Pigouvian Taxes and the Social Cost of Carbon

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Lecture Overview

- Last class we learned markets will be inefficient when there are externalities. Today we discuss economists' solution to this problem: Pigouvian taxes.
- We will then discuss ongoing efforts to estimate the social cost of carbon, which is the basis for a Pigouvian tax on carbon emissions.

Piguovian Taxes

The power of taxation: Pigou (1920)

- Negative externalities mean that the price firms are willing to accept to supply oil is too low (it excludes social marginal costs)
- Pigou (1932) proposed that the situation could thus be remedied by taxing the good at a rate equal to the **marginal external cost**
- This would cause the firm to "internalize" the external cost, making the private marginal cost curve equivalent to the social marginal cost curve
- Pigou reasoned that markets would then achieve the socially optimal outcome

Oil market example

- Ignore market power for a minute.
- Assume that the competitive price of oil is \$50/bbl
- Imagine that the full external costs of one barrel of oil are \$10/bbl.
- You should be able to graph the DWL from this outcome (and also understand where it comes from conceptually)

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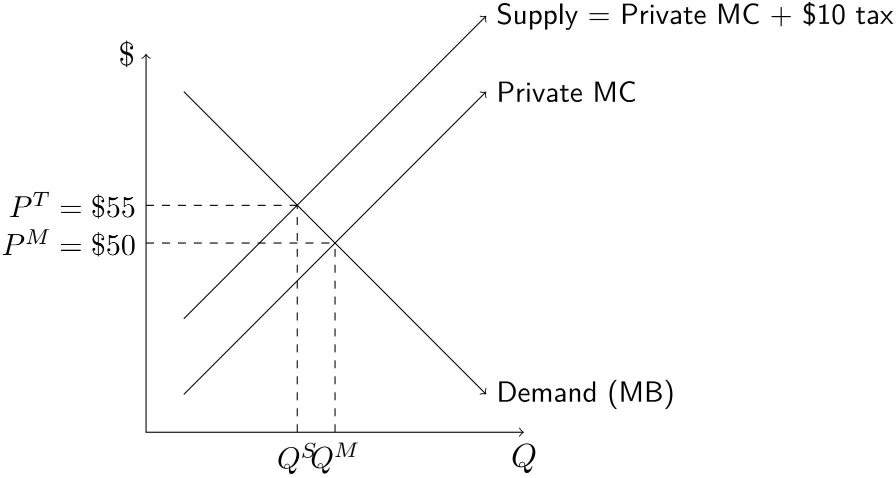
Now add a \$10 dollar tax to the price of oil

- This shifts the **private MC curve** upward so that it is now equivalent to the **social MC curve**.
  - Now when Exxon considers producing one more barrel of oil, it will take into account the full social cost of that barrel of oil.

Once the tax is imposed, the market will be efficient



Note: Here price increase only $5. We will discuss why next week.

Some notes on the Pigouvian solution

- Assuming we have the correct marginal external cost, Pigouvian taxes yield the efficient outcome.
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- Assuming we have the correct marginal external cost, Pigouvian taxes yield the efficient outcome.
- Is oil consumption eliminated?
- Piguovian taxes remove **inefficient** externality generating activities, but do not eliminate all externalities.
- Which barrels of oil are still consumed? Cases where MB - MC is very large.
- Which get eliminated? Situations where consumption wasn't *that* valuable to begin with.
- This is a key benefit of Pigouvian taxes over more perscriptive, non-economic environmental policy (bans, etc)
- See Catie Hausman swear jar video.

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No.

- For the barrels of oil still consumed, they still cause real harm to people who aren't involved.
- But, if we got the tax right, this harm is now "worth it" to the people who are consuming and producing the oil.
  - Ie the gains to those parties are large enough that they *could* compensate the harmed parties and still be better off.
- Importantly, the harmed parties are typically not actually compensated.... This would require additional policy.

How do we set the right Pigouvian tax?

- Pigouvian tax should include the full social cost of adding one more unit of pollution, in dollars, summed across all affected parties.
- This is difficult to do in general.
- We'll talk through a particularly challenging and important case: climate change.

