Climate Change, Economic Growth and Development

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Special Course during the Climate Strike Week 2019 at UL

Two empirical perspectives

The “ecologists” view

- Natural capital (ecosystems) deteriorates massively
  1. Ocean fishery
  2. Rainforests
  3. CO2-capacity of the atmosphere
- For many ecosystems, there may be a point of no return
- To be clear: mankind is responsible!
- Ecosystems are used as a source of income

- Are people “poor” because they suffer resource scarcity?

Two empirical perspectives

The “economists” view

- Economists argue that the price of natural capital is not high
- Do people suffer resource scarcity because they are “poor”?

Some growth rates in the 20^{th} century

Rough estimates

Variable	growth factor
World population	4
GDP	14
Industrial Production	40
Energy use	16
Cattle population	4
Fish catch	35
Carbon emissions	10

Is economic growth always bad for the ecology?

- Better health care
- Clean water
- Clean air
- Knowledge and problem awareness

- Is “nature” a luxury good or a necessity?

Nature may be more important to developing countries than we acknowledge

- Poor people benefit most from large biodiversity
  1. Extensive use of local goods
  2. Informal (subsistence-)economy
  3. Little trade
- Damages to nature negatively affect composition of consumption bundle, with no substitution
- 65%-75% of people in poor regions live in rural areas

Place of ecology in the economic mainstream: Nearly negligible

- "Poverty is much more pressing"
- Why: Bounded rationality, confirmation bias and limited information on developments in other places
- But: elasticity of substitution between natural capital and other forms of capital could be less than one
    1. Natural capital cannot be well substituted
    2. Marginal productivity of physical and human capital decreases as natural capital depletes
    3. The worlds' poorest people live in especially fragile natural environments
- Exception: Nobel price of William Nordhaus, 2018

Ecology as a focus of development policy: Slowly emerging

- 17% of 11’000 World Bank development projects (1947-2007) have ecology as major theme
- Share is increasing, but slowly
- It should be possible to develop policies that alleviate poverty **and** help the ecology

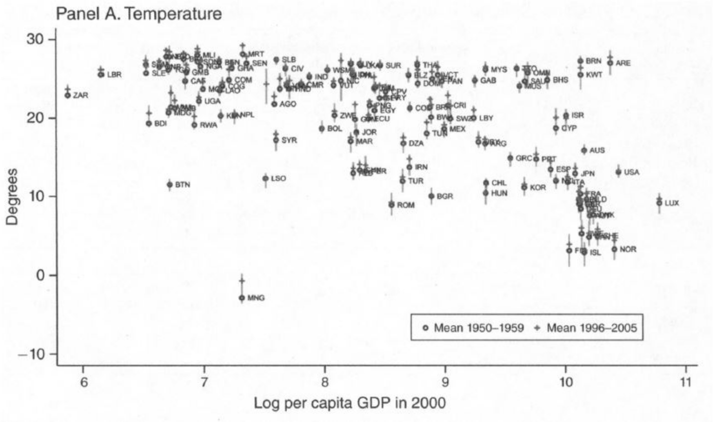
Why should economists care about climate change?

- Higher temperatures have negative consequences for several important determinants of economic growth
  1. Agricultural productivity (if too hot)
  2. Mortality
  3. Physical performance
  4. Cognitive performance
  5. ...
- Rising sea levels
- Higher probability of natural catastrophes
- Migration

- All these problems affect poor people overproportionally!

Average temperatures and GDP per capita

Dell et al. (2012)



Two lectures: a plan

- Tuesday:
  1. How are climate change and CO2 emissions translated into economics?
  2. How can we derive a global carbon price?
  3. How much are future damages worth today?
- Friday:
  1. How high may climate damages be?
  2. How are they distributed across the world?
  3. Who should pay for carbon emissions?
- Important questions not adressed:
  1. How is the economy going to develop over the next 100 years?
  2. How strong will temperature increases be due to CO2 emissions?

Related presentation during the climate strike week

- “Oekologische, Oekonomische und soziale Aspekte der CO_2-Bepreisung”, Prof. Bruckner (Tuesday, 13:15-14:45)
- “Lecture on calculating the economic costs of greenhouse gas emissions, Part II”, Prof. Quaas (Wednesday, 13:00-15:00)
- “The Dynamic Integrated Climate-Economy model (The contribution of William Nordhaus)”, Prof. Steger (Thursday, 9:15-10:45)

Why does natural capital deplete?

Market failures

- Weak enforcements of property rights to natural capital
- Often, there is no or a very low price to use natural capital
  1. Natural capital services do not offer enough of a financial return
  2. Distorted incentives to switch to/invent clean technologies
  3. Savings rates should be different if (depletion of) natural capital is accounted for
     - Decline in forest cover in Indonesia and Malaysia: net savings rates 20-30% lower
     - Depreciation of forests, soil and fisheries in Costa Rica: 10% of GDP / 33% of capital accumulation

Market failure and externalities

- Market failures create *externalities*
- Actions by one agent have *unintended and uncompensated* side effects on other agents $\longrightarrow$ *unilateral externality*
  1. Factory spills toxics into rivers, negatively affecting fishers (Coase; 1960)
  2. Logging of trees: affects people downstream, and potentially the world
  3. Pollution from cars
- General problem: the side effects do not have a price

Solving unilateral externalities

Taxing

- General approach: give the side effect a price
- Taxes: the government sets a price, *polluter pays*
- Implicitly, the government holds the property right
- Problems
  1. Distribution: what shall be done with the pollution taxes?
  2. Wrong tax only solves part of the problem

Solving unilateral externalities

Coase theorem: trading certificates on a market

- Introduce property rights to natural capital
- Install a market where these property rights can be traded
- Variant 1: factory pays fishers for pollution
- Variant 2: fishers pay factory to avoid pollution

Solving unilateral externalities

Problems with the Coase theorem

- Weak enforcements of property rights in many developing countries $\longrightarrow$ no punishment for pollution
- Markets for individual rights may be small and inefficient
- Markets may be set up badly. Example:
    - One polluting firm and many fishers
    - (Avoiding) pollution becomes a *public good* on the farmers side
    - **Freeriding with common property rights**

Common property resources

- Many natural resources are *common property resources*
- (Over-)Use by any party is a negative externality for all other parties $\longrightarrow$ *reciprocal externality*
- Other names:
  1. Free-riding
  2. Tragedy of the commons

Common property resources

CO2 emissions

- Atmosphere, climate and CO2-concentration are common property resources
- Whenever one country produces more CO2 than its “fair share”, other countries are affected
  1. Emit less to avoid negative consequences for all?
  2. Emit more for reasons of fairness?
  3. Impose sanctions?

