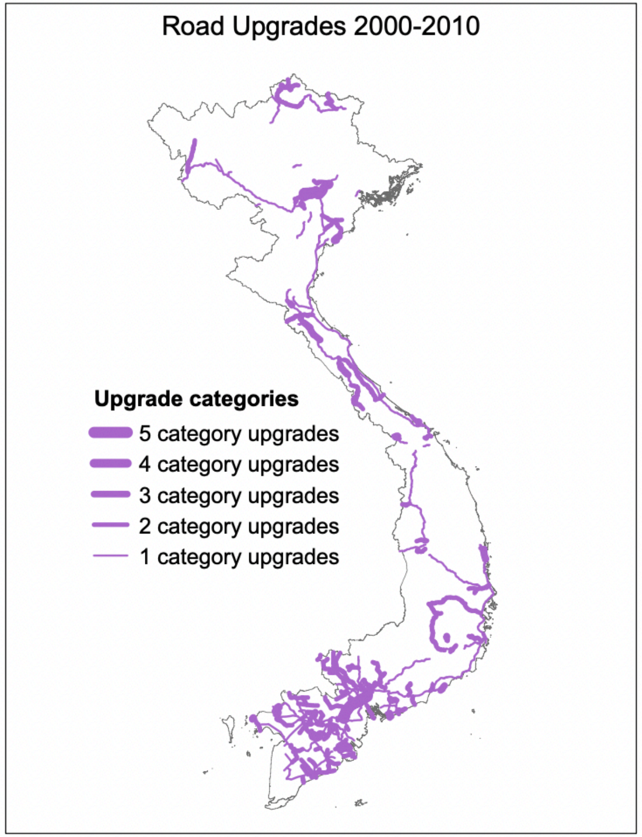
Balboni (2021) "*Infrastructure Investments and the Persistence of Coastal Cities*"

- Are transportation investments in Vietnam forward looking?

Adaptation to Coastal Flooding

Balboni (2021)'s setting in Vietnam: high activity/infrastructure density in coastal regions

- Improving dense regions: high present returns



Adaptation to Coastal Flooding

Balboni (2021)'s setting in Vietnam: high activity/infrastructure density in coastal regions

- Improving dense regions: high present returns

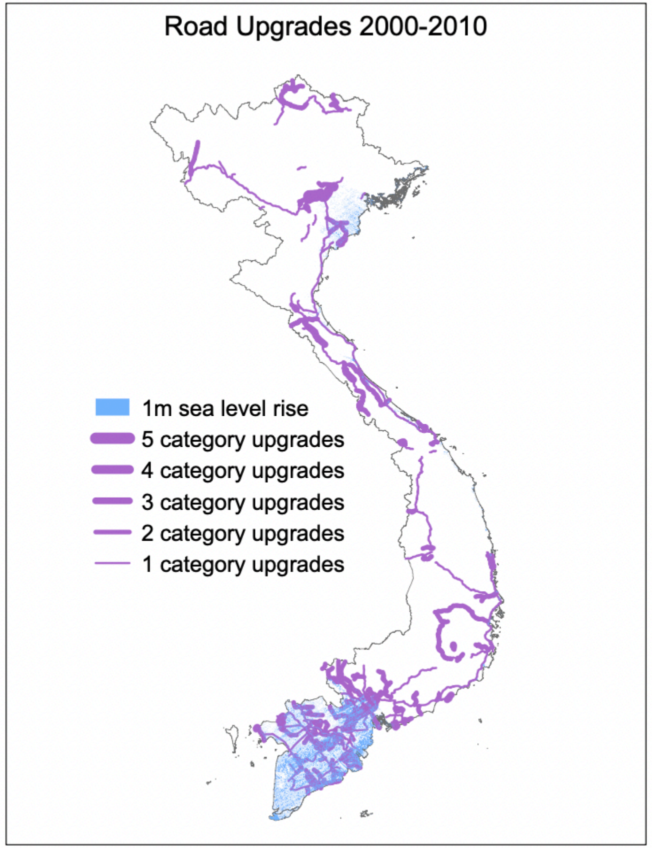
- Not as much with coastal flooding

Balboni's dynamic (gradual) framework:

- Coastal favoritims: high long-term costs

It squares with evidence of urban lock-in

- High urban development rates in hazardous areas (Kocornik et al., 2020, Ghandi et al.; 2023)



Adaptation to Coastal Flooding

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Tension between:

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Moreover, moral hazard rising from

- **High sunk investments**
- Existence of post-disaster aid

Who should move: capital, people, or none?