Climate Change

A very brief primer on climate change

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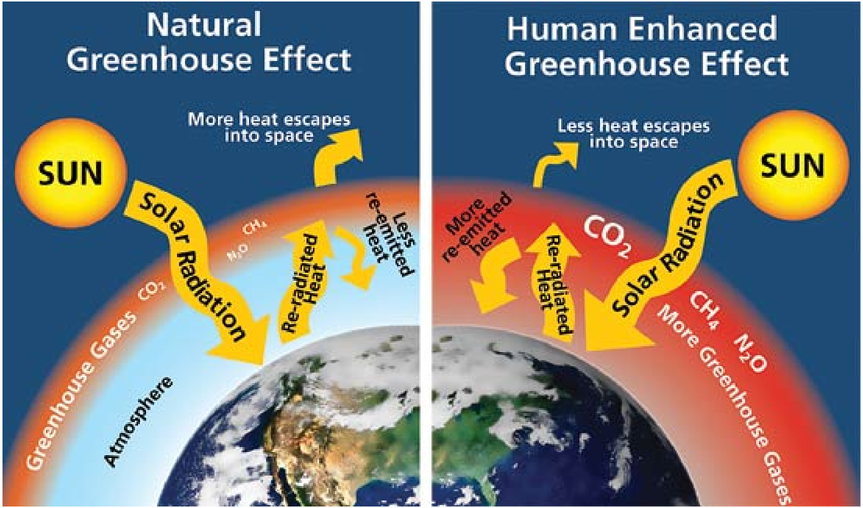
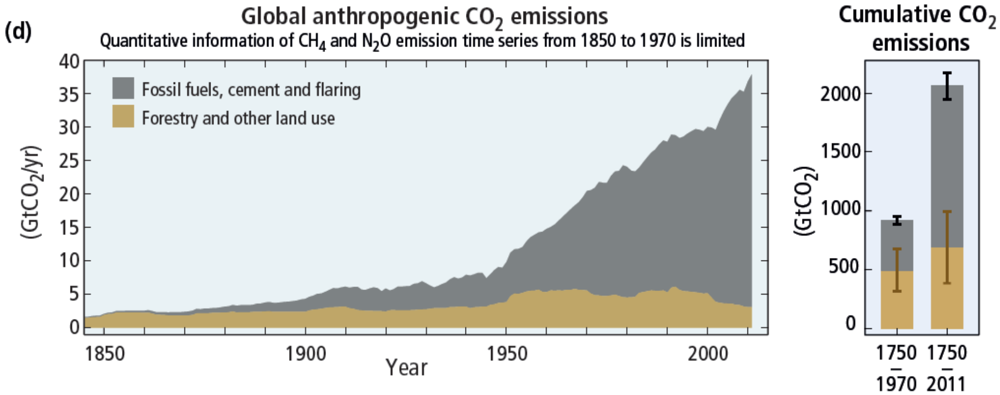
- How many people have talked about climate change in another class?
- We're going to accept the scientific consensus that climate change is real, and that it is caused by human activity. I will very briefly summarize that next.
- For more intro on the science, check out this IPCC Infographic and the links therein