Common property resources

CO2 emissions

- Reaction depends on many dimensions. Think about
  1. Visibility of non-compliance
  2. Existence of international treaties
  3. Sanction mechanisms
  4. Degree of rivalry
  5. ...

Common property resources

How to avoid free-riding

- Sociologically, cooperation appears to be habit forming
- Universal acceptance of a common goal (avoid climate change?)
  1. Agreement on the importance to avoid emissions
  2. Agreement on the contract design
  3. Decentralize responsibilities wherever possible
- Create a property and a trading mechanism
  1. Transparent measurement of CO2 emissions
  2. Sanctions

Climate change and economic growth

Recap so far

- Climate change is a threat
- As “climate” is a public good, we need to tackle this threat together
- Agree on a common policy
- But:

What effect will a given policy have?

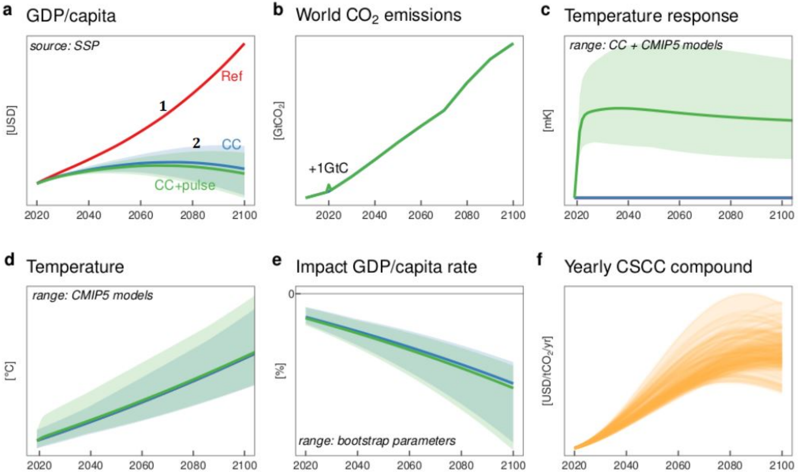
The effect of climate policies

How to build a model?

- In order to speak about these issues, we need a model
- Integrated assessment models (IAM) combine
  1) Population dynamics
  1) A dynamic (socioeconomic) model describing future economic development
  1) A transfer from GDP to CO2 emissions
  2) A climate model to describe the evolution of CO2 stock in the atmosphere
  3) A function calculating (monetary) damages from climate change

The effect of climate policies

How to build a model?



Setting a price to carbon emissions

- From this, we can calculate the *social costs of carbon* / *shadow price* of CO2 emissions
- *Shadow price*: how much are we willing to sacrifice to avoid current and future damages from one additional ton of CO2?
- Two extreme possibilities
  1. Polluting the world today may make it uninhabitable in the future
  2. Easiest way to stop pollution: human extinction
- Reality is somewhere in between: we are willing to avoid some pollution
- Social costs of carbon incorporate
  - Broad definition of *well-being*
  - Future developments
  - Substitution effects

Measuring social well-being

- Every policy affects future consumption possibilities
- Let $U(c_t)$ be the utility derived from consumption at time t
- See consumption as a broad concept, including natural resources
- Social well-being is the discounted sum of future consumption

$$V_0 = \sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t U(c_t)$$

- Choose a consumption path such that well-being is maximized
- Utility contains some aversion against inequality (across people and across time)

Social well-being and climate change

- Feedback in a dynamic socioeconomic model: Future consumption is influenced by
  1. Physical capital accumulation and savings
  2. Population growth
  3. **Carbon price**: affects amount and composition of consumption
- Damage function: current and future generations may suffer from
  1. Higher temperatures
  2. Food and water scarcity
  3. Rising sea levels
  4. Natural catastrophes
  5. ...
- Climate change is a risk to well-being

Social well-being and climate change

Trade-off between present and future?

- How is present and future linked in the model?
  - *Discount rates* δ: direct trade-offs
  - Lower discount rates imply higher importance of future $\longrightarrow$ fewer emissions today
  - *Inequality aversion in the utility function* α: consumption smoothing across time
  - Higher aversion implies stronger smoothing
  - If future consumption drops: start saving today $\longrightarrow$ fewer emissions today

Policy comparison

Scenario analysis

- Different scenarios entail different future consumption developments
- Analysis: Maximize social well-being for every scenario
- Possible scenarios
  1. Current climate policies
  2. Alternative climate policies
  3. Different economic scenarios
  4. Fixed two-degree target
  5. ...

Policy comparison

Scenario analysis

- For a given scenario, we can derive projections for
  1. Economic development
  2. Carbon emissions
  3. Global temperatures
  4. Climate damages
  5. Carbon prices
  6. ...

Policy comparison: Nordhaus (2018)

Four scenarios

- "Business-as-usual":
  1. minimal policies to reduce emissions
  2. non-cooperative behavior
- Optimum policy:
  1. maximizes social welfare
  2. implicitly: cooperative behavior
- Limiting global temperature increase to 2.5 degrees
  1. add temperature increase as condition
- "Stern policy":
  1. Extremely low discount rate $\delta = 0.1\%$ (Stern; 2007)
- All scenarios but the "Stern policy" use $\delta = 1.5\%, \alpha = 1.45\%$

Policy comparison: Nordhaus (2018)

CO2 emissions

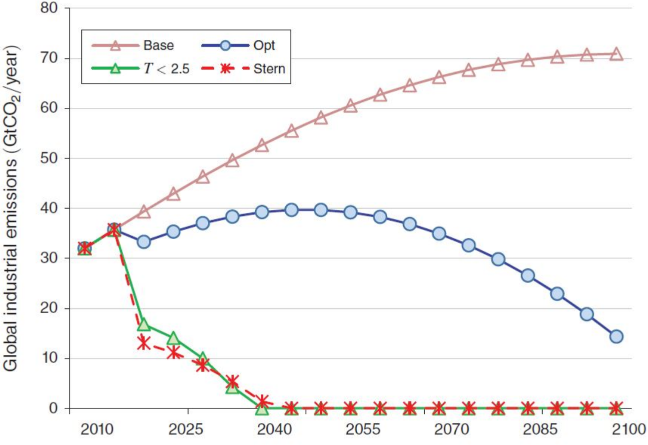


FIGURE 2. ACTUAL AND PROJECTED EMISSIONS OF CO_2 IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios require zero emissions before mid-century.

