Externalities and Corrective Taxes

September 15, 2025

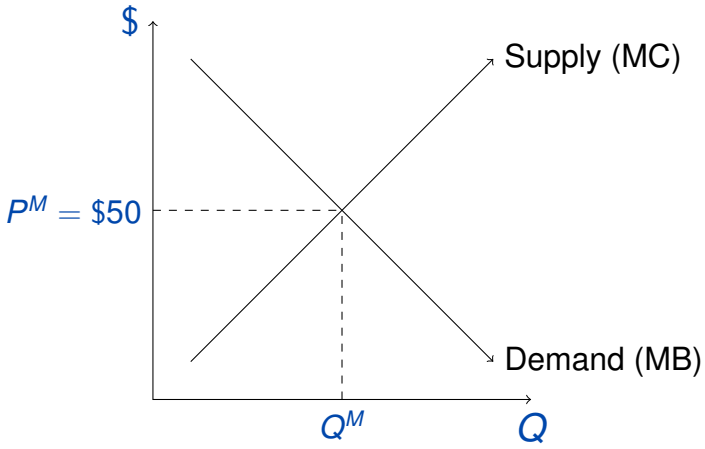
Outline

- When markets work
- Market failures from externalities
- Pigouvian Correction
- Social Cost of Carbon

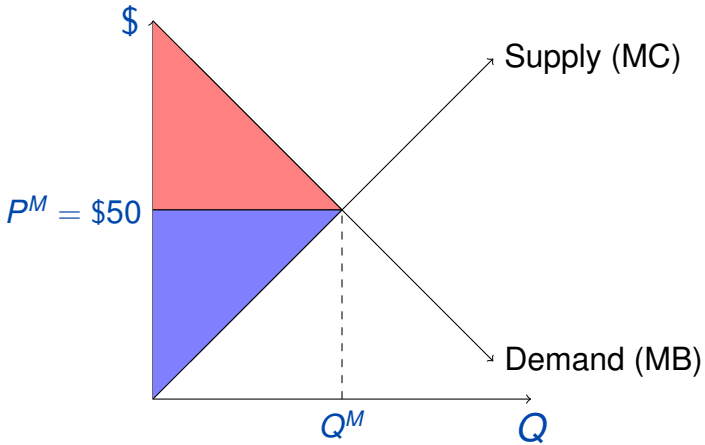
Markets & Market Failures

Logic of free exchange in a typical market

Market clears where Marginal Benefit = Marginal Cost. Why?



What are the net benefits from this equilibrium?



So this equilibrium maximizes private welfare.
What about social welfare?

Efficiency of markets

Efficiency requires social marginal benefits = social marginal cost

The market outcome will only be efficient when the following conditions are met:

1. Firms and consumers have perfect information about the quality of the good being traded
2. The market is competitive, meaning that firms and consumers take price as given
(*remember DWL from imperfect competition?)*

Efficiency of markets

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1. Firms and consumers have perfect information about the quality of the good being traded
2. The market is competitive, meaning that firms and consumers take price as given
(*remember DWL from imperfect competition?)*
3. **The market is complete, meaning that all the relevant costs and benefits are borne by the firms and consumers involved in the transactions.**

What if we look at the market for oil?

Oil is associated with many other **social** costs
List some of them?

Oil generates many externalities

An **externality** exists when the consumption or production choices of one person or firm enter the utility or production function of another entity without that entity's permission or compensation.

Some important externalities for oil:

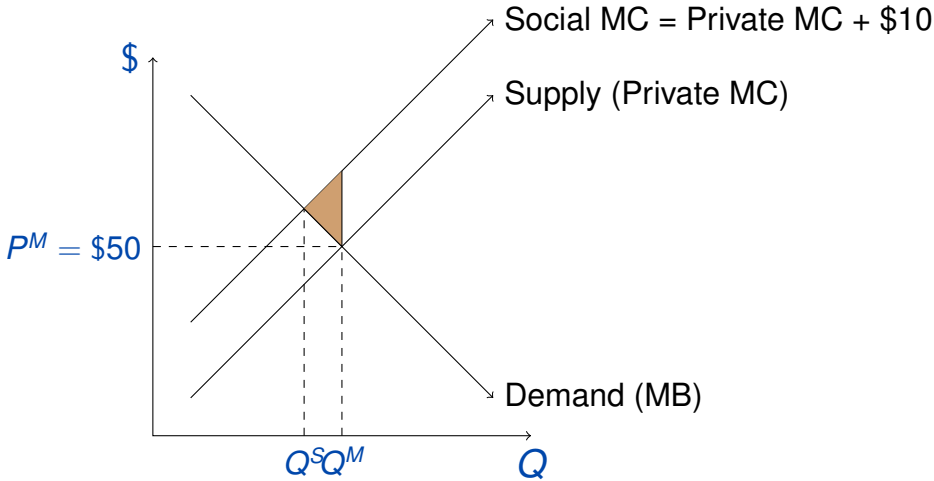
- Local air pollution
- Oil spills and other accidents
- Climate change
- National security

