Applied Economics Issues

Climate and the Economy

Ewen Gallic

Aix Marseille School of Economics – Aix Marseille Université

Academic Year 2025

Key reference for this session

- Before talking in a bit more details about some specific examples, we will first consider a broad overview of the challenges brought by climate change for economics.
- This overview is built using an article by William Nordhaus:
  - Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review* 109:1991–2014, doi: 10.1257/aer.109.6.1991

Outline

1. Global Warming

Source of Global Warming

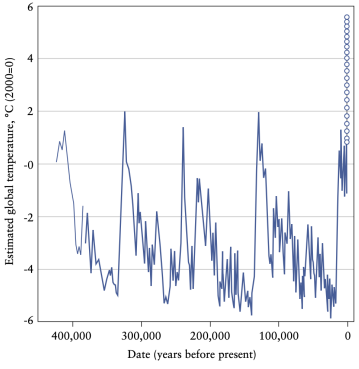
- From the work of earth scientists, we know that the main source of global warming comes from the **burning of fossil fuels** (coal, oil, natural gas).
- This releases **carbon dioxide** (CO_2) and other greenhouse gases (GHG).
- GHGs accumulate in the atmosphere, which generates trap heat and leads to:
  - surface warming of land and oceans,
  - feedback effects in atmosphere, oceans, and ice sheets,
  - impacts on ecosystems and human activities sensitive to climate.
- See the AR6 synthesis report from the IPCC (Calvin et al., 2023)

Weather and Climate

- **Weather** refers to **short-term atmospheric conditions**.
  - the time scale is usually in minutes, days, or weeks.
  - for example: today's temperature, a storm this weekend.
- **Climate** refers to the **long-term statistical average of weather**.
  - the time scale is longer: usually, 30 years.
  - for example: average temperature and rainfall patterns over 30 years.

Variation of Global Temperature (1/4)

- Average global temperature has increased since the industrial revolution.
- Warming trend accelerates in the late 20th and early 21st centuries.
- Current levels are unprecedented in the historical record.



Estimated global temperature variations for the last 400,000 years along with model projections for the next two centuries. *Source*: Nordhaus (2013, p. 201)

Variation of Global Temperatures (2/4): variance-preserving

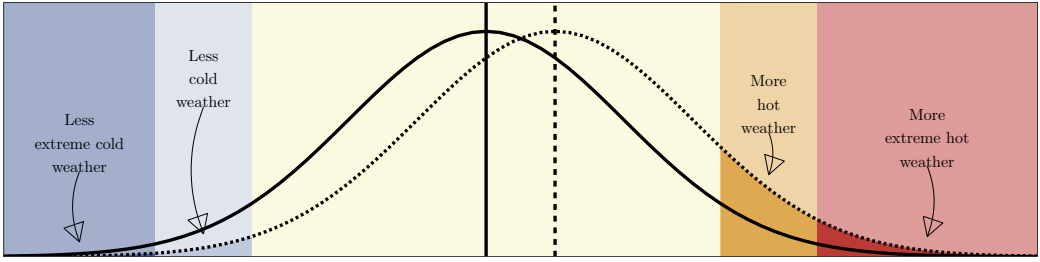


Figure 1: Effects of Climate Change on the Distribution of Temperatures: **increase in the mean**. The solid and dotted lines represent the previous climate distribution and the new climate distribution, respectively. Source: reproduction of Figure 1.8 from Cubasch et al. (2013).

Variation of Global Temperatures (3/4): mean-preserving

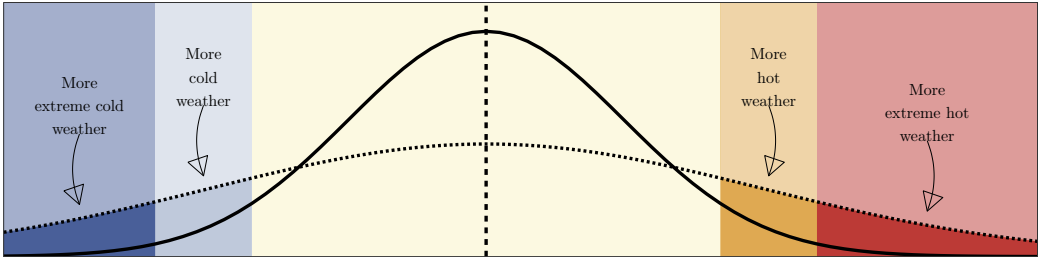


Figure 2: Effects of Climate Change on the Distribution of Temperatures: **increase in the variance**. The solid and dotted lines represent the previous climate distribution and the new climate distribution, respectively. Source: reproduction of Figure 1.8 from Cubasch et al. (2013).

Variation of Global Temperatures (4/4)

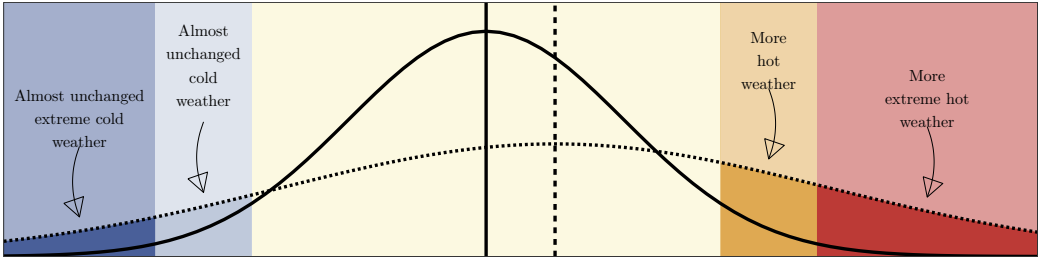


Figure 3: Effects of Climate Change on the Distribution of Temperatures: **increase in both the mean and the variance**. The solid and dotted lines represent the previous climate distribution and the new climate distribution, respectively. Source: reproduction of Figure 1.8 from Cubasch et al. (2013).

- These are examples. CC can translate to higher-order changes to the distribution.

Impacts of Climate Change

More generally, the impacts of climate change are broad (Calvin et al. (2023)):

- **Physical impacts**
  - Rising temperatures, melting ice sheets, sea-level rise, extreme weather.
- **Ecological impacts**
  - Biodiversity loss, ocean acidification, forest fires, shifting ecosystems.
- **Socio-economic impacts:**
  - Agriculture yields, coastal communities, health and mortality, migration, conflict.

Applied Economics and Climate Change

- We know **why** the planet is warming: GHG emissions from human activity.
- The question is now: **how should societies respond?**
- This is particularity challenging. The impacts are global, unevenly distributed, and they increase with temperature.
- Economics provide frameworks to investigate central questions:
  - **understanding externalities** (emissions are a global negative externality, markets alone will not fix the issue),
  - **designing policies** (carbon taxes? cap-and-trade? subsidies for clean tech?) with cost–benefit analysis for example (quantify damages vs. abatement costs),
  - **measuring costs** (in agriculture, housing markets, etc.)
  - **exploring equity and distribution** of the impacts (who bears the costs of abatement? Who suffers most from climate damages?)

2. Climate Change as a Good

2.1. Reminders

Rivalry and Excludability

Rivalry

A good is **rival** if one person's consumption reduces the amount available for others.

- Ex: eating an apple,
- Non-rival example: watching a TV broadcast.

Excludability

A good is **excludable** if it is possible to prevent someone from using it without paying.

- Example: movie theater ticket,
- Non-excludable example: clean air.

Types of Goods

	Excludable	Non-excludable
Rival	**Private Goods** (e.g., food, clothing, cars)	**Common Goods** (e.g., fisheries, forest, groundwater)
Non-rival	**Club Goods** (e.g., streaming services, toll roads, private parks)	**Public Goods** (e.g., air, national defense, knowledge)

Taxonomy of goods by rivalrousness and excludability

- Climate change: **how about climate change?**

Types of Goods

	Excludable	Non-excludable
Rival	**Private Goods** (e.g., food, clothing, cars)	**Common Goods** (e.g., fisheries, forest, groundwater)
Non-rival	**Club Goods** (e.g., streaming services, toll roads, private parks)	**Public Goods** (e.g., air, national defense, knowledge)

Taxonomy of goods by rivalrousness and excludability

- Climate change: non-rival, non-excludable → public good (see Samuelson (1954, REStat)).

Climate Change as a Global Externality

Externality

An **externality** arises when the costs or benefits of an action spill over to others and are not reflected in market prices.

- **Negative externality**: GHG emissions cause damages (warming, sea-level rise, extreme weather) not paid for by the emitter.
- **Positive externality**: knowledge spillovers from clean technology innovation benefit all countries.
- When costs or benefits cross national borders and affect people and countries that are not directly involved, externalities are said to be **global**.

Examples of Global Externalities

- **Historical examples**
  - Spread of infectious diseases (e.g., plague, pandemics),
  - Religious conflicts or marauding armies.
- **Modern examples**
  - Nuclear proliferation,
  - International financial crises,
  - Cybersecurity threats.
- **Climate change**
  - Greenhouse gas emissions anywhere affect ecosystems, weather, and economies worldwide.

Key Challenges (1/4)

- **Global scope**: emissions in a country affect the entire planet.
  - No nation can solve the problem on its own. There is a need for **cooperation**.
- **Diffuse benefits vs. concentrated costs**
  - While the **benefits** of a stable climate are **shared globally**,
  - the costs of **abatement** are **borne nationally** (higher energy costs, transition for carbon-intensive industries, etc.).

Key Challenges (2/4)

Two other key challenges recalled by (Tirole and Tribe, 2017, Chap. 8):

> While most of us are prepared to make small gestures for the environment, we are not willing to give up our cars, pay much more for electricity, restrict our consumption of meat, or moderate our air travel to distant places. And while local sustainable development initiatives are praiseworthy, they will absolutely not be enough by themselves. In reality, we would like everyone else to do these things for us—or rather for our grandchildren. As irresponsible as it may be, our common policy is easy to explain. It is the result of two factors: **selfishness with regard to future generations** and the **free rider problem**. In other words, the benefits of reducing climate change remain global and distant in time, while the costs of that eduction are local and immediate.

Key Challenges (3/4)

- **Free-riding incentive**
  - *"unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interest,* rational, self-interested individuals will not act to achieve their common or group interests." (Olson, 1965)
  - Each country prefers others to cut emissions while maintaining its own growth.
  - This weakens international cooperation.
- **Long-term horizon and uncertainty**
  - Damages unfold slowly, across generations,
  - Scientific and economic uncertainties complicate policy design.

