Economics 2
Fall 2024

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LECTURE 9

Externalities and Climate Change

I. Overview

Market Failure

- When markets do not lead to an efficient outcome
- First example was monopoly—a profound lack of competition.
- This lecture is about externalities, an important source of market failures.
- Economic activity can create external harm (external means not taken into account by the market participants).

Externality

- An externality arises whenever the actions of one economic agent **directly** affect another economic agent outside the market mechanism
- A power plant that pollutes a river used for recreation is an externality
- A power plant that increases its price of electricity because of a shift in demand is NOT an externality (as this is a market mechanism)

SUV Externalities Example

- Example: negative externalities of driving a gas powered large Sport Utility Vehicle:
  - 1. Environmental externality: carbon emissions and global warming
  - 2. Infrastructure externality: Larger cars wear down the roads more
  - 3. Safety externality on other drivers: The odds of having a fatal accident increase if hit by a bigger car
  - 4. Congestion externality: driving a car adds to traffic which increases travel time for others

Quiz:

Question: Which of these is NOT a negative externality?

- A. Cigarette smoking that damages your future health.
- B. Texting while driving which increases accident risk.
- C. Pesticide runoff from farms that pollutes land/water.
- D. Noise related to a construction project.
- E. All are negative externalities

Quiz

Example: Suppose you have a beehive in your garden to produce homemade honey you sell to fellow students. Does this produce externalities?

A. Yes, a negative externality if neighbors get stung by your bees.

B. Yes, a positive externality as the bees help with pollination in the organic farm next door.

C. Yes, a positive externality because fellow students love to stop by and discuss my beehive hobby.

D. All of A, B, and C

Quiz

Example: suppose you are still talking when I start lecturing. Is this an externality as economists define it? Only 1 answer is correct.

A. No, because this has nothing to do with markets

B. No, because I was engrossed in the conversation and did not even notice class had started

C. Yes, but only if the background noise makes it harder for the students to understand the lecture.

D. No, because many students were also talking so my talking does not make any difference.

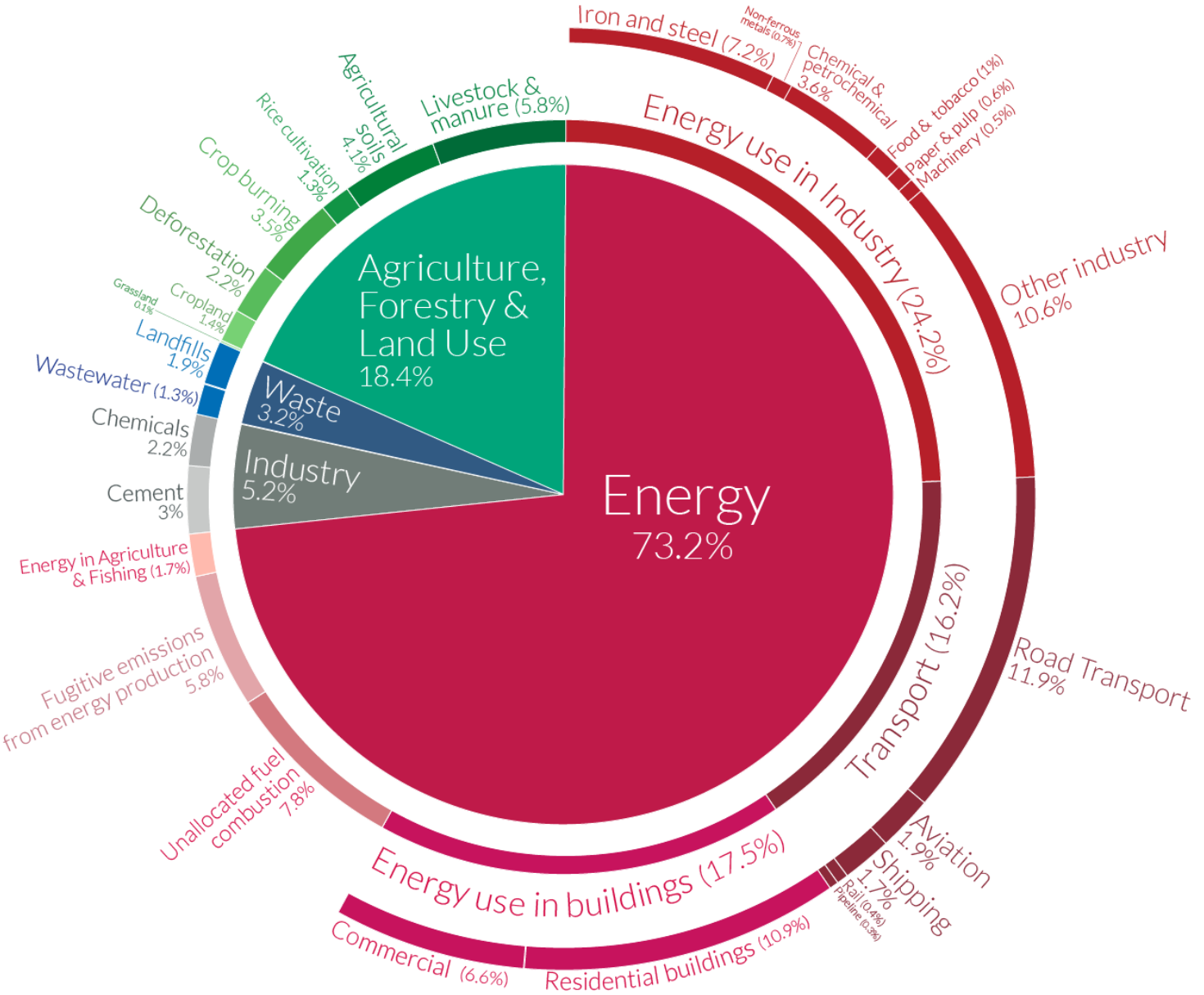
E. Yes, because the rule is to be quiet when class starts