The greenhouse effect makes the earth habitable

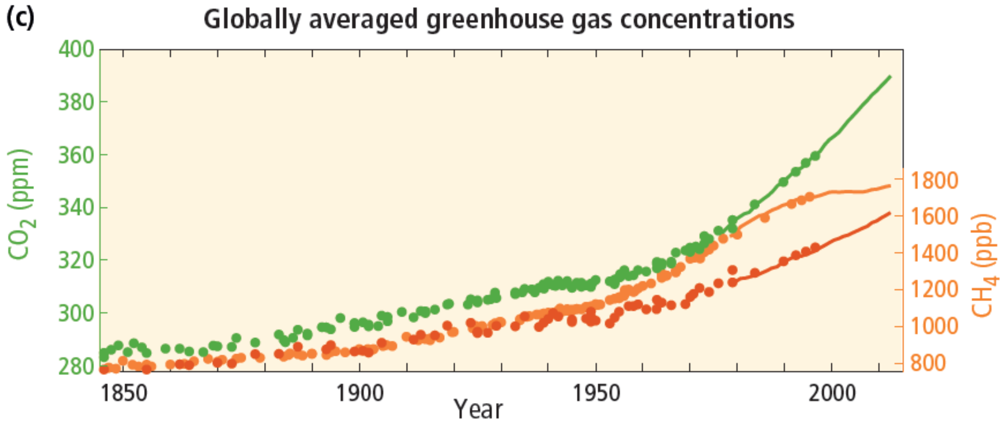


Source

Humans took a lot of previously sequestered carbon and put it in the atmosphere

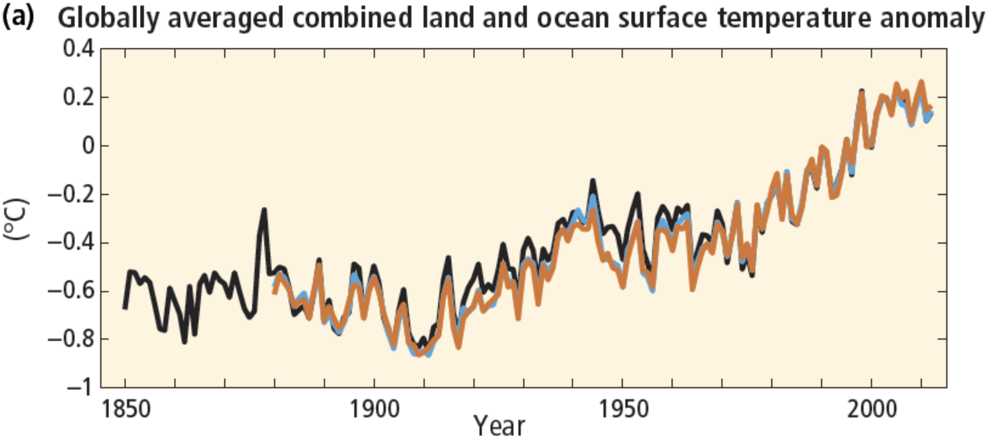


Caused a dramatic increase in the GHG *stock*



Carbon dioxide remains in the atmosphere for hundreds of years.

Temperature has risen with this stock



Global combined land and ocean surface temperature anomalies relative to the average from 1986 to 2005. (IPCC 2014)

Climate change is "the mother of all externalities" (Stavins 2013)

- Energy in almost everything and most energy fossil based
- But it is also at the most problematic point in a two dimensional taxonomy of pollutants
  1. How pollution dissipates across space (local vs global)
  2. How pollution dissipates across time (flow vs stock)

Categorizing pollutants: Spatial dimension

- Some externalities only effect people very close to the source of pollution (**local** pollutants)
  - Example: Carbon monoxide
  - Relatively few people are affected, and they are easy to identify
- Others dissipate across space and affect many people
  - Example: Sulfur dioxide emissions from coal plants in Midwest caused acid rain in the Northeast and Canada

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GHGs are a **uniformly** mixing (global) pollutant

- GHGs dissipate and we all share the same atmosphere.
- **Implication:** When someone emits CO2 in Beijing, it has the same effect as if it were in Boston (and vice versa)

Categorizing pollutants: Temporal dimension

Are damages at a point in time t driven primarily by current emissions or earlier emissions?

- E_t = emissions of pollutant
- D_t = decay of pollutant
- S_t = stock of pollutant

$$S_t = S_0 + \sum_{i=1}^{t} E_i - \sum_{i=1}^{t} D_i$$

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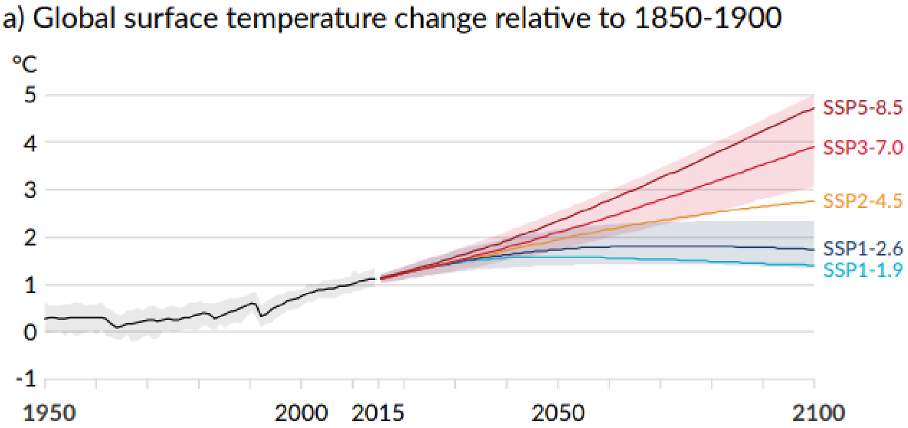
- Pure flow pollutant: $D_t = E_t$
  - noise
- Pure stock pollutant: $D_t = 0$
  - climate change

