Economics 134 L10. Climate Change IV

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Climate change

Climate change:

1. One of the greatest challenges of our time
2. Raises new and interesting economic issues
   1. ~~balancing energy use with decarbonization (L7)~~
   2. ~~discounting and long-run environmental policy (L8)~~
   3. ~~risk, uncertainty, and irreversibility (L9)~~
   4. international negotiation and cooperation (today)

International aspects of global climate change

Up until now, we have thought about climate change from the perspective of a world government.

- allowed us to assess global benefits and costs
- over long horizons, accounting for uncertainty

Three separate but related international issues:

- **benefits** — expected climate damage differs across countries
- **costs** — future economic development, as well as ownership of coal and oil reserves, differ across countries
- **coordination** — a stable climate is a public good, raising concerns with free-riding

First, we'll consider these issues empirically, then we'll view them through the lens of a model.

Distribution of benefits

Distribution of costs

Coordination problem

Sources of climate impacts

Several expected effects of climate change:

- food production
- health impacts
- water scarcity
- sea level rise

Vulnerability depends on local economic and climatological conditions.

0. Increasing drought risk

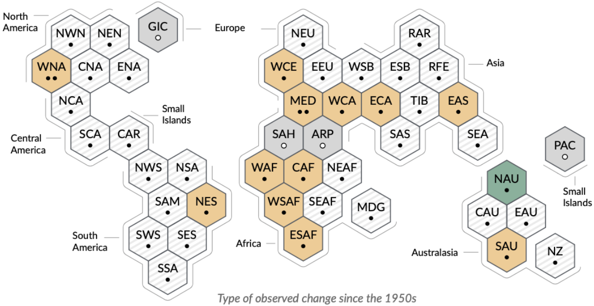
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions

Type of observed change
in agricultural and ecological drought

- Increase (12)
- Decrease (1)
- Low agreement in the type of change (28)
- Limited data and/or literature (4)

Confidence in human contribution
to the observed change

- ●●● High
- ●● Medium
- ● Low due to limited agreement
- ○ Low due to limited evidence



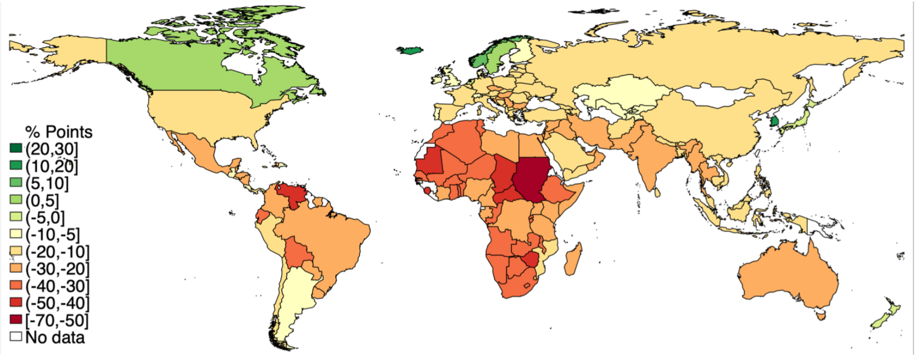
Type of observed change since the 1950s

Each hexagon corresponds to one of the IPCC AR6 WGI reference regions

NWN *North-Western North America*

IPCC AR6 WGI reference regions: **North America: NWN** *(North-Western North America),* **NEN** *(North-Eastern North America),* **WNA** *(Western North America),* **CNA** *(Central North America),* **ENA** *(Eastern North America),* **Central America: NCA** *(Northern Central America),* **SCA** *(Southern Central America),* **CAR** *(Caribbean),* **South America: NWS** *(North-Western South America),* **NSA** *(Northern South America),* **NES** *(North-Eastern South America),* **SAM** *(South American Monsoon),* **SWS** *(South-Western South America),* **SES** *(South-Eastern South America),* **SSA** *(Southern South America),* **Europe: GIC** *(Greenland/Iceland),* **NEU** *(Northern Europe),* **WCE** *(Western and Central Europe),* **EEU** *(Eastern Europe),* **MED** *(Mediterranean),* **Africa: MED** *(Mediterranean),* **SAH** *(Sahara),* **WAF** *(Western Africa),* **CAF** *(Central Africa),* **NEAF** *(North Eastern Africa),* **SEAF** *(South Eastern Africa),* **WSAF** *(West Southern Africa),* **ESAF** *(East Southern Africa),* **MDG** *(Madagascar),* **Asia: RAR** *(Russian Arctic),* **WSB** *(West Siberia),* **ESB** *(East Siberia),* **RFE** *(Russian Far East),* **WCA** *(West Central Asia),* **ECA** *(East Central Asia),* **TIB** *(Tibetan Plateau),* **EAS** *(East Asia),* **ARP** *(Arabian Peninsula),* **SAS** *(South Asia),* **SEA** *(South East Asia),* **Australasia: NAU** *(Northern Australia),* **CAU** *(Central Australia),* **EAU** *(Eastern Australia),* **SAU** *(Southern Australia),* **NZ** *(New Zealand),* **Small Islands: CAR** *(Caribbean),* **PAC** *(Pacific Small Islands)*