II. Negative Externalities

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data

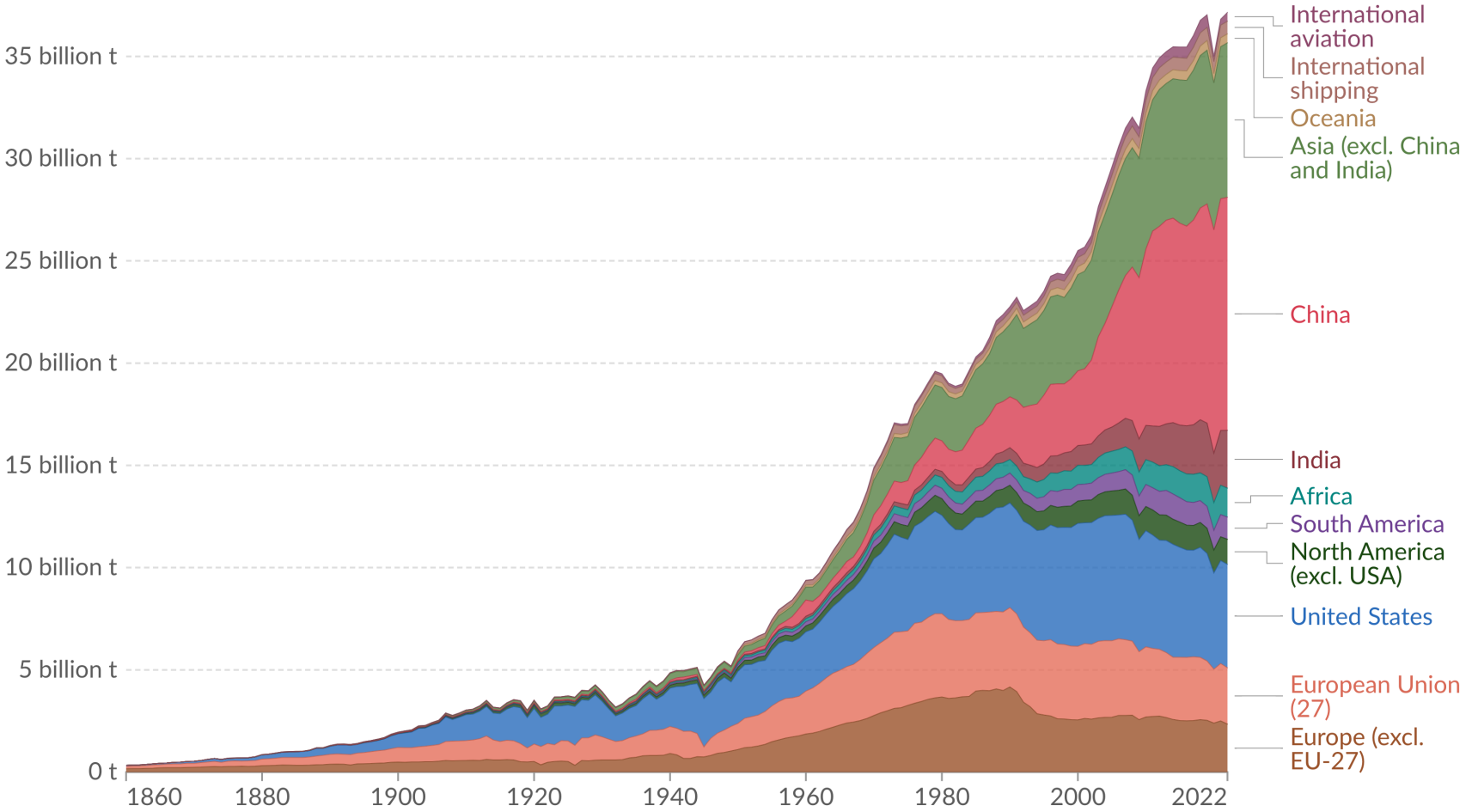


Source: Climate Watch, the World Resources Institute (2020).