Policy comparison: Nordhaus (2018)

Stock of CO2 in the atmosphere

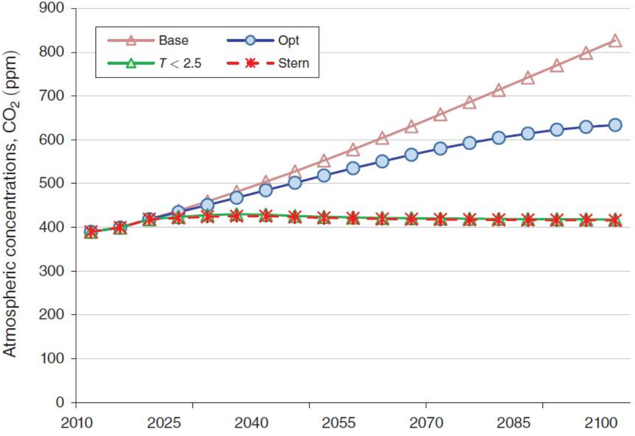


FIGURE 3. CONCENTRATIONS OF CO_2 IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios require concentrations emissions close to current levels.

Policy comparison: Nordhaus (2018)

Global temperature

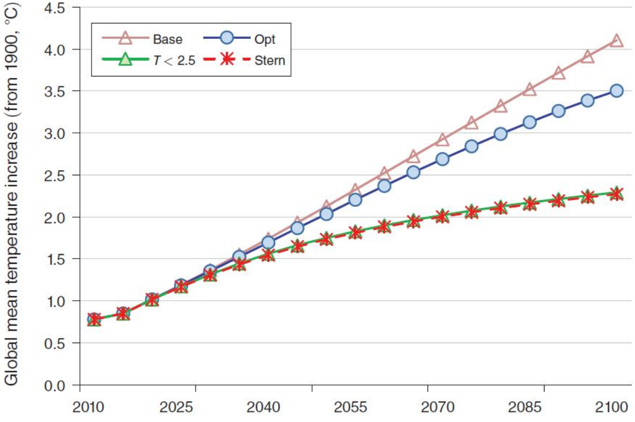


FIGURE 4. TEMPERATURE CHANGE IN DIFFERENT SCENARIOS

Note: The two most ambitious scenarios cannot limit temperature to 2.5°C in the best-guess projections.

Policy comparison: Nordhaus (2018)

Well-being and damages

Table 2—Abatement, Damages, and Net Impacts of Different Policy Scenarios, Best-Guess Parameters

					Difference from base	
Scenario	Objective	Damages	Abatement cost	Damages plus abatement	Objective	Damages plus abatement
Base or business as usual	4,491.07	134.2	0.4	134.6	0.0	0.0
Optimal controls	4,520.56	84.6	20.1	104.7	29.5	29.9
2.5 degree maximum						
Maximum	4,441.32	43.1	134.6	177.8	−49.7	−43.2
Max for 100 years	4,456.81	45.7	117.6	163.3	−34.3	−28.8
Stern Review abatement		46.2	155.7	201.9	na	−67.3

Policy comparison: Nordhaus (2018)

Social costs of carbon

TABLE 3—GLOBAL SOCIAL COST OF CARBON UNDER DIFFERENT ASSUMPTIONS FOR BEST-GUESS PARAMETERS

Scenario	2015	2020	2025	2030	2050
Base parameters					
Baseline[a]	30.0	35.7	42.3	49.5	98.3
Optimal controls[b]	29.5	35.3	41.8	49.2	99.6
2.5 degree maximum					
Maximum[b]	184.1	229.0	284.0	351.0	1,008.4
Max for 50 years[b]	147.2	183.2	227.2	280.4	773.5
Stern Review discounting					
Uncalibrated[b]	256.5	299.6	340.7	381.7	615.6

Policy comparison

Summary (for the moment)

- Policies that lead to lower global temperatures...
    1. imply lower emissions
    2. lead to lower welfare and GDP
    3. imply higher carbon prices

Sources of uncertainty

- Recommendations are subject to large uncertainty
- Feedback effects in climate models potentially not well understood
- Tipping points in climate change
- Extraplating economic damages from climate
- Small changes in economic growth cumulate over a long time
- **Missing knowledge on key model parameters (discount rates,...)**

Social well-being and climate change

The effect of discount rates

- Stern (2007): $\delta = 0.1\%$
- Nordhaus (2007, 2018): $\delta = 1.5\%$
- Thought experiment:
  1. Suppose a loss of 1 million €in 100 years
  2. How much are we willing to pay to avoid this loss *today*?
  3. Stern: $\sim$ 900'000 €
  4. Nordhaus: $\sim$ 220'000 €

Discount rates: what is correct?

- Discounting *social welfare* is tricky
  1. Not directly measurable
  2. Lots of (unknown and untestable) assumptions
- “Prescriptive discounting” vs. “descriptive discounting” is one of the most controversial point for the calculation of fair carbon prices

Assuming discount rates on a normative basis

- Put yourself in the shoes of a "social planner"
- How should the well-being of current and future generations be balanced?
- Use ethical and philosophical arguments to derive a "fair" social discount rate
  1. Utilitarian tradition: intergenerational neutrality $\longrightarrow \delta = 0$
  2. Sustainable development: Each generation should leave behind at least as much as it inherited $\longrightarrow \delta =??$
  3. Rawls "veil of uncertainty": maximize welfare of poorest generation $\longrightarrow \delta > 0$ (although this is disputable)

