Intermediate Microeconomics

Spring 2025

Week 10(a): Externality – empirical lecture

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Environmental Economics

- Idealistic response to dramatic change in environment: we should preserve environment in its original state, no matter the cost

- Environmental economists take a more practical perspective

  1. Tradeoff between economic benefits and environmental costs → need to price environmental damage

  2. Humans have adapted in the past (e.g., using air-conditioning), mitigating costs of environmental change

Environmental Economics

- Examples:
- building a new oil pipeline or permitting fracking for oil and gas
  - These policies could have significant benefits by reducing costs of resources and effectively increasing people's incomes
  - What is the environmental damage created by these policies?

Environmental Economics

- Examples:
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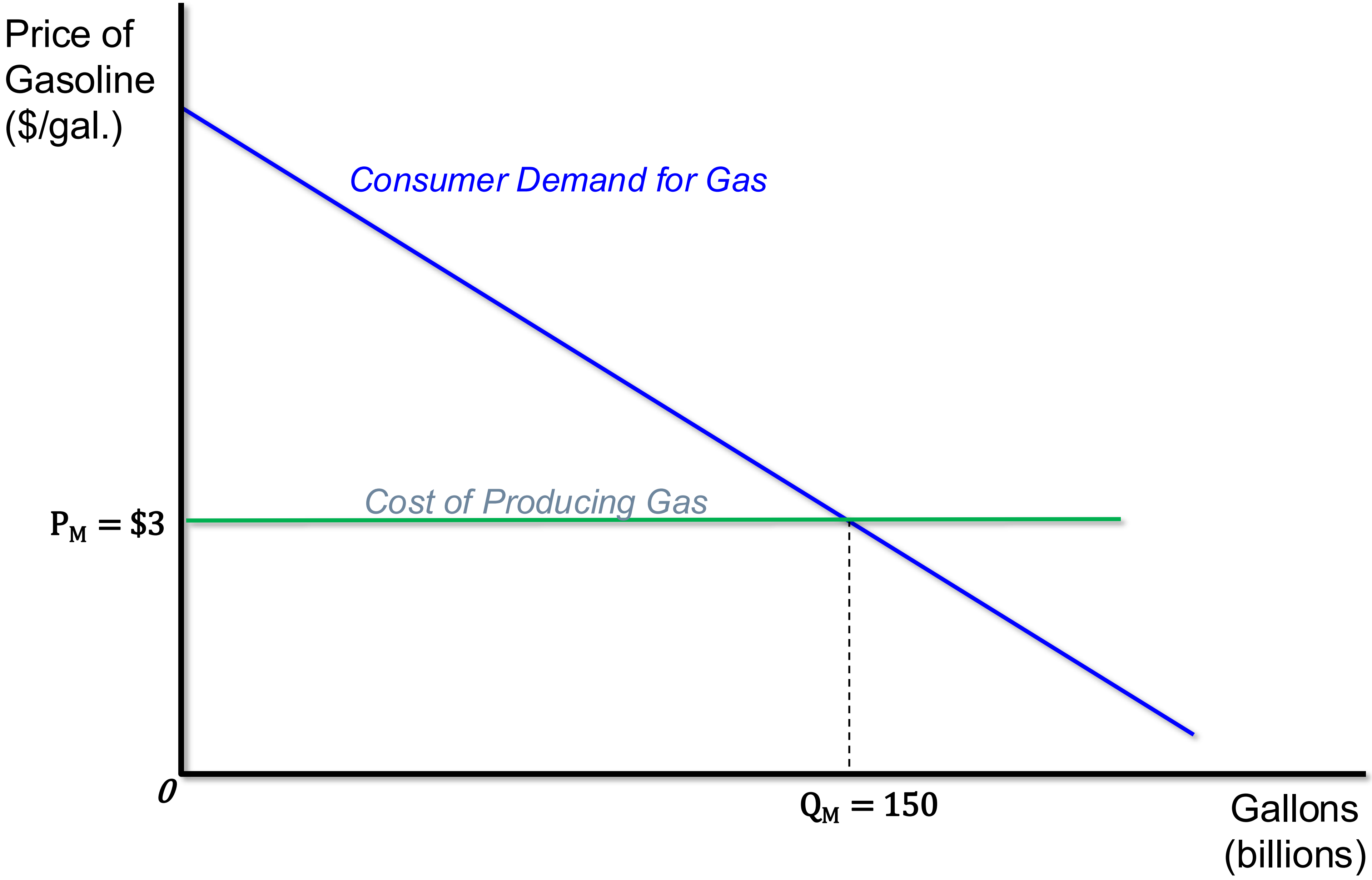
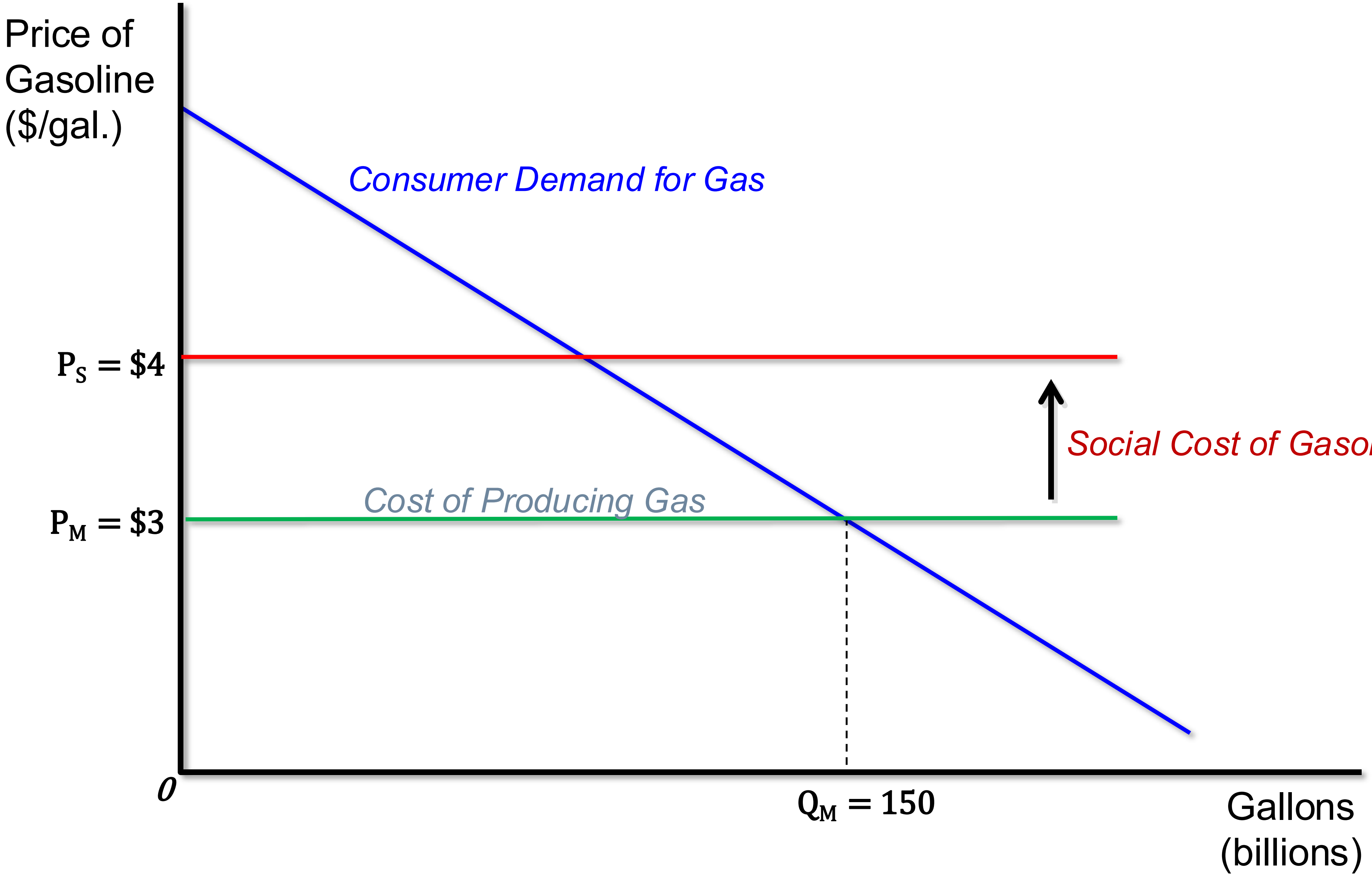
  - These policies could have significant benefits by reducing costs of resources and effectively increasing people’s incomes
  - What is the environmental damage created by these policies?

- What are some questions that environmental economists ask?
  - The value of mitigating pollution
  - How agents respond to climate change policies
  - Whether investment tax credits for wind power are cost-effective