1. Agricultural impacts



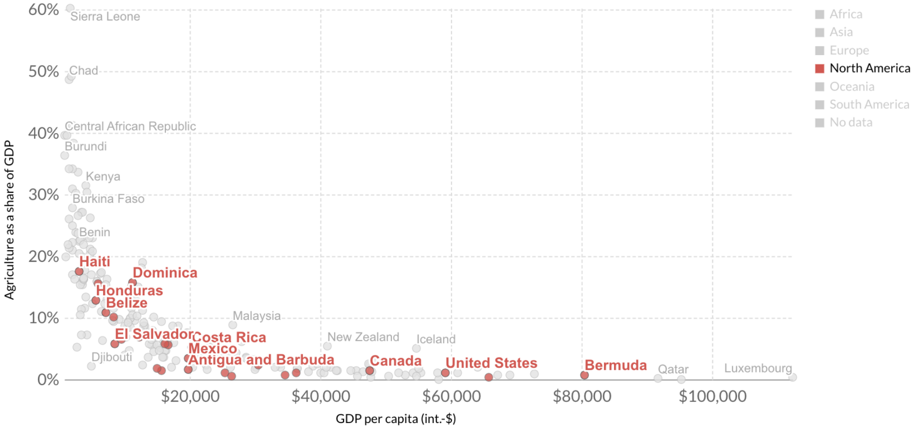
Projected impacts of climate change on agricultural productivity by 2100 (Nath 2023)

Share of agriculture falls with national income

Source: Data compiled from multiple sources by World Bank

OurWorldInData.org/employment-in-agriculture • CC BY

North America



Source: Data compiled from multiple sources by World Bank

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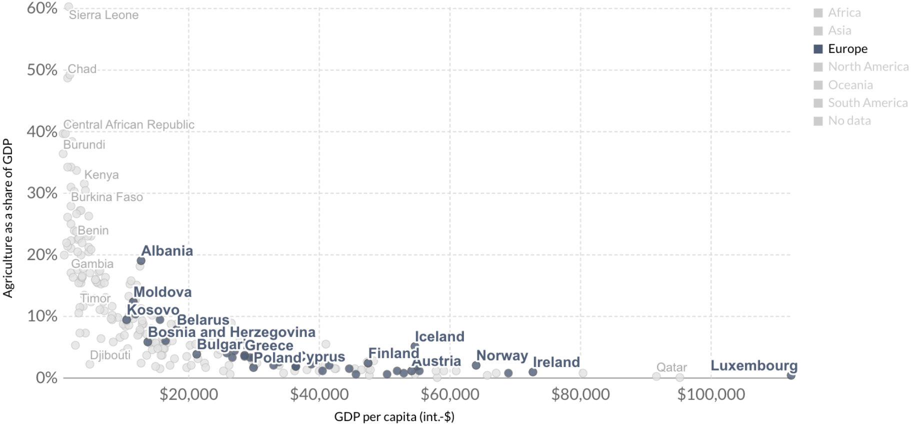
Europe



Source: Data compiled from multiple sources by World Bank

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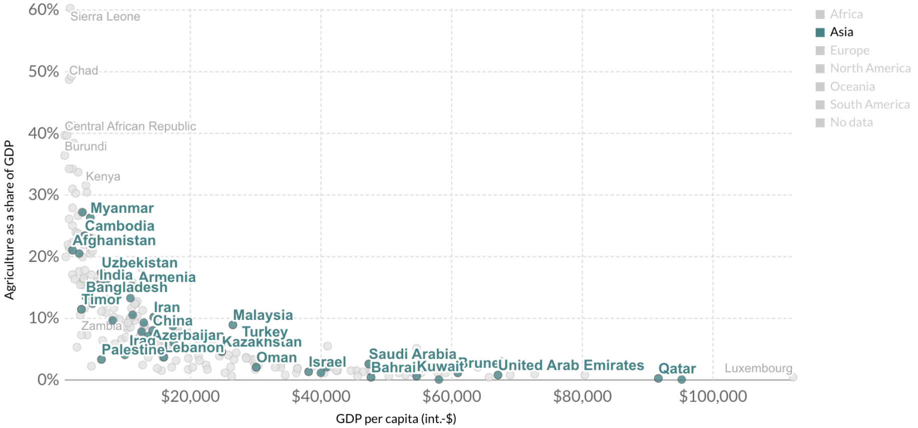
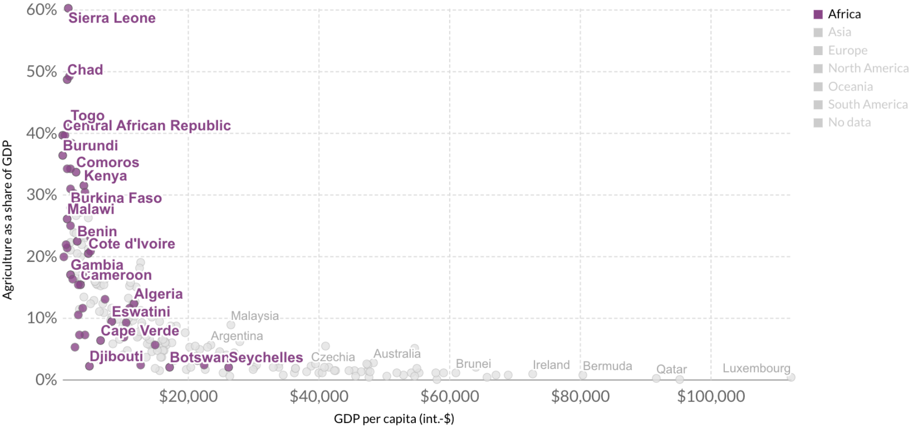
Asia