Setting discount rates on a positive basis

- Idea: saving on financial markets tells us, how much we value the future
- *Ramsey equation* links discount rates δ to market interest rates r and average economic growth g

$$r = \delta + \alpha g$$

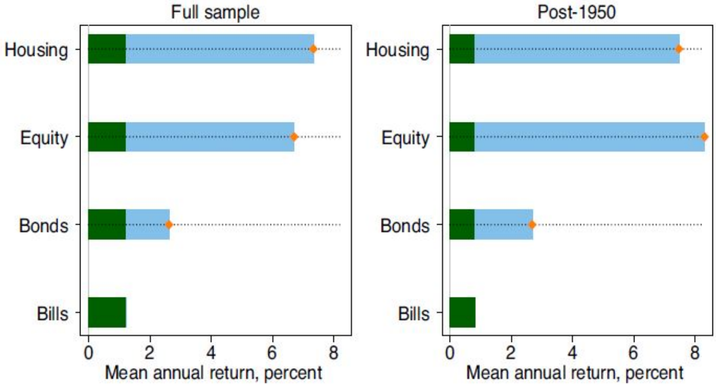
- Nordhaus (2018) used $\delta = 1.5\%, \alpha = 1.45\%, r = 4.25\%$
- Problems
  1. Elasticity of intertemporal substitution α: probably in the range of 1% to 3%
  2. Determination of “market interest rates” r, see following slides

The effect of discount rates

- Nordhaus (2018) assumed real interest rate $r = 4.25\%$ (on average)
- Use history to derive a number
  1. Safe assets or risky assets?
  2. Long-run data from developed economies, or short-run worldwide data?

Safe returns are low

Jordà et al. (2019)



The effect of discount rates

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- Use history to derive a number
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- Is history the correct benchmark for the coming 100 years?

Safe returns are potentially decreasing

Jordà et al. (2019)

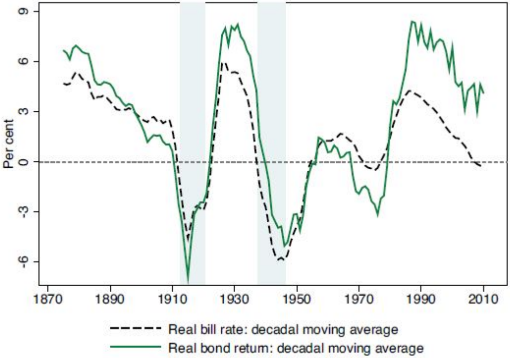

FIGURE X

Trends in Real Returns on Bonds and Bills

Mean returns for 16 countries, weighted by real GDP. Decadal moving averages.

The effect of discount rates

- Nordhaus (2018) assumed real interest rate $r = 4.25\%$ (on average)
- Use history to derive a number
  1. Safe assets or risky assets?
  2. Long-run data from developed economies, or short-run worldwide data?
- Is history the correct benchmark for the coming 100 years?
  1. Real interest rate should decrease when population growth slows down

Policy comparison: Nordhaus (2018)

Social costs of carbon

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Max for 50 years[b]	147.2	183.2	227.2	280.4	773.5
Stern Review discounting					
Uncalibrated[b]	256.5	299.6	340.7	381.7	615.6
Alternative discount rates[a]					
2.5%	111.1	133.4	148.7	162.3	242.6
3%	71.6	85.3	94.4	104.0	161.7
4%	34.0	39.6	44.5	49.8	82.1
5%	18.9	21.7	24.8	28.1	48.4

Consumption and GDP as a welfare index

Cautionary note

- Above, we used consumption and GDP to measure welfare
- Best understood concept
  1. Measurement is easy
  2. Future projections are fairly accurate
- Problems with using consumption/GDP as welfare index
  1. Does not capture distributional aspects
  2. Is measured in (sometimes distorted) market prices
  3. Does not account for capital depreciation:
  4. Creates problem with comparing welfare of different generations
- Social well-being is not identical to GDP

Correlation of social well-being and other development measures

Dasgupta (2010)

Table 1 The progress of poor nations

Country/ region	I/Y[a] (%)	% Annual growth rate 1970-2000 Population (per head)	TFP[b]	Comprehensive wealth (per head)	GDP (per head)	Δ HDI[c]
Sub-Saharan Africa	−2.1	2.7	0.1	−2.81	−0.1	+
Bangladesh	7.1	2.2	0.7	−0.79	1.9	+
India	9.5	2.0	0.6	−0.45	3.0	+
Nepal	13.3	2.2	0.5	−0.37	1.9	+
Pakistan	8.8	2.7	0.4	−1.42	2.2	+
China	22.7	1.4	3.6	4.47	7.8	+

Adapted from Arrow et al. (2004) and Dasgupta (2001a).
[a]Comprehensive investment as a share of GDP (average over 1970-2000).
[b]Total factor productivity.
[c]Change in HDI between 1970 and 2000.

Policy conclusions

- Future damages of climate change cannot be ignored $\longrightarrow$ ACT NOW!
- There is large uncertainty with respect to
  1. Socioeconomic forecasts: how will the economy develop, and how much carbon would be produced?
  2. Climate models: how much pollution is allowed?
  3. Estimated damages: **see Friday lecture**
  4. Correct time discount rates: philosophical vs. measurement arguments, with a tendency towards low discount rates
- Preview: damages (and carbon price) are likely (much) higher than presented today

Policy conclusions

Taxes or certificates?

- Government decides on a price for CO2
- Firms and households emit as long as return is higher than tax
- Advantages of taxes
    1. Central solution
    2. CO2 property rights: in the hand of the government
    3. Possibility to differentiate prices $\longrightarrow$ fairness?
- Disadvantages
    1. No direct control over emission quantity
    2. Fewer uncertainty on quantity than price $\longrightarrow$ policy goal should be quantity
    3. Inefficiencies arising from taxes and/or redistribution. Example: “Pendlerpauschale”

Policy conclusions

Taxes or certificates?

- CO_2 certificates (the right to emit) are traded on market
- Firms and households with the largest willingness to pay hold certificates
- Advantages of certificates
  1. Regulate the quantity of CO_2 emissions
  2. Prices endogenously $\longrightarrow$ knowledge of correct discount rates and damages not necessary
  3. Not subject to government (in-)action
- Disadvantages
  1. Prices could be fluctuating $\longrightarrow$ source of economic volatility
  2. How to assign initial certificates (i.e. property rights)? $\longrightarrow$ fairness?
  3. Prices could be wrong under uncertain future developments

Policy conclusions

Taxes or certificates?