Annual CO_2 emissions by world region

Our World in Data

Emissions from fossil fuels and industry[1] are included, but not land-use change emissions. International aviation and shipping are included as separate entities, as they are not included in any country's emissions.

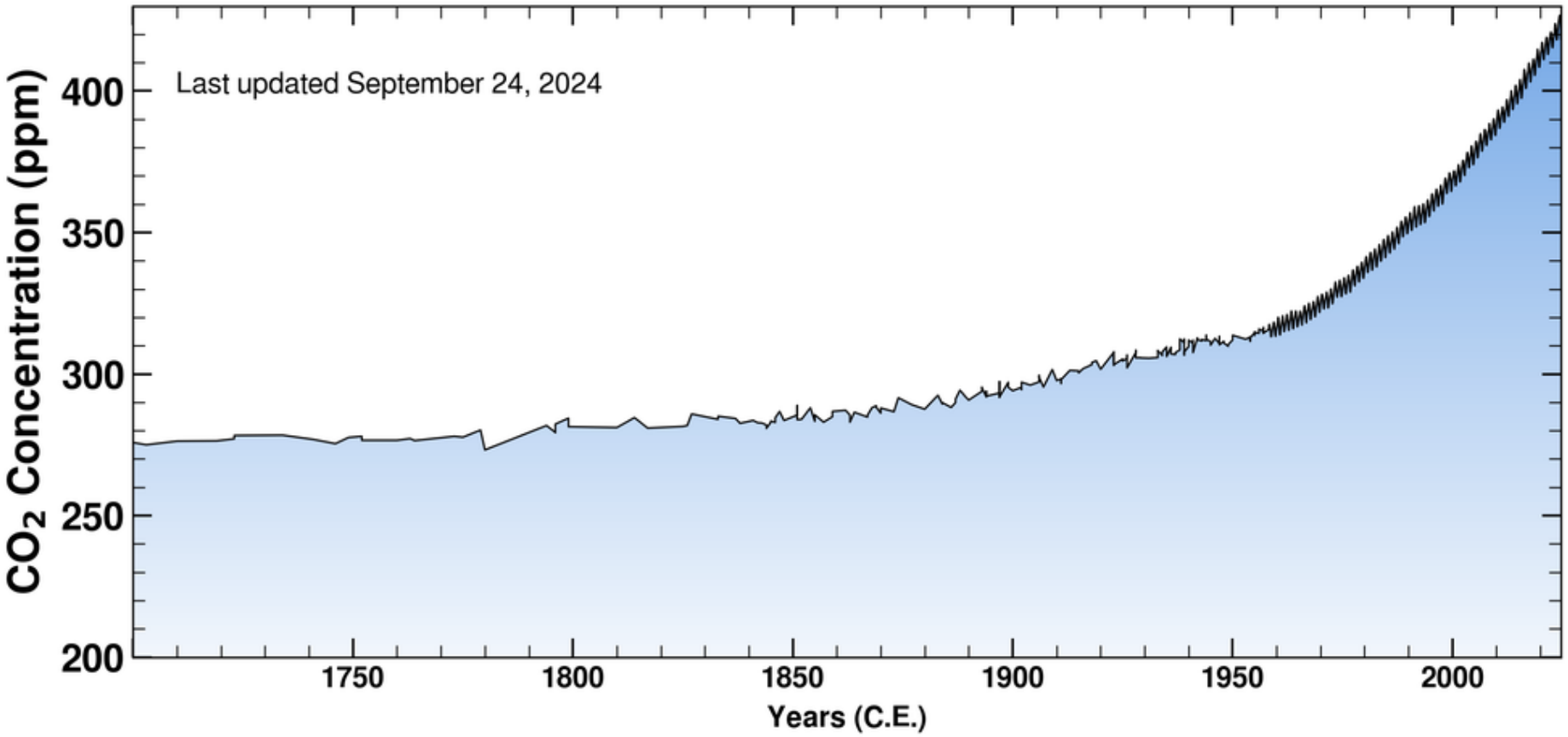


Data source: Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Atmospheric CO_2 Concentration