Source: Data compiled from multiple sources by World Bank

Africa



Source: Data compiled from multiple sources by World Bank

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Employment in agriculture

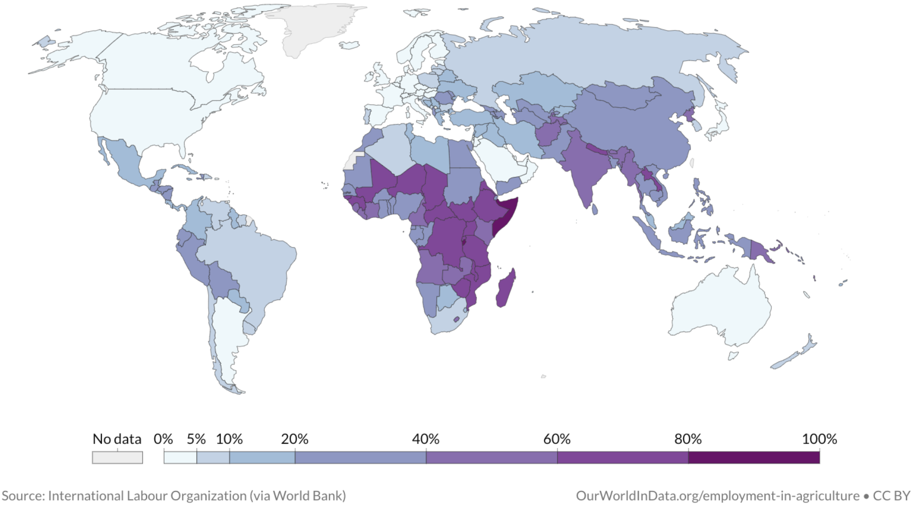
Labor shares for agriculture differ dramatically.

Some examples:

South Sudan	60.4%
India	42.6%
China	25.3%
Russia	5.8%
Australia	2.6%
France	2.5%
U.S.	1.4%
U.K.	1.1%

$\hookrightarrow$ Very different vulnerabilities to shocks in agricultural productivity

Employment in agriculture



Share of the labor force employed in agriculture, 2019.

2. Health impacts

Climate Impact Lab:

- Carleton, Tamma; Jina, Amir; Delgado, Michael; Greenstone, Michael; Houser, Trevor; Hsiang, Solomon; Hultgren, Andrew; Kopp, Robert E.; McCusker, Kelly; Nath, Ishan; Rising, James; Rode, Ashwin; Seo, Hee Kwon; Viaene, Arvid; Yuan, Jiacan; Zhang, Alice Tianbo (2022). "**Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits**," Quarterly Journal of Economics

Simple research design:

- data on **mortality**, temperature, and income to learn how excess mortality correlates with temperature and income
- then scale the estimates by future ↑ temperature to predict future damages

Data on mortality and global temperature

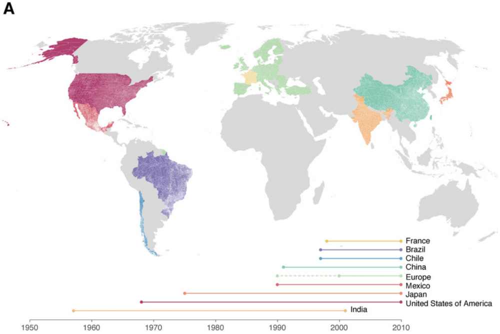


Figure 2: Mortality statistics used in generating empirically-based climate change mortality impact projections.