My subjective reading and conclusion:

1) German CO_2 tax proposal is ridiculously low

2) Certificates would be better than taxes

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Climate change, economic development and growth

Recap of part I

- CO_2 emissions have negative consequences for (nearly) everyone $\longrightarrow$ negative externality
- The economists solution: CO_2 emissions should have a price
- Integrated assessment model (IAM) combines
  1) Population dynamics
  1) A dynamic (socioeconomic) model describing future economic development
  1) A transfer from GDP to CO_2 emissions
  2) A climate model to describe the evolution of CO_2 stock in the atmosphere
  3) A function calculating (monetary) damages from climate change
- compare outcomes under different policies (temperature increase, optimal carbon price, discounted value of future utility...)

Climate change, economic development and growth

Recap of part I

- Model always maximizes discounted value of future utility (under restrictions)

$$V_0 = \sum_{t=0}^{\infty} \left(\frac{1}{1+\delta} \right)^t U(c_t)$$

- Important and controversial: discount rate δ
- Thought experiment:
  1. Suppose a loss of 1 million €in 100 years
  2. How much are we willing to pay to avoid this loss *today*?
  3. Stern (2007): $\sim$ 900'000 €
  4. Nordhaus (2018): $\sim$ 220'000 €

This lecture

How are losses and benefits distributed internationally?

- How do increased temperatures affect different countries (revisit damage function)?
- What would be the national effects of a global climate policy?
- How does this interact with economic development?

Local temperatures and GDP

- Higher temperatures have negative consequences for several important determinants of economic growth
  1. Agricultural productivity (if too hot)
  2. Mortality
  3. Physical performance
  4. Cognitive performance
  5. ...
- Microeconomic evidence!

Local temperatures and GDP

- Unclear if microeconomic results have aggregate macroeconomic effects
- Use international panel data to estimate the effect of higher temperature on GDP growth rates
- Show two recent papers:
    1. Dell et al. (2012): Temperature relevant only for poor countries
    2. Burke et al. (2015): Temperature relevant everywhere

Temperature and economic growth

Dell et al. (2012)

- Measures for every country the year-on-year change in the average temperature: $T_{i,t}$
- Assume a linear relationship between temperature changes and economic growth

$$g_{i,t} = c_i + c_t + \rho T_{i,t} + \varepsilon_{i,t}$$

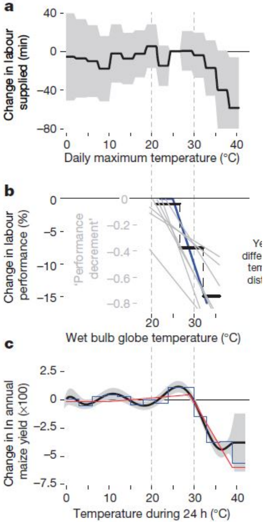
- Find that the effect is small and statistically insignificant
- **BUT**: it is significant for poor countries
- A 1℃ increase in temperatures leads to 1.3% slower growth
- Conclusions:
  1. poor countries will suffer most from temperature increase
  2. development and economic convergence harder to achieve

Critique towards Dell et al. (2012)

- Do we really care about the effect of temperature changes?
- Negative temperature effects may only kick in when it is hot

Negative temperature effects only at higher temperatures

Burke et al. (2015)

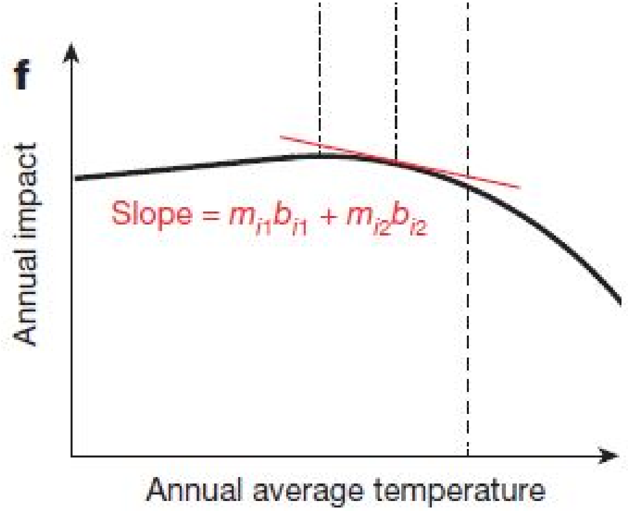


Temperature and economic growth

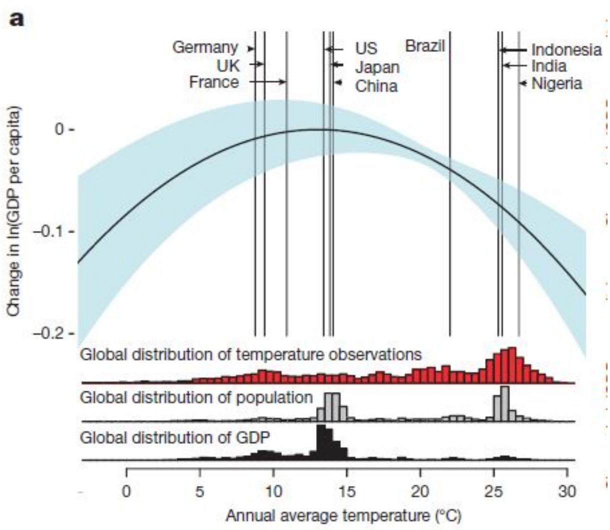
Burke et al. (2015)

- World distribution of temperatures
  1. Rich countries mostly have temperate climate
  2. Many poor countries are hot
  3. Maybe, Dell et al. (2012) have only picked up part of the story?
- Approach: estimate a nonlinear relationship between contemporaneous temperature levels and economic growth

Missing result for rich countries bad estimation?