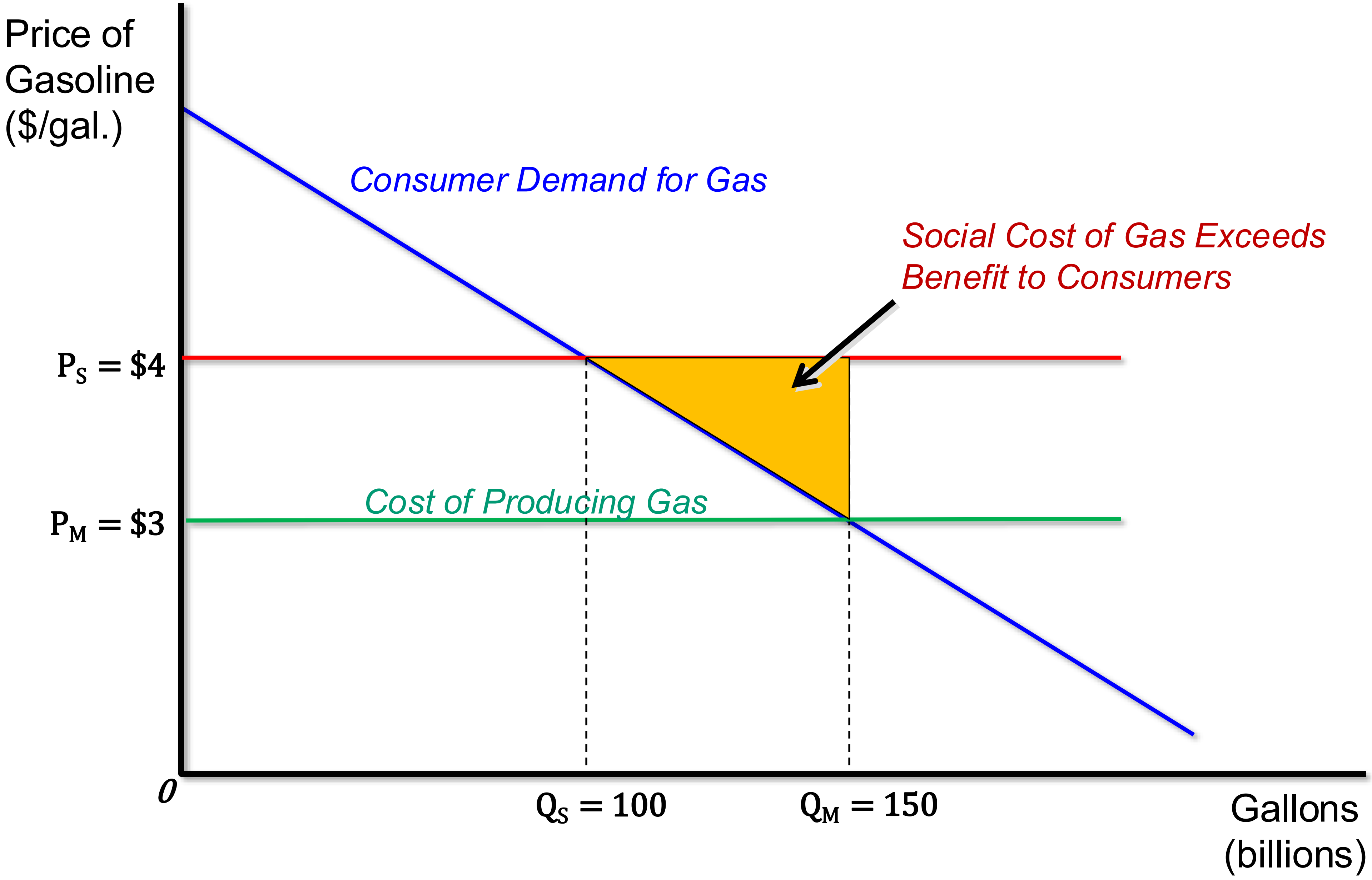
Economics of Externalities



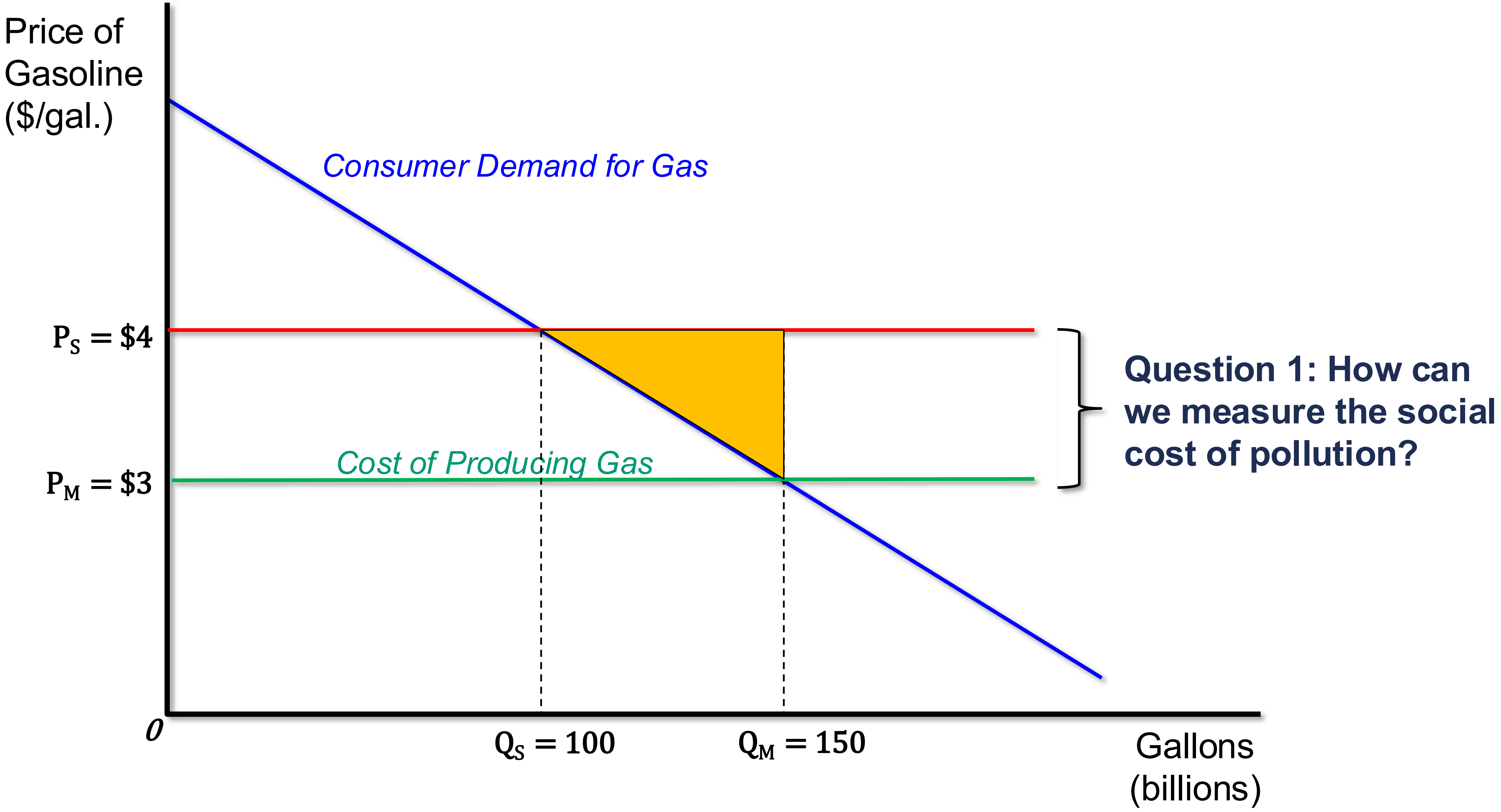
Economics of Externalities



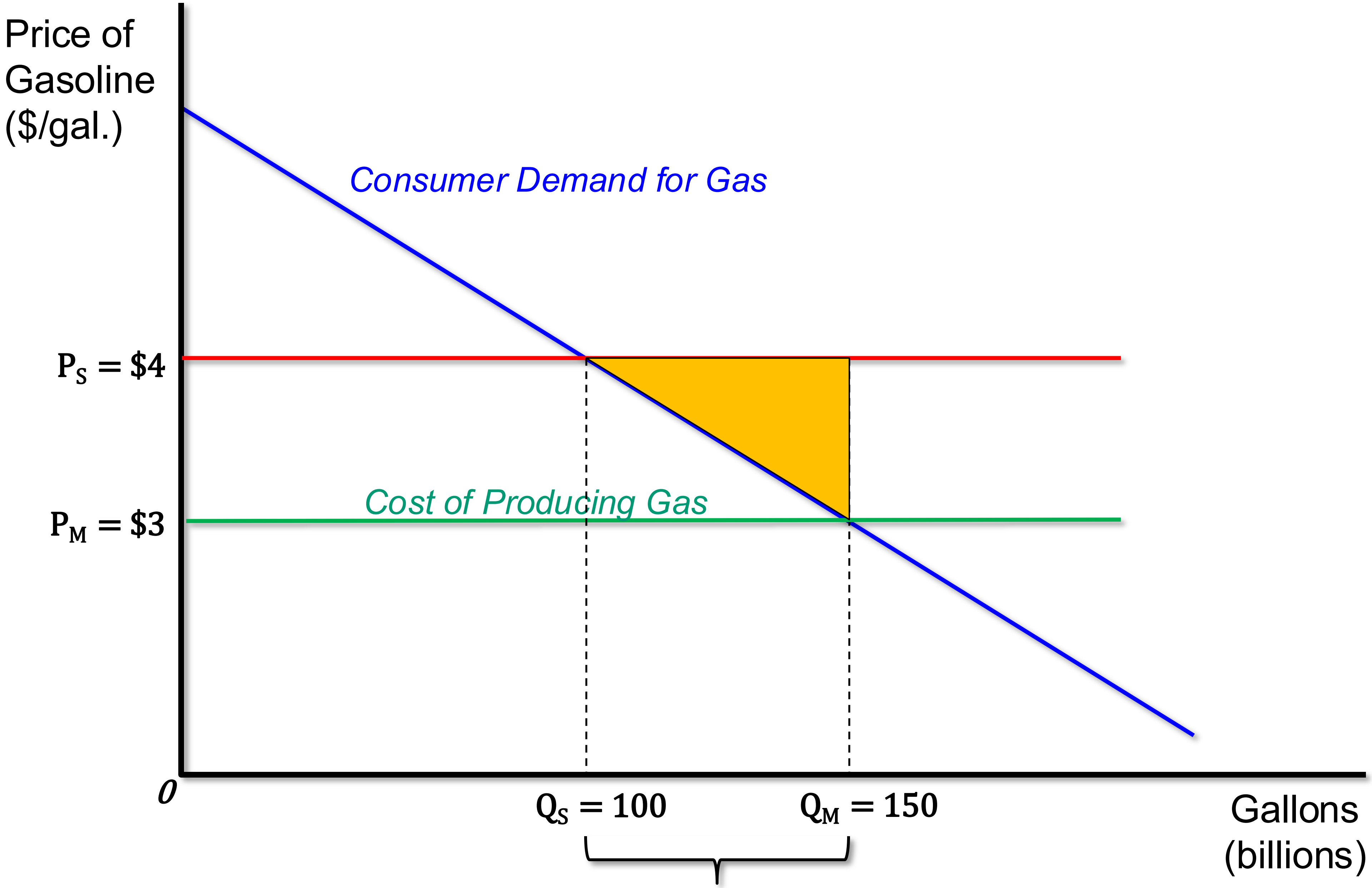
Economics of Externalities



Two Key Questions in Environmental Economics



Two Key Questions in Environmental Economics



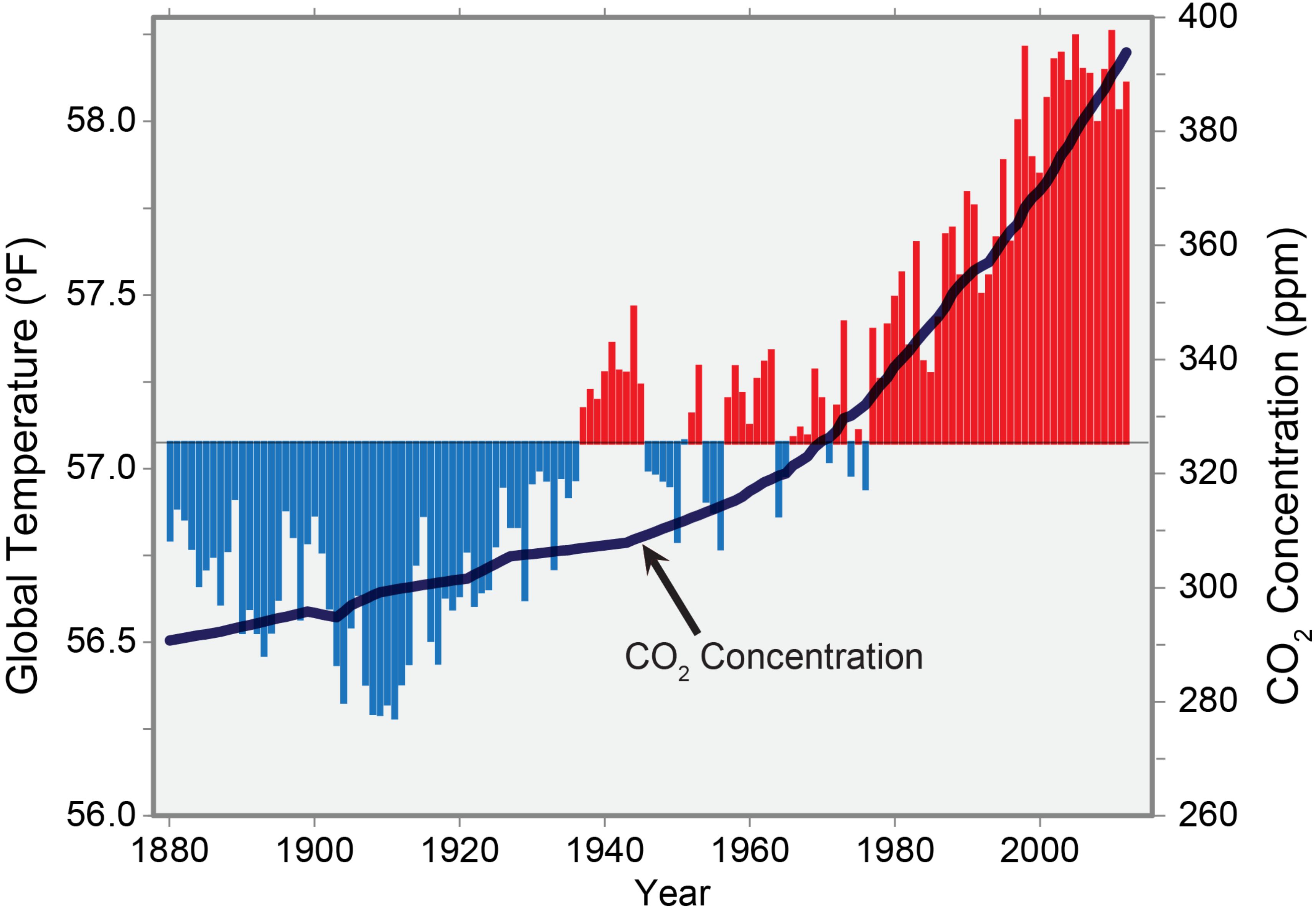
Question 2: What policies can we use to reduce pollution/improve environment?