None of these are paid for by oil producers or consumers.

What is the socially efficient level of oil consumption?

Assume externalities of $10 per barrel.
Find Q^S. What is the market DWL?

Market outcome no longer maximizes welfare



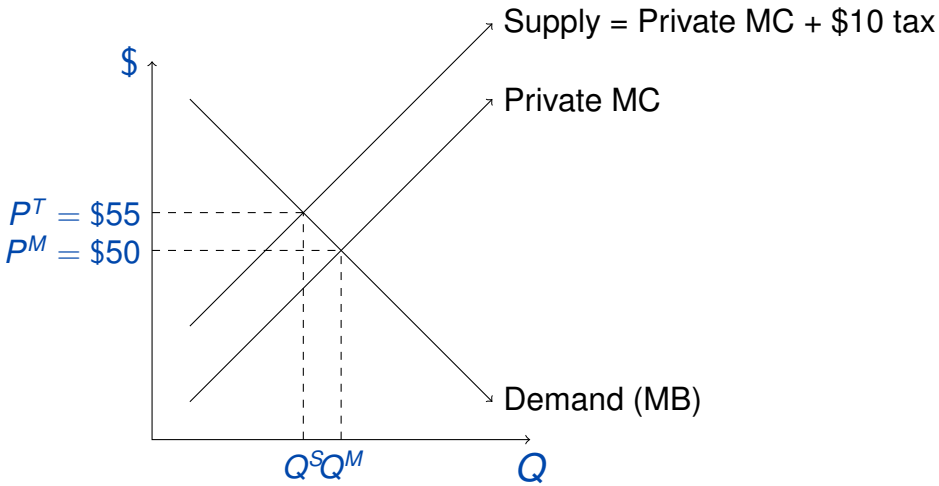
For exam, make sure you can identify externalities and describe / graph their corresponding DWL.

Pigou

Pigouvian Taxes

- 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

Pigouvian Taxes



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.
- Questions to think about:
  - Is oil consumption eliminated?
  - Are externalities from oil eliminated?

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- Assuming we have the correct marginal external cost, Pigouvian taxes yield the efficient outcome.
- Questions to think about:
  - Is oil consumption eliminated?
  - Are externalities from oil 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 example.

Setting the tax: Application to Climate Change

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.