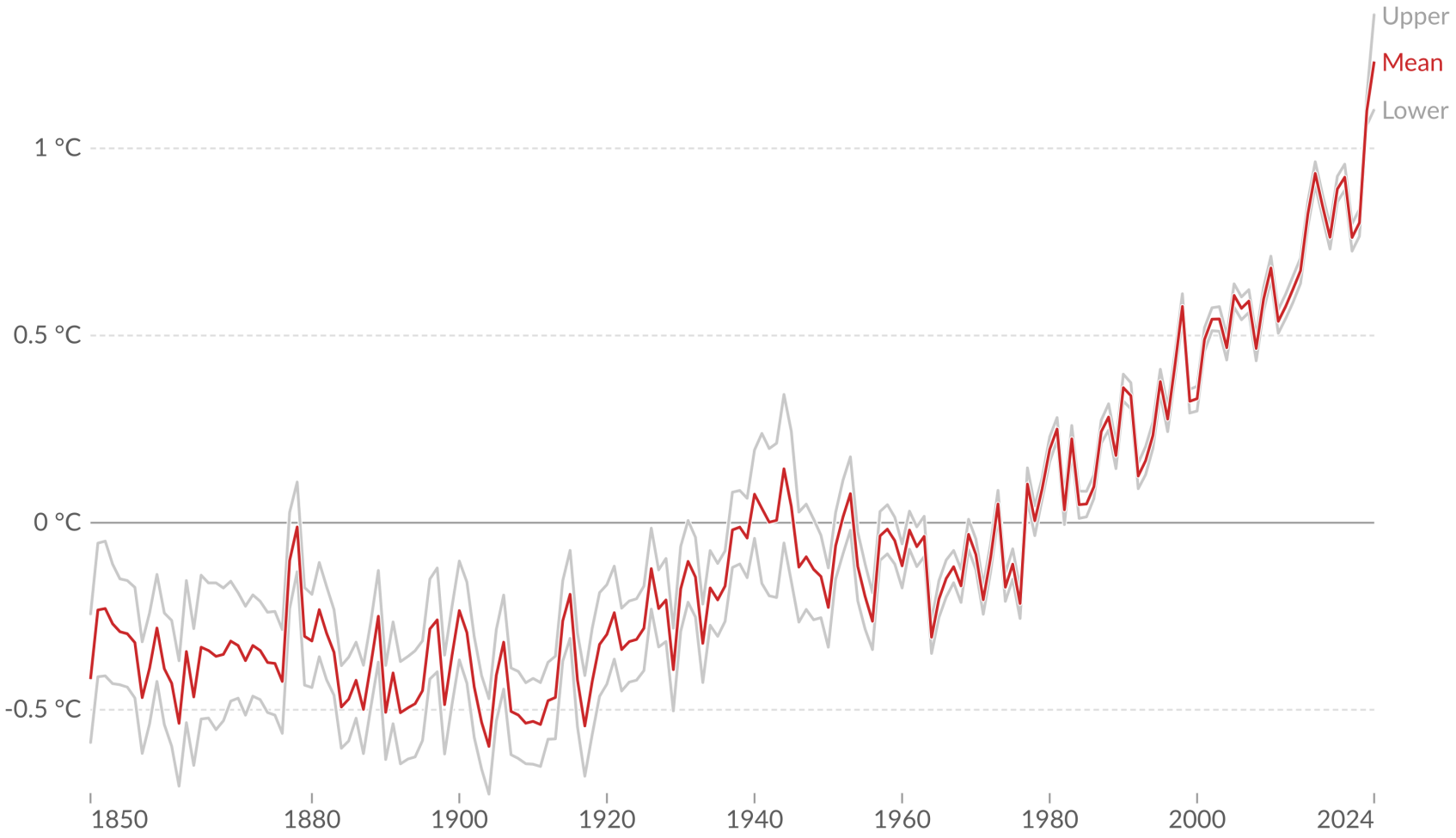
Source: Scripps Institution of Oceanography: Keeling Curve, Hawaii Observatory
https://keelingcurve.ucsd.edu/

Atmospheric CO_2 concentration is the cumulative CO_2 emissions since industrialization because CO_2 lasts 300 to 1000 years in atmosphere

Average temperature anomaly, Global

Our World in Data

Global average land-sea temperature anomaly relative to the 1961-1990 average temperature baseline.



Data source: Met Office Hadley Centre (2024)

OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY

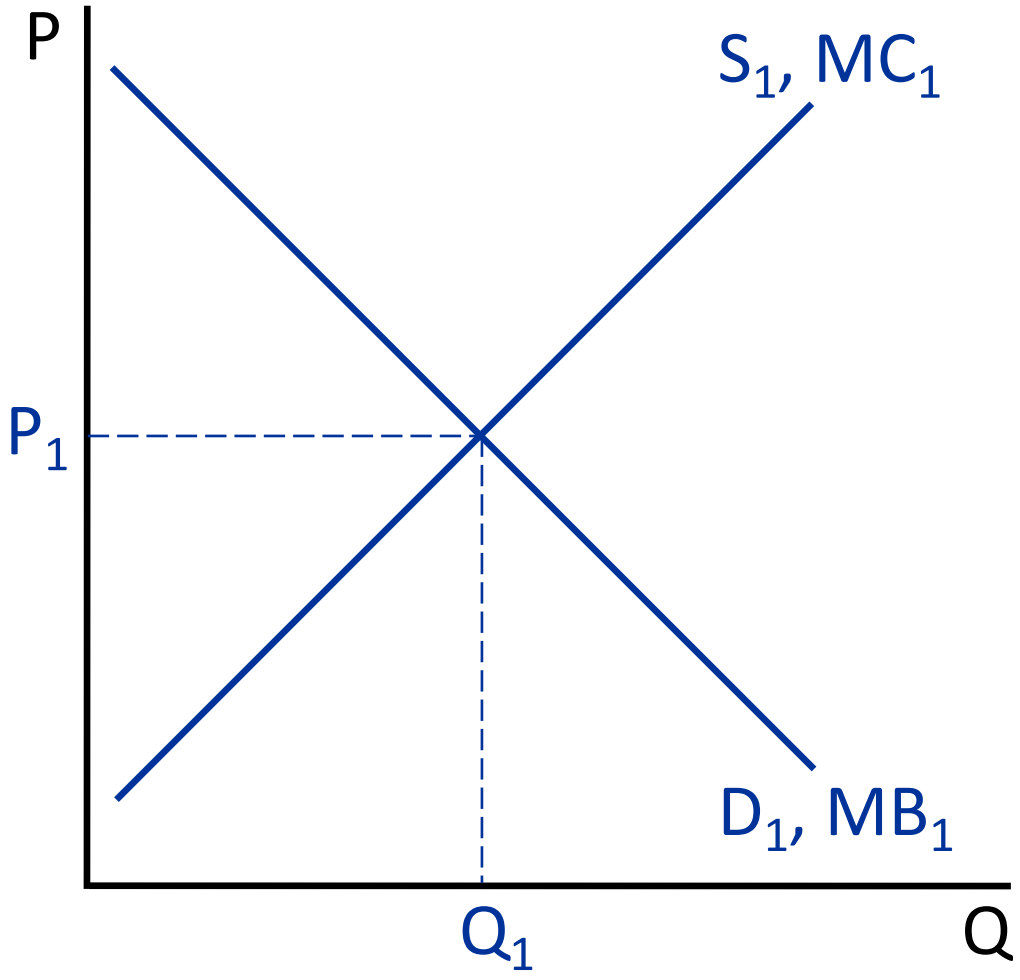
Note: The gray lines represent the upper and lower bounds of the 95% confidence interval.

Temperature gains are approximately proportional to atmospheric CO_2

Negative Externality Econ Modeling

- There are negative effects on agents outside the market mechanism
- These negative effects can be measured in $ costs (for economists, anything that matters can be measured in $ costs, a strong assumption)
- Negative externalities can result from either the consumption or the production of a good
  - Consumption negative externality: emitting CO_2 when driving a gas powered car
  - Production negative externality: emitting CO_2 when producing electricity in coal power plant

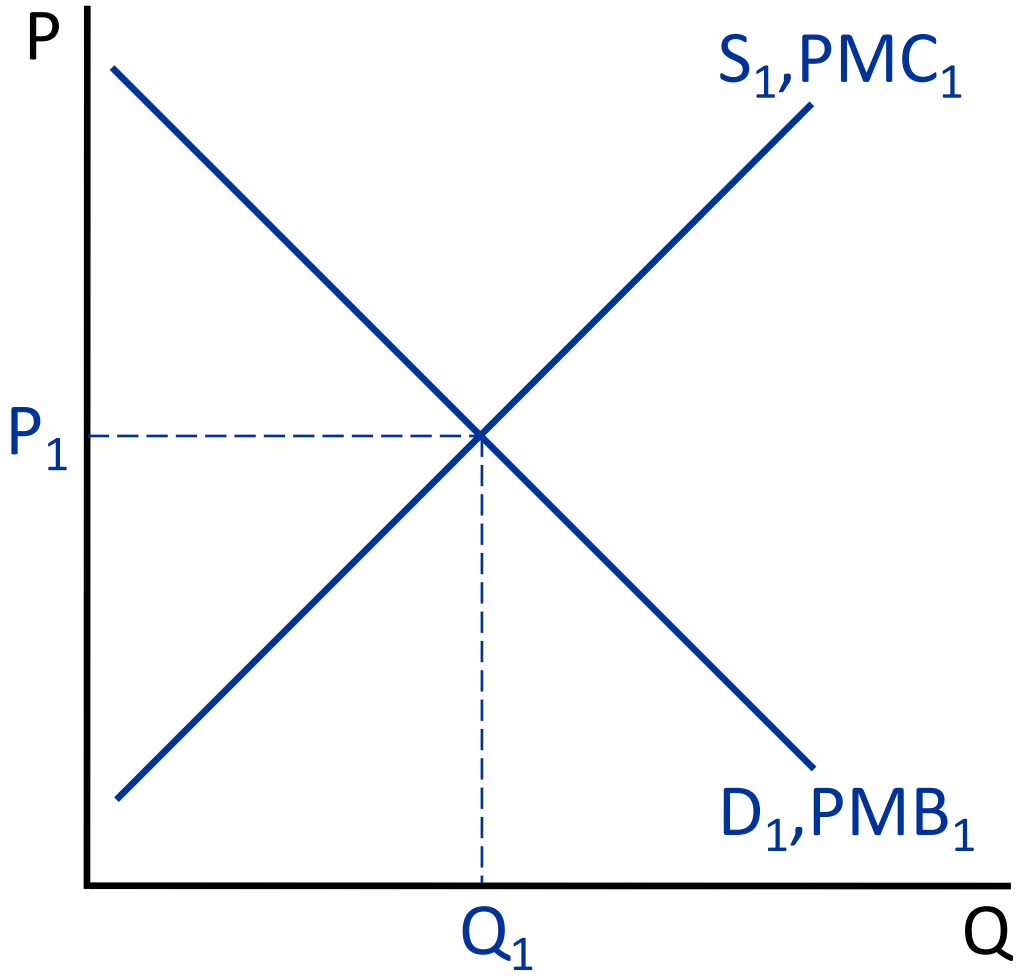
Market for Coal Powered Electricity



Some Terminology

- “Private” refers to the people participating in the market (the buyers and sellers, and the government if there is a tax or a subsidy).
- “Social” includes effects on people both in the market and outside the market.