Key Challenges (4/4)

- **Limited effectiveness of agreements**
  - International treaties (e.g., Kyoto, Paris) rely on voluntary commitments.
  - Enforcement mechanisms are weak or absent.
  - Tirole and Tribe (2017, Chap. 8) mentions three flaws to the voluntary commitment nature of the Paris COP21:
    1. gives incentive for **greenwashing** (to appear much "greener" than one actually is), since the countries can choose their reference point as they wish,
    2. does not address the **free-riding issue**,
    3. the **(non)credibility of promises**.

2.2. National vs. Global Public Goods

National Public Goods

National Public Goods

Non-rival and non-excludable goods, whose benefits are confined within a country.

- Examples: clean air standards, national flood defenses, public health system.
- Actors: citizens, national government, domestic industries.
- Issue: mostly political, not technical (regulations are feasible but may be resisted by powerful interest groups).
- **Costs**: concentrated on a few groups (e.g., polluting industries).
- **Benefits**: diffuse across many citizens.

Global Public Goods

Global Public Goods

Non-rival and non-excludable goods, whose benefits extend across countries and generations.

- Examples: climate stability, ozone layer protection, biodiversity conservation.
- Actors: sovereign states, international organizations, global industries.
- Issue: coordination and incentive problems (no global authority to enforce cooperation).
- **Costs**: borne nationally (e.g., emission reductions).
- **Benefits**: spill over globally, creating strong incentives to free-ride.

National vs. Global Public Goods (recap)

	National Public Goods	**Global Public Goods**
Definition	Non-rival, non-excludable within a country	Non-rival, non-excludable across all countries
Examples	Clean air standards	Climate stability
Actors	Citizens, government, domestic industries	Sovereign nations, international organizations, global industries
Issue	Political: institutions may favour concentrated interests over diffuse public welfare	Coordination: no global authority, incentives to free-ride
Costs	Concentrated on a few groups	Borne nationally
Benefits	Diffuse across many citizens	Spill over to all countries

3. Approaches to Slowing Climate Change

Three Main Approaches to Slowing Climate Change

- Nordhaus (2019, AER) lists three main approaches to slowing climate change:
  1. **Mitigation**: reduce GHG emissions at the source.
  2. **Carbon Removal**: extract CO_2 from the atmosphere.
  3. **Geoengineering**: alter Earth's radiation balance to offset warming.
- Only mitigation is currently feasible at scale, but removal and geoengineering are part of the policy debate.

Mitigation

Mitigation

- Reduce emissions from fossil fuels, industry, and agriculture.
- The tools to do so: carbon taxes, emissions trading, renewable energy, energy efficiency.
- The solutions are scalable and offer long-term effectiveness.
- However, they are **costly** and **require global cooperation**.

Carbon Removal

Carbon Removal

- Extract CO_2 from the atmosphere (hence, negative emissions).
- How ? Afforestation (panting trees), BECCS (bioenergy with carbon capture and storage), direct air capture.
- This offers a permanent removal and can complement mitigation.
- However, carbon removal techniques are not yet scalable and they have high energy, land, and cost requirements.

Geoengineering (Solar Radiation Management)

Geoengineering

- Reduce warming by reflecting sunlight back into space.
- How? Stratospheric aerosols, cloud brightening, space reflectors.
- This offers low direct costs and rapid cooling potential.
- But, geoengineering techniques are associated with large uncertainties, uneven regional effects, and they do not allow us to solve ocean acidification.

Approaches to Slowing Climate Change: Wrap-up

Strategy	**Benefits**	**Costs / Risks**
Mitigation	Proven feasible; reduces emissions at source; long-term effectiveness	Expensive transition; politically difficult; needs global cooperation
Carbon Removal	Permanent CO_2 removal; complements mitigation	Not scalable yet; high costs; energy and land requirements
Geoengineering	Low direct cost; rapid cooling; possible emergency backup	Uncertain effects; uneven global impacts; does not fix acidification; moral hazard

4. Impacts and Costs of Climate Change

Vulnerable Systems

- Some systems are vulnerable to climate change, e.g.:
  - Agriculture
    - especially if rainfed (Mendelsohn, 2009),
    - and in South Africa/Southern Asia (Lobell et al. 2008, Science),
  - Coastal communities impacted by sea-level rise
    - Agarwal et al. (2025, J. Public Econ.); Keys and Mulder (2020, NBER),
  - Forests impacted by wildfires
    - Wang and Lewis (2024, JEEM); Meier et al. (2023, JEEM).
- Some damages may be **irreversible** if thresholds are crossed (e.g., ice sheet collapse, coral reef extinction).

4.1. IAMs

Economic Costs of Climate Change

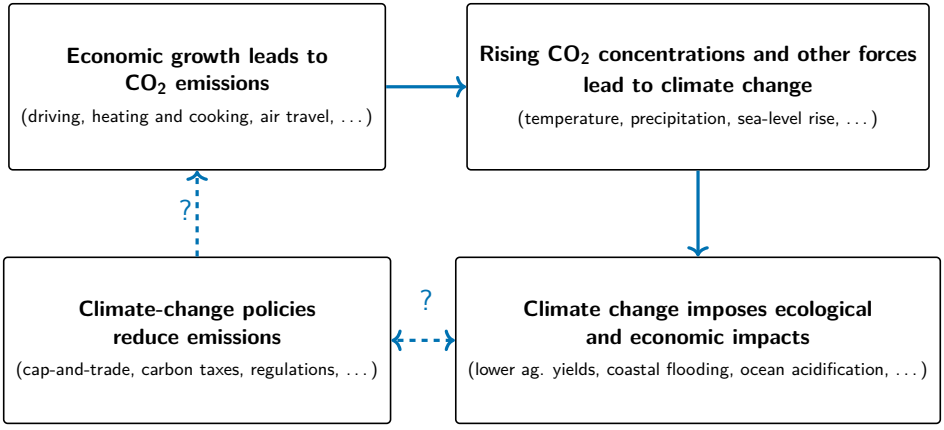
- One of the ways to measure the economic costs of climate change consists in using **Integrated Assessment Models** (IAMs) (see Meadows et al., 1972).
- IAMs link together:
  - **Economy**: growth, emissions, energy use,
  - **Climate system**: CO_2 accumulation, temperature rise,
  - **Impacts of climate**: damages to output, ecosystems, health
  - **Policies**: carbon pricing, abatement, adaptation
- IAMs aim to provide a unified (cost-benefit) framework to assess the **economic costs of climate change** and evaluate **policy responses**
- They allow to design carbon prices and evaluate policy scenarios.

IAMs

There are many types of IAMs (see Wang and Mullahy 2006 for a broad history since the 1970's). The main recent ones are:

- DICE (Dynamic Integrated model of Climate and the Economy) (Nordhaus 2010, PNAS)
  - single global economy, focus on intertemporal optimization of consumption,
  - note: RICE is a regional extension.
- FUND (Climate Framework for Uncertainty, Negotiation and Distribution) (Anthoff and Tol 2013, Clim. Change)
  - emphasizes regional distribution of costs/benefits, allows for adaptation and differentiated sectoral damages.
- PAGE (Policy Analysis of the Greenhouse Effect) (Hope 2012, Clim. Change)
  - explicitly incorporates uncertainty and risk analysis

The Circular Flow of Global Warming Science, Impacts, and Policy



Circular flow of global warming science, impacts, and policy (DICE model).
Source: Nordhaus (2019).

Economic Optimization in IAMs (1/2)

IAMs are typically set up as an **intertemporal optimization problem**; objective: maximise the **intergenerational welfare** (discounted utility of consumption):

$$\max_{c(t)} W = \max_{c(t)} \left[\int_0^{\infty} U[c(t)] e^{-\rho t} \, dt \right] \tag{1}$$

subject to:

$$M(y(t); z(t); \alpha; \varepsilon). \tag{2}$$

- $c(t)$: consumption
- $y(t)$: other endogenous variables (e.g., global temperature)
- $z(t)$: exogenous variables (e.g., population)
- α: parameters (e.g., climate sensitivity)
- ρ: pure rate of time preference
- ε: random variables

Economic Optimization in IAMs (2/2)

- In other words, IAMs ask: **how should society balance the costs of reducing emissions today against the future damages of climate change?**
- How it works:
  1. Project future **economic growth** and resulting **emissions**,
  2. Translate emissions into **climate change** (temperature rise),
  3. Estimate **economic damages** from higher temperatures (costs are estimated as a percentage of the output),
  4. Model the **costs of policies** (carbon pricing, technology switch).
- The model **optimizes consumption and investment** over time, choosing an **emissions path** that maximizes long-run welfare.
- The model outputs, as a by-product, the **social cost of carbon**, i.e., the monetary value of the **damage** caused by one extra ton of CO_2 (Pearce, 2003).

The Social Cost of Carbon

How to measure the social cost of carbon (SCC)?

- In IAMs, the global economy and climate system is simulated **with and without an extra ton of emissions**.
- The SCC is the difference in the present value of consumption between these two scenarios (see Wang et al. (2019, J. Cleaner Prod.) for different formulas).
- Economically, it is the **shadow price of carbon**, the value of tighter emissions constraints.
- This measure can be used to define the **optimal carbon tax**, which should equal the SCC.
- For example, if SCC= \$40tCO_2: emitting one extra ton of CO_2 today reduces the present value of world consumption by \$40.

The Social Cost of Carbon

- There is no consensus in the value of the SCC
  - In a review based on meta-analysis, Wang et al. (2019) found that the estimated SCC range from $-13.36/\$tCO_2$ to $+2386.91/\$tCO_2$, with a mean value of $54.70\$/tCO_2$,
  - the estimation strongly depends on key parameters such as climatic sensitivity α, intergenerational discount rate ρ (Pizer et al. 2014, Science).

Critiques of IAMs (1/2)

IAMs are not perfect tools. In a position paper, Pindyck (2013, JEL) argues that they are *"close to useless"* for policy analysis:

- they rely on **arbitrary inputs**: the discount rate and the risk aversion are chosen arbitrarily, and these choices have a huge impact on SCC,
- the **damage functions** linking temperature to GDP are *ad-hoc*, not theory- or data-driven,
- the **climate sensitivity** (how temperature would change from a doubling of CO_2) involves uncertain or unknowable feedback loops.
- since they provide SCC that seem precise, IAMs create an **illusion of precision**, but in reality IAMs can be tuned to yield almost any result,
- They ignore the possibility of **catastrophic outcomes** (either economic or climatic).