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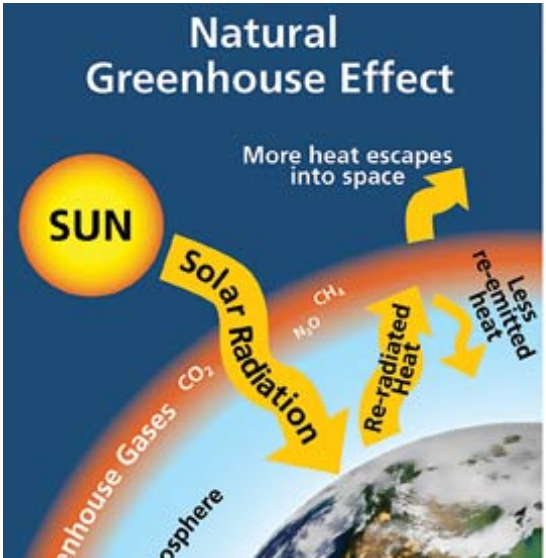
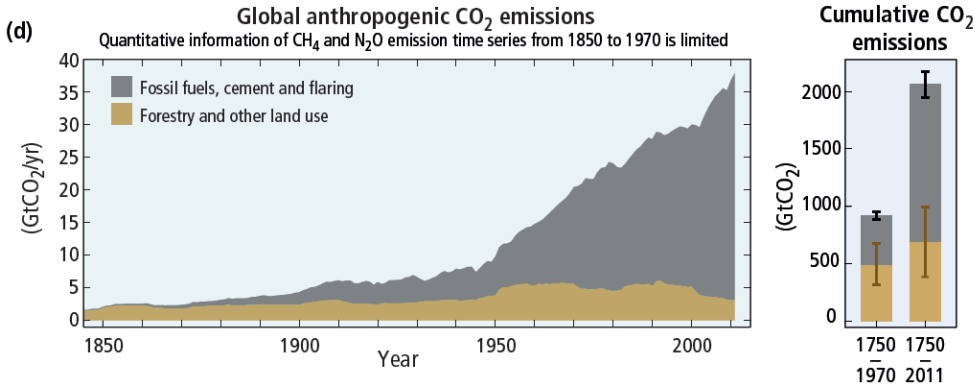
- Pigouvian tax should include the full social cost of adding one more unit of pollution, in dollars, summed across all affected parties.
- Climate change is “the mother of all externalities” Stavins (2013).
  - For more intro on the science, checkout the IPCC or “Why the global warming skeptics are wrong” by Nordhaus
- Several aspects make calculating the correct tax particularly challenging
  1. many affected parties and activities
  2. across many many years

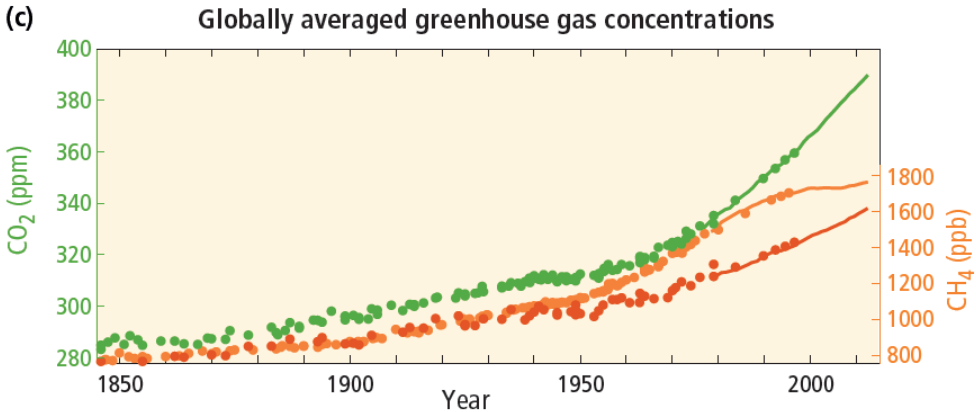
Temperature depends on the stock of greenhouse gases (GHGs) in atmosphere



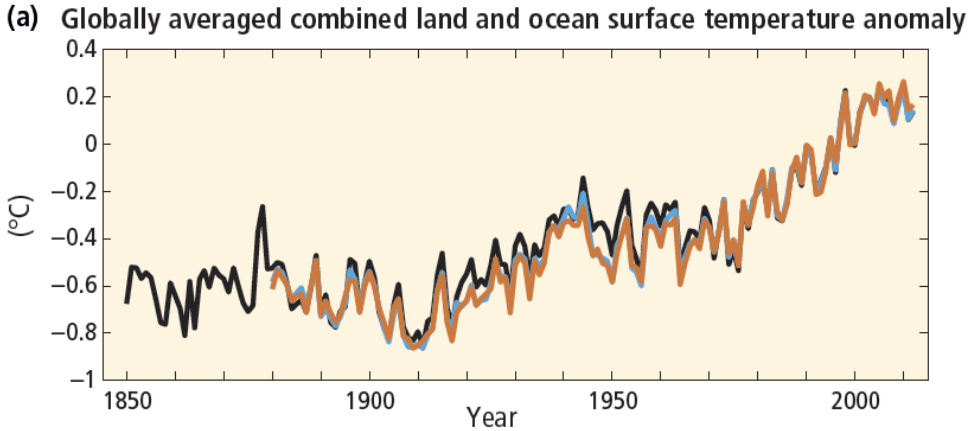
Humans took a lot of previously sequestered carbon and put it in the atmosphere