Non-linear economic losses from climate change

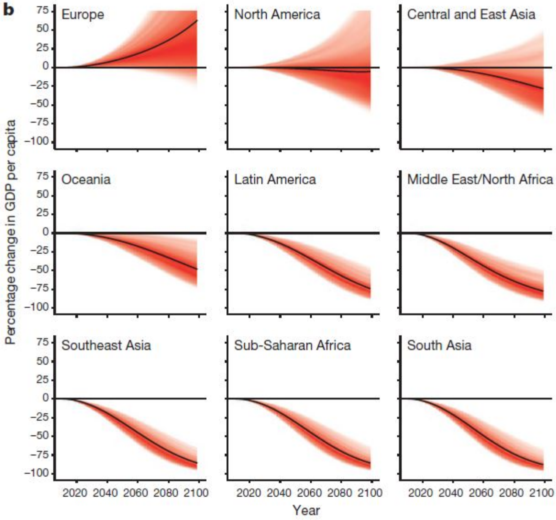


Temperature and economic growth

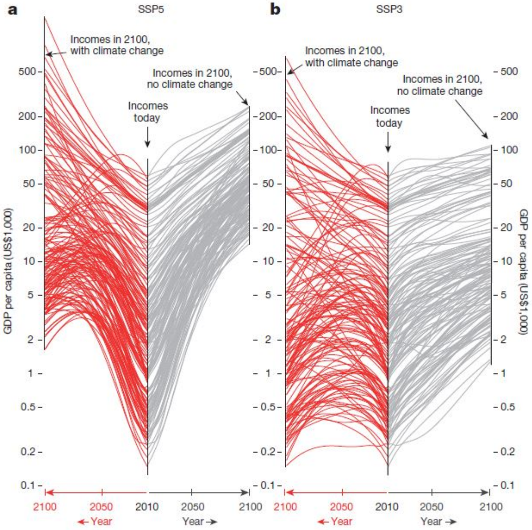
Burke et al. (2015)

- “Optimal” temperature at around 15 ℃
- Poor countries experience slower growth because they are in hotter regions
- Some rich countries would (in this specification) benefit from global warming

Isn't this all uncertain?



Economic convergence is seriously affected!



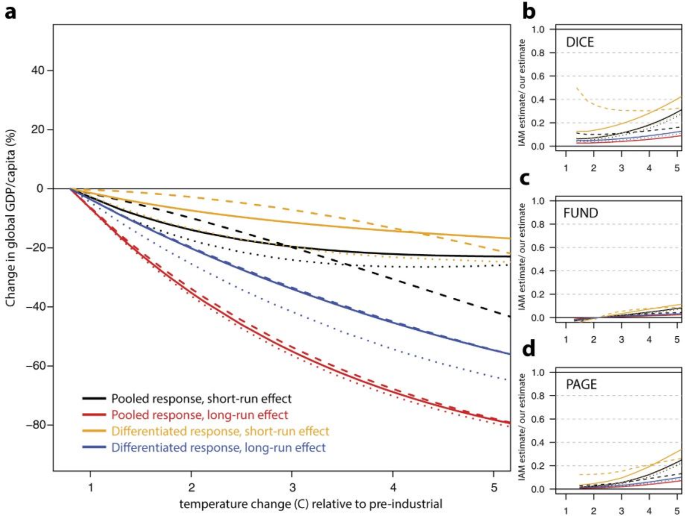
Temperature and economic growth: robustness

Burke et al. (2015)

- No differentiation between rich and poor countries necessary $\longrightarrow$ climate affects everyone
- The time window does not matter $\longrightarrow$ extrapolation more convincing
- Estimation provides a lower bound on damages
  1. Long-run damages of temperature increases are higher
  2. Missing elements: non-temperature damages from climate change
     - Rising sea levels
     - Increasing frequency of natural catastrophes

Comparison to damage functions in IAM models

Findings from Tuesday are too low!



What have we learned so far?

- Due to their location in hot regions, poor countries face higher risk than rich countries
- Uncertainty is mostly large in regions with potentially positive effects
- Baseline result is robust and – if anything – understates future damages
- Economic convergence and development in poor regions may be seriously at risk
- Carbon price of Nordhaus (2018) may be much too low

Carbon prices: who has to pay?

- Suppose a global carbon price of 10€(much too low)
- With emissions of around 35 billion tons: 350 billion €
    1. Who has to pay?
    2. Who gets the money?
- Net redistribution matters
- Suppose that the 350 billion € are divided by the world population (10 billion): everyone gets 35€
- Thus, we only have to talk about the first question

Carbon prices: who has to pay

- Simple payment schemes:
  1. Producers: every ton emitted costs 10€
  2. Consumers: every ton embedded in consumption costs 10€
  3. (Note: difference matters due to trade)
  4. Damages: Payments according to damage shares
- More elaborate payment schemes could take into account
  1. Income differences
  2. Past pollution (“historic right”)
  3. Bonus for positive externalities (CO2-saving inventions)
  4. ...

Payment proportional to damages

What should we expect?

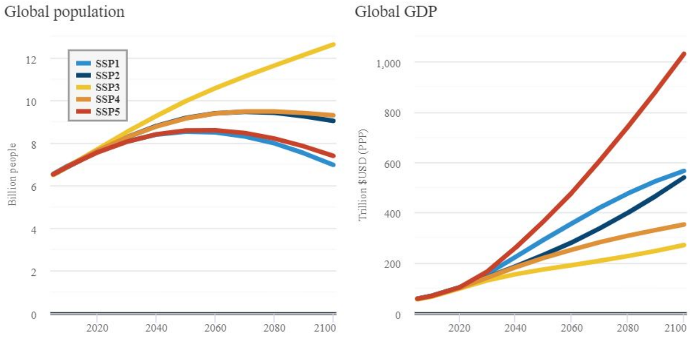
- Damages are unequally distributed across the world
  1. India: high potential damages
  2. Germany: low potential damages
- (People in) India should have a stronger incentive to avoid climate change
- Consequence:
  1. They should also contribute more
  2. In the extreme: India should be willing to pay Germany to avoid pollution

A model for country-specific social costs of carbon

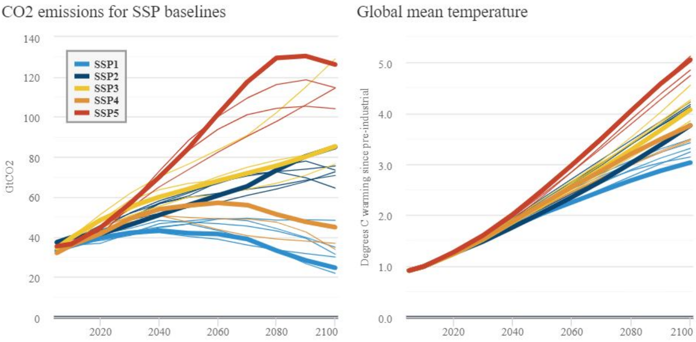
Ricke et al. (2018)