Empirical Applications

- Social cost of climate change
- Social cost of air pollution

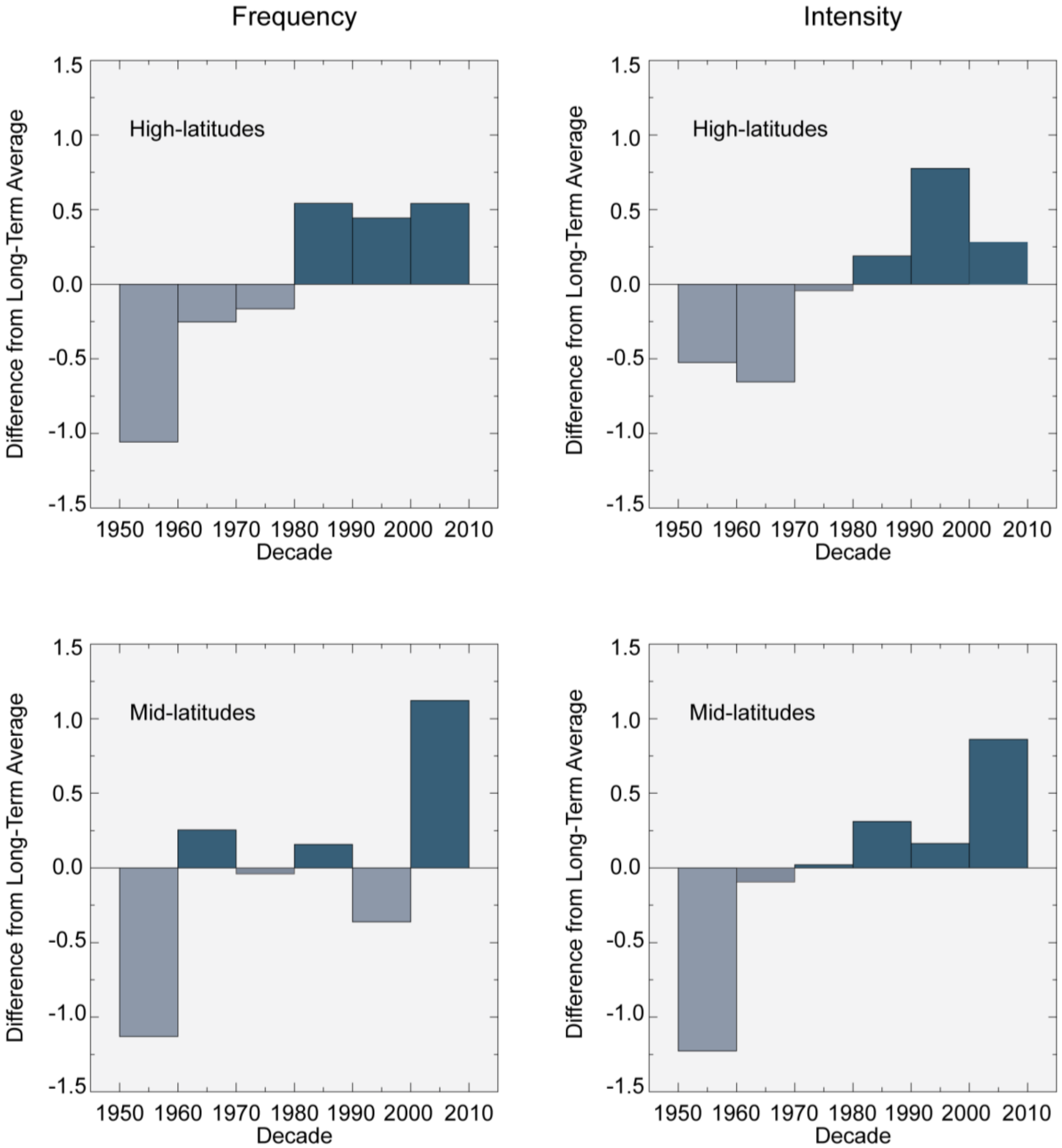
Example: Social Costs of Climate Change

Trends in Global Temperature and Carbon Dioxide Concentration



Source: Karl, Melillo, Peterson 2009

Trends in Frequency and Intensity of Winter Storms



Source: CCSP 2008

Social Cost of Carbon

- Researchers have estimated social costs of many different types of pollution, ranging from toxic air pollution to water pollution
- Given link between CO_2 emissions and climate change, carbon emissions have received the most attention
- Governments now use estimates of “social cost of carbon” when evaluating alternative policies
- Conceptual question: how much does an additional unit of carbon emissions cost society due to environmental damage?
  - Calculating this cost is challenging and is the subject of much research

Estimating the Social Cost of Carbon

- Three general steps in estimating the social cost of carbon:
  1. Predict impact of 1 extra ton of CO_2 on climate using a climate forecasting model
  2. **Measure impacts of changes in climate on economic productivity, health, property damage, etc.**
  3. Calculate current social cost by converting future costs to current dollars (discounting)

- First question is the subject of research in environmental science

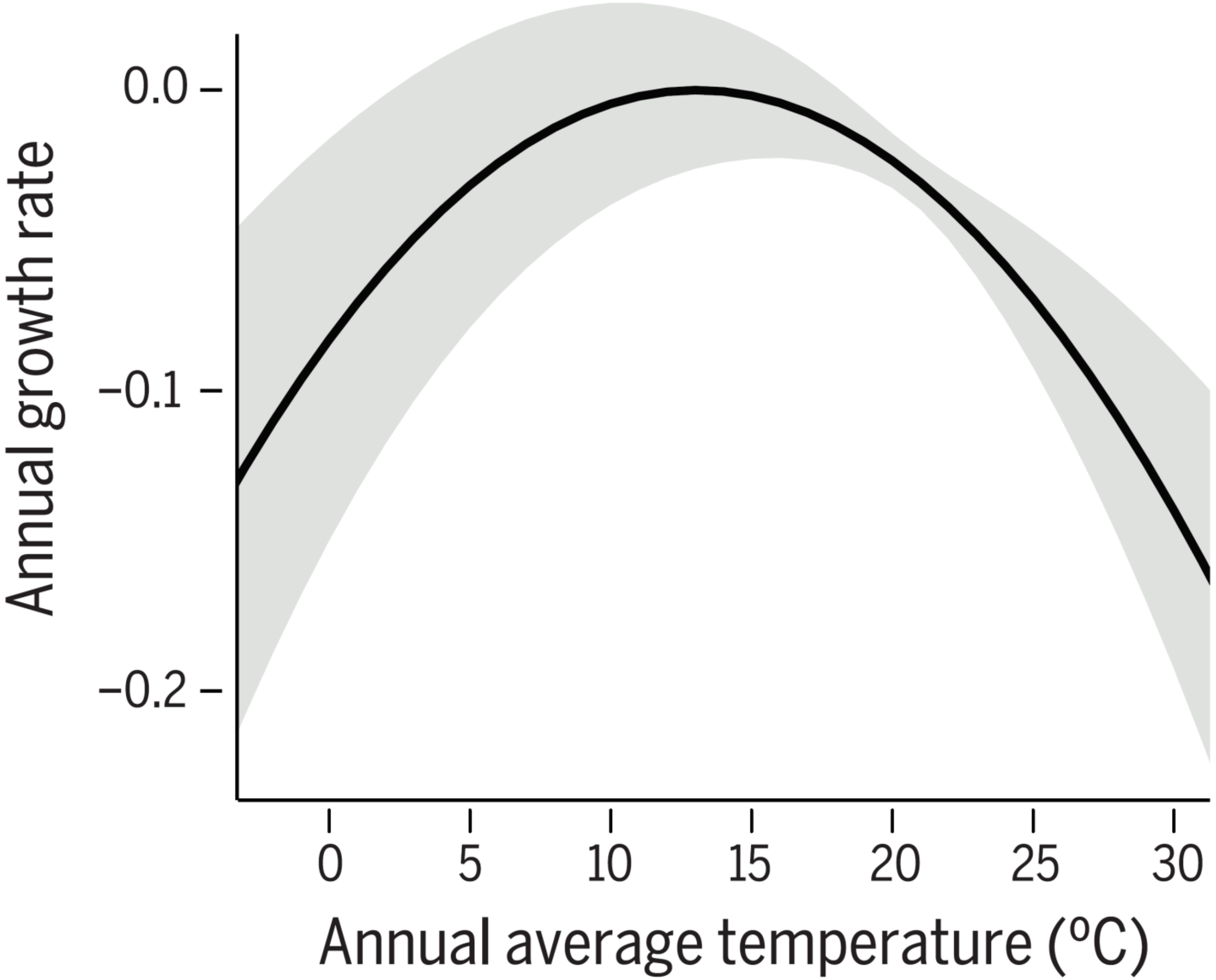
- Focus here on how big data is enabling social scientists to obtain better answers in step 2

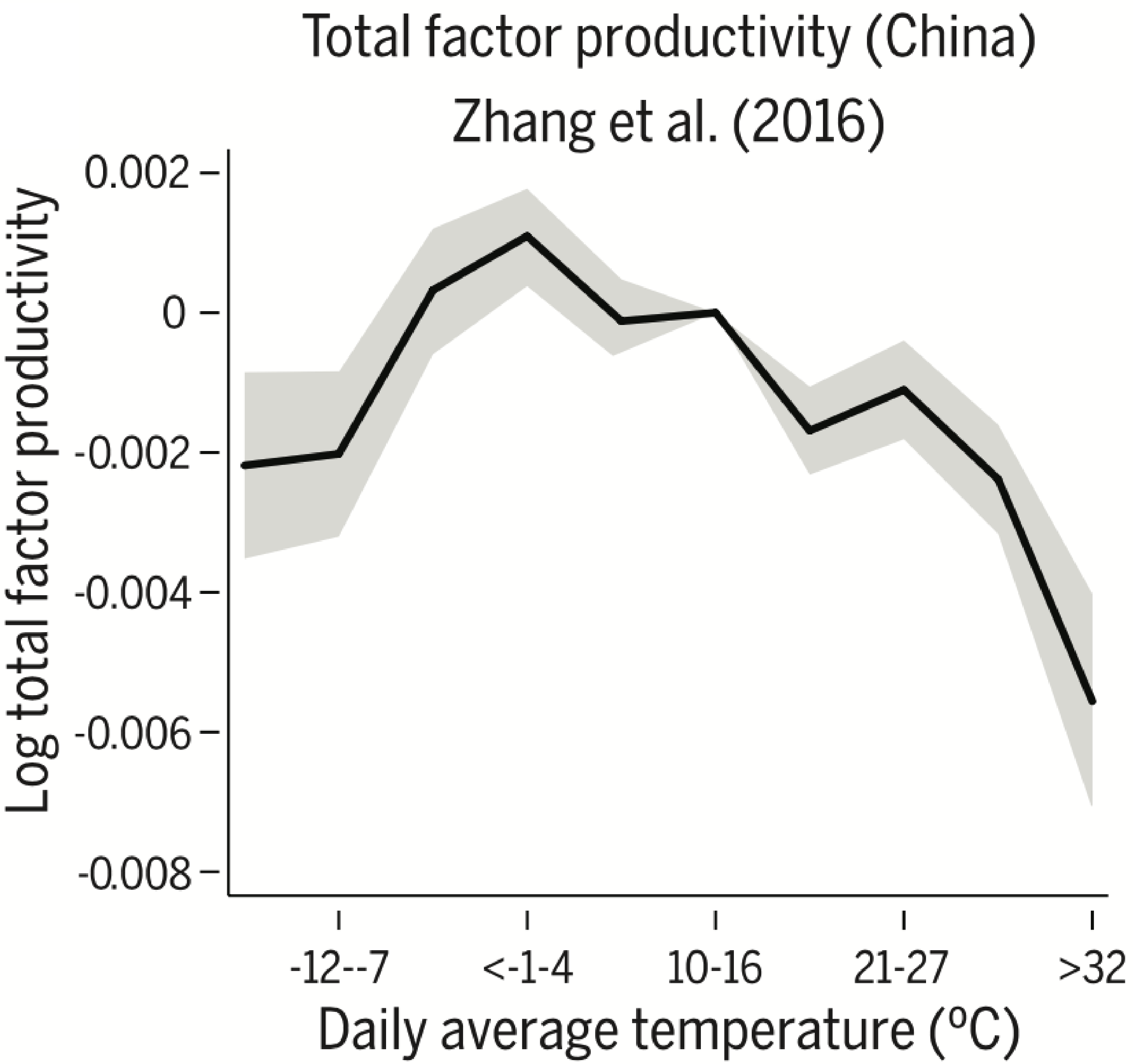
Estimating the Impacts of Climate Change