Caused a dramatic increase in the GHG *stock*

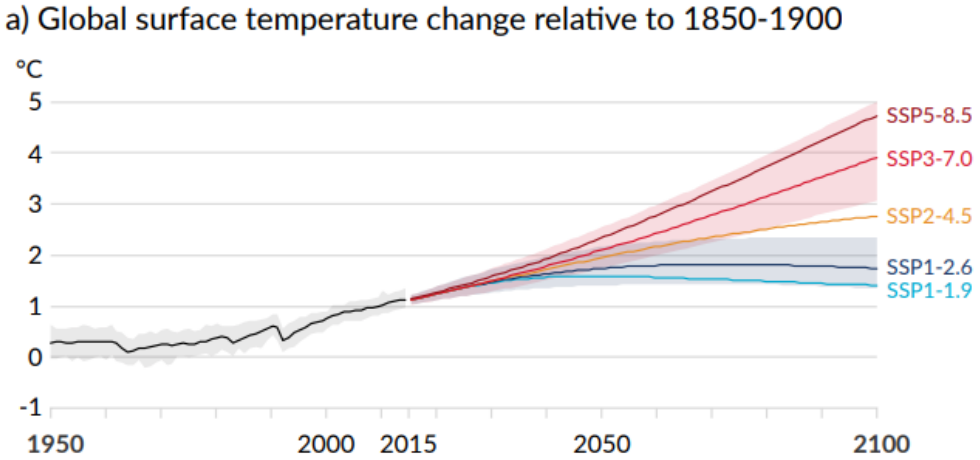


Temperature has risen with this stock



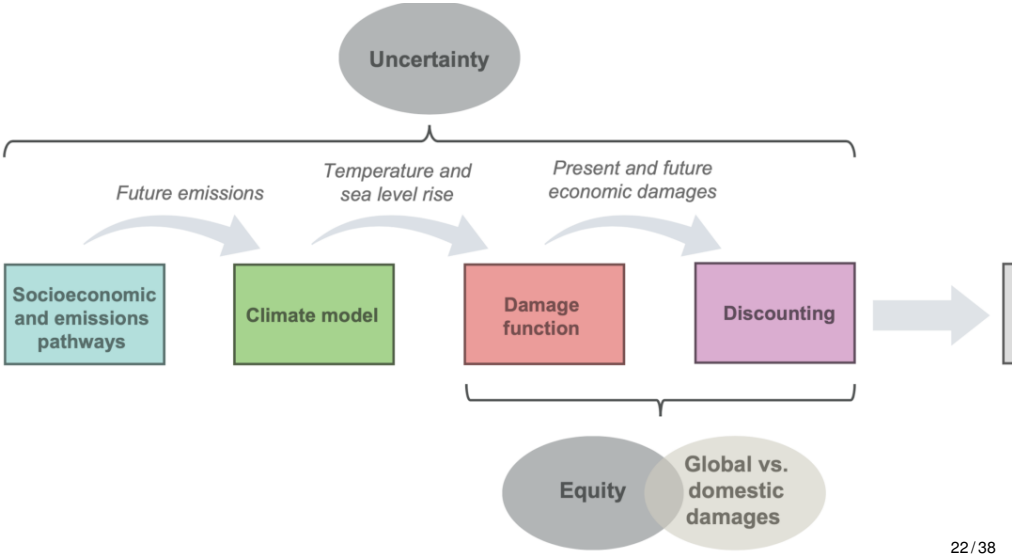
Global combined land and ocean surface temperature anomalies relative to the average from 1986 to 2005. (IPCC 2014)

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)

Four key steps in calculating SCC



Mapping Temperature to Damages

- Let's assume science can tell us how much temperature will change as a function of emissions
  - ie every 1000 tons of CO_2 emitted increases temperature by 0.1 degrees
- What are the ways that temperature change will impact people?