Critiques of IAMs (2/2)

For more critiques, see, e.g., Auffhammer (2018, JEP) or Rose (2012).

According to Pindyck (2013, JEL), climate policy should:

- be based on viewing abatement as **insurance** against low-probability catastrophic outcomes,
- use **plausible ranges** of outcomes and probabilities rather than IAM outputs.

4.2. Alternative Approaches for Assessing Impacts and Costs

Empirical Analysis

- IAMs are not the only tools used in applied economics to investigate or model the impacts of climate change.
- A lot of studies use **empirical data**, using the methods mentioned in the previous session (natural experiments, econometrics, panel data, quasi-experimental variation).
- The central idea is that climate impacts can be studied directly through observed variation in weather and climate shocks.
- Carleton and Hsiang (2016, Science) provides a nice overview of the social and economic impacts of climate and cites many empirical economic papers.

4.2.1. Agriculture

Agriculture

- As previously mentioned, agriculture is highly sensitive to temperature and precipitation, especially **rainfed crops**.
- Some studies focus on the impacts on **agricultural yields** (which threatens food security), e.g.:
  - Schlenker and Roberts (2009, PNAS): crop yields fall sharply above heat thresholds,
  - Deschênes and Greenstone (2007, AER): weather shocks reduce U.S. ag. output.
- Some explore **adaptation techniques**, e.g.:
  - crop selection and switching to more resilient varieties (Di Falco and Veronesi 2013, Land Econ.),
  - changing crop mix (Aragón et al. 2021, AEJ: Econ. Pol.),
  - planting dates (Zhao et al., 2025).

4.2.2. Health

Exercise

If temperature increases by 2°C in Aix-en-Provence, what health effects would you expect in the short and long run?

Exercise

If temperature increases by 2°C in Aix-en-Provence, what health effects would you expect in the short and long run?

Reasoning from the viewpoint of:

- **Public health researchers**: which outcomes can we *observe and measure*?
- **Economists**: how can we *value* these outcomes economically?
- **Policy makers**: which effects justify *immediate policy intervention*?

Health (1)

- Temperatures outside a range are harmful to human health and lead to **premature mortality** (see Basu, 2002 for a review).
  - E.g., using U.S. historical data, Deschênes and Greenstone (2011, AEJAE) show nonlinear effects between mortality and daily temperatures: extremely cold and hot days are associated with elevated mortality rates,
  - Similar results are found in Mexico (Cohen and Dechezleprêtre 2022, AEJEP).
  - The effects are **unequally distributed** across countries, as shown in Carleton et al. (2022, QJE)
    - using subnational historical data from 40 countries, they show that an additional hot day (>32°C) increases mortality and that the magnitude of the effect is larger in poorer countries.
    - they estimate that the release of an additional ton of CO_2 today will cause mortality-related damages of \$36.6 under a high-emissions scenario (by applying the value of a statistical life to projected deaths).

Value of a Statistical Life (1/2)

A few words on the **Value of a Statistical Life** (VSL):

- From Thaler and Rosen (1976, NBER): "*the value of a life is the amount members of society are willing to pay to save one.*"
- it "*defines the monetary value of a (small and similar among the population) mortality risk reduction that would prevent one statistical death and, therefore, should not be interpreted as how much individuals are willing to pay to save an identified life.*" Andersson and Treich (2011)
- One of the ways to estimate it is based on individuals' **willingness to pay** (approached attributed to Drèze, 1962, but the paper cannot be accessed online).

Value of a Statistical Life (2/2)

- Andersson and Treich (2011) give a nice intuition to understand the VSL concept:

  "Suppose that in a city composed of 100,000 identical individuals, there is an investment project that will make the city's roads safer. It is known that on average 5 individuals die every year on these roads, and the project is expected to reduce from 5 to 2 the number of expected fatalities per year. Suppose now that each member of the city is willing to pay \$150 annually to benefit from this reduction in mortality risk induced by the project. Then the corresponding VSL would be \$150×100,000/3 =\$5 million. Indeed \$15 million could be collected in this city to save 3 statistical lives, and so the value of a statistical life could be established at \$5 million."

- In climate economics, VSL allows converting mortality impacts of heat or pollution into **monetary damages**.

- Viscusi (2015, AJHE) reports that the values used by U.S. government agencies vary between \$6 to \$10 millions of 2013 USD.

Health (2)

- Beyond mortality, **morbidity and healthcare spending** are also strongly affected.
- Barwick et al. (2024, REStat) use daily healthcare spending by city, in China, and find that:
  - a short-run increase of 10 $\mu g/m^3$ in $PM_{2.5}$ raises healthcare transactions by 0.65%, and a medium-run increase raises them by 2.65%,
  - stronger effects in spendings in children's hospitals $\rightarrow$ increased vulnerability for younger populations,
  - non-healthcare spending falls in the short term $\rightarrow$ economic spillovers,
  - an anticipation of poor air quality increases current-day spending $\rightarrow$ **avoidance behaviour** (reduced outdoor activities to mitigate exposure).
  - the elevated $PM_2.5$ level relative to the WHO's annual standards entails at least \$42 billion added healthcare expenditure in 2015.

4.2.3. Growth

Productivity and Growth

- Long observed correlation: "*hot countries tend to be poor*" Dell et al. (2009, AER)
- de Secondat de Monstesquieu (1758, Chap. II, Livre III): "*Nous avons déjà dit que la grande chaleur énervait la force et le courage des hommes; et qu'il yavait dans les climats froids une certaine force de corps et d'esprit qui rendait les hommes capables des actions longues, pénibles, grandes et hardies. Cela se remarque non seulement de nation à nation, mais encore dans le même pays, d'une partie à une autre. [...] Il ne faut donc pas être étonné que la lâcheté des peuples des climats chauds les ait presque toujours rendus esclaves, et que le courage des peuples des climats froids les ait maintenus libres.*"
- The debate today:
  - Are **climate factors** themselves key drivers of prosperity?
  - Or are they correlated with other determinants (institutions, trade, colonial history) as argued by Acemoglu et al. (2002, QJE)?

Temperature and Output

- Evidence shows **sectoral output losses** from heat, especially in agriculture (as we previously mentioned).
- But effects extend beyond agriculture:
  - worker productivity and absenteeism (Somanathan et al. 2021, JPE),
  - heat stress and labor efficiency (Hsiang 2010, PNAS),
  - mortality and health impacts (Burgess et al., 2017),
  - conflict risk (Hsiang et al. 2013, Science).
- The mechanisms put forward by Dell et al. (2012, AEJ Macro):
  1. lower level of output (productivity losses, absenteeism).
  2. reduced capacity of the economy to **grow** over time.

Temperature and Economic Growth

- More specifically, Dell et al. (2012, AEJ Macro) find that:
  - in poor countries, a 1°C hotter year reduces GDP growth by ≈1.3 p.p.,
  - in rich countries, little to no effect.
  - This suggests that temperature affects not just **levels of output**, but also the **growth rate** in developing countries.
- Burke et al. (2015, Nature) show, using yearly data on 166 countries over the period 1960–2010, that the relationship between temperatures and economic growth is nonlinear: the change in log per capita GDP peaks at $a \approx$13–15°C, declines sharply above.
  - this implies that climate change threatens to slow growth and development, particularly in tropical and poorer regions.

4.2.4. Sea-Level Rise

Coastal Areas and Climate Risks

- With climate change, there is an increasing risks of **flooding**:
  - the IPCC reports that the global mean sea level is expected to rise between 0.43 m and 0.84 m by 2100 relative to the level in 1986–2005 Calvin et al. (2023)
- This threatens:
  - **communities**: via displacement, migration,
  - **infrastructure**: ports, transport, housing,
  - **markets**: property values, insurance, lending.
- Who bears the costs? Property owners, insurers, mortgage lenders, governments.

Climate Risks and Housing Markets

- Housing markets are starting to reflect **climate risks**, through **prices**.
  - Bernstein et al. (2019, JFE) find that U.S. homes exposed to SLR sell for 6.6% less than comparable unexposed homes.
  - Yet, Hino and Burke (2021, PNAS) show that properties in 100-year flood zones in the U.S. are overvalued by 8.5%.
  - As recalled by Bakkensen and Barrage (2021, RFS), mispricing may create a **climate-related housing bubble**.
- There is a need to understand how to better inform people on risks:
  - Agarwal et al. (2025, J. Pub. Econ.): Singapore PM's 2019 speech triggered a 7.2% fall in SLR-prone housing prices (2016–2023, DiD).
  - Adaptation announcements mitigated depreciation to 0.6%.
- $\rightarrow$ markets partially adjust to new information on climate risks, but often under-react.

Mispricing and Inequality

- To try to better cope with the **potential bubble**, the **overvaluation of risky assets** (houses exposed to high climate-related risks) needs to be documented.
  - Gourevitch et al. (2023, Nature CC) exhibit that U.S. coastal housing are overvalued by $121–237B.
  - They show that the overvaluation is concentrated where flood disclosure laws are weak and climate concerns low.
- The literature has highlighted **distributional issues**:
  - Gourevitch et al. (2023, Nature CC) also showed that the overvaluation is widespread among low-income households, which can be explained as follows:
    - low-income households locate in hazardous areas (cheaper housing) (Bakkensen and Ma 2020, JEEM),
    - poorer areas face higher flood losses due to weaker public protection infrastructure (Seong et al., 2021).
- $\rightarrow$ potential loss of home equity and wealth for already vulnerable populations.

Insurance Markets and Affordability

- As climate risks intensify, **availability and affordability of homeowners insurance is uncertain**.
- Keys and Mulder (2024, NBER):
  - U.S. average nominal premiums increased by 33% between 2020 and 2023 (from \$1,902 to \$2,530, i.e., a 13% real increase),
  - A 1 s.d. increase in disaster risk leads to an increase in average annual premium of \$335,
  - Lower-income and racialized areas pay disproportionately higher premiums.
- As a consequence:
  - Insurance may become inaccessible in high-risk zones.
  - Risk of widening inequality in housing and financial markets.

Exercise

Suppose sea level rise will damage $1B of coastal property. Who ultimately pays? homeowners, insurers, taxpayers, or future generations? How?