Immobile capital $\rightarrow$ moral hazard

- Sunk investment: too high to be left behind
- Real estate developers expect a sea wall

Hsiao (2023) "*Sea Level Rise and Urban Adaptation in Jakarta*"

- Imperfect political commitment $\rightarrow$ coastal lock-in
- Integrated approach (e.g., in-land investment) $\downarrow$ coastal demand

Adaptation to Coastal Flooding

Coastal flooding: physical damage to immobile capital (e.g., buldings, roads)

Tension between:

- Gradual increase of water levels
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Moreover, moral hazard rising from

- High sunk investments
- **Existence of post-disaster aid**

Who should move: capital, people, or none?

Post-disaster aid $\rightarrow$ moral hazard

- Economic agents expect to receive aid
- Aid is funded by all tax-payers, but transfered only to damaged agents

Fried (2022) "*Seawalls and Stilts: A Quantitative Macro Study of Climate Adaptation*"

- Presence of aid $\downarrow$ private adaptation
- However, subsisdies for investment $\uparrow$ climate adaptation

Global Mortality Costs of Climate Change

Accounting for Adaptation

Global Mortality Costs of Climate Change

- Climate impacts are not exclusively economic, but also on life quality
- Extreme temperatures are particularly important
  - Affect the likelihood of mortality
  - Older age-groups are particularly vulnerable (Deschenes and Moretti, 2009)
- Carleton et al. (2022) "*Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits*"
  - Infer age-specific mortality-temperature relationship at global scale
  - Find an U shaped relationship: extreme temperatures matter, especially for elderly
  - Spatially heterogeneous results (e.g., northern EU benefits from less cold winters)

Global Mortality Costs of Climate Change

- **<u>For today:</u>** overview of Carleton et al. (2022)'s paper

  1. Conceptual framework: how does temperature affect mortality risk?
  2. Global estimates on age-specific, mortality-temperature (causal) relationship

- Next classes (based on overall interest):
  - Inferring adaptation costs
  - Mortality risk + benefits and costs of adaptation = $ cost of future emissions (e.g., SCC)

Global Mortality Costs of Climate Change: Conceptual Framework

- Climate and weather: joint distribution $\mathbf{C}$ of weather realizations $\mathbf{c}$
- Mortality risk: $f \equiv f(\mathbf{c}, \mathbf{b})$, where
- $\mathbf{b} \equiv \{b_q, \ldots, b_K\}$ is a composite of K choice variables that affect mortality risk (i.e., adaptation) that depends on income Y

Hence, mortality risk at period t is

$$P(\text{death}|Y_t, \mathbf{C}_t) = f(\mathbf{b}(Y_t, \mathbf{C}_t), \mathbf{c}(\mathbf{C}_t))$$

And mortality effects of climate change is

$$f(\mathbf{b}(Y_t, \mathbf{C}_t), \mathbf{c}(\mathbf{C}_t)) - f(\mathbf{b}(Y_t, \mathbf{C}_{t0}), \mathbf{c}(\mathbf{C}_{t0}))$$

Carleton et al. (2022) estimate these (and other) effects with global data!