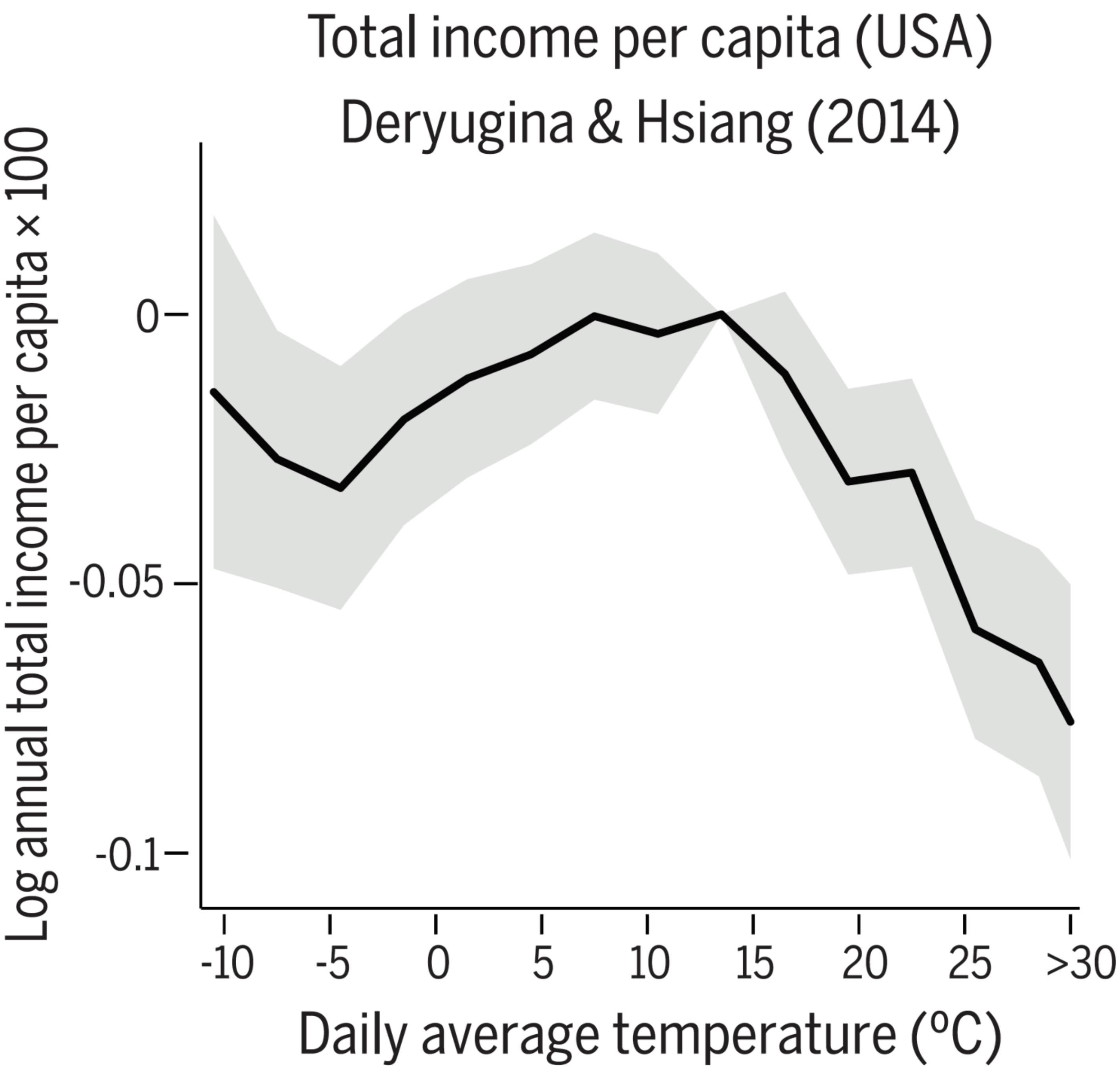
- Carleton and Hsiang (2016) compile results of several of these studies

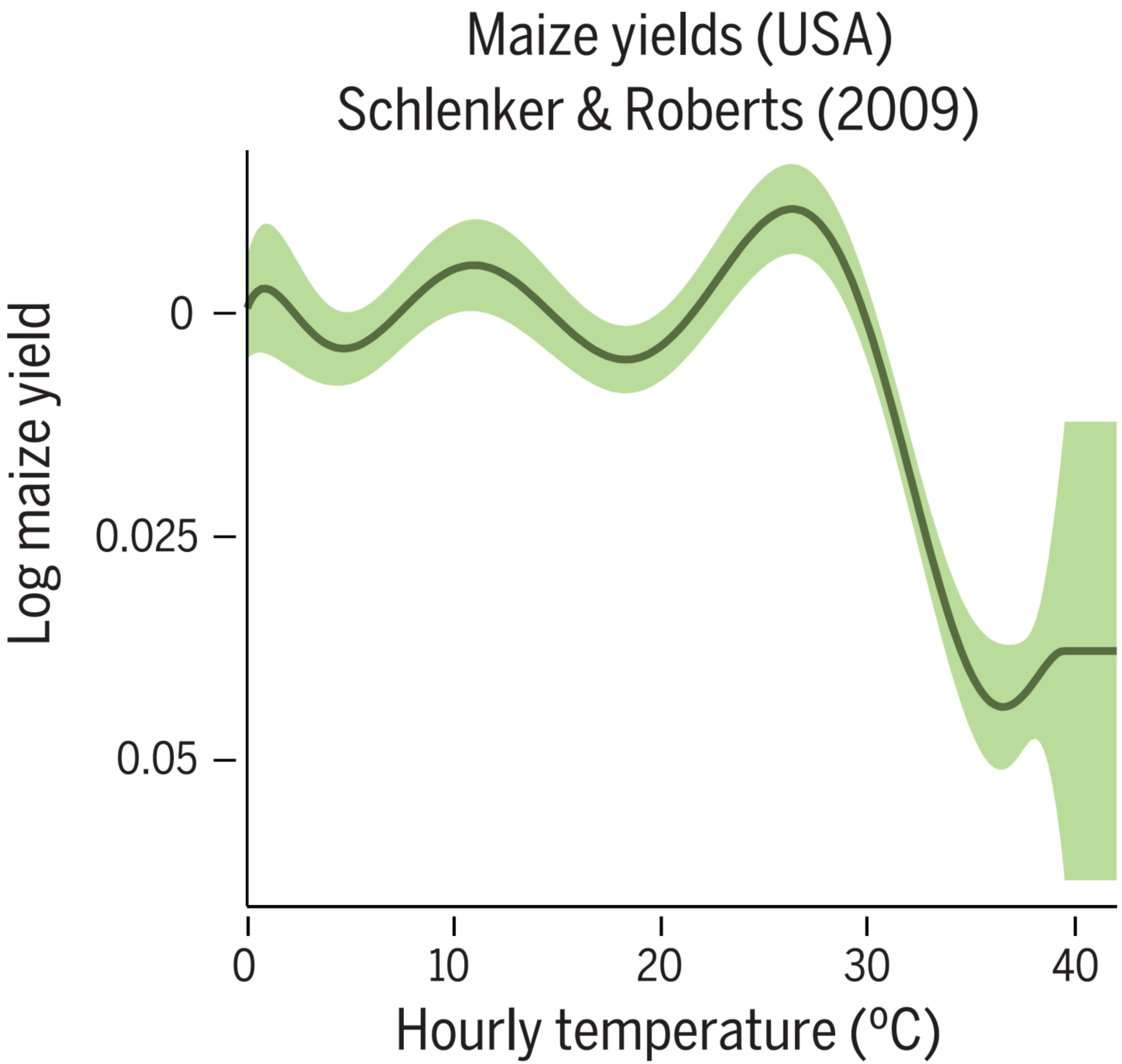
Gross domestic product per capita (global)

Burke et al. (2015)