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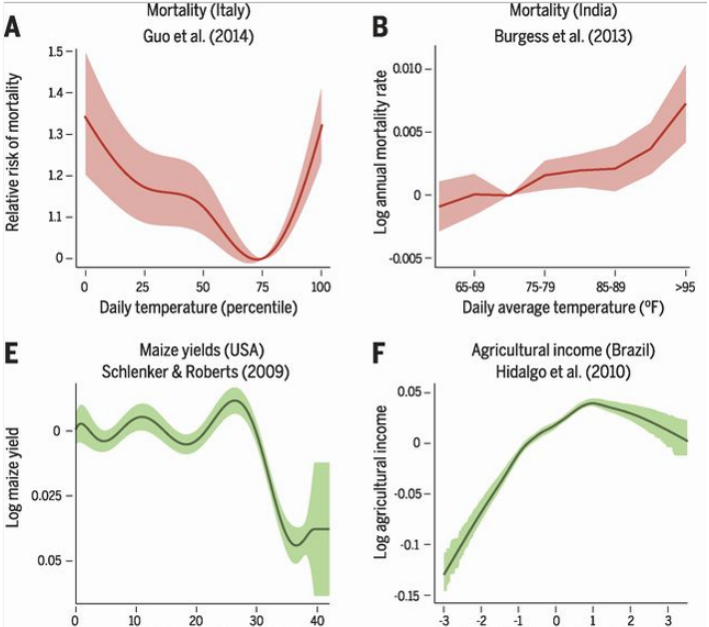
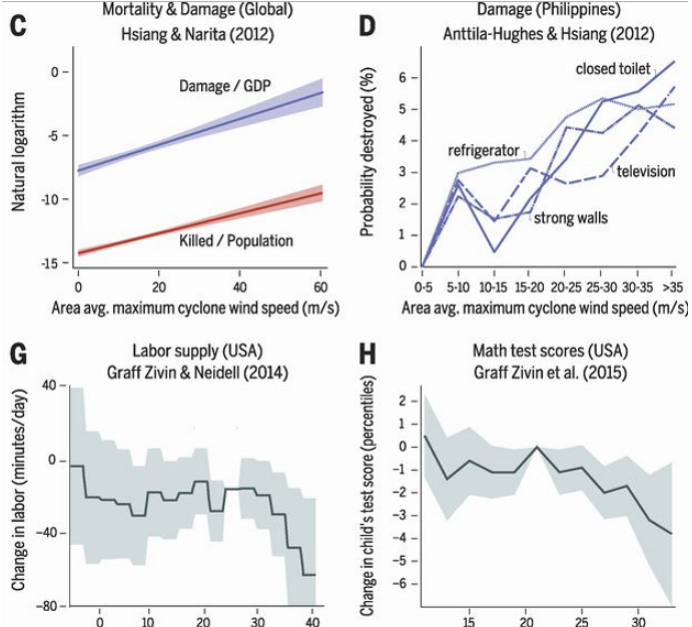
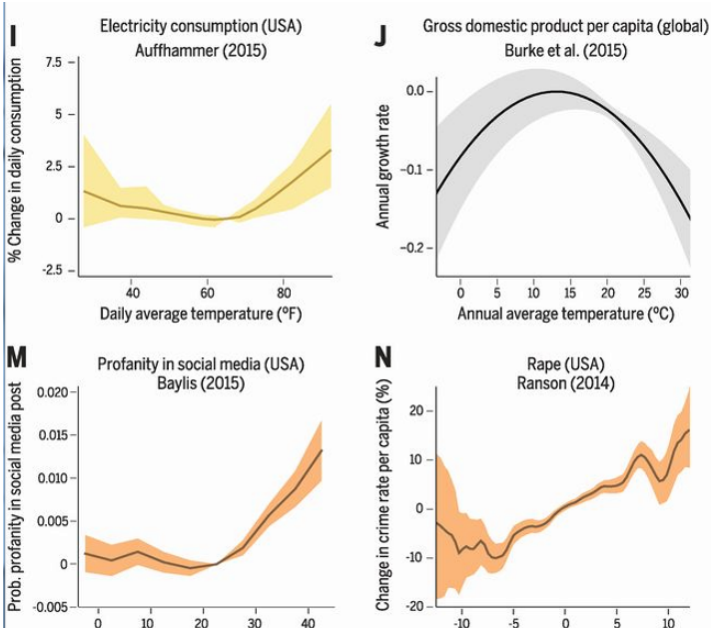
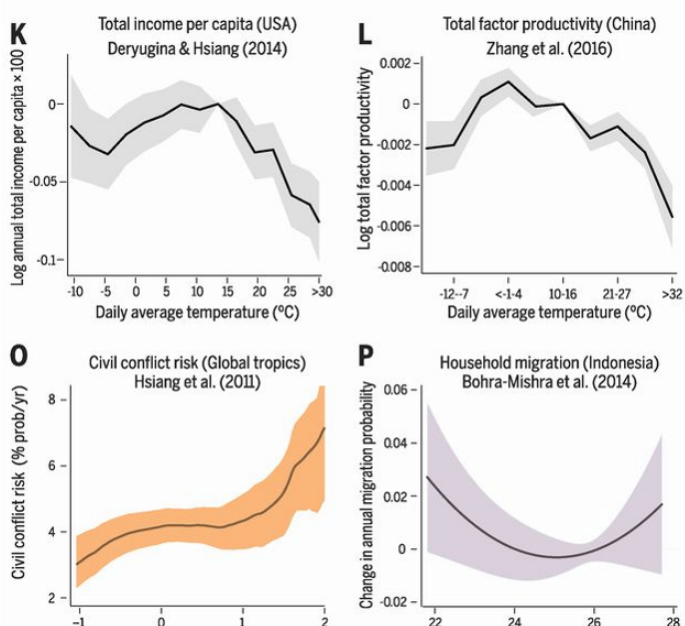
There is a growing body of evidence showing wide ranging effects of climate change (in many different MICRO contexts)