4.2.5. Migration

Environmental Migrants

The International Organization for Migration defines environmental migrants as follows:
"*Environmental migrants are persons or groups of persons who, for compelling reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad.*"
(Laczko and Aghazarm, 2010)

Why Migration?

- **Climate-related hazards**
  - Sea-level rise (Jacobson, 1988)
  - Extreme events (droughts, floods, storms)
  - Agricultural impacts (Barrios et al. 2006, J. Urb. Econ.; Munshi 2003, QJE)
- **Transmission channels** In their review, Berlemann and Steinhardt (2017) recall that if weather shocks occur and they affect food production, they may lead to:
  - **income losses** from reduced agricultural productivity,
  - **food insecurity**: declining supply *rightarrow* higher prices $\rightarrow$ famine,
  - **health risks** linked to malnutrition and disease spread.

Coping Strategies

- Migration is viewed a common **adaptation strategy** in response to environmental stress (Sedova and Kalkuhl 2020, World Dev.).
- There is a trade-off between staying and adapt in place vs. displacement as a "survival strategy" (as coined in Barrios et al. 2006, J. Urb. Econ.).
- But, as reported in Sedova and Kalkuhl (2020, World Dev.), the causal link between weather events and migration is not universal:
  - some shocks push people into cities,
  - others reduce international migration due to financial constraints.

Displacement Pathways

- **Internal migration**
  - drought in Syria (2010s): 1.5m rural farmers → urban peripheries (Kelley et al. 2015, PNAS),
  - rural–urban migration in sub-Saharan Africa (Barrios et al. 2006, J. Urb. Econ.).
- **Cross-border migration**
  - Mexico: rainfall shocks → increased US migration via labour networks (Munshi 2003, QJE),
  - Sub-Saharan Africa: weather anomalies lead to a decrease in rural wages, which entails rural–urban flows, puttins pressure on urban wages, leading to international migration (Marchiori et al. 2012, JEEM).

Evidence from Recent Studies

- Cai et al. (2016, JEEM): positive link between temperature and international outmigration, but only significant in the most agriculture-dependent countries.
- Sedova and Kalkuhl (2020, World Dev.): mixed evidence, especially for rainfall. They recall that the effects interact with age, gender, wealth.
- Missirian and Schlenker (2017, Science): nonlinear positive effect of deviations of temperatures from a moderate optimum (20°C) on EU asylum applications
  - Moderate climate scenario (RCP 4.5): +28% asylum applications by 2100.
- Marchiori et al. (2012, JEEM): 5m displaced in SSA due to temperature and precipitation anomalies during the period 1960–2000.

Impacts of Migration

- **Sending areas**
  - Berlemann and Steinhardt (2017) recalls that the loss of skilled workers leads to brain drain,
  - which increases the vulnerability of left-behind populations.
- **Receiving areas**
  - Challenges: urban overcrowding, social/ethnic tensions, demand for housing and jobs.
  - Opportunities: labour force, positive effect on productivity of local workers,
- **International**
  - Pressure on asylum systems and international relations.

Climate & Migration: To Go Further

Some nice reviews to go further on this topic:

- Berlemann and Steinhardt (2017)
- Hoffmann et al. (2021)

4.2.6. Social Interactions

Preliminary Exercise

Can climate influence the frequency or intensity of violent behaviour?

You can think about:

- physiological or psychological,
- economic channels,
- social or institutional channels.

Social Interactions: Crime and Weather Shocks

- In what follows, we will focus on interaction between the weather and crime, and more specifically, domestic violence.
- The links between **weather** an **crimes** has been extensively studied in the (economic, but not only) literature.
- 👉 Let us begin with general crime models for theoretical grounding.

The Economics of Crime: Becker (1968, JPE)

- Becker (1968, JPE) viewed crime as an **economic decision** made under uncertainty.
- Individuals weigh the **expected benefits** of committing an offence against the **expected costs** if caught and punished.
- The decision rule writes

$$\mathbb{E}(U_{\text{crime}}) = \underbrace{p\,U(Y-f)}_{\text{if caught}} + \underbrace{(1-p)\,U(Y+g)}_{\text{if not caught}}$$

where:

- p: probability of being caught,
- f: monetary/fine equivalent of punishment,
- g: illegal gain,
- Y: initial income.

- Individuals commit the crime if

$$E(U_{\text{crime}}) > U(Y).$$

- Hence, crime can be reduced by increasing either the **probability of detection (p)** or the **severity of punishment (f)**.

Economic Intuition Behind Becker's Model

- For Becker, crime is not only a moral or psychological act, it can be modelled as a **rational choice under risk**.
- The expected utility depends on:
  - **incentives** (potential gain g),
  - **deterrence** (probability and severity of punishment),
  - **opportunity cost** (alternative legal earnings).
- In Becker's model:
  - $\uparrow p$ or $\uparrow f \Rightarrow$ lower crime (deterrence effect),
  - $\uparrow g$ or $\downarrow$ legal income $\Rightarrow$ higher crime (opportunity effect).

From Becker to Weather Shocks

- Becker's model predicts that when legitimate income opportunities fall, the **expected utility of crime increases**.
- If we apply the model to weather shocks (e.g., droughts, floods, heatwaves), these shocks can:
  - reduce agricultural and informal income,
  - weaken local enforcement or deterrence,
  - increase stress and social tension.
- This creates both:
  - a **behavioural channel** (stress, aggression),
  - and an **economic channel** (crime as income substitution).

The Household Context

- In what comes next, we will have a brief overview of the **behavioural channel** and the **economic channel**.
- We will mostly focus on the **household context**:
  - in such a context, the individual choice framework generalizes: partners bargain over joint resources, and violence may enter the strategy set as a coercive tool to shift payoffs.

Opening Example: Witch Killings in Tanzania (Miguel, 2005, REStud) (1/4)

- In Miguel (2005, REStud): examination of the link between **extreme rainfall shocks** and **murders of elderly women** accused of witchcraft.
- **Some context** :
  - In rural Tanzania, **witch killings** (targeting elderly women) have long been tolerated in some regions.
  - These acts surge **following years of extreme rainfall shortfalls**, i.e., droughts that destroy crops and incomes.

Opening Example: Witch Killings in Tanzania (Miguel, 2005, REStud) (2/4)

Research Question in Miguel (2005, REStud)

Can weather-induced income shocks trigger social violence?

The paper investigates **two competing theories**:

1. **Scapegoat theory**: people under stress direct aggression at symbolic targets ('witches') to vent frustration,
2. **Income shock theory**: negative shocks that worsen economic stress lead to violence against vulnerable members.

Opening Example: Witch Killings in Tanzania (Miguel, 2005, REStud) (3/4)

- The empiric study relies on village-level data on weather and killings of elderly women (1990–2001).
- It compares variation across years and districts, and it exploits rainfall shocks as **exogenous income fluctuations**.
- **Main findings**:
  - Witch killings rise sharply after extreme droughts but not after floods.
  - This result aligns with the **income shock hypothesis**:
    - Drought → crop failure → income loss → food scarcity → targeting of elderly women perceived as economic burdens.
  - On the other hand, the **scapegoat hypothesis** is not supported, because no similar increase in other crimes is observed.

Opening Example: Witch Killings in Tanzania (Miguel, 2005, REStud) (4/4)

- How do we interpret these results?
  - These killings reflect economic motives under distress, not superstition alone,
  - Violence becomes a perverse coping mechanism in contexts with **weak social safety nets**.
- What are the **policy implications**?
  - Strengthening formal insurance systems or providing social pensions for elderly women ($\approx$ turning them into an 'asset') could reduce such violence by easing consumption pressure on households.
  - This paper shows that income instability can translate into gendered violence, especially where women have limited economic value or protection.

Gender-Based Violence

> Gender-based violence takes many forms: physical, sexual, emotional, and psychological. Examples include female genital mutilation, killing in the name of so-called 'honor', murder, forced and early marriage, and sex trafficking. Two of the most prevalent types of violence that women experience are intimate partner violence (IPV) and non-partner sexual violence (NPSV). Almost one in three women across the world have experienced one or both of these forms of violence at least once in their lifetime.

Source: Violence against women and girls – what the data tell us, World Bank, 2022

Intimate Partner Violence

> **Intimate Partner Violence** (IPV) includes psychological, sexual, and physical violence committed by a current or former intimate partner or husband. All IPV statistics refer to 'ever-partnered' women. This means that the denominator for calculating these estimates only includes women who have ever been in an intimate relationship or in a marriage.

Source: Violence against women and girls – what the data tell us, World Bank, 2022

Gender-Based Violence: Some Facts

> More than 1 in 4 women (26%) aged 15 years and older have suffered violence at the hands of their partners at least once since the age of 15. Applying this percentage to the 2018 population data from World Population Prospects, the WHO estimates that 641 million women have been affected. And an estimated 245 million (or 10% of women ages 15 and above) have experienced IPV in the last 12 months alone.

Source: Violence against women and girls – what the data tell us, World Bank, 2022

Consequences and Societal Costs

Gender-based violence and intimate partner violence have consequences and societal costs (see, e.g., Rizzotto et al. 2025, Rev. Econ. Household):

- **On health**: physical injuries, trauma, depression, suicide risk.
- **On victim's children**: emotional distress, lower educational outcomes.
- **In the economy**: reduced productivity, absenteeism, long-term earnings loss.
- **In the social sphere**: perpetuation of gender inequality and intergenerational transmission.

Linking Domestic Violence to Climate Change (1/2)

- We observe emerging evidence showing that weather shocks can exacerbate IPV through multiple channels (see Thurston et al. 2021, BMJ Global Health for a review).
- Why does domestic violence respond to weather shocks?
  1. households may be **under stress** because of droughts and heatwaves that reduce income, food security, and emotional well-being.
  2. **women often bear disproportionate burdens** (Gevers et al., 2020):
     - care needs rise during/after weather shock, so that women's unpaid workload expands and leaves them with less time for paid work, education, leisure,
     - because of resource scarcity, women must travel longer distances to fetch resources (such as food or water),
     - men often need to temporarily migrate to find work, leaving women behind to manage the household and making them more exposed to violence.

Linking Domestic Violence to Climate Change (2/2)

- Why does domestic violence responds to weather shocks?
  3. weather shock can induce **behavioural response**:
     - financial strain can **increase tensions and conflicts** within the household (Sekhri and Storeygard 2014, JDE; Díaz and Saldarriaga 2023, JHE) (the inability to meet basic needs causes frustration, guilt, anger),
     - increase in **anxiety and stress** (psychological distress because of financial insecurity, loss of status or control) (Díaz and Saldarriaga 2023, JHE)
     - increase in **alcohol consumption** as a coping device, leading to worsen judgment and drop in self-control (Bloch and Rao 2002, AER).