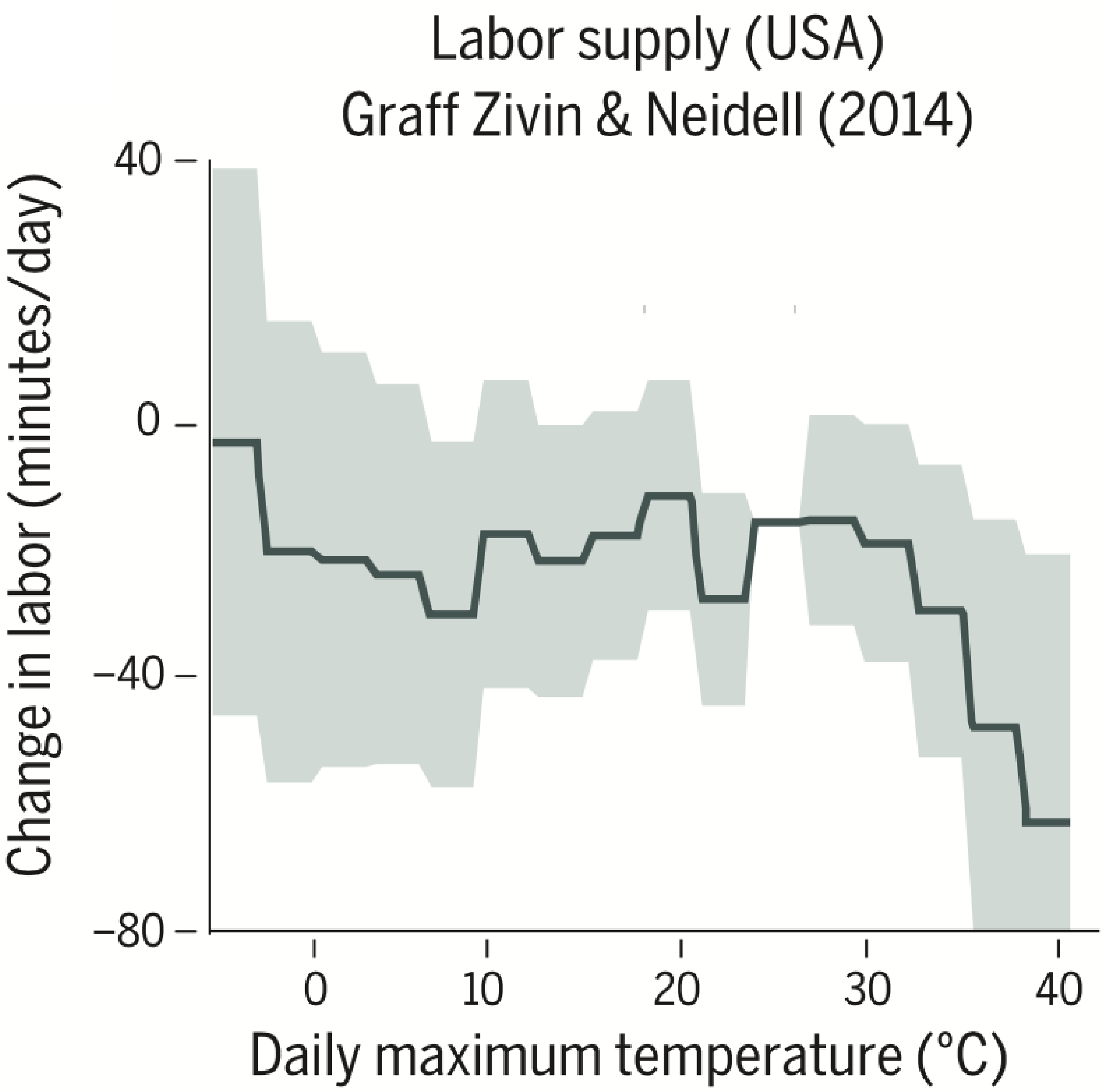


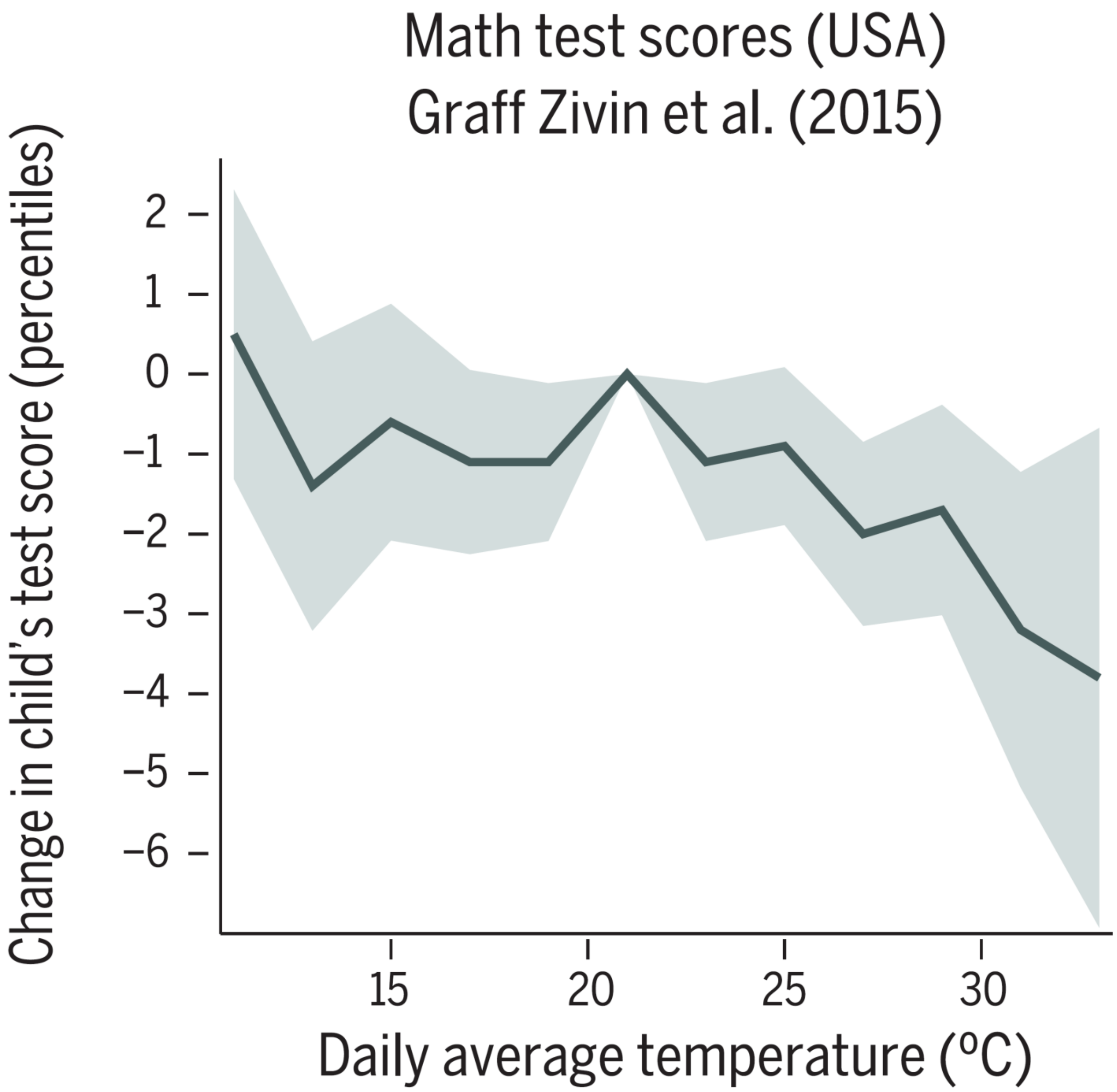

Total factor productivity (China)
Zhang et al. (2016)
Log total factor productivity
0.002
0
-0.002
-0.004
-0.006
-0.008
-12--7
<-1-4
10-16
21-27
>32
Daily average temperature (ºC)


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 (ºC)

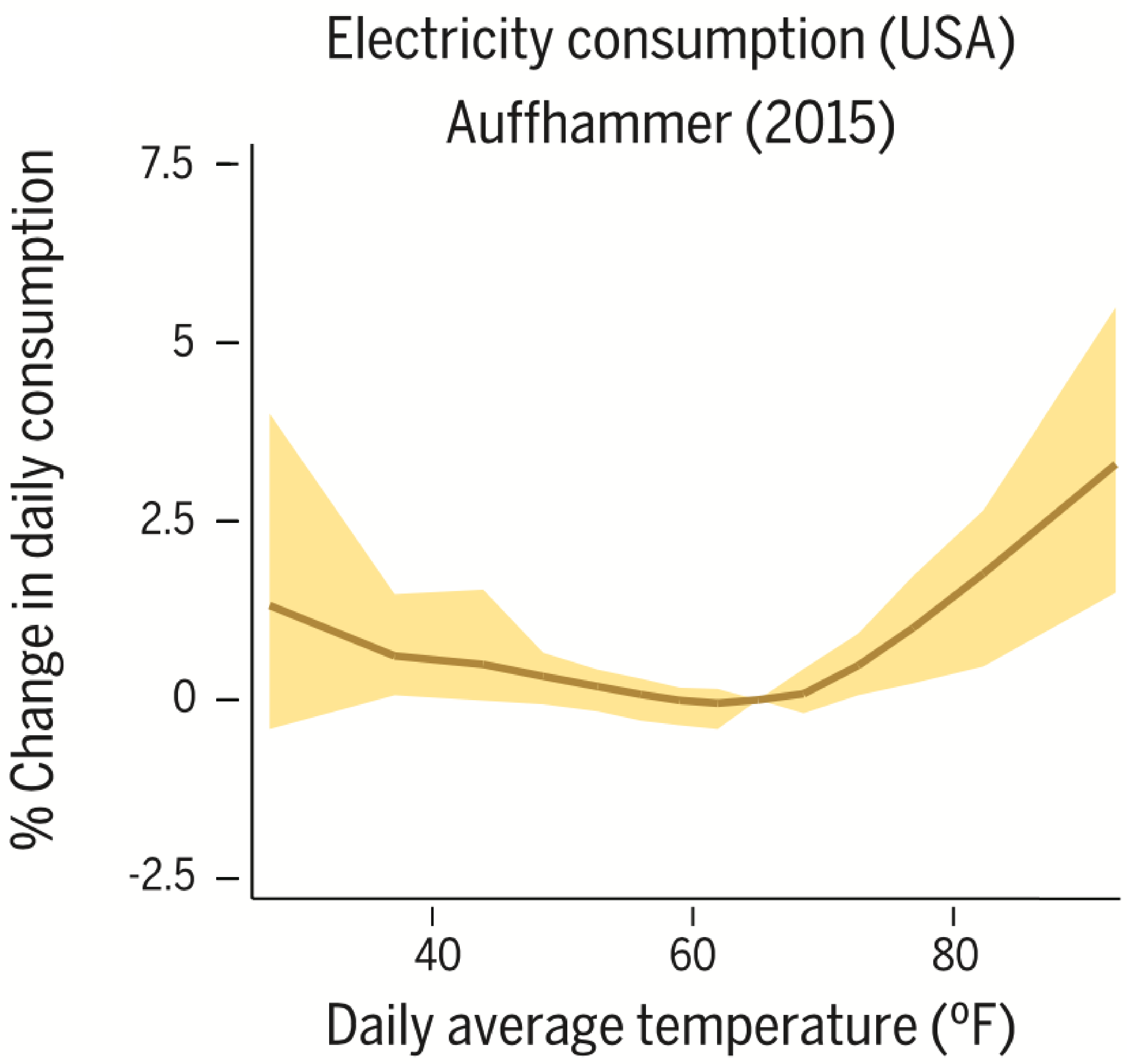


Maize yields (USA)
Schlenker & Roberts (2009)
Log maize yield
0
0.025
0.05
0
10
20
30
40
Hourly temperature (°C)