Data on mortality and global temperature

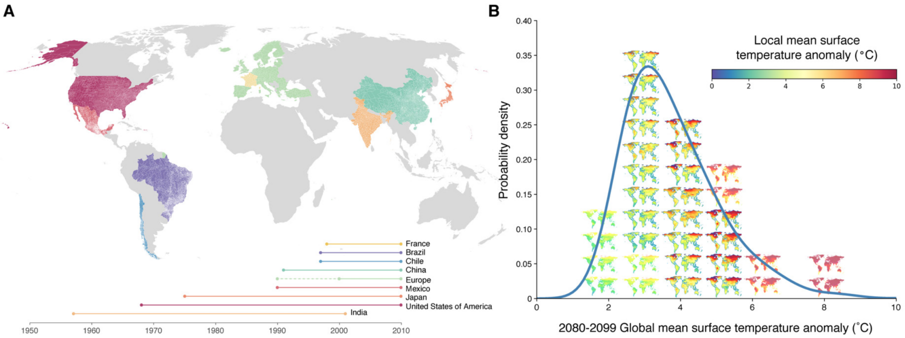
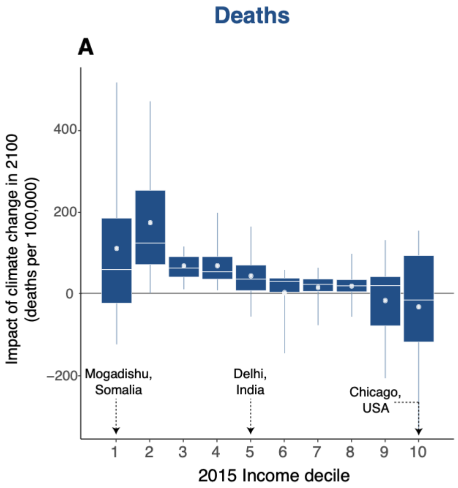
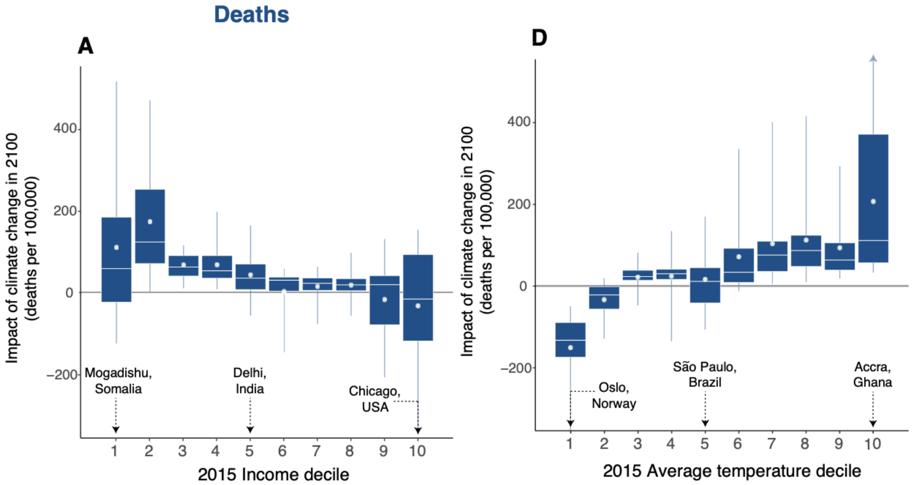


Figure 2: Mortality statistics and future climate projections used in generating empirically-based climate change mortality impact projections.

Lower-income countries are more vulnerable



Hotter countries are more vulnerable



Health outcomes by country

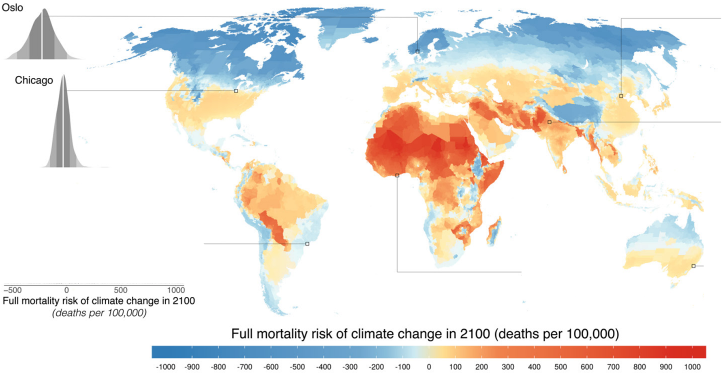
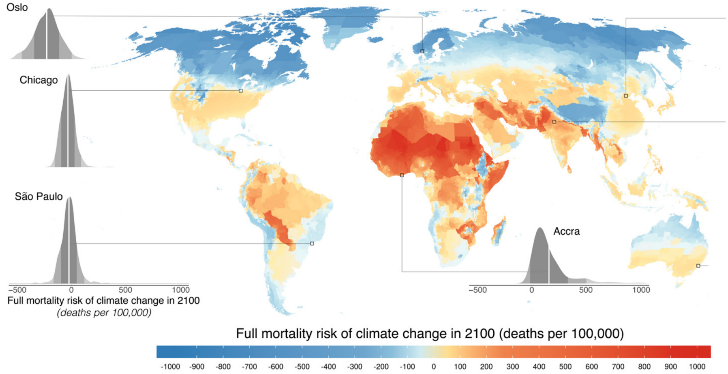


Figure 8: The mortality risk of future climate change.