Two main theoretical mechanisms

According to Rizzotto et al. (2025, Rev. Econ. Household), there seems to be, at the moment, **two main mechanisms**:

1. A **heat stress channel**:
   - the exposure to high temperatures affects human physiology and emotional regulation.
2. An **income channel**:
   - a negative weather shock can reduce agricultural output, wages, and local economic activity.

The Heat Stress Channel

"*The temperature-aggression hypothesis is the theoretical statement that uncomfortable temperatures cause increases in aggressive motivation and, under the right conditions, in aggressive behavior.*" (Anderson et al., 2000, p. 65)

"*Although the physiological mechanism linking temperature to aggression remains unknown, the causal association appears robust across a variety of contexts*" (Hsiang et al. 2013, Science)

Laboratory Evidence

- Baron and Bell (1976) conducted two laboratory experiments manipulating **ambient temperature** (73°F, 84°F, 93°F) (≈ 23°C, 29°C, 34°C).
- Participants received either **positive or negative evaluations** from a confederate and could then **administer electric shocks** to that person.
- The paper finds that:
  - under positive evaluation (no provocation): aggression **increased** with temperature.
  - under negative evaluation (provoked): aggression **decreased** at high temperature, suggesting that subjects preferred to escape discomfort → **Negative Affect Escape Model**,
  - a **cooling drink** before administrating electric shocks reduced aggression, confirming mediation by **negative affect**.
- ⇒ heat influences aggression through **affective arousal**, **not by physiology alone**. The relationship is **curvilinear**: aggression rises with moderate discomfort, then falls when heat becomes overwhelming.

From Cohn and Rotton (1997, J. Pers. Soc. Psychol.):

" *As Bell (1992) observed, heat sometimes led to higher levels of aggression; at other times, it led to lower levels of aggression; and at still other times, heat had no effect on aggression. Baron and Bell (1976) advanced what is now called the* Negative Affect Escape (NAE) model *to reconcile these inconsistent results. According to the NAE model, relationships between heat and aggression are mediated by negative affect. Initially, moderately high levels of heat tend to increase aggression, but as discomfort intensifies, people become more interested in escaping, which conflicts with aggressive tendencies.*"

From the Lab to the Field (1/2)

- Cohn and Rotton (1997, J. Pers. Soc. Psychol.) test the NAE model using police reports of assaults in Minneapolis (1987–1988), matched with 3-hour temperature data.
- The paper shows that:
  - Assaults increased up to ≈75°F (24°C), then declined at higher temperatures.
  - Non-violent crime shows no consistent pattern.
  - This supports the curvilinear "inverted-U" pattern predicted by the NAE model: moderate heat increases aggression; extreme heat promotes escape.
  - When aggregated to daily data, the nonlinear pattern disappears.

From the Lab to the Field (2/2)

- Recent papers using high-resolution data find a mostly monotonic increase in violent and family crimes with heat.
  - Ranson (2014, JEEM) argues that the mixed results found in early field literature could be due to a lack of geographic and temporal resolution in their crime and weather data, and because of quality issues with US aggregate crime statistics in the 1970s and 1980s (because of different sources of datasets measuring somewhat different crimes, as reminded in Levitt 2004, JEP)
- Ranson (2014, JEEM): U.S. counties (1980–2009): violent crime rises roughly linearly with temperature.
- Cohen and Gonzalez (2024, AEJ: Econ Policy): $+1°C \rightarrow +1.78\%$ in daily charges (Mexico); strongest for violent and family violence crimes.

IPV and the Heat Stress Channel

- Michael and Zumpe (1986, Am. J. Psychiatry), using monthly data (1981–1984) from 23 U.S. shelters aiding battered women, reported evidence on seaonality of IPVn with a max. in **July-August**, coinciding with peak ambient temperature:
  - IPV occurrence may possibly be linked to temperature-related changes in aggressivity, but this is purely correlational, **not a causal identification**.

Testing the Heat–Stress Hypothesis: Rizzotto et al. (2025)

- Rizzotto et al. (2025, Rev. Econ. Household) examines:
  - immediate effects of weather shocks on domestic violence → assumed to be caused by **acute stress**,
  - effects of prolonged periods of drought or extreme heat → assumed to be caused by **chronic stress**.
- The paper uses daily municipal panel data in Brazil, between 2010–2019: hospital assault reports, hotline calls, and female homicides.
  - the hospital data provide information on the aggressor's relationship,
  - the hotline calls correspond to cases of violence against women.
- Two-way fixed-effects model:

$$Y_{it} = \alpha + \beta_1 \,\text{Weather}_{i,t-1} + \gamma_i + \lambda_t + \varepsilon_{it},$$

where γ_i = municipality×year FE, λ_t = calendar-date FE.

Testing the Heat–Stress Hypothesis: Rizzotto et al. (2025)

- Rizzotto et al. (2025, Rev. Econ. Household) finds that:
  - Higher daily max temperature $\rightarrow$ immediate and short-lived increase in reports ($+1.5\%$ in per capita daily assaults rate and $+0.9\%$ hotline calls, no significant impact of homicides).
  - Results with rainfall are inconsistent.
  - No evidence of persistent or cumulative effects over weeks or months.

Two main theoretical mechanisms (bis)

We previously mentioned that, according to Rizzotto et al. (2025, Rev. Econ. Household), there seems to be, at the moment, **two main mechanisms**:

1. A **heat stress channel**:
   - the exposure to high temperatures affects human physiology and emotional regulation.
2. An **income channel**:
   - a negative weather shock can reduce agricultural output, wages, and local economic activity.

- We have highlighted physiological and affective mechanisms in the previous slides.
- 👉 Let us now move to the income channel, which relies on incentives and bargaining.

The Income Channel

The assumed mechanism works as follows:

- A weather shock occurs (e.g., a drought, or rainfall deficits).
- It lowers agricultural output, leading to **income loss**.
- Consequently, household consumption falls.
- This generates stress, alcohol use, conflicts.
- Intimate partner violence may become a **coping or control mechanism** under financial strain
  - 👉 let us see how.

Bargaining Power within the Household

- Households can be viewed not as a single decision-maker but as a **group of individuals with possibly conflicting preferences**.
- Each partner's influence on decisions depends on their bargaining power, which is shaped by:
  - individual income and assets,
  - access to credit and networks,
  - outside options (e.g. ability to leave),
  - social and legal norms.
- As explained in Eswaran and Malhotra (2011, Can. J. Econ.), violence can be interpreted as a strategic tool in this bargaining process:
  - the incentive for male partners to use violent as a tool to regain control over household decision-making increases with reduced (relative) income.
  - violence can also be used to **extract financial resources from the family**.

Empirical Illustrations of Financial Extraction from the Family

- Corno et al. (2020, Econometrica) study how households use **marriage transfers** to cope with income shocks in Sub-Saharan Africa (bride price) and India (dowry).
  - gendered bargaining decisions: during droughts (negative income shocks), families **advance or delay child marriages** depending on the direction of transfers.
- Sekhri and Storeygard (2014, J. Dev. Econ.) investigates rainfall shocks and **dowry-related violence** in India.
  - A one s.d. dry shock $\rightarrow$ 7.8% increase in dowry deaths and 4.4% rise in domestic violence.
  - Mechanism: in times of financial distress, **violence becomes a means of extracting additional transfers** from the bride's family.
- Both studies show that when **income shocks alter household bargaining positions**, women's safety and autonomy are often at risk.

How weather shocks alter bargaining power

- Following an income shock, there may be changes in relative economic contribution:
  - When male income falls (in male-dominated agriculture sector), the relative contribution of men in the household income drops, which leads to a **decrease of their bargaining power**.
  - Two opposite effects may follow:
    1. **empowerment effect** : women gain relative control over resources and decisions, which is assumed to lower IPV (Díaz and Saldarriaga 2023, JHE).
    2. **backlash effect** : men feel threatened in their representation, they use violence to reassert control → increase in IPV (Anderberg et al. 2015, EJ, Aguilar-Gómez and Salazar-Díaz 2025).

Theoretical Interpretation

- Theoretically, household decision problems (how income is spent, who works, who eats first, who controls money) can be placed into a **bargaining framework** (Nash bargaining).
- **Collective household models** (Chiappori 1992, JPE) view the household as a group of individuals with distinct preferences.
- Decisions result from a bargaining process that depends on each member's **threat point** $\overline{U}_i$, i.e., the level of well-being each person can guarantee themselves if no collective agreement is reached.
- For any given income combination, the outcome of the decision process is supposed to maximize the product $(U_1 - \overline{U}_1)(U_2 - \overline{U}_2)$ under the budget constraint.
- ⚙ More details on the Nash bargaining framework.

Theoretical Interpretation: Model

- In a collective labour model, the collective labour supply will be the solution of the Nash bargaining program:

$$\arg\max_{L,C} \left\{ \left(U_1(L_1, C_1) - \overline{U}_1\right)\left(U_2(L_2, C_2) - \overline{U}_2\right) \right\}$$
$$\text{s.t.} \quad w_1 L_1 + w_2 L_2 + C_1 + C_2 \leq (w_1 + w_2) T + y,$$

- where
  - L_i: leisure quantity,
  - C_i : quantity of private consumption good,
  - w_i: wage
  - y: non-labour income
  - T: total available time
  - $\overline{U}_i$: threat point

Theoretical Interpretation: Threat Point (1/3)

- **The threat points** $\overline{U}_i$ can be understood as individual utility levels when divorce is involved:
  - if agent's i's wage (or non-labour income) when divorced is w_i (or y_i), then $\overline{U}_i = V_i(w_i, y_i)$, where V_i is i's indirect utility function.
- each partner's threat point captures their **welfare outside the relationship**: their ability to leave or separate; their access to own income; the legal protection; social norms,
  - the higher an individual threat point, the greater their bargaining power,
  - if an individual's threat point is low, they are more dependent and their partner can push decisions in their favour.