Market for Coal Powered Electricity



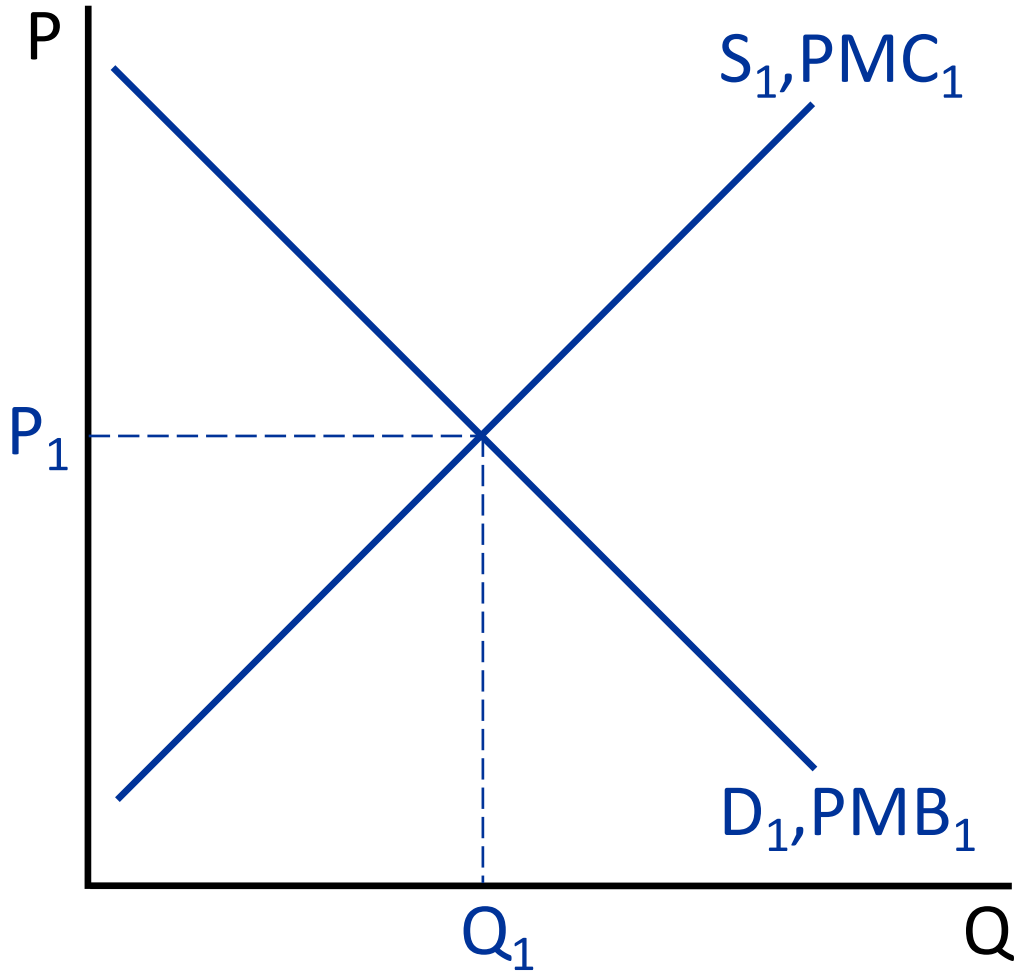
PMC is the private marginal cost (we used to call this MC)

PMB is the private marginal benefit (we used to call this MB)