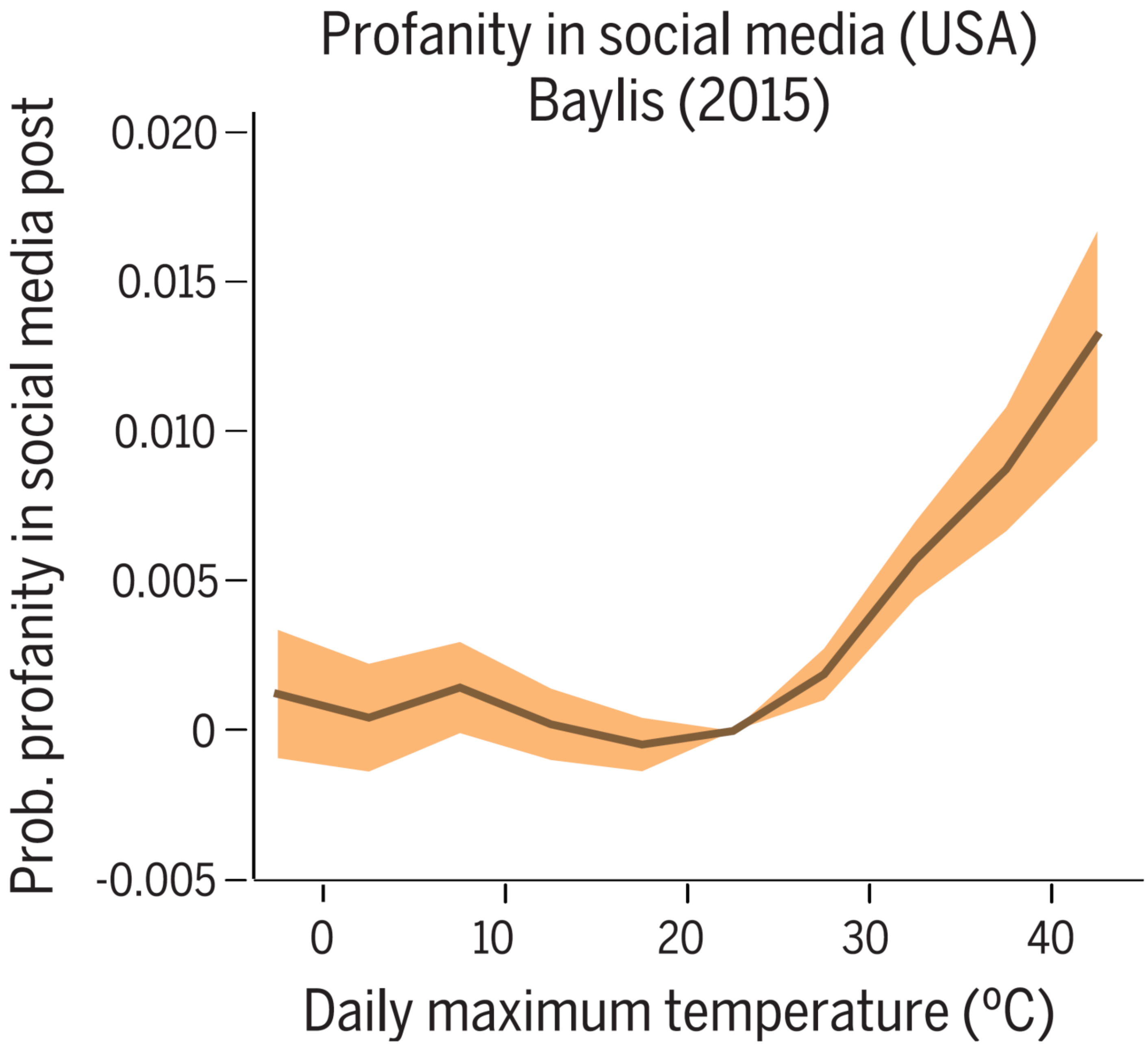

Labor supply (USA)
Graff Zivin & Neidell (2014)
40
0
−40
−80
Change in labor (minutes/day)
0
10
20
30
40
Daily maximum temperature (°C)

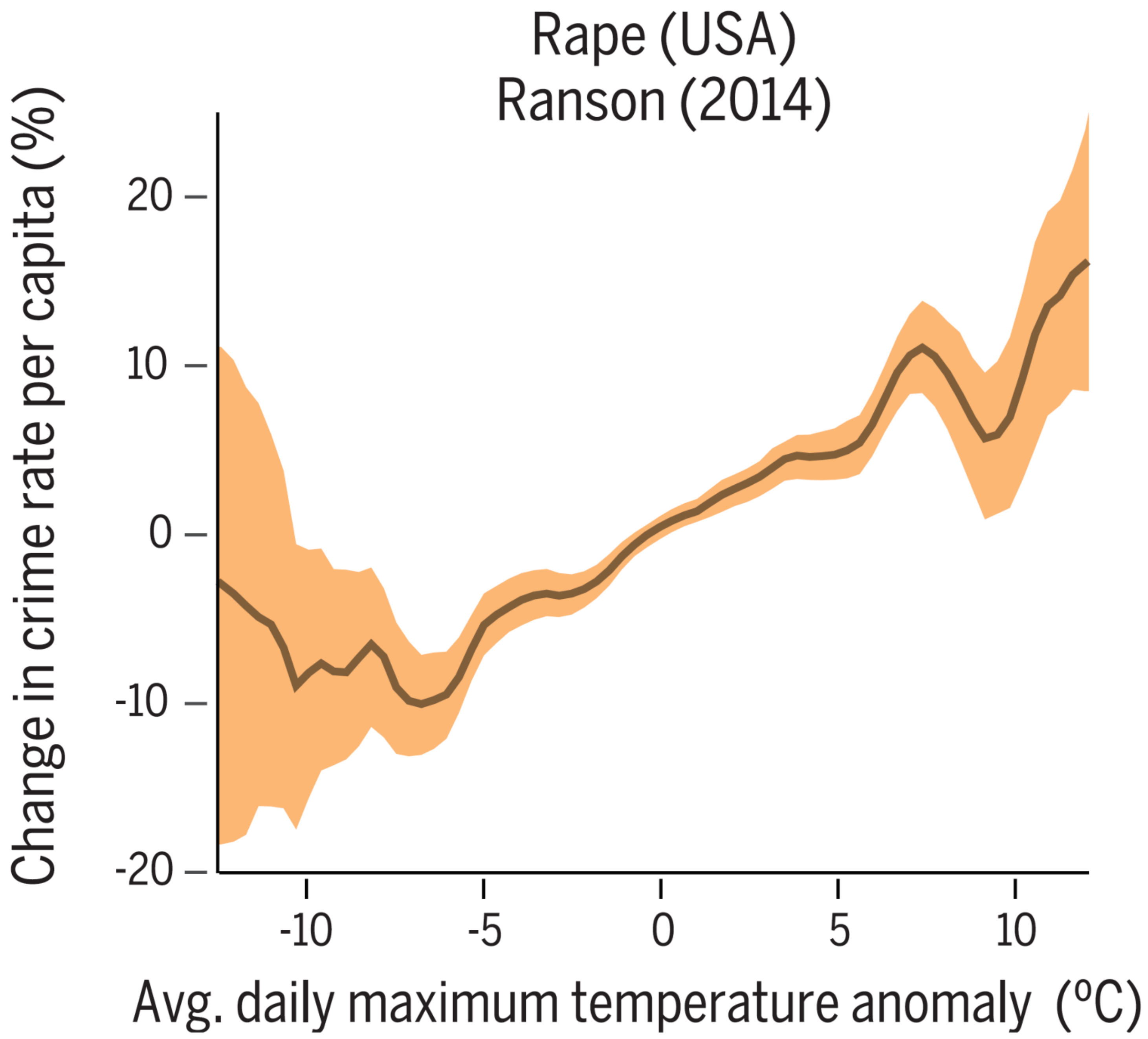


Math test scores (USA)
Graff Zivin et al. (2015)
Change in child's test score (percentiles)
2
1
0
−1
−2
−3
−4
−5
−6
15
20
25
30
Daily average temperature (ºC)

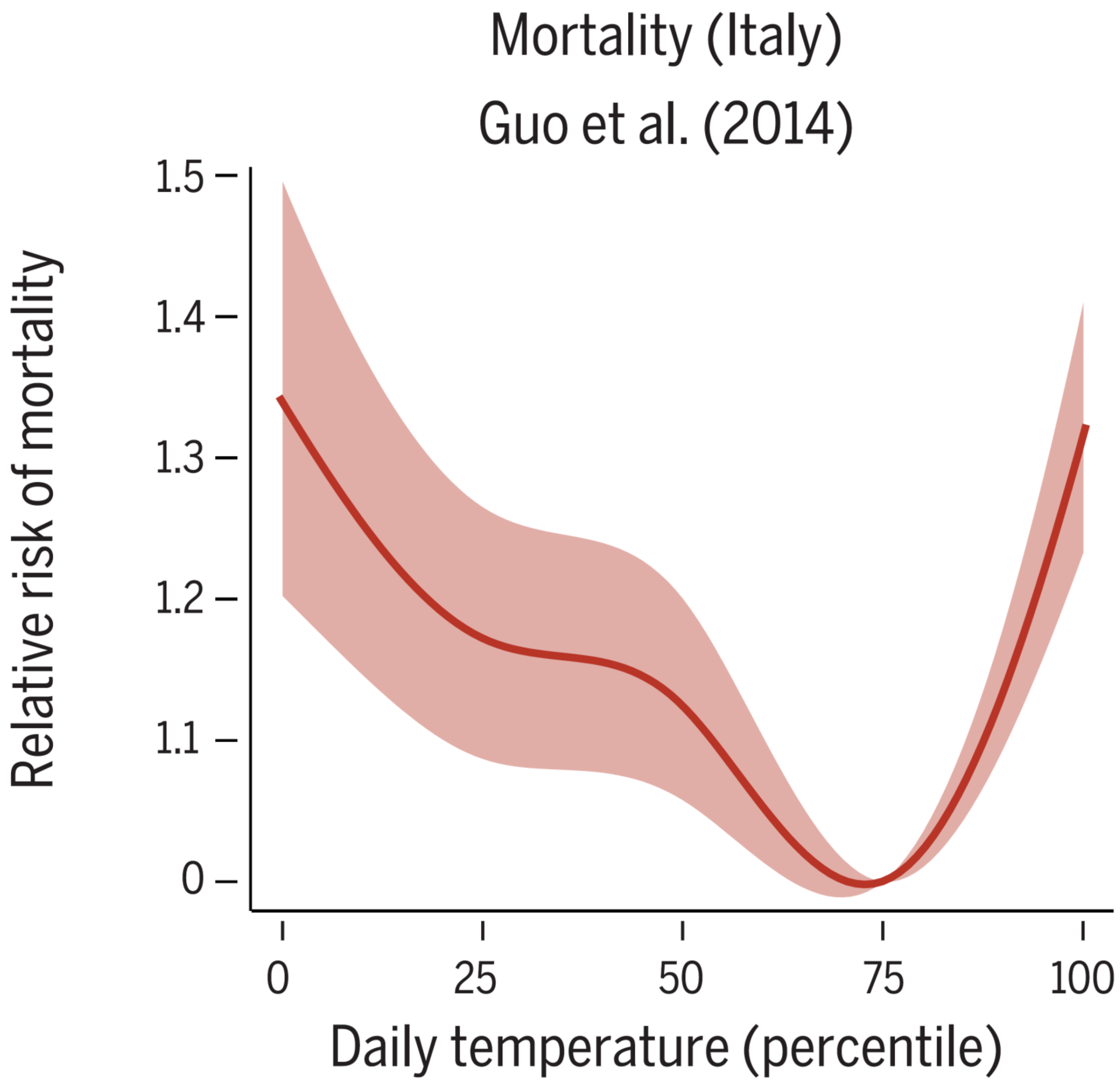


Electricity consumption (USA)
Auffhammer (2015)
% Change in daily consumption
7.5
5
2.5
0
-2.5
40
60
80
Daily average temperature (ºF)


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
Daily maximum temperature (°C)



Rape (USA)
Ranson (2014)
Change in crime rate per capita (%)
20
10
0
-10
-20
-10
-5
0
5
10
Avg. daily maximum temperature anomaly (°C)


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)