Theoretical Interpretation: Threat Point (2/3)

The threat point can vary with income, employment of norms shift. For example :

- assume a woman **gains access to her own income** (work/government cash transfer)
  - her economic role strengthen,
  - her outside options rise, so her threat point rises as well,
  - her bargaining power increases.
- or, assume that **social norms** make divorce or separation acceptable:
  - leaving an abusive partner becomes less costly, the threat point rises
  - her bargaining power increases.
- on the other hand, if divorce is stigmatized:
  - the cost of exit is high, the threat point is low.
  - her bargaining power decreases.

Theoretical Interpretation: Wrap-Up

To wrap-up:

- If a partner's threat point **decreases**:
  - their bargaining power decreases,
  - they become more dependent and thus more exposed to violence,
  - but the **other partner** may also use violence instrumentally to extract transfers or reassert control (Eswaran and Malhotra 2011, Can. J. Econ.).
- If a partner's threat point **increases**:
  - their bargaining power increases,
  - they can better resist coercion and are less vulnerable to violence, yet, in contexts where female empowerment challenges traditional gender norms, a "**backlash effect**" may emerge:
    - men may respond violently to perceived loss of dominance (Anderberg et al. 2015, EJ)

Empirical Illustrations: Income and Economic Stress

- Díaz and Saldarriaga (2023, JHE) provides one of the clearest tests of the **income channel**.
- Using survey data from rural Peru, the paper estimates the impact of **dry shocks during the cropping season** on physical IPV.
  - Exposure to a dry shock $\rightarrow$ +8.5 percentage points in probability of physical IPV.
  - Mechanisms:
    - income and consumption expenditures per capita decline (–20% and –15%, resp.),
    - increases in male alcohol intake and marital control,
    - decreases in women's employment and financial autonomy.
- The paper links drought-induced income shocks to IPV through both **economic hardship** and **bargaining-power loss**.

Empirical Illustrations: Policy Buffers and Adaptation

- Sarma (2022, World Dev.) evaluates India's **MNREGA employment guarantee scheme** as an insurance mechanism.
- MNREGE: this program guarantees 100 days of rural employment: aims at stabilizing household income. It mandates that 1/3 of beneficiaries should be women.
- The paper finds that:
  - during the initial phase of implementation, MNREGA **mitigated** the effect of adverse rainfall shocks on reported domestic-violence crimes by ∼8–22%.
  - the effects are concentrated in **dry shocks during agricultural months**.
- **For policy implications**:
  - **social insurance** and **employment programs** can **weaken the income-violence link**.

Wrap-Up: Domestic Violence and Weather Shocks

- **Climate shocks can exacerbate intimate partner and family violence** through multiple channels: economic, behavioural, and psychological.
- Two main mechanisms:
  1. **Heat–stress**: high temperatures → irritability, impulsivity, aggression (Cohen and Gonzalez 2024, AEJ: Applied; **? ?**, Rev. Econ. Household).
  2. **Income shocks** Weather shock → stress, loss of bargaining power, male backlash (Miguel 2005, REStud; Díaz and Saldarriaga 2023, JHE).
- Some of the main findings from empirical evidence:
  - income shocks raise IPV through financial strain and bargaining dynamics,
  - high temperatures cause **acute, short-lived spikes** in violence,
  - social protection programs (e.g., MNREGA) **buffer** these effects by stabilizing income (Sarma 2022, World Dev.).

Wrap-Up: Domestic Violence and Weather Shocks

- **Policy insight:**
  - Climate adaptation must integrate **gender-sensitive safety nets** and **public-health preparedness** for heat waves.
- IPV represent some of the **hidden costs of climate change.**

5. Next session

Next session

- Each of you will work in pairs.
- You are assigned two articles to read in full. For the others, you only need to read the abstracts.
- For your assigned article, try to answer the following questions:
  - What is the main research question?
  - Why is it relevant (economic/policy context)?
  - What is already known in the literature, and what gap does this paper address?
  - How does the paper answer the question? (briefly describe the data or method.)
  - What are the main findings, and what do they mean?
  - What are the policy implications?
  - What are the main limitations?

What you are expected to do

- Prepare a short written summary (max. 1 page) covering the questions from the previous slide.
- Work in pairs.
- For each paper, two groups will be assigned:
  - One group prepares a short presentation (about 8 slides, max. 15 minutes).
  - The other group acts as discussants: 2–3 minutes of comments or questions after the presentation.
    - prepare 2–3 short questions or comments for the paper you will not present. These can ask for clarification, link the paper to bigger issues, point to potential weaknesses, or suggest implications. Do not worry about technical details, focus on whether your questions are clear, relevant, and show you engaged with the paper.

Climate and Health

- Barwick et al. (2024, REStat): pollution → healthcare costs (using credit- and debit- card transactions)
  - Barwick, P. J., Li, S., Rao, D. and Zahur, N. B. (2024). The healthcare cost of air pollution: Evidence from the world's largest payment network. *Review of Economics and Statistics* : 1–52 doi: 10.1162/rest_a_01430.
- Carleton et al. (2022, QJE): climate change → mortality → costs
  - Carleton, T., Jina, A., Delgado, M., Greenstone, M., Houser, T., Hsiang, S., Hultgren, A., Kopp, R. E., McCusker, K. E., Nath, I., Rising, J., Rode, A., Seo, H. K., Viaene, A., Yuan, J. and Zhang, A. T. (2022). Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits. *The Quarterly Journal of Economics* 137: 2037–2105, doi: 10.1093/qje/qjac020

Climate and Productivity

- Somanathan et al. (2021, JPE): temperature variations → workers' productivity → costs
  - Somanathan, E., Somanathan, R., Sudarshan, A. and Tewari, M. (2021). The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing. *Journal of Political Economy* 129:1797–1827, doi: 10.1086/713733.

Carbon Pricing and Carbon Taxation

- Colmer et al. (2025, REStud): evaluation of the environmental and economic consequences of market-based regulations
  - Colmer, J., Martin, R., Muûls, M. and Wagner, U. J. (2024). Does pricing carbon mitigate climate change? firm-level evidence from the European Union emissions trading system. *Review of Economic Studies* 92:1625–1660, doi: 10.1093/restud/rdae055.
- Konradt and Weder di Mauro (2023, JEEA): carbon pricing → inflation dynamics
  - Konradt, M. and Mauro, B. Weder di (2023). Carbon taxation and greenflation: Evidence from Europe and Canada. *Journal of the European Economic Association* 21: 2518–2546, doi: 10.1093/jeea/jvad020

Sea Level Rise

- Agarwal et al. (2025, J. Public Econ.):
  - Agarwal, S., Qin, Y., Sing, T. F. and Zhan, C. (2025). Sea level rise risks, adaptation strategies, and real estate prices in Singapore. *Journal of Public Economics* 241:105290, doi: 10.1016/j.jpubeco.2024.105290.

Climate Change & Migration

- Sedova and Kalkuhl (2020, World Dev.)
  - Sedova, B. and Kalkuhl, M. (2020). Who are the climate migrants and where do they go? Evidence from rural India. *World Development* 129: 104848, doi: 10.1016/j.worlddev.2019.104848

Climate Change and Social Interactions

- Evans et al. (2025, REStat):
  - Evans, M. F., Gazze, L. and Schaller, J. (2025). Temperature and maltreatment of young children. *The Review of Economics and Statistics* 1–37 doi: 10.1162/rest_a_01564.

6. Appendix

References I

Acemoglu, D., Johnson, S. and Robinson, J. A. (2002). Reversal of fortune: Geography and institutions in the making of the modern world income distribution. *The Quarterly Journal of Economics* 117: 1231–1294, doi: 10.1162/003355302320935025.

Agarwal, S., Qin, Y., Sing, T. F. and Zhan, C. (2025). Sea level rise risks, adaptation strategies, and real estate prices in Singapore. *Journal of Public Economics* 241: 105290, doi: 10.1016/j.jpubeco.2024.105290.

Aguilar-Gómez, S. and Salazar-Díaz, A. (2025). Droughts and domestic violence: Measuring the gender-climate nexus. doi: 10.18235/0013368, working paper.

Anderberg, D., Rainer, H., Wadsworth, J. and Wilson, T. (2015). Unemployment and domestic violence: Theory and evidence. *The Economic Journal* 126: 1947–1979, doi: 10.1111/ecoj.12246.

Anderson, C. A., Anderson, K. B., Dorr, N., DeNeve, K. M. and Flanagan, M. (2000). Temperature and aggression. Advances in Experimental Social Psychology Volume 32. Academic Press, 63–133, doi: 10.1016/s0065-2601(00)80004-0.

Andersson, H. and Treich, N. (2011). *The Value of a Statistical Life*. Edward Elgar Publishing. doi: 10.4337/9780857930873.00025.

Anthoff, D. and Tol, R. S. J. (2013). The uncertainty about the social cost of carbon: A decomposition analysis using fund. *Climatic Change* 117: 515–530, doi: 10.1007/s10584-013-0706-7.

References II

Aragón, F. M., Oteiza, F. and Rud, J. P. (2021). Climate change and agriculture: Subsistence farmers' response to extreme heat. *American Economic Journal: Economic Policy* 13: 1–35, doi: 10.1257/pol.20190316.

Auffhammer, M. (2018). Quantifying economic damages from climate change. *Journal of Economic Perspectives* 32: 33–52, doi: 10.1257/jep.32.4.33.

Bakkensen, L. A. and Barrage, L. (2021). Going underwater? flood risk belief heterogeneity and coastal home price dynamics. *The Review of Financial Studies* 35: 3666–3709, doi: 10.1093/rfs/hhab122.

Bakkensen, L. A. and Ma, L. (2020). Sorting over flood risk and implications for policy reform. *Journal of Environmental Economics and Management* 104: 102362, doi: 10.1016/j.jeem.2020.102362.

Baron, R. A. and Bell, P. A. (1976). Aggression and heat: The influence of ambient temperature, negative affect, and a cooling drink on physical aggression. *Journal of Personality and Social Psychology* 33: 245–255, doi: 10.1037//0022-3514.33.3.245.

Barrios, S., Bertinelli, L. and Strobl, E. (2006). Climatic change and rural–urban migration: The case of sub-saharan africa. *Journal of Urban Economics* 60: 357–371, doi: 10.1016/j.jue.2006.04.005.

Barwick, P. J., Li, S., Rao, D. and Zahur, N. B. (2024). The healthcare cost of air pollution: Evidence from the world's largest payment network. *Review of Economics and Statistics* : 1–52doi: 10.1162/rest_a_01430.