Total Private Surplus

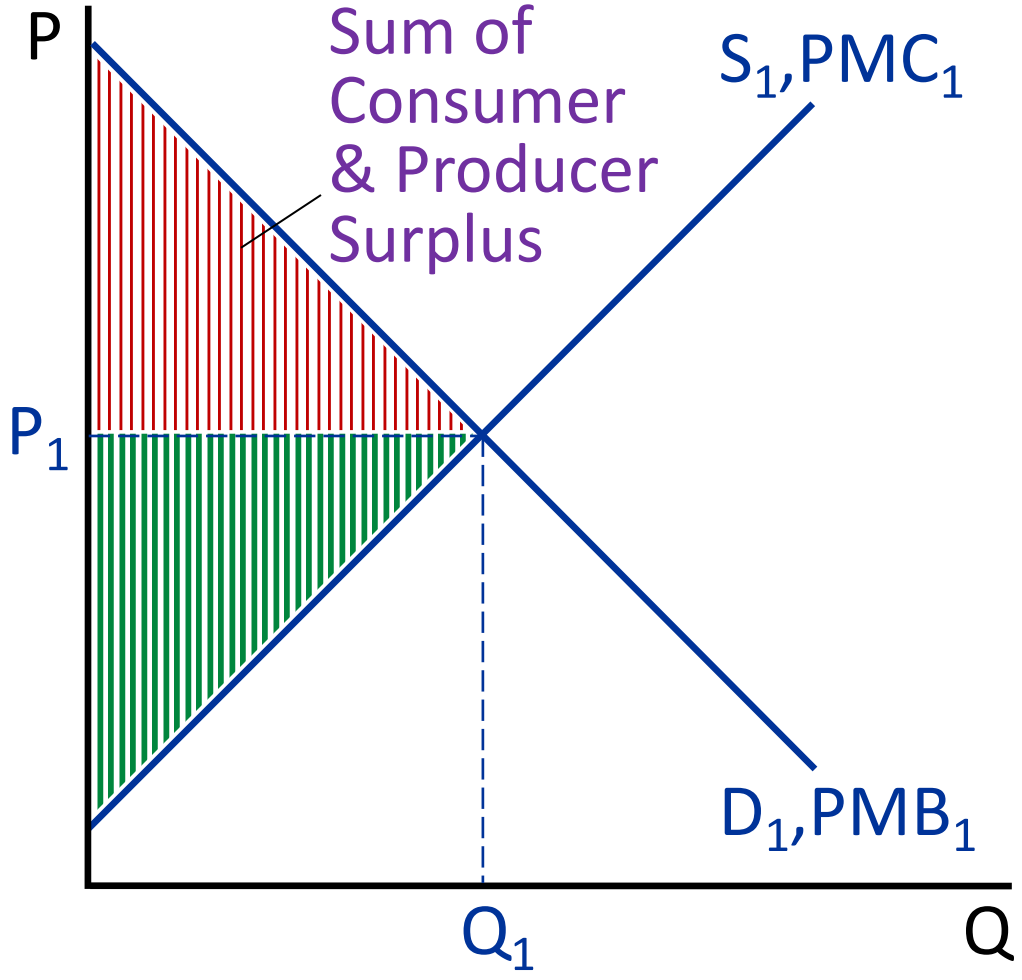
- Sum of consumer surplus and producer surplus (plus government revenue and minus government expenditure).

Review of Welfare Analysis



PMC is the private marginal cost; PMB is the private marginal benefit.

Market produces economic surplus for participants: consumers and producers



PMC is the private marginal cost (we used to call this MC)

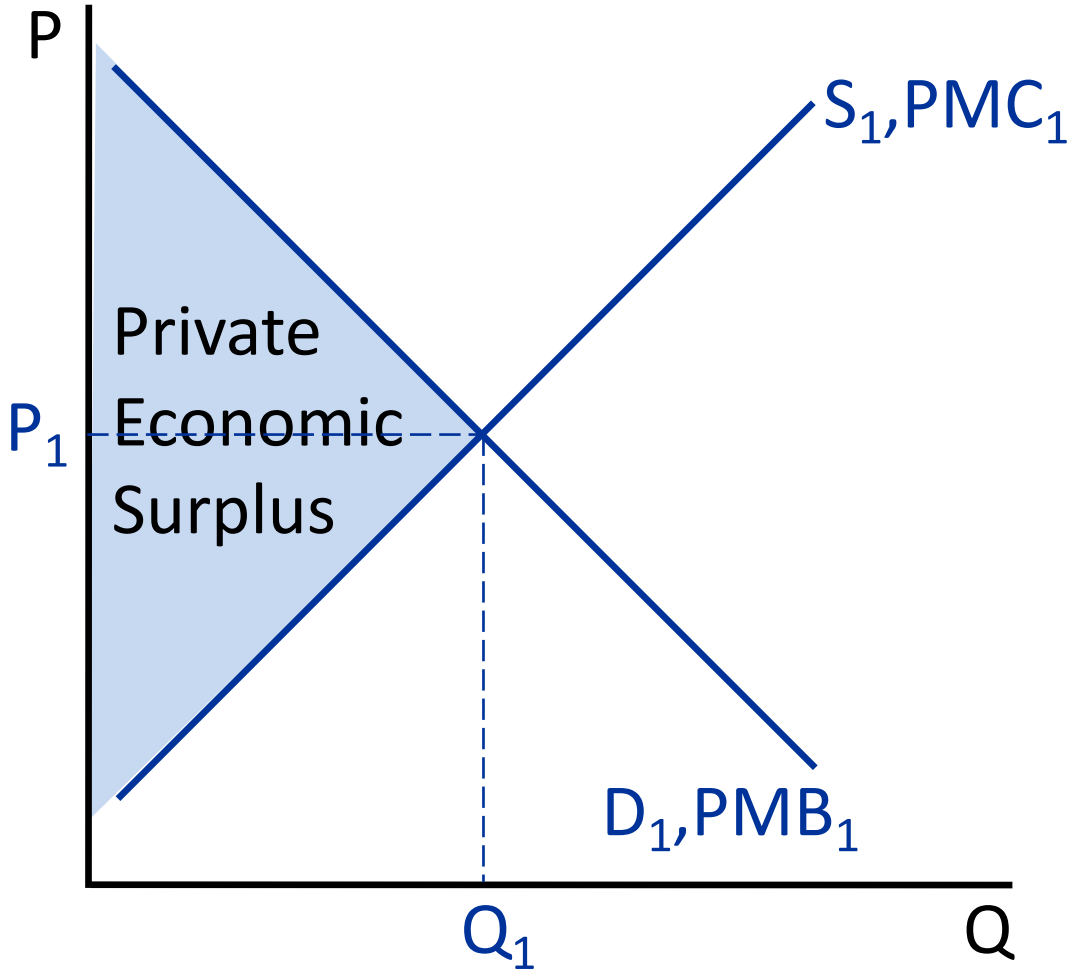
PMB is the private marginal benefit (we used to call this MB)