Health outcomes by country



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Health outcomes by country

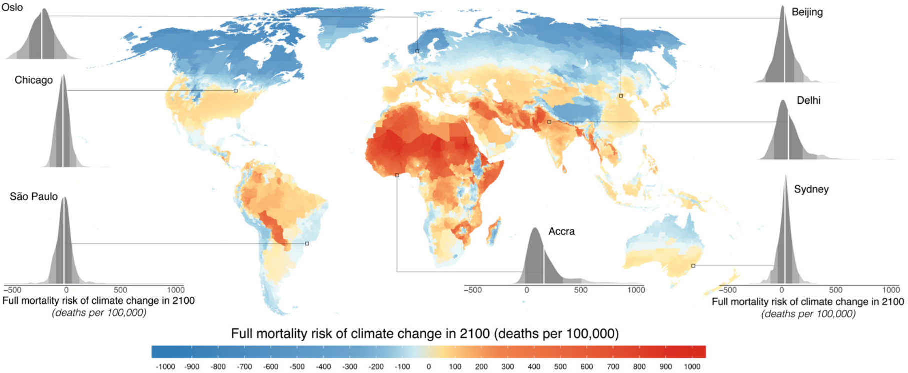


Figure 8: The mortality risk of future climate change.

Distribution of benefits

Distribution of costs

Coordination problem

Abatement costs across countries

Who will bear the cost of (efficient) climate mitigation?

- countries that rely heavily on fossil fuels (now and in the future)
- countries that own fossil fuels

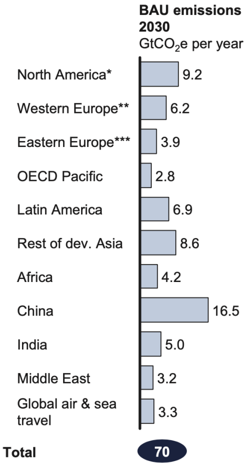
The former depends (mostly) on current and future economic output.

The latter depends on geographic variation.

1. Efficient abatement requires collective action

Exhibit 3.2.1

Regional split – BAU emissions and abatement potential



* United States and Canada
** Includes EU27, Andorra, Iceland, Lichtenstein, Monaco, Norway, San Marino, Switzerland

1. Efficient abatement requires collective action

Exhibit 3.2.1

Regional split – BAU emissions and abatement potential

	BAU emissions 2030 $GtCO_2e$ per year	**Abatement potential 2030** $GtCO_2e$ per year	**Emissions reduction relative to 2030 BAU** Percent
North America*	9.2	5.1	-55
Western Europe**	6.2	3.2	-51
Eastern Europe***	3.9	1.9	-49
OECD Pacific	2.8	1.4	-51
Latin America	6.9	4.5	-66
Rest of dev. Asia	8.6	5.7	-67
Africa	4.2	2.8	-68
China	16.5	8.4	-51
India	5.0	2.7	-53
Middle East	3.2	1.4	-43
Global air & sea travel	3.3	0.8	-24
Total	**70**	**38**	**-54**

* United States and Canada
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	BAU emissions 2030 $GtCO_2e$ per year	**Abatement potential 2030** $GtCO_2e$ per year	**Emissions reduction relative to 2030 BAU** Percent	**Emissions reduction relative to 2005** Percent
North America*	9.2	5.1	-55	-43
Western Europe**	6.2	3.2	-51	-43
Eastern Europe***	3.9	1.9	-49	-37
OECD Pacific	2.8	1.4	-51	-43
Latin America	6.9	4.5	-66	-52
Rest of dev. Asia	8.6	5.7	-67	-58
Africa	4.2	2.8	-68	-57
China	16.5	8.4	-51	7
India	5.0	2.7	-53	33
Middle East	3.2	1.4	-43	16
Global air & sea travel	3.3	0.8	-24	43
Total	**70**	**38**	**-54**	**-30**