Basu, R. (2002). Relation between elevated ambient temperature and mortality: A review of the epidemiologic evidence. *Epidemiologic Reviews* 24: 190–202, doi: 10.1093/epirev/mxf007.

References III

Becker, G. S. (1968). Crime and punishment: An economic approach. *Journal of Political Economy* 76: 169–217.

Bell, P. A. (1992). In defense of the negative affect escape model of heat and aggression. *Psychological Bulletin* 111: 342–346, doi: 10.1037/0033-2909.111.2.342.

Berlemann, M. and Steinhardt, M. F. (2017). Climate change, natural disasters, and migration—a survey of the empirical evidence. *CESifo Economic Studies* 63: 353–385, doi: 10.1093/cesifo/ifx019.

Bernstein, A., Gustafson, M. T. and Lewis, R. (2019). Disaster on the horizon: The price effect of sea level rise. *Journal of Financial Economics* 134: 253–272, doi: 10.1016/j.jfineco.2019.03.013.

Bloch, F. and Rao, V. (2002). Terror as a bargaining instrument: A case study of dowry violence in rural India. *American Economic Review* 92: 1029–1043, doi: 10.1257/00028280260344588.

Burgess, R., Deschenes, O., Donaldson, D. and Greenstone, M. (2017). Weather, climate change and death in india.

Burke, M., Hsiang, S. M. and Miguel, E. (2015). Global non-linear effect of temperature on economic production. *Nature* 527: 235–239, doi: 10.1038/nature15725.

Cai, R., Feng, S., Oppenheimer, M. and Pytlikova, M. (2016). Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management* 79: 135–151, doi: 10.1016/j.jeem.2016.06.005.

References IV

Calvin, K., Dasgupta, D., Krinner, G., Mukherji, A., Thorne, P. W., Trisos, C., Romero, J., Aldunce, P., Barret, K., Blanco, G., Cheung, W. W., Connors, S. L., Denton, F., Diongue-Niang, A., Dodman, D., Garschagen, M., Geden, O., Hayward, B., Jones, C., Jotzo, F., Krug, T., Lasco, R., Lee, Y.-Y., Masson-Delmotte, V., Meinshausen, M., Mintenbeck, K., Mokssit, A., Otto, F. E., Pathak, M., Pirani, A., Poloczanska, E., Pörtner, H.-O., Revi, A., Roberts, D. C., Roy, J., Ruane, A. C., Skea, J., Shukla, P. R., Slade, R., Slangen, A., Sokona, Y., Sörensson, A. A., Tignor, M., Vuuren, D. van, Wei, Y.-M., Winkler, H., Zhai, P., Zommers, Z., Hourcade, J.-C., Johnson, F. X., Pachauri, S., Simpson, N. P., Singh, C., Thomas, A., Totin, E., Alegría, A., Armour, K., Bednar-Friedl, B., Blok, K., Cissé, G., Dentener, F., Eriksen, S., Fischer, E., Garner, G., Guivarch, C., Haasnoot, M., Hansen, G., Hauser, M., Hawkins, E., Hermans, T., Kopp, R., Leprince-Ringuet, N., Lewis, J., Ley, D., Ludden, C., Niamir, L., Nicholls, Z., Some, S., Szopa, S., Trewin, B., Wijst, K.-I. van der, Winter, G., Witting, M., Birt, A. and Ha, M. (2023). *IPCC, 2023: Climate Change 2023: Synthesis Report, Summary for Policymakers. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland.*. doi: 10.59327/ipcc/ar6-9789291691647.001.

Carleton, T., Jina, A., Delgado, M., Greenstone, M., Houser, T., Hsiang, S., Hultgren, A., Kopp, R. E., McCusker, K. E., Nath, I., Rising, J., Rode, A., Seo, H. K., Viaene, A., Yuan, J. and Zhang, A. T. (2022). Valuing the global mortality consequences of climate change accounting for adaptation costs and benefits. *The Quarterly Journal of Economics* 137: 2037–2105, doi: 10.1093/qje/qjac020.

References V

Carleton, T. A. and Hsiang, S. M. (2016). Social and economic impacts of climate. *Science* 353, doi: 10.1126/science.aad9837.

Chiappori, P.-A. (1992). Collective labor supply and welfare. *Journal of Political Economy* 100: 437–467, doi: 10.1086/261825.

Cohen, F. and Dechezleprêtre, A. (2022). Mortality, temperature, and public health provision: Evidence from Mexico. *American Economic Journal: Economic Policy* 14: 161–192, doi: 10.1257/pol.20180594.

Cohen, F. and Gonzalez, F. (2024). Understanding the link between temperature and crime. *American Economic Journal: Economic Policy* 16: 480–514, doi: 10.1257/pol.20220118.

Cohn, E. G. and Rotton, J. (1997). Assault as a function of time and temperature: A moderator-variable time-series analysis. *Journal of Personality and Social Psychology* 72: 1322–1334, doi: 10.1037/0022-3514.72.6.1322.

Colmer, J., Martin, R., Muûls, M. and Wagner, U. J. (2025). Does pricing carbon mitigate climate change? firm-level evidence from the European Union emissions trading system. *Review of Economic Studies* 92: 1625–1660, doi: 10.1093/restud/rdae055.

Corno, L., Hildebrandt, N. and Voena, A. (2020). Age of marriage, weather shocks, and the direction of marriage payments. *Econometrica* 88: 879–915, doi: 10.3982/ecta15505.

References VI

Cubasch, U., Wuebbles, D., Chen, D., Facchini, M., Frame, D., Mahowald, N. and Winther, J. (2013). Climate change 2013: the physical science basis. *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge, United Kingdom and New York, NY, USA* : 119–158.

Dell, M., Jones, B. F. and Olken, B. A. (2009). Temperature and income: Reconciling new cross-sectional and panel estimates. *American Economic Review* 99: 198–204, doi: 10.1257/aer.99.2.198.

Dell, M., Jones, B. F. and Olken, B. A. (2012). Temperature shocks and economic growth: Evidence from the last half century. *American Economic Journal: Macroeconomics* 4: 66–95, doi: 10.1257/mac.4.3.66.

Deschênes, O. and Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. *American Economic Review* 97: 354–385, doi: 10.1257/aer.97.1.354.

Deschênes, O. and Greenstone, M. (2011). Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather in the US. *American Economic Journal: Applied Economics* 3: 152–185, doi: 10.1257/app.3.4.152.

Di Falco, S. and Veronesi, M. (2013). How can african agriculture adapt to climate change? a counterfactual analysis from Ethiopia. *Land Economics* 89: 743–766, doi: 10.3368/le.89.4.743.

Díaz, J.-J. and Saldarriaga, V. (2023). A drop of love? rainfall shocks and spousal abuse: Evidence from rural Peru. *Journal of Health Economics* 89: 102739, doi: 10.1016/j.jhealeco.2023.102739.

References VII

Drèze, J. (1962). L'utilité sociale d'une vie humaine. *Revue Française de Recherche Opérationnelle* 23: 93–118.

Eswaran, M. and Malhotra, N. (2011). Domestic violence and women's autonomy in developing countries: theory and evidence. *Canadian Journal of Economics/Revue canadienne d'économique* 44: 1222–1263, doi: 10.1111/j.1540-5982.2011.01673.x.

Evans, M. F., Gazze, L. and Schaller, J. (2025). Temperature and maltreatment of young children. *The Review of Economics and Statistics* : 1–37doi: 10.1162/rest_a_01564.

Gevers, A., Musuya, T. and Bukuluki, P. (2020). Why climate change fuels violence against women. United Nations Development Programme.
https://www.undp.org/blog/why-climate-change-fuels-violence-against-women.

Gourevitch, J. D., Kousky, C., Liao, Y., Nolte, C., Pollack, A. B., Porter, J. R. and Weill, J. A. (2023). Unpriced climate risk and the potential consequences of overvaluation in us housing markets. *Nature Climate Change* 13: 250–257, doi: 10.1038/s41558-023-01594-8.

Hino, M. and Burke, M. (2021). The effect of information about climate risk on property values. *Proceedings of the National Academy of Sciences* 118, doi: 10.1073/pnas.2003374118.

Hoffmann, R., Šedová, B. and Vinke, K. (2021). Improving the evidence base: A methodological review of the quantitative climate migration literature. *Global Environmental Change* 71: 102367, doi: 10.1016/j.gloenvcha.2021.102367.

References VIII

Hope, C. (2012). Critical issues for the calculation of the social cost of co2: why the estimates from PAGE09 are higher than those from PAGE2002. *Climatic Change* 117: 531–543, doi: 10.1007/s10584-012-0633-z.

Hsiang, S. M. (2010). Temperatures and cyclones strongly associated with economic production in the caribbean and central america. *Proceedings of the National Academy of Sciences* 107: 15367–15372, doi: 10.1073/pnas.1009510107.

Hsiang, S. M., Burke, M. and Miguel, E. (2013). Quantifying the influence of climate on human conflict. *Science* 341, doi: 10.1126/science.1235367.

Jacobson, J. L. (1988). Environmental refugees: a yardstick of habitability. *Bulletin of Science, Technology & Society* 8: 257—-258, doi: 10.1177/027046768800800304.

Kelley, C. P., Mohtadi, S., Cane, M. A., Seager, R. and Kushnir, Y. (2015). Climate change in the fertile crescent and implications of the recent Syrian drought. *Proceedings of the National Academy of Sciences* 112: 3241–3246, doi: 10.1073/pnas.1421533112.

Keys, B. and Mulder, P. (2020). *Neglected No More: Housing Markets, Mortgage Lending, and Sea Level Rise*. doi: 10.3386/w27930.

Keys, B. and Mulder, P. (2024). *Property Insurance and Disaster Risk: New Evidence from Mortgage Escrow Data*. doi: 10.3386/w32579.

References IX

Konradt, M. and Mauro, B. Weder di (2023). Carbon taxation and greenflation: Evidence from Europe and Canada. *Journal of the European Economic Association* 21: 2518–2546, doi: 10.1093/jeea/jvad020.

Laczko, F. and Aghazarm, C. (2010). *Migration, the environment and climate change: assessing the evidence.*. International Organization for Migration.

Levitt, S. D. (2004). Understanding why crime fell in the 1990s: Four factors that explain the decline and six that do not. *Journal of Economic Perspectives* 18: 163–190, doi: 10.1257/089533004773563485.