More Terminology

- External Marginal Cost: The additional cost to people outside the market when one more unit is produced and consumed (sometimes called marginal damage)
- Social Marginal Cost: Private marginal cost plus external marginal cost.

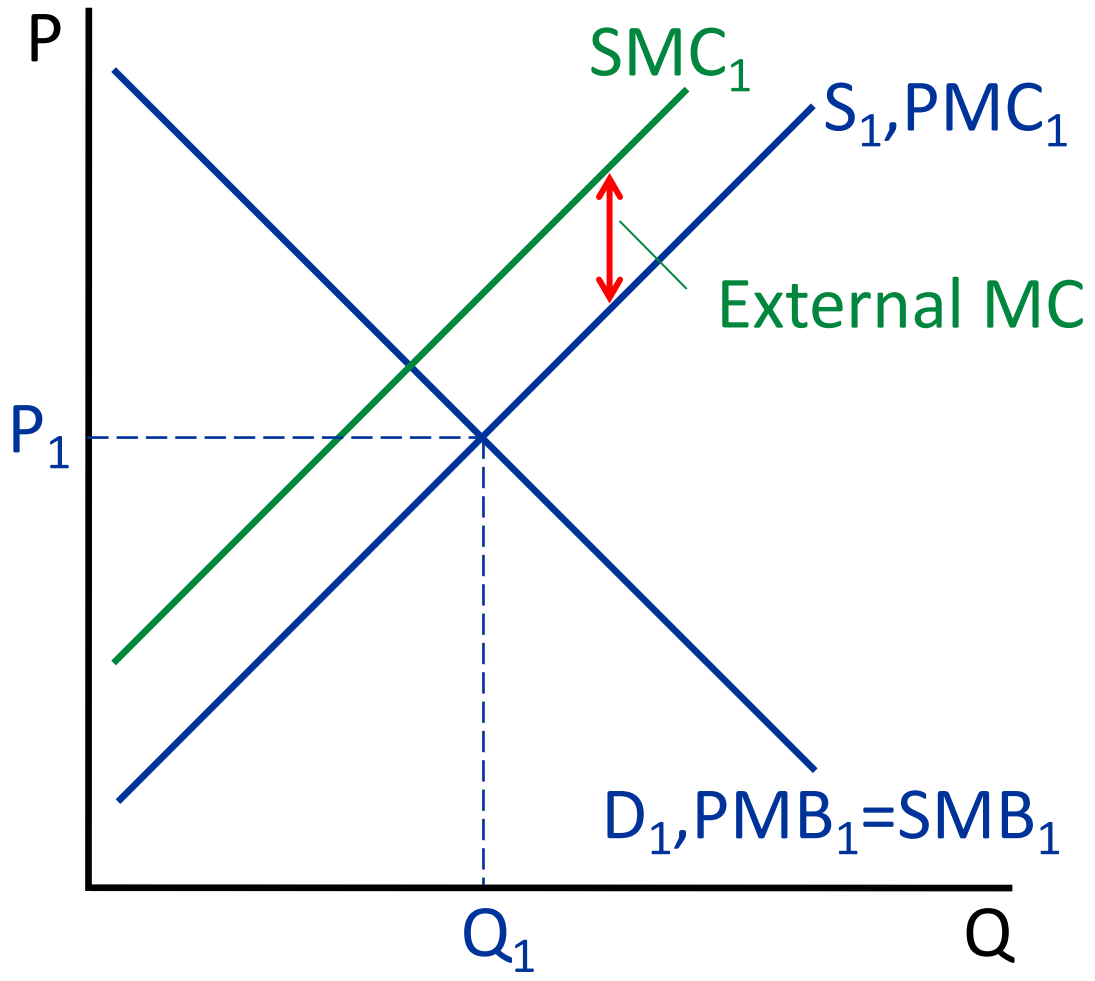
Negative Production Externality

(Market for Coal Powered Electricity)



Negative Production Externality