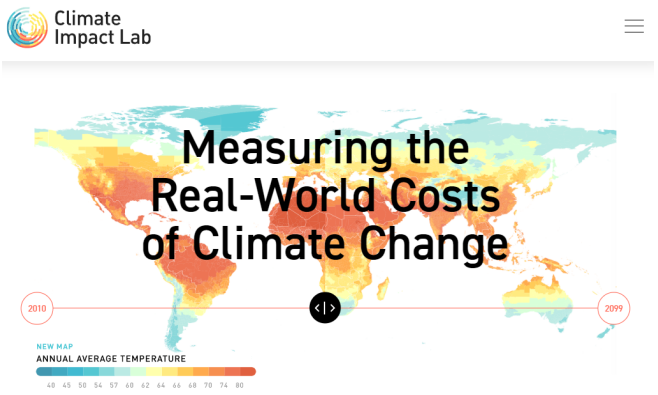

A
Mortality (Italy)
Guo et al. (2014)
Relative risk of mortality
1.5
1.4
1.3
1.2
1.1
0
0
25
50
75
100
Daily temperature (percentile)
B
Mortality (India)
Burgess et al. (2013)
Log annual mortality rate
0.010
0.005
0
-0.005
65-69
75-79
85-89
>95
Daily average temperature (°F)
E
Maize yields (USA)
Schlenker & Roberts (2009)
Log maize yield
0
0.025
0.05
0
10
20
30
40
F
Agricultural income (Brazil)
Hidalgo et al. (2010)
Log agricultural income
0.05
0
-0.05
-0.1
-0.15
-3
-2
-1
0
1
2
3


C
Mortality & Damage (Global)
Hsiang & Narita (2012)
Damage / GDP
Killed / Population
Natural logarithm
0
-5
-10
-15
0
20
40
60
Area avg. maximum cyclone wind speed (m/s)
D
Damage (Philippines)
Anttila-Hughes & Hsiang (2012)
closed toilet
refrigerator
television
strong walls
Probability destroyed (%)
0
1
2
3
4
5
6
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)
40
0
-40
-80
0
10
20
30
40
H
Math test scores (USA)
Graff Zivin et al. (2015)
Change in child's test score (percentiles)
2
1
0
-1
-2
-3
-4
-5
-6
15
20
25
30


I
Electricity consumption (USA)
Auffhammer (2015)
% Change in daily consumption
7.5
5
2.5
0
-2.5
40
60
80
Daily average temperature (°F)
J
Gross domestic product per capita (global)
Burke et al. (2015)
Annual growth rate
0.0
-0.1
-0.2
0
5
10
15
20
25
30
Annual average temperature (°C)
M
Profanity in social media (USA)
Baylis (2015)
Prob. profanity in social media post
0.020
0.015
0.010
0.005
0
-0.005
0
10
20
30
40
N
Rape (USA)
Ranson (2014)
Change in crime rate per capita (%)
20
10
0
-10
-20
-10
-5
0
5
10