Lobell, D. B., Burke, M. B., Tebaldi, C., Mastrandrea, M. D., Falcon, W. P. and Naylor, R. L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Science* 319: 607–610, doi: 10.1126/science.1152339.

Marchiori, L., Maystadt, J.-F. and Schumacher, I. (2012). The impact of weather anomalies on migration in sub-Saharan Africa. *Journal of Environmental Economics and Management* 63: 355–374, doi: 10.1016/j.jeem.2012.02.001.

Meadows, D. H., Meadows, D. L., Randers, J. and Behrens III, W. W. (1972). *The Limits to Growth: a Report to the Club of Rome*. Universe Books, New York.

Meier, S., Elliott, R. J. and Strobl, E. (2023). The regional economic impact of wildfires: Evidence from Southern Europe. *Journal of Environmental Economics and Management* 118: 102787, doi: 10.1016/j.jeem.2023.102787.

References X

Mendelsohn, R. (2009). The impact of climate change on agriculture in developing countries. *Journal of Natural Resources Policy Research* 1: 5–19, doi: 10.1080/19390450802495882.

Michael, R. P. and Zumpe, D. (1986). *American Journal of Psychiatry* 143: 637–640, doi: 10.1176/ajp.143.5.637.

Miguel, E. (2005). Poverty and witch killing. *The Review of Economic Studies* 72: 1153–1172, doi: 10.1111/0034-6527.00365.

Missirian, A. and Schlenker, W. (2017). Asylum applications respond to temperature fluctuations. *Science* 358: 1610–1614, doi: 10.1126/science.aao0432.

Monstesquieu, C. de Secondat de (1758). *De l'esprit des lois*.

Munshi, K. (2003). Networks in the modern economy: Mexican migrants in the U. S. labor market. *The Quarterly Journal of Economics* 118: 549–599, doi: 10.1162/003355303321675455.

Nash, J. F. (1950). The bargaining problem. *Econometrica* 18: 155, doi: 10.2307/1907266.

Nordhaus, W. (2019). Climate change: The ultimate challenge for economics. *American Economic Review* 109: 1991–2014, doi: 10.1257/aer.109.6.1991.

Nordhaus, W. D. (2010). Economic aspects of global warming in a post-Copenhagen environment. *Proceedings of the National Academy of Sciences* 107: 11721–11726, doi: 10.1073/pnas.1005985107.

Nordhaus, W. D. (2013). *The Climate Casino: Risk, Uncertainty, and Economics for a Warming World*. Yale University Press.

References XI

Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups*. Harvard University Press.

Pearce, D. (2003). The social cost of carbon and its policy implications. *Oxford Review of Economic Policy* 19: 362–384, doi: 10.1093/oxrep/19.3.362.

Pindyck, R. S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature* 51: 860–872, doi: 10.1257/jel.51.3.860.

Pizer, W., Adler, M., Aldy, J., Anthoff, D., Cropper, M., Gillingham, K., Greenstone, M., Murray, B., Newell, R., Richels, R., Rowell, A., Waldhoff, S. and Wiener, J. (2014). Using and improving the social cost of carbon. *Science* 346: 1189–1190, doi: 10.1126/science.1259774.

Ranson, M. (2014). Crime, weather, and climate change. *Journal of Environmental Economics and Management* 67: 274–302, doi: 10.1016/j.jeem.2013.11.008.

Rizzotto, J. S., Sims, K. M. and Gibbs, H. K. (2025). Hot tempers: Differential effects of heat and drought on domestic violence. *Review of Economics of the Household* doi: 10.1007/s11150-025-09806-0.

Rose, S. K. (2012). The role of the social cost of carbon in policy. *WIREs Climate Change* 3: 195–212, doi: 10.1002/wcc.163.

Samuelson, P. A. (1954). The pure theory of public expenditure. *The Review of Economics and Statistics* 36: 387, doi: 10.2307/1925895.

References XII

Sarma, N. (2022). Domestic violence and workfare: An evaluation of India's MGNREGS. *World Development* 149: 105688, doi: 10.1016/j.worlddev.2021.105688.

Schlenker, W. and Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to u.s. crop yields under climate change. *Proceedings of the National Academy of Sciences* 106: 15594–15598, doi: 10.1073/pnas.0906865106.

Sedova, B. and Kalkuhl, M. (2020). Who are the climate migrants and where do they go? Evidence from rural India. *World Development* 129: 104848, doi: 10.1016/j.worlddev.2019.104848.

Sekhri, S. and Storeygard, A. (2014). Dowry deaths: Response to weather variability in India. *Journal of Development Economics* 111: 212–223, doi: 10.1016/j.jdeveco.2014.09.001.

Seong, K., Losey, C. and Gu, D. (2021). Naturally resilient to natural hazards? urban–rural disparities in hazard mitigation grant program assistance. *Housing Policy Debate* 32: 190–210, doi: 10.1080/10511482.2021.1938172.

Somanathan, E., Somanathan, R., Sudarshan, A. and Tewari, M. (2021). The impact of temperature on productivity and labor supply: Evidence from Indian manufacturing. *Journal of Political Economy* 129: 1797–1827, doi: 10.1086/713733.

Thaler, R. and Rosen, S. (1976). The value of saving a life: evidence from the labor market. In *Household production and consumption*. NBER, 265–302.

References XIII

Thurston, A. M., Stöckl, H. and Ranganathan, M. (2021). Natural hazards, disasters and violence against women and girls: a global mixed-methods systematic review. *BMJ Global Health* 6: e004377, doi: 10.1136/bmjgh-2020-004377.

Tirole, J. and Tribe, K. (2017). *Economics for the Common Good*. Princeton University Press, hardcover ed.

Viscusi, W. K. (2015). The role of publication selection bias in estimates of the value of a statistical life. *American Journal of Health Economics* 1: 27–52, doi: 10.1162/ajhe_a_00002.

Wang, H. and Mullahy, J. (2006). Willingness to pay for reducing fatal risk by improving air quality: A contingent valuation study in Chongqing, China. *Science of The Total Environment* 367: 50–57, doi: 10.1016/j.scitotenv.2006.02.049.

Wang, P., Deng, X., Zhou, H. and Yu, S. (2019). Estimates of the social cost of carbon: A review based on meta-analysis. *Journal of Cleaner Production* 209: 1494–1507, doi: 10.1016/j.jclepro.2018.11.058.

Wang, Y. and Lewis, D. J. (2024). Wildfires and climate change have lowered the economic value of western U.S. forests by altering risk expectations. *Journal of Environmental Economics and Management* 123: 102894, doi: 10.1016/j.jeem.2023.102894.

Zhao, Q., Wu, L., Huo, F., Li, Z. and Li, Y. (2025). Assessing the impacts of shifting planting dates on crop yields and irrigation demand under warming scenarios in Alberta, Canada. *Agricultural Water Management* 309: 109304, doi: 10.1016/j.agwat.2025.109304.

IAMs: Theoretical Formulation (Optional)

Planner's problem in the spirit of DICE models:

$$\max \sum_{t=0}^{\infty} \beta^t L_t \, u\left(\frac{c_t}{L_t}\right)$$

subject to:

$$\begin{aligned} Y_t &= A_t F(K_t, L_t)\,[1 - \Omega(T_t)], \\ c_t + I_t + \Phi(\mu_t) Y_t &= Y_t, \quad K_{t+1} = (1-\delta)K_t + I_t, \\ E_t &= \sigma_t (1 - \mu_t) Y_t, \\ M_{t+1} &= \mathcal{C}(M_t, E_t), \\ T_{t+1} &= \mathcal{T}(T_t, M_{t+1}). \end{aligned}$$

- μ_t: abatement rate, $\Phi(\mu_t)Y_t$: abatement cost.
- $\Omega(T_t)$: damages; E_t: emissions; M_t: carbon stock; T_t: temperature.

The social cost of carbon is the shadow price of emissions. Go back

What Is a Bargaining Problem?

- A **bargaining situation** arises whenever two (or more) agents can **cooperate** to obtain mutual gains, but must **agree on how to share** those gains.
- Fro example:
  - two firms negotiating a joint venture,
  - two countries dividing emission permits,
  - two partners deciding how to split household income.
- If they fail to agree, each agent obtains an **outside option** (the **threat point**), i.e., the payoff they can guarantee alone.
- A bargaining problem is defined by:

$$(\mathcal{U},\ \overline{U}_1, \overline{U}_2)$$

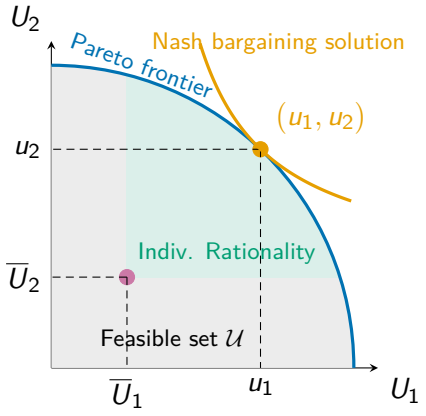
where $\mathcal{U}$ is the set of all feasible utility pairs, and $(\overline{U}_1, \overline{U}_2)$ are the threat points.

The Idea of Nash Bargaining

- Introduced by Nash (1950, Econometrica).
- The **Nash Bargaining Solution (NBS)** describes the outcome that rational, cooperative agents would agree on, given their threat points.
- Nash proposed that the solution should:
  - be **Pareto efficient**: no other feasible allocation can make one better off without hurting the other,
  - be **symmetric**: if players are identical, they should get the same outcome,
  - respect **invariance to affine transformations**,
  - satisfy **independence of irrelevant alternatives**.
- Under these axioms, the solution maximizes the product of each player's gain over their threat point:

$$\max_{(U_1,U_2)\in\mathcal{U}} (U_1 - \bar{U}_1)(U_2 - \bar{U}_2)$$

Geometric Intuition



Go back

- Each point (U_1, U_2) in the set $\mathcal{U}$: a possible agreement between agents 1 and 2.
- $(\overline{U}_1, \overline{U}_2)$ is the **threat point** (utilities if they fail to agree).
- The curved boundary is the **Pareto frontier**, i.e., the efficient allocations (one's gain requires the other's loss).
- The **Nash solution** maximizes the product of utility gains:

$$\max_{(U_1,U_2)\in\mathcal{U}} (U_1 - \overline{U}_1)(U_2 - \overline{U}_2)$$

- Intuitively: each partner's improvement over their outside option is balanced: neither can gain more without reducing the other's proportional gain.