Even if we stop now, warming will remain



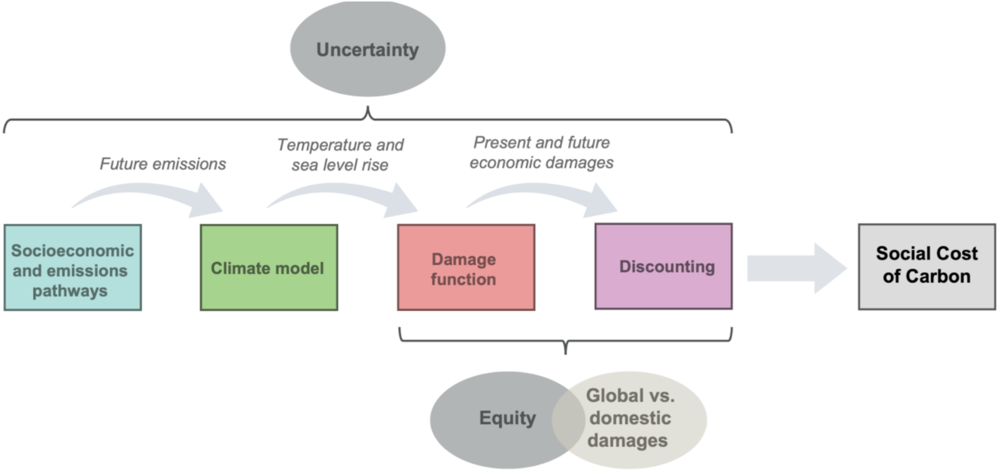
SSP1-1.9 – net zero emissions by 2050.
SSP2-4.5 – net zero by 2100.
(Useful description of scenarios here)

Social Cost of Carbon

In 2009 the US formed an inter-agency working group to come up with a social cost of carbon (SCC)

- Initial motivation: Cost-benefit analysis
  - US was considering a number of costly climate policies.
    - Fuel economy standards, renewable energy subsidies, etc.
  - In order to see if these policies were worth it, we needed to know how much the benefits of reducing CO2 emissions were worth in dollars.
- If done properly, this would also give us the efficient Pigouvian tax on CO2 emissions.
  - Need to compute the **marginal damages** of CO2 emissions, summed across all affected parties, in dollars.

Four key steps in calculating SCC



Carelton & Greenstone 2022

Mapping Temperature to Damages

- Let's assume science can tell us how much temperature will change as a function of emissions
  - i.e., every 1000 tons of CO2 emitted increases temperature by 0.1 degrees
- What are the ways that temperature change will impact people?