- Use Shared Socioeconomic Pathways (SSP) for different scenarios of future GDP development
  1. SSP1: Sustainability (“Taking the Green Road”)
  2. **SSP2: Middle of the Road (“Business as Usual”)**
  3. SSP3: Regional Rivalry (“The Rocky Road”)
  4. SSP4: Inequality (“A Road Divided”)
  5. SSP5: Fossil-fueled development (“Taking the Highway”)

Shared Socioeconomic Pathways



Shared Socioeconomic Pathways

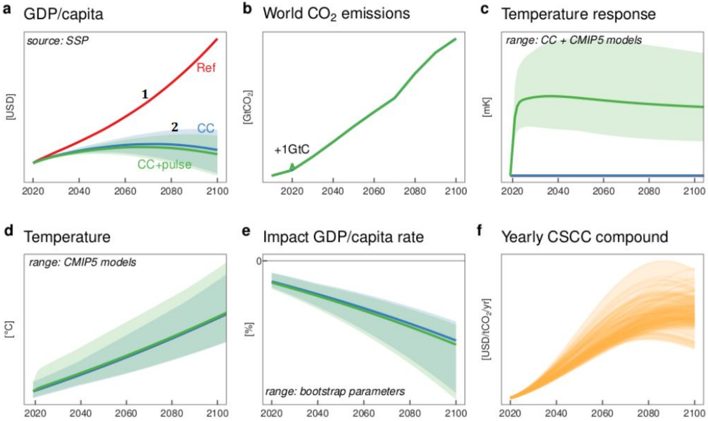


A model for country-specific social costs of carbon

Ricke et al. (2018)

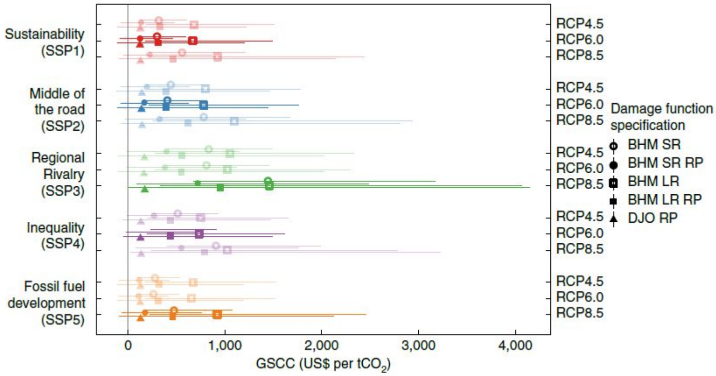
- Use Shared Socioeconomic Pathways (SSP) for different scenarios of future GDP development
- Match to Representative Concentration Pathways (RCP) for temperature responses
- **Short-run** damage estimates from Burke et al. (2015)
- Carbon price / social cost of carbon (SCC): discount damages using $\delta = 2\%$
- **Problem:**
  1. no feedback of high carbon prices on socioeconomic pathways (other than SSP1)
  2. Question answered: what are the (social) costs of not acting?
  3. Relevant question: what are the costs **and** the actions?

A model for country-specific social costs of carbon



The global price of carbon (GSCC)

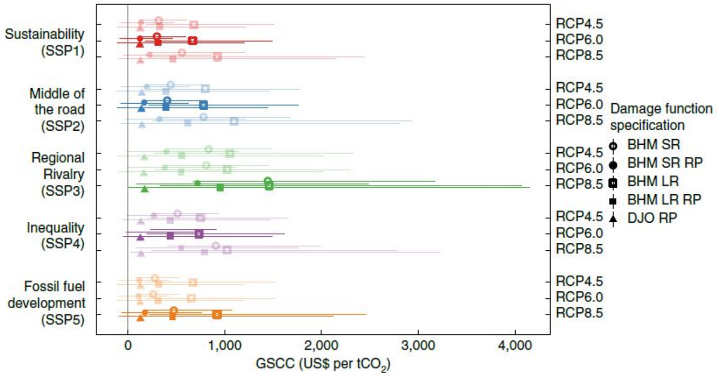
Ricke et al. (2018)



Nordhaus (2018) (Tuesday): 35-230, with feedback effects

The global price of carbon (GSCC)

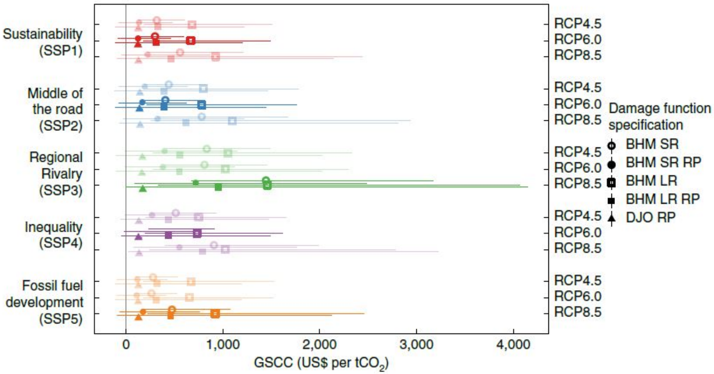
Ricke et al. (2018)



Nonlinearity of damages has huge impacts, but also implies high uncertainty

The global price of carbon (GSCC)

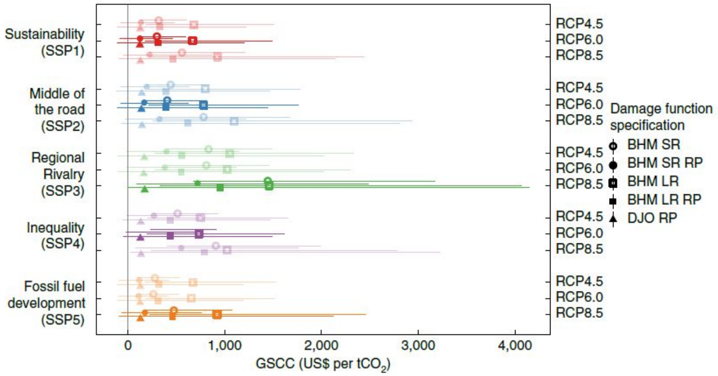
Ricke et al. (2018)



SSP3: we need cooperation!