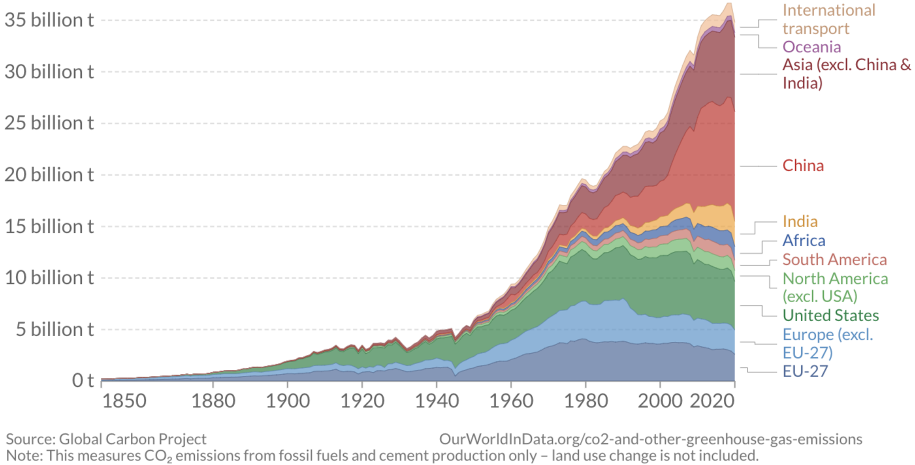
Developed regions
-45 to -55% vs. 2030 BAU
-35 to -45% vs. 2005

Developing regions, forestry
-65 to -70% vs. 2030 BAU
-50 to -60% vs. 2005

Developing regions, non forestry
-40 to -55% vs. 2030 BAU
+5 to +35% vs. 2005

* United States and Canada
** Includes EU27, Andorra, Iceland, Lichtenstein, Monaco, Norway, San Marino, Switzerland

2. Regional carbon emissions



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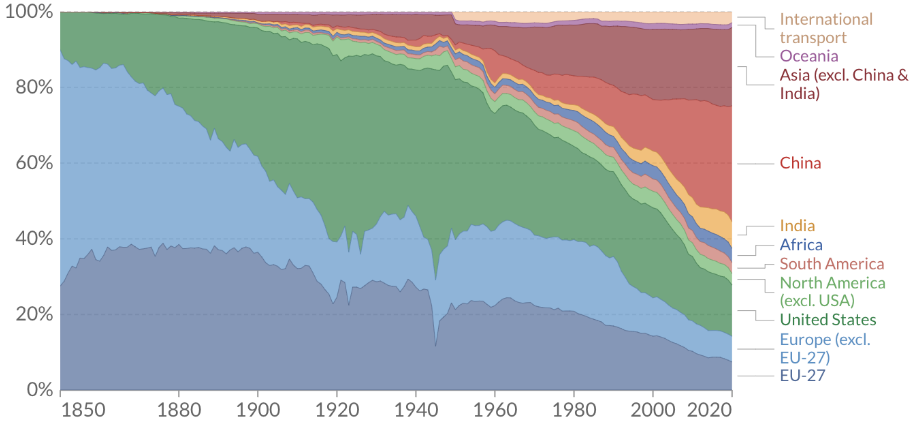


Source: Global Carbon Project OurWorldInData.org/co2-and-other-greenhouse-gas-emissions
Note: This measures CO_2 emissions from fossil fuels and cement production only – land use change is not included.

2. The changing sources of carbon emissions

Total emissions (billion tonnes CO_2/year)

	2000	2020
Africa	0.9	1.3
India	1.0	2.4
China	3.4	**10.7**
Russia	1.5	1.6
Europe	2.6	**2.4**
U.S.	6.0	**4.7**

	2000	2020
Africa	3.5%	3.8%
India	3.4%	7.0%
China	13.6%	**30.6%**
Russia	5.9%	4.6%
Europe	10.1%	**6.9%**
U.S.	23.8%	**13.5%**

Back-of-the-envelope calculation

Suppose that a country's utility is

$$u(c_i) = \frac{1}{1-\theta} c_i^{1-\theta}$$

for $\theta = 2$.

United States (2020)

- 20.9 trillion GDP, 330 million people $\implies$ 63,300 USD per capita
- 4.7 billion tCO_2 $\implies$ about 14.2 tCO_2 per capita
- carbon price of 57 euros / tCO_2 (EU ETS, 1 July 2021) or about \$65
- \$923 per capita, or 1.4% of c_i
- $u(63.3 - 0.9) - u(63.3) \approx -0.00023$

China (2020)

- 14.7 trillion GDP, 1.4 billion people $\implies$ 10,500 USD per capita
- 10.7 billion tCO_2 $\implies$ about 7.6 tCO_2/person; about \$500/person (4.8%)
- $u(10.5 - 0.5) - u(10.5) \approx -0.00476$