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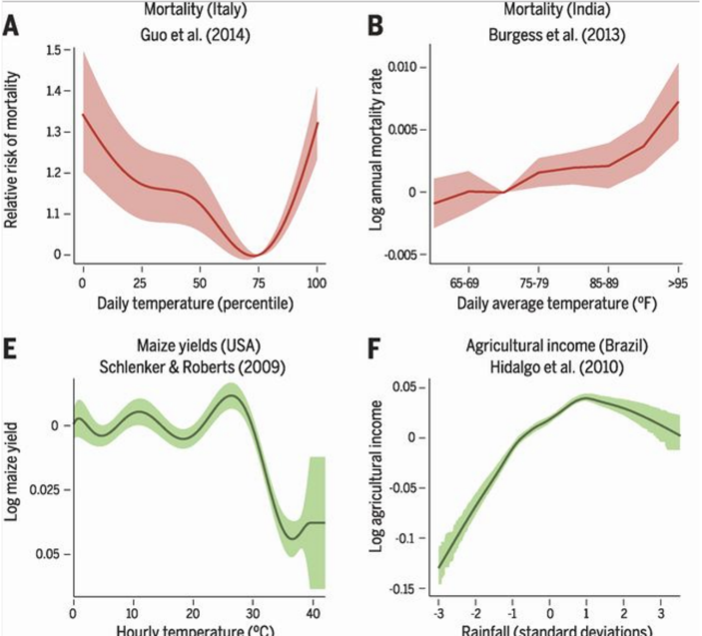
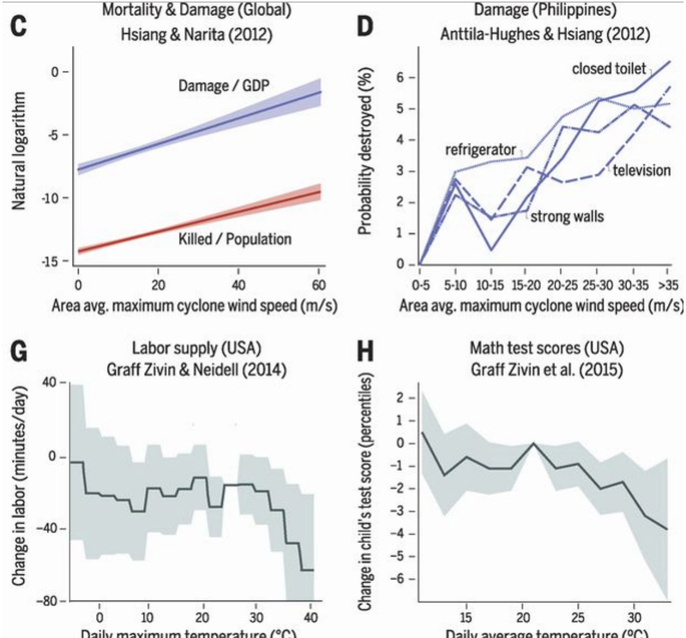
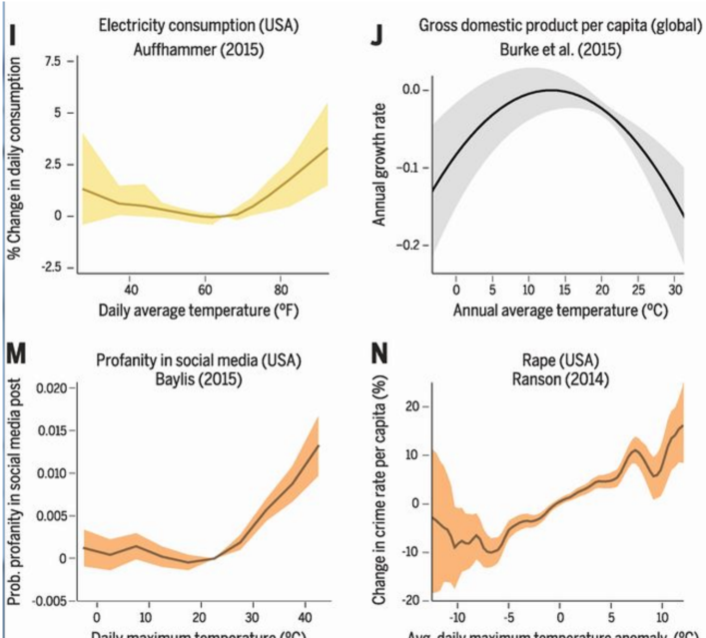
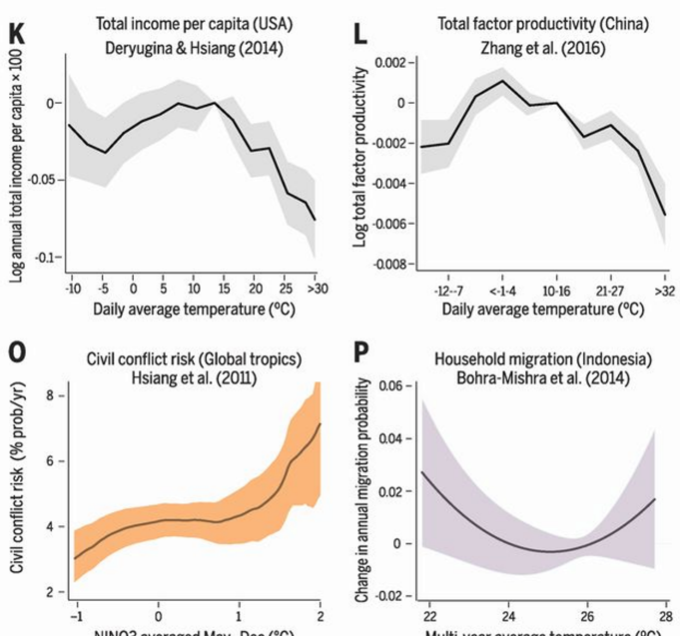
There is a growing body of evidence showing wide ranging effects of climate change (in many different MICRO contexts)