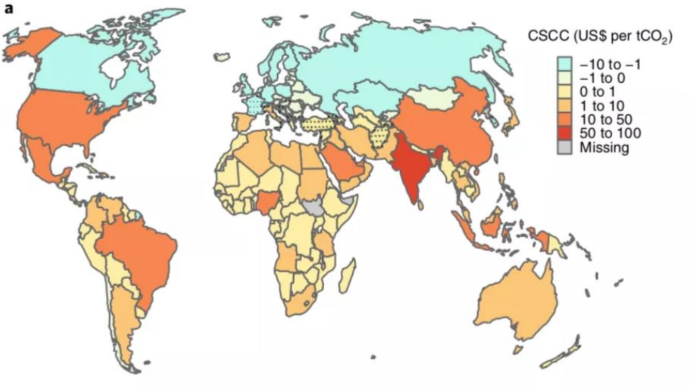
The global price of carbon (GSCC)

Ricke et al. (2018)



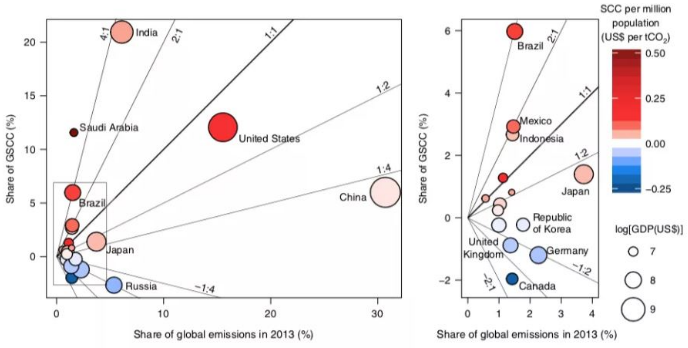
SSP5: “Inventing our way out of the problem” may not work well

Social cost of carbon by country



The social cost of carbon for individual countries in dollars per ton of carbon dioxide emissions. | Nature Climate Change

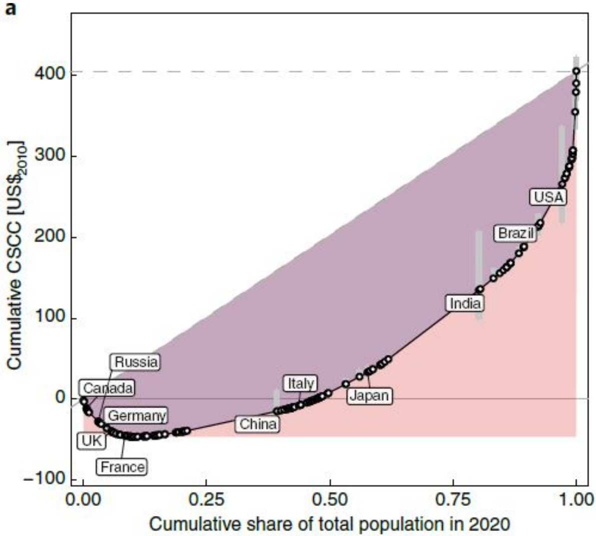
Social cost of carbon: relation to emissions



A figure comparing the social cost of carbon within a country to its share of global emissions. | Nature Climate Change

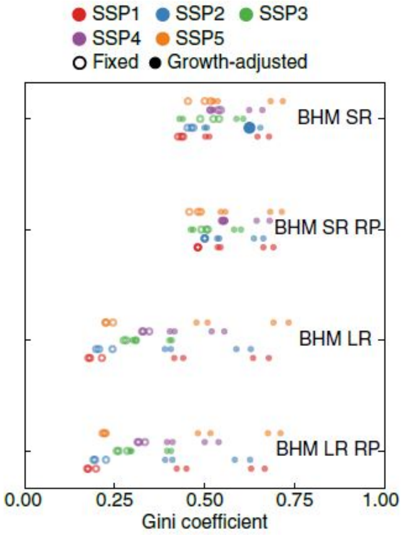
Social cost of carbon: highly unequal across the world

Lorenz curve



Social cost of carbon: highly unequal across the world

Gini coefficient



Social costs of carbon

Points of critique

- Results **overstate** true problem: no feedback effects of high social costs
  1. Recommendation: Social costs should be reflected in carbon prices
  2. High carbon prices change behavior
     - Carbon-saving technologies
     - Avoiding travels
     - ...
- Results **understate** true problem: damages do not contain natural catastrophes, rising sea levels,...
- Results **understate** true problem: discount rate too high (see Tuesday)

International distribution of damages

- Damages and social costs of carbon are highly unequally distributed across the world
- Especially poor countries are negatively affected
- Climate change puts a heavy burden on economic development
- Implication: it is hard to fight global inequality and climate change at the same time!
- Social costs of carbon are very uncertain, and may have a bias

Taxes or certificates?

- Argument pro certificates (Tuesday) holds even more
  1. We want to regulate the quantity of CO_2 emissions
  2. We are too unsure about the “correct” price to set a tax

- Not discussed: uncertainty about the maximum quantity of CO_2 emissions
  1. Uncertainty how CO_2 emissions translate to temperature increases
  2. Uncertainty about the temperature increase we are willing to accept
- **BUT:** the uncertainty on quantities translates into price uncertainties

References I

Burke, M., Hsiang, S. M. and Miguel, E. (2015). Global non-linear effect of temperature on economic production, *Nature* **527**(7577): 235.

Coase, R. H. (1960). The problem of social cost, *Classic papers in natural resource economics*, Springer, pp. 87–137.

Dasgupta, P. (2010). The place of nature in economic development, *Handbook of development economics*, Vol. 5, Elsevier, pp. 4977–5046.

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**(3): 66–95.

Jordà, Ò., Knoll, K., Kuvshinov, D., Schularick, M. and Taylor, A. M. (2019). The rate of return on everything, 1870–2015, *The Quarterly Journal of Economics* **134**(3): 1225–1298.

Nordhaus, W. (2018). Projections and uncertainties about climate change in an era of minimal climate policies, *American Economic Journal: Economic Policy* **10**(3): 333–60.

References II

Nordhaus, W. D. (2007). A review of the stern review on the economics of climate change, *Journal of economic literature* **45**(3): 686–702.

Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M. (2018). Country-level social cost of carbon, *Nature Climate Change* **8**(10): 895.

Stern, N. H. (2007). *The economics of climate change: the Stern review*, Cambridge University Press.