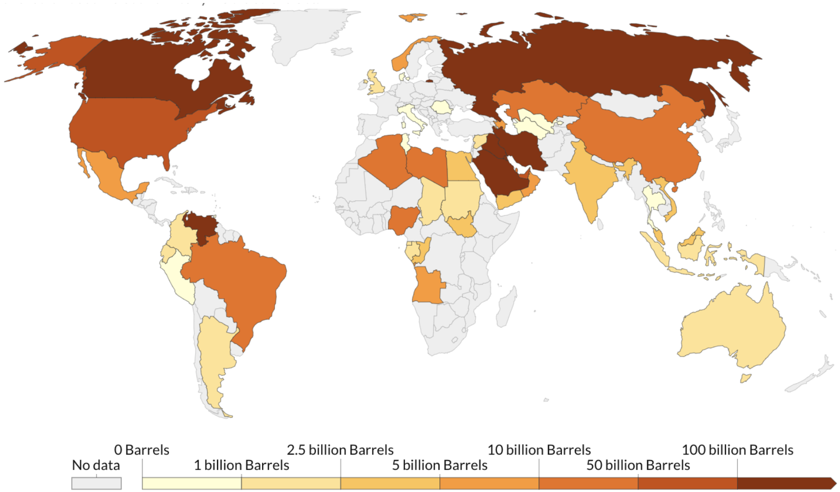
Obtains because $u'(c_{\text{US}})/u'(c_{\text{CN}}) \approx 1/6$ and $1.4/4.8 \approx 1/3$.

3. Resource endowments

Oil, coal, and gas reserves concentrated in a handful of countries.

	oil billion bbl	**coal** billion tonnes	**gas** trillion m^3
U.S.	68.8	248.9	12.6
China	–	143.2	–
India	–	115.1	–
Russia	107.8	162.2	37.4
Saudi Arabia	297.5	–	6.0
Iran	157.8	–	32.1
Venezuela	303.8	–	–

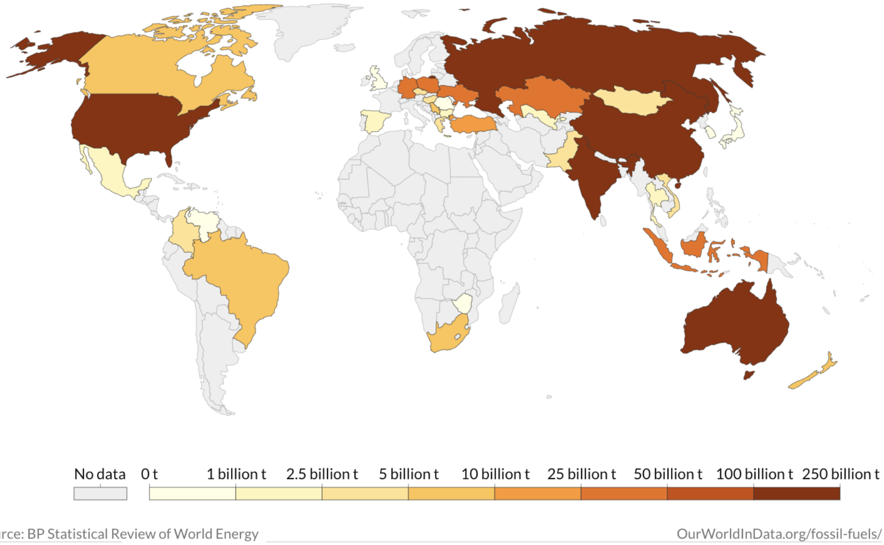
Oil reserves



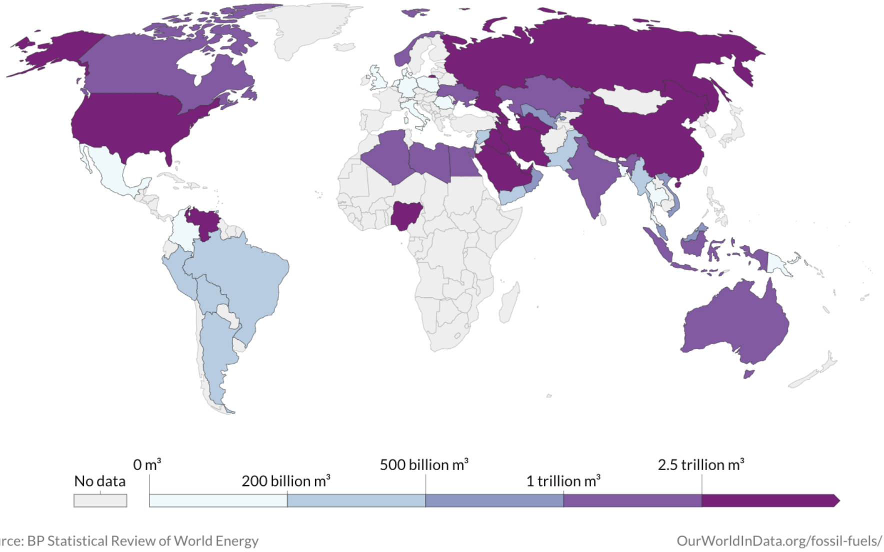
Source: Statistical Review of World Energy - BP (2021)

OurWorldInData.org/energy

Coal reserves



Gas reserves



Distribution of benefits

Distribution of costs

Coordination problem

Free-riding on climate change mitigation

Recall our public goods example.