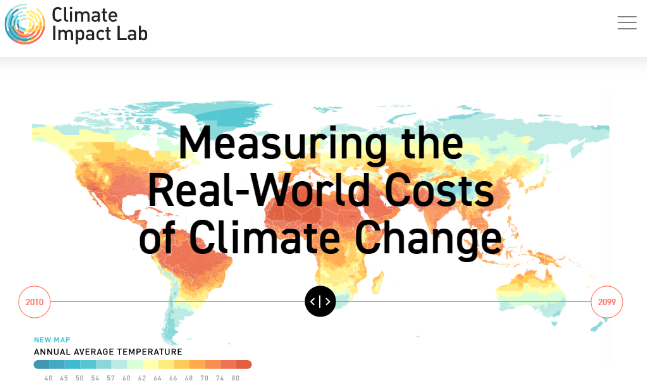

A
Mortality (Italy)
Guo et al. (2014)
Relative risk of mortality
Daily temperature (percentile)
B
Mortality (India)
Burgess et al. (2013)
Log annual mortality rate
Daily average temperature (°F)
E
Maize yields (USA)
Schlenker & Roberts (2009)
Log maize yield
Hourly temperature (°C)
F
Agricultural income (Brazil)
Hidalgo et al. (2010)
Log agricultural income
Rainfall (standard deviations)


C
Mortality & Damage (Global)
Hsiang & Narita (2012)
Natural logarithm
Damage / GDP
Killed / Population
Area avg. maximum cyclone wind speed (m/s)
D
Damage (Philippines)
Anttila-Hughes & Hsiang (2012)
Probability destroyed (%)
closed toilet
refrigerator
television
strong walls
0-5
5-10
10-15
15-20
20-25
25-30
30-35
>35
Area avg. maximum cyclone wind speed (m/s)
G
Labor supply (USA)
Graff Zivin & Neidell (2014)
Change in labor (minutes/day)
Daily maximum temperature (°C)
H
Math test scores (USA)
Graff Zivin et al. (2015)
Change in child's test score (percentiles)
Daily average temperature (°C)


I
Electricity consumption (USA)
Auffhammer (2015)
% Change in daily consumption
Daily average temperature (°F)
J
Gross domestic product per capita (global)
Burke et al. (2015)
Annual growth rate
Annual average temperature (°C)
M
Profanity in social media (USA)
Baylis (2015)
Prob. profanity in social media post
N
Rape (USA)
Ranson (2014)
Change in crime rate per capita (%)

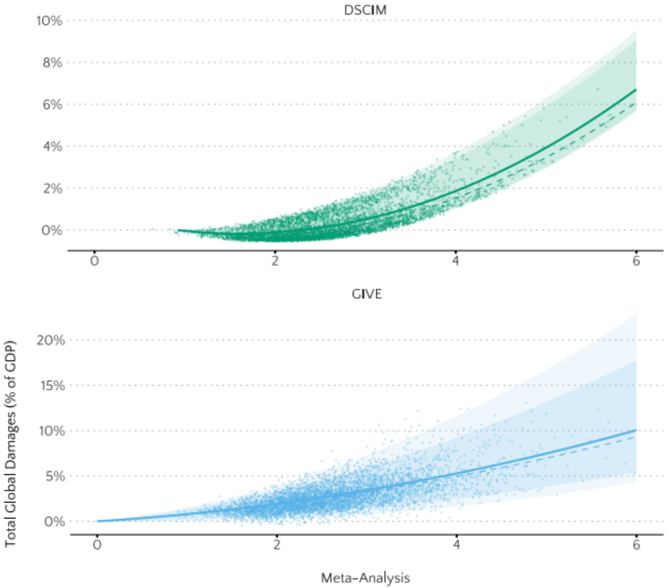

K
Total income per capita (USA)
Deryugina & Hsiang (2014)
Log annual total income per capita × 100
0
-0.05
-0.1
-10 -5 0 5 10 15 20 25 >30
Daily average temperature (°C)
L
Total factor productivity (China)
Zhang et al. (2016)
Log total factor productivity
0.002
0
-0.002
-0.004
-0.006
-0.008
-12--7 <-1-4 10-16 21-27 >32
Daily average temperature (°C)
O
Civil conflict risk (Global tropics)
Hsiang et al. (2011)
Civil conflict risk (% prob/yr)
8
6
4
2
-1 0 1 2
P
Household migration (Indonesia)
Bohra-Mishra et al. (2014)
Change in annual migration probability
0.06
0.04
0.02
0
-0.02
22 24 26 28

Challenge is to combine all these micro estimates into one global damage calculation



For now, IAMs rely on crude, black box functions translating temperature changes to dollars.