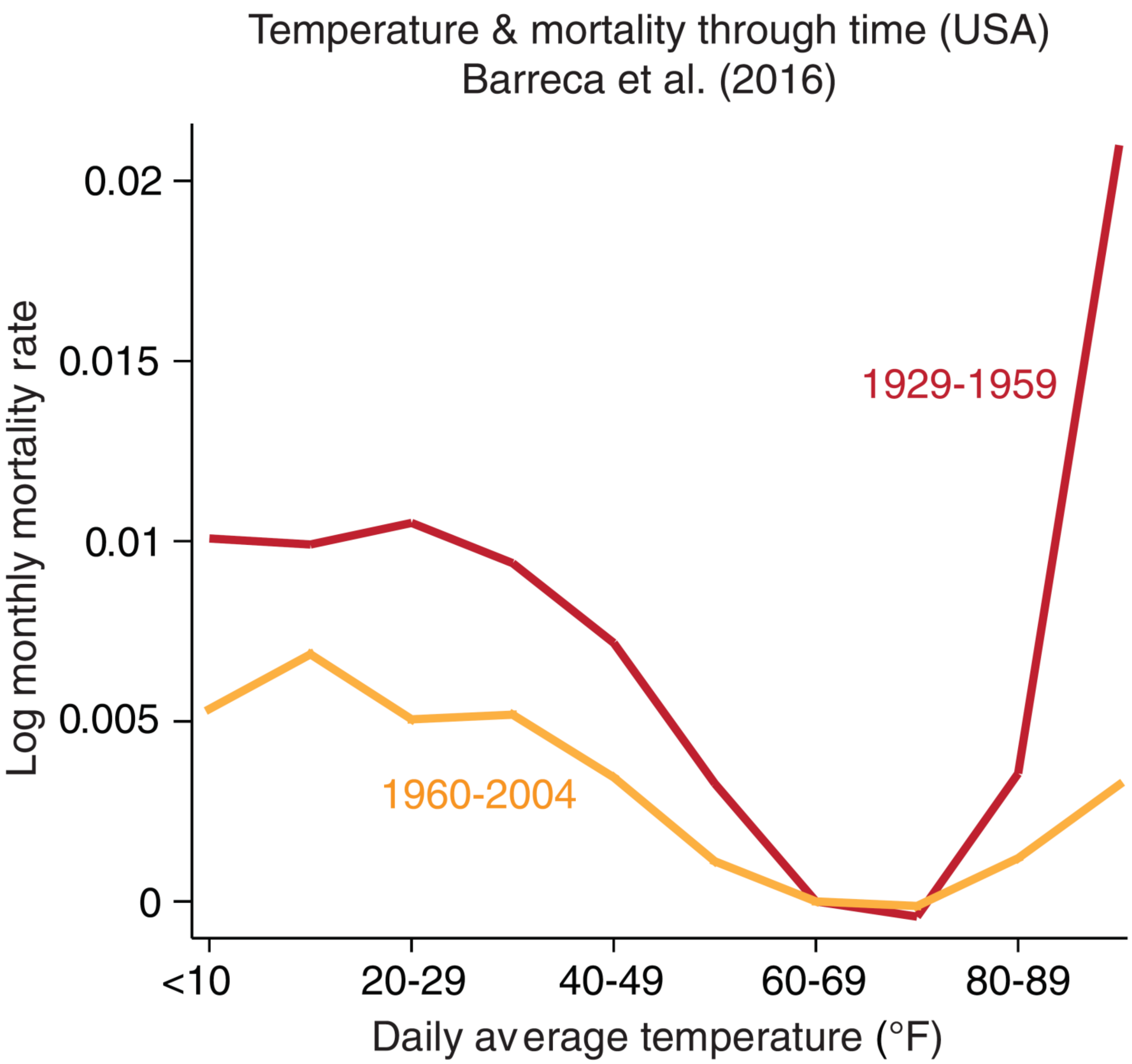
Estimating the Impacts of Climate Change

- Burke et al. (2015) predict that climate change by 2100 will lower global GDP by 23%

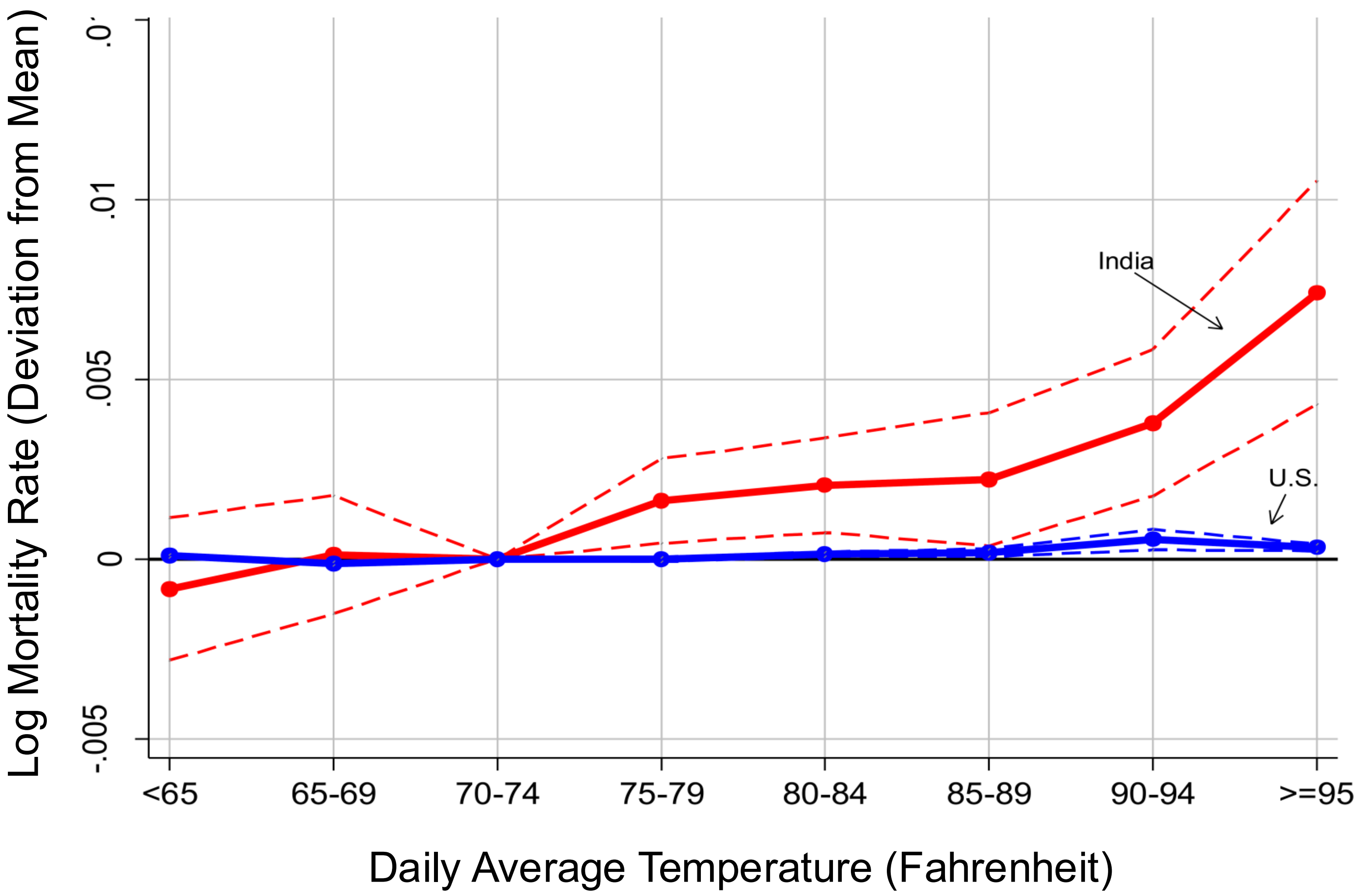
- This estimate is based on short-run fluctuations in temperature, though Burke et al. argue that long-term impacts are likely to be similar
  - No evidence that relationship between temperature and GDP has changed in recent years

Effects of Adaptation

- How do these short-run impacts change if society has time to adapt?
- Challenge: difficult to directly identify causal impacts of long-term trends in climate
  - Lots of other things are changing as climate changes
- Instead, compare effects of short-run changes in places that have had time to adapt vs. places that have not
  - Ex: does a heat wave have smaller effects in areas that experience heat waves regularly?
  - Do temperature fluctuations have smaller costs in advanced economies?


Temperature & mortality through time (USA)
Barreca et al. (2016)
Log monthly mortality rate
0.02
0.015
0.01
0.005
0
1929-1959
1960-2004
<10
20-29
40-49
60-69
80-89
Daily average temperature (°F)

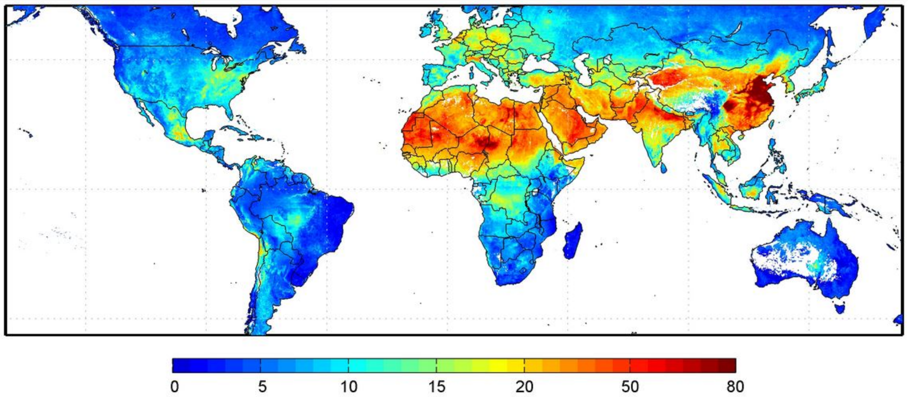
Impact of Daily Temperature Fluctuations on Mortality Rates in India vs. the U.S.



Source: Burgess, Deschenes, Donaldson, Greenstone 2017

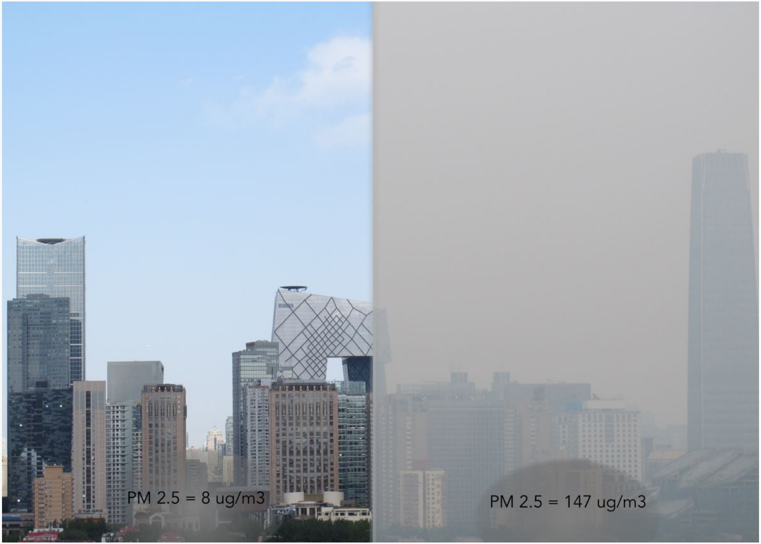
Example: Social Costs of Pollution

Fine particulate matter ($PM_{2.5}$) exposure around the world



Source: NASA

Beijing, low- vs. high-pollution days



Source: Thomas Talhelm

Today

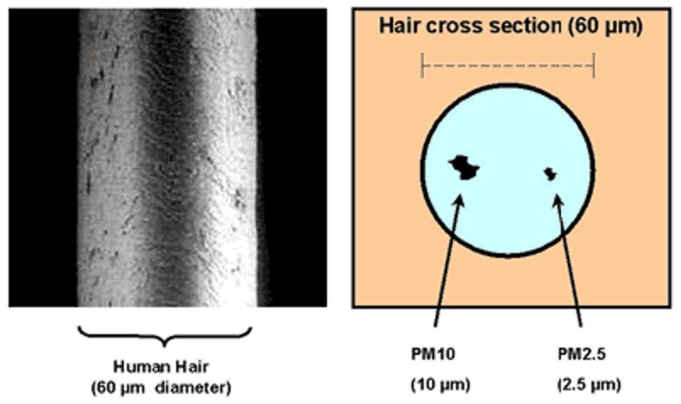
- Frontier research on the social costs of air pollution

    1. Measuring the social costs of pollution
    2. Evaluating society's willingness to pay for pollution reduction
    3. Enforcement of environmental regulation