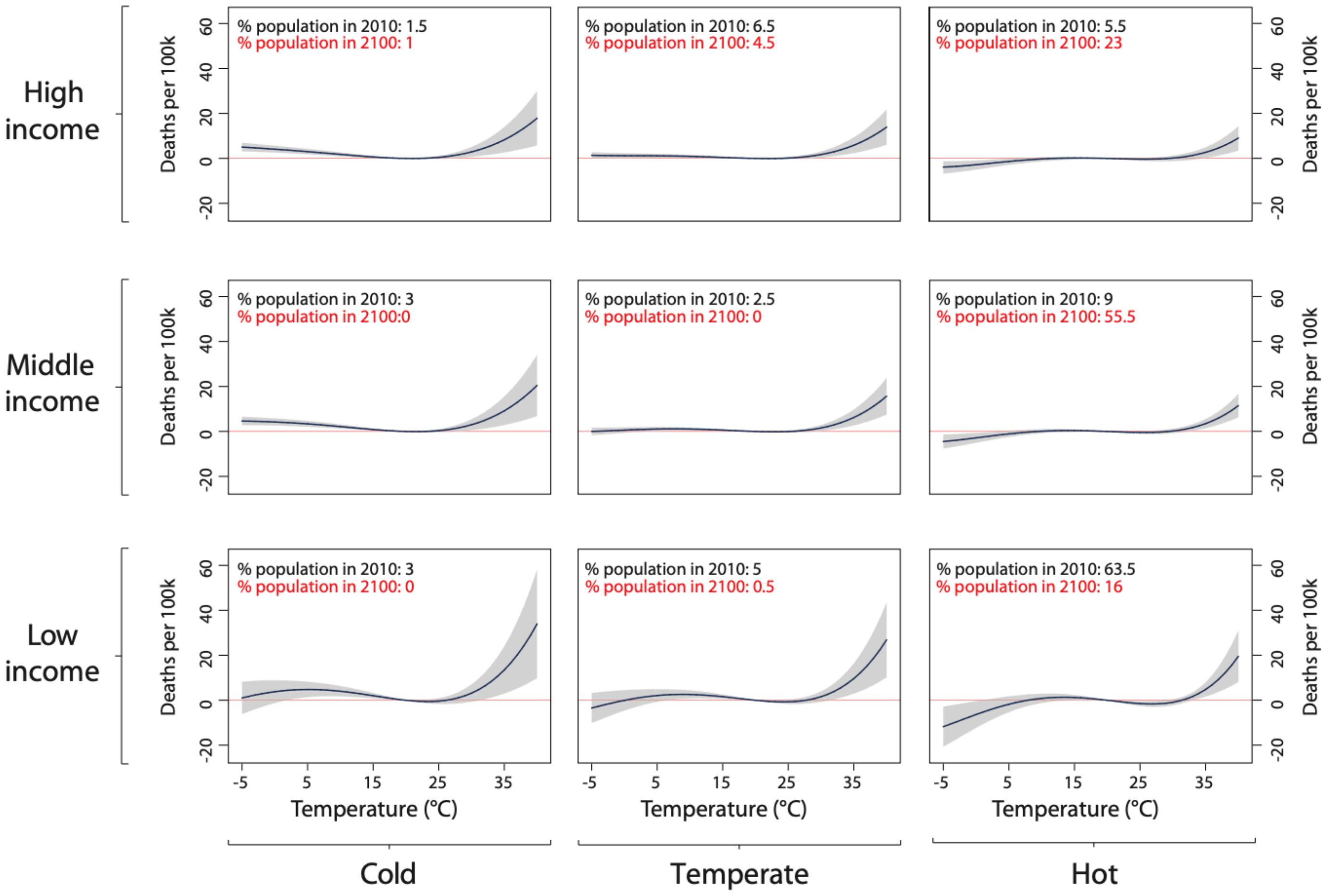
Global Mortality Costs of Climate Change: Data