Figure 2.3.2: Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Mean Surface Temperature in the three Damage Modules



Discounting

Dealing with time

- The previous section described the damages from a temperature increase at some point in the future.
- Since benefits are in the future, but costs (taxes) need to be imposed today, we need to put future damages in present value terms.
- In economics, **discount rates** facilitate sensible inter-temporal comparisons.

Important question: What discount rate should we use?

Question: Would you prefer to receive \$10K today or \$10K one year from now?

(Ignore inflation and uncertainty about payment)

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- How about \$10K today or \$20K next year?
- How about \$10K today or \$15K next year, etc...?

What amount of money a year from now makes you indifferent between that and $10K today?

- take that future value (FV)
- divide by the present value (PV=10K)
- subtract 1 and call that number (r)

$$\frac{FV}{PV} - 1 = r$$

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- That number (r) is your consumption rate of interest, your "personal" discount rate (or one year)
- The larger r is, the more you need to be paid in the future to give up utility today.

What are some reasons to discount?

Why is your r > 0?

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Why is your r $>$ 0?

Some reasons:

- immediate gratification
- could invest it, or pay off debt (time value of money)
- expect to be wealthier in the future

Discount rates facilitate sensible inter-temporal comparisons

The future value of money invested presently at the rate, r, for t years:

$$FV = PV(1+r)^t$$

To get the present value of some future payment t years from now:

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When external costs C span many years (as in climate change), we need to compute the present value of damages across all future years

$$\text{Present Value} = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t}$$

What discount rate should we use?

- Conceptually, useful to think about opportunity cost of capital
- For personal investments?
  - if borrowing: borrowing rate ($\approx 5 - 35\%$)
  - if investing: rate of return (stock market $\approx 7\%$)
- What about businesses making an investment?
  - also their borrowing rate ($\approx 3 - 10\%$).
- Often we'll adjust for risk
  - MBAs sometimes use "hurdle rates" to do this

What discount rate should *the government* use?

- One school of thought is the market rate
  - for activities the private sector also undertakes, using a lower discount rate for the government would be inefficient
- The government can borrow at lower rates ($\approx 1 - 3\%$) **up to a point**
- When performing **Regulatory Impact Analysis** (RIA), the government typically provides cost-benefit calculations under both 3% and 7% discount rates.

Some projects warrant using a *social* discount rate

- Some projects involve actions fundamentally distinct from anything provided by the private sector.
- For example, when policy transfers utility to/ from people who are not even alive yet.
- Is there any reason to value people alive today more than people in the future?

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Conceptually, there are two reasons to discount across generations:

1. future generations will be better off
2. we value current generation more

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These yield discount rates between 0 and 9%!

Social Cost of Carbon by discount rate

Discount Rate (%)	Social Cost of Carbon (2025 US$ per Ton CO)
1.5%	$337
2.0%	$202
2.5%	$129
3.0%	$87

Source: RFF. Numbers converted to 2025 US$ using the US GDP deflator.

How big is \$200 per ton of CO2?

- Burning one gallon of gasoline produces .0089 tons of CO_2 (approx 20 pounds).
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- Global emissions are about 40 billion tons of CO_2 per year.
- Total global damages are about $40 \times 200 = \$8.0$ trillion per year.
- This is about 7.5% of global GDP.

Summary

- Markets are efficient when all costs and benefits are borne by the parties involved in the transaction. Externalities thus lead to market failure.
- Pigouvian taxes can restore efficiency, but do not eliminate all externalities.
- Climate change is a particularly challenging externality to price due to the many affected parties and long time scales involved.
  - Know the basic science of climate change, and the difference between local vs global and flow vs stock pollutants.
- In 2009 the US formed an inter-agency working group to come up with a social cost of carbon (SCC) for use in regulatory impact analysis.
  - A particularly challenging aspect of this is the choice of discount rate, which can dramatically change the SCC.
- Under the recently revised SCC, the US government estimates that the social cost of carbon is about \$200 per ton of CO_2.
- This implies a tax of about \$1.78 per gallon of gas, and global damages of about 7.5% of global GDP.