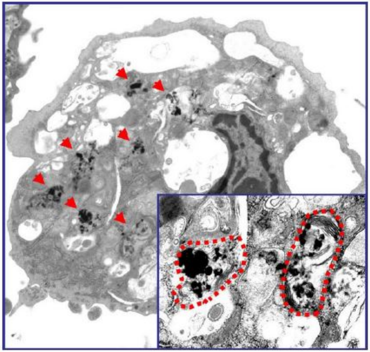
- Focus on the application of "big data": large datasets that allow researchers to tease out the causal relationship between pollution and social/health/economic outcomes

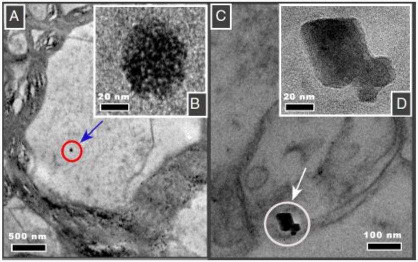
Measuring the social costs of pollution

Particulate matter



Particulate matter in lung and brain





PM in lung tissue[+]

PM in brain tissue*

Source: [+] Araujo, et al. (2008); *Maher et al. (2016)

Understanding consequences of pollution exposure

- "Real" experiment: randomly assign subjects to high vs. low pollution environment, and observe their differences in health / economic outcomes
- Cannot run such experiment with human subjects
- "Natural experiments": naturally occurred events that are good approximation to real experiments
    - Natural disasters
    - Government policies

Ebenstein et al. (2017)

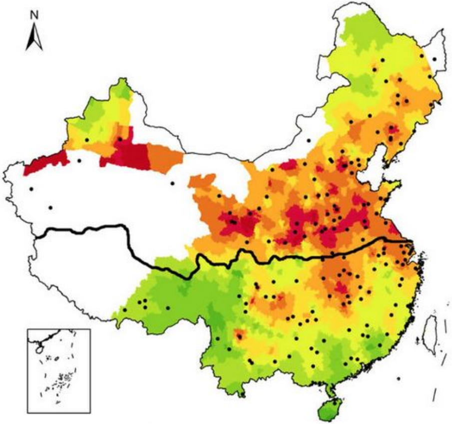
- Explore cross-city difference in pollution levels due to China's Winter Heating Policy
- Due to budget constraint, the central government provides free coal-based heating in winter **only in cities to the north of the Huai River**
- Research idea: the policy creates a sharp increase in pollution as one goes north of the Huai River
- Compare pollution and mortality rate in cities just to the south vs. north of the Huai River (known as "regression discontinuity" approach)

Source: Reuters

Pollution North vs. South of the Huai River

Figure 1

Pollution in China and the Huai River/Qinling Mountain Range



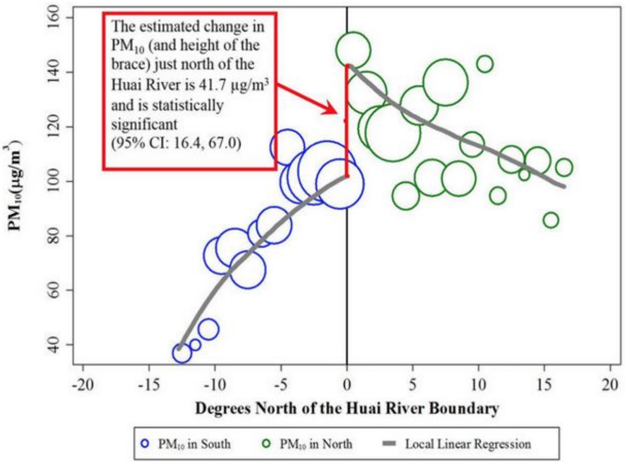
Notes : China's Huai River/Qinling Mountain Range winter heating policy line and PM10 concentrations. Black dots indicate the DSP locations. Coloring corresponds to interpolated PM10 levels at the 12 nearest monitoring stations where green, yellow, and red indicate areas with relatively low, moderate, and high levels of PM10, respectively. Areas left in white are not within an acceptable range of any station.

Source: Ebenstein et al. (2017)

Pollution increases sharply at the Huai River

Figure 2

Particulate Matter Levels (PM_{10}) South and North of the Huai River Boundary



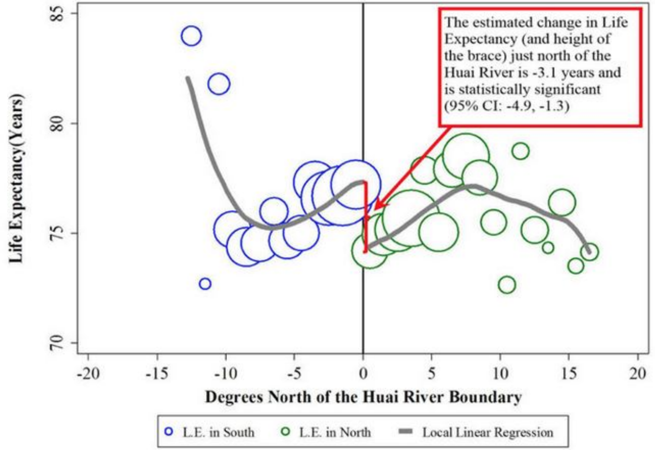
Notes : Fitted values from a local linear regression of PM10 exposure on distance from the Huai River, estimated separately on each side of the river.

Source: Ebenstein et al. (2017)

Life expectancy decreases sharply at the Huai River

Figure 3

Life Expectancy South and North of the Huai River Boundary



Notes : Fitted values from a local linear regression of life expectancy on distance from the Huai River, estimated in the same manner as in Figure 2.

Source: Ebenstein et al. (2017)

Willingness to Pay for Pollution Reduction

"Willingness to pay" for air quality

- Basic idea: even at high pollution levels, people might still want to spend the next $ in consumption, rather than in pollution reduction, vice versa

- Research challenge: such "willingness to pay" (WTP) is very difficult to measure
    - How much money are you willing to pay to reduce $PM_{2.5}$ by 10 units for the next year?
    - Subjective answers to this type of questions tend to be inaccurate

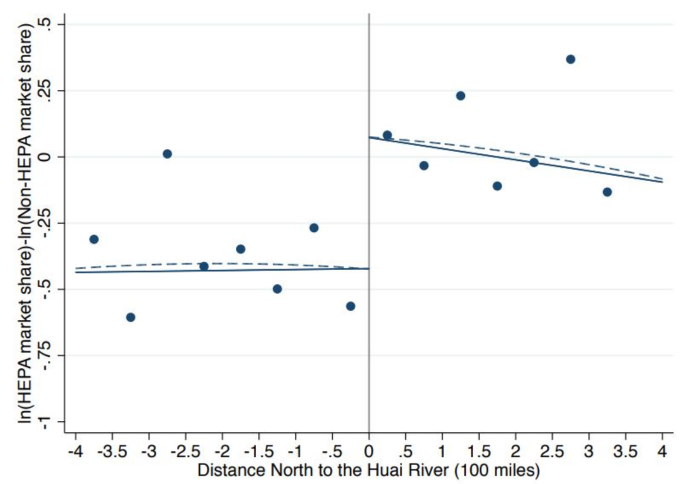
“Willingness to pay” for air quality (cont.)

- Big data helps us to reveal WTP through people’s consumption pattern
  - Suppose a commodity (e.g., air purifier / medication) can reduce your pollution exposure by X units
  - We observe you spend $Y on the commodity
  - You could have spent $Y on other stuff that give you happiness (e.g., food), but you **chose** to spend it on reducing pollution
  - This tells us about your WTP for air quality (assuming you are a “rational” consumer)
  - In economics, this approach is called “revealed preference”

Ito and Zhang (2016)

- Research idea: air purifiers can reduce household air pollution exposure, but they are costly
- So, the extent to which household is willing to spend money on air purifiers, rather than on other goods, reveal their willingness to pay for cleaner air
- Data: Administrative sales records for air purifiers in Chinese cities
- Following Ebenstein et al. (2017), test if air purifier sales are higher in cities just to the north of the Huai River

Air purifiers sales increases sharply the Huai River



Source: Ito and Zhang (2016)

Ito and Zhang (2016)

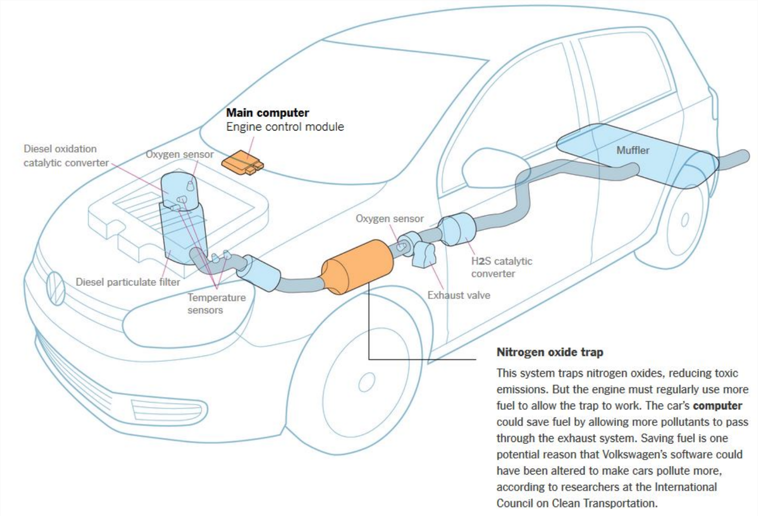
- Air purifiers sales increase sharply among cities just to the North of Huai River; this change is plausibly due to higher levels of PM_{10}
- The average household in China is willing to pay \$13.4 per year to reduce PM_{10} pollution by 10 units

Enforcement of Environmental Regulations

Environmental monitoring is often incomplete

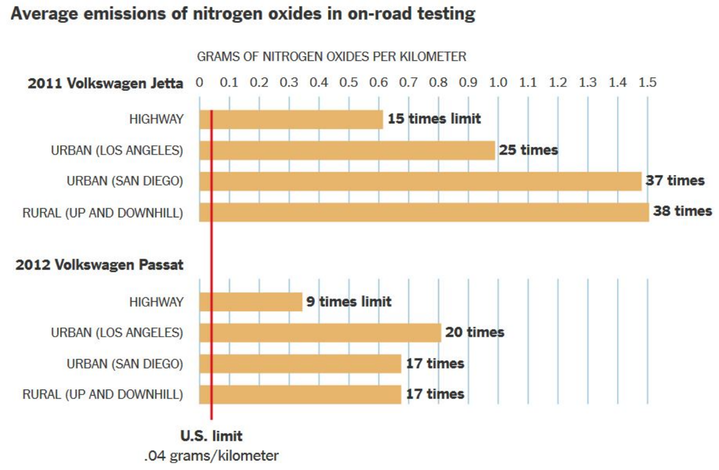
- Accurate information on pollution is valuable for the society
- But, pollution data are often very expensive to collect, and government resources are often limited
- In reality, environmental monitoring is often **incomplete**:
    - Pollution is only monitored at certain locations on certain days
    - Plant & vehicle emissions are only tested irregularly

Volkswagen emissions scandal: computer system that turns on emission control only during regulatory testings



Source: The International Council on Clean Transportation

When tested on the road, some VW cars emit almost 40 times the permitted levels of nitrogen oxides



Source: Center for Alternative Fuels, Engines and Emissions

Bottom line

- While the microeconomic theory of externalities seems pretty clear-cut, measuring (and regulating) externalities in the real world is very challenging
- Past 10-20 years saw major progress in research that address important questions about the social costs of climate change and air pollution
- Most of these research uses “big data” to tease out the causal relationship between pollution and social/health/economic outcomes
- If you are interested, take an empirical class to learn more about how microeconomics work in the real world