TABLE I

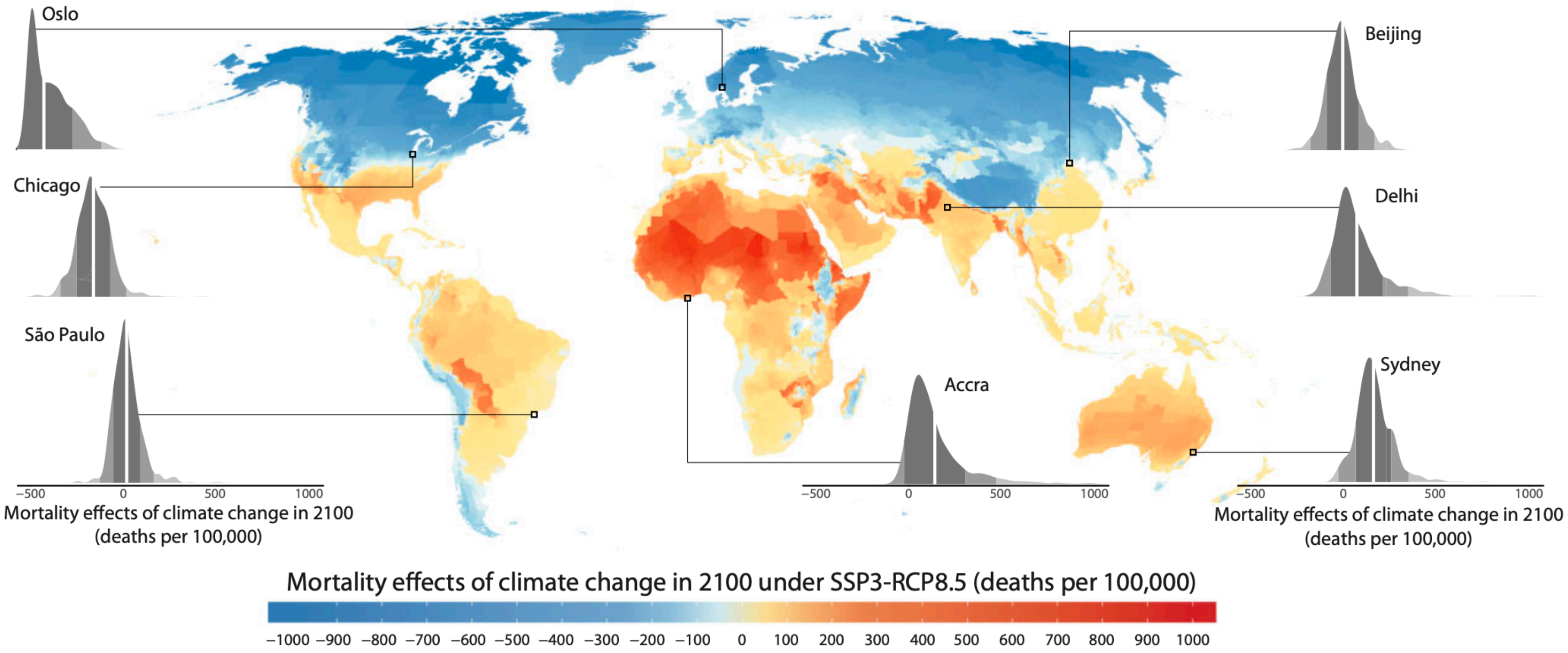
HISTORICAL MORTALITY AND CLIMATE DATA

Country	N	Spatial scale[c]	Years	Age categories	Average annual mortality rate*[a]: All-age	Average annual mortality rate*[a]: >64 yr.	Global pop. share[d]	Average covariate values*[b]: GDP per capita[e]	Average covariate values*[b]: Avg. daily temp.[f]	Average covariate values*[b]: Annual avg. days >28°C
Panel A: Mortality records										
Brazil	228,762	ADM2	1997–2010	< 5, 5–64, >64	525	4,096	0.028	11,192	23.8	35.2
Chile	14,238	ADM2	1997–2010	< 5, 5–64, >64	554	4,178	0.002	14,578	14.3	0
China	7,488	ADM2	1991–2010	< 5, 5–64, >64	635	7,507	0.193	4,875	15.1	25.2
EU	13,013	NUTS2[g]	1990[h]–2010	< 5, 5–64, >64	1,014	5,243	0.063	22,941	11.2	1.6
France[i]	3,744	ADM2	1998–2010	0–19, 20–64, >64	961	3,576	0.009	31,432	11.9	0.3
India[j]	12,505	ADM2	1957–2001	All ages	724	–	0.178	1,355	25.8	131.4
Japan	5,076	ADM1	1975–2010	< 5, 5–64, >64	788	4,135	0.018	23,241	14.3	8.3
Mexico	146,835	ADM2	1990–2010	< 5, 5–64, >64	561	4,241	0.017	16,518	19.1	24.6
United States	401,542	ADM2	1968–2010	< 5, 5–64, >64	1,011	5,251	0.045	30,718	13	9.5
All countries	**833,203**	**–**	**–**	**–**	**780**	**4,736**	**0.554**	**20,590**	**15.5**	**32.6**

Global Mortality Costs of Climate Change: (some) Results



Global Mortality Costs of Climate Change: Projections



See you next class!

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