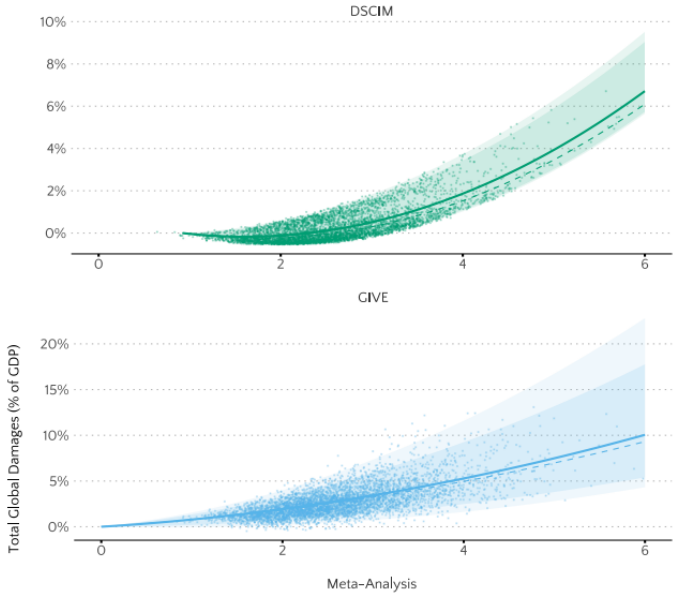

K
Total income per capita (USA)
Deryugina & Hsiang (2014)
Log annual total income per capita × 100
0
-0.05
-0.1
-10 -5 0 5 10 15 20 25 >30
Daily average temperature (°C)
L
Total factor productivity (China)
Zhang et al. (2016)
Log total factor productivity
0.002
0
-0.002
-0.004
-0.006
-0.008
-12--7 <-1-4 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

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

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

The cost of a stock pollutant is incurred over 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 need to be imposed in the today, we need to put future damages in present value terms.
- Discount rates facilitate sensible inter-temporal comparisons
- The future value (FV) of money invested now at rate, r, for t years:

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

- To get the present value (PV) of some payment t years from now:

$$PV = \frac{FV}{(1 + r)^t}$$

To compute the social cost of carbon, we need to compute the present value of damages across all future years

Present Value of future damages is the present value of the benefits (B) gained in year t from a 1 unit change in emissions today, summed across all years.

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

What discount rate to use?

- Two reasons to discount across generations:
  1. future generations will be better off
  2. we value current generation more
- Ramsey (1928) inter-generational discount rate formula:

$$r = \eta g + \rho$$

- Common assumptions yield discount rates between 0 and 9%!
- US OMB typically uses 3% or 7%
- Anything above 3% makes it hard to justify any abatement today

The Incredible Shrinking PV: The Influence of the Discount Rate

The choice of discount rate can have a surprisingly large effect on the present value (PV) of future costs or benefits, especially when those costs or benefits come many years in the future. The following table illustrates this point. For example, the PV of $1,000 received 100 years from now is $138 using a discount rate of 2 percent but barely more than a dollar using a discount rate of 7 percent.

Present value of $1,000

	T years from now			
Discount rate	$T = 10$	$T = 50$	$T = 100$	$T = 200$
1%	$905	$608	$370	$137
2%	$820	$372	$138	$19
3%	$744	$228	$52	$2.7
5%	$614	$87	$7.6	$0.06
7%	$508	$34	$1.2	$0.001
10%	$386	$8.5	$0.07	$0.00001

Social Cost of Carbon by discount rate

Discount Rate (%)	Social Cost of Carbon (US$ per Ton CO_2)
1.5%	$308
2.0%	$185
2.5%	$118
3.0%	$80

RFF

How big is \$185 per ton of CO_2?

- Burning one gallon of gasoline produces .0089 tons of CO_2 (approx 20 pounds).
- Pigouvian tax per gallon is $.0089 \times 185 = \$1.65$.

How big is \$185 per ton of CO_2?

- Burning one gallon of gasoline produces .0089 tons of CO_2 (approx 20 pounds).
- Pigouvian tax per gallon is $.0089 \times 185 = \$1.65$.
- Global emissions are about 40 billion tons of CO_2 per year.
- Total global damages are about $40 \times 185 = \$7.4$ trillion per year.
- This is about 7% 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.
- IAMs are used to estimate the social cost of carbon, which is currently estimated at about $185 per ton of CO_2.
- This implies a tax of about $1.65 per gallon of gas, and global damages of about 7% of global GDP.