Individuals dislike contributing g_i, but benefit from the total level $G = \sum_{i=1}^{N} g_i$, obtaining utility

$$u_i(g_i; G) = -\frac{1}{2} g_i^2 + \theta_i G.$$

We showed that, for each i, the first-best required contributions of

$$g_i^{\text{FB}} = \sum_{i=1}^{N} \theta_i,$$

but that the privately optimal contribution was just $g_i^* = \theta_i$ (**underprovision**).

Noncooperative outcome

We'll adapt this example to N countries. Costs γ_i and benefits θ_i of climate protection will differ across countries,

$$u(g_i; G) = -\frac{\gamma_i}{2} g_i^2 + \theta_i G$$

$\hookrightarrow$ think about g_i as investments to protect the climate (e.g., forgone profits from not burning fossil fuels, or costly investments in clean technology)

I. No cooperation. When each country maximizes its own welfare, then climate protection for each i is

$$g_i^* = \theta_i / \gamma_i.$$

That is, without any international cooperation, countries who expect

- substantial damage from climate change (high θ_i)
- relatively low costs of reducing emissions (low γ_i)

each will invest more in climate protection.

Discussion

Already, this creates some interesting predictions.

1. Collective action problem is **severe**: when $N = 10$, $G^* = \frac{1}{10} G^{\text{FB}}$.

2. Suggests that the **combination** of high benefits θ_i and low emissions reduction costs γ_i determine extent of unilateral action.

One can tell various stories:

- E.U.: high θ_i (wealth, strong environmental preferences), relatively low γ_i (limited growth in energy demand)
- U.S.: mixed θ_i, moderate γ_i (very energy-intensive, a lot of natural resources)
- China: high θ_i (significant exposure), high γ_i (rapidly growing economy)
- Russia: low θ_i (limited exposure), moderate γ_i (lots of oil)

Coordination

II. Perfect cooperation. When countries maximize their total surplus, then each invests

$$g_i^{\text{FB}} = \frac{1}{\gamma_i} \sum_{j=1}^{N} \theta_j,$$

so that

- everyone should invest a lot more
- countries with the lowest mitigation costs (low γ_i) should invest the most

The distributional outcomes of moving from **I** to **II** depend on these two relative effects. Country *i*'s net benefit from cooperating is

- greater if it has a relatively higher θ_i
- **less** if it has a lower γ_i

Unless we can transfer resources between countries, there is **no guarantee** that every country will be better off!

Transfers

Turns out that **net benefits** for i are

$$\theta_i B_i - \frac{1}{\gamma_i} C_i,$$

where

- C_i measures the additional contribution that i needs to make, and
- B_i measures the additional climate protection that i gets

$C_i = \frac{1}{2} \sum_{j \neq i} \theta_j^2$ and $B_i = \sum_{j \neq i} (1/\gamma_j) \sum_{j \neq i} \theta_j$.

Total world net benefits are always positive, but some countries may **lose**.

To obtain a Pareto improvement, country i needs a transfer of at least

$$\max \left\{ 0, \frac{1}{\gamma_i} C_i - \theta_i B_i \right\}$$

in order to not be worse off from cooperating.

Issues

Major concerns with climate change:

- developing countries **most vulnerable** (high θ_i)
- low levels of development make reducing emissions much more costly (high γ_i)
- rich countries much safer (lower θ_i; can adapt)
- but they have the resources to pay for emissions reduction (low γ_i)

Schelling's argument

Schelling (1992)

> *I appear to have reached the conclusion that the developed world has no self-interest in expensively curtailing carbon consumption and that the developing cannot afford to incur economic penalties to slow the greenhouse effect. There is a mismatch between those who may be vulnerable to climate change and those who can afford to do anything about it.*

Climate change as a **foreign aid** problem.

(U.S. spends 0.7% of its federal budget on foreign aid...)

A new Marshall Plan:

> *I believe distribution of Marshall Plan and defense-support funds to Europe is the only model of multilateral negotiation involving resources commensurate with the cost of greenhouse abatement.*

Concluding thoughts

Four aspects of the current state of the economics of climate change:

- optimal policy
  - estimated **global damages** $\gg$ costs, but costs nontrivial
- long-run effects
  - systematic framework to value the future
  - range of conclusions, but typically $r \in [1.4\%, 5.5\%]$
- uncertainty
  - much is known; much is not
  - can address in systematic way: e.g., 90% chance that 2020 SCC $\in [\$5, \$152]$
  - irreversibility raises additional thorny issues
- collective action
  - **significant underprovision** without binding international agreement
  - uneven net benefits $\implies$ need large transfers to attain a Pareto outcome
    - e.g., from developed to developing countries

Next time

Wednesday's lecture: introduction to environmental markets.

Problem set 2 due this Thursday, 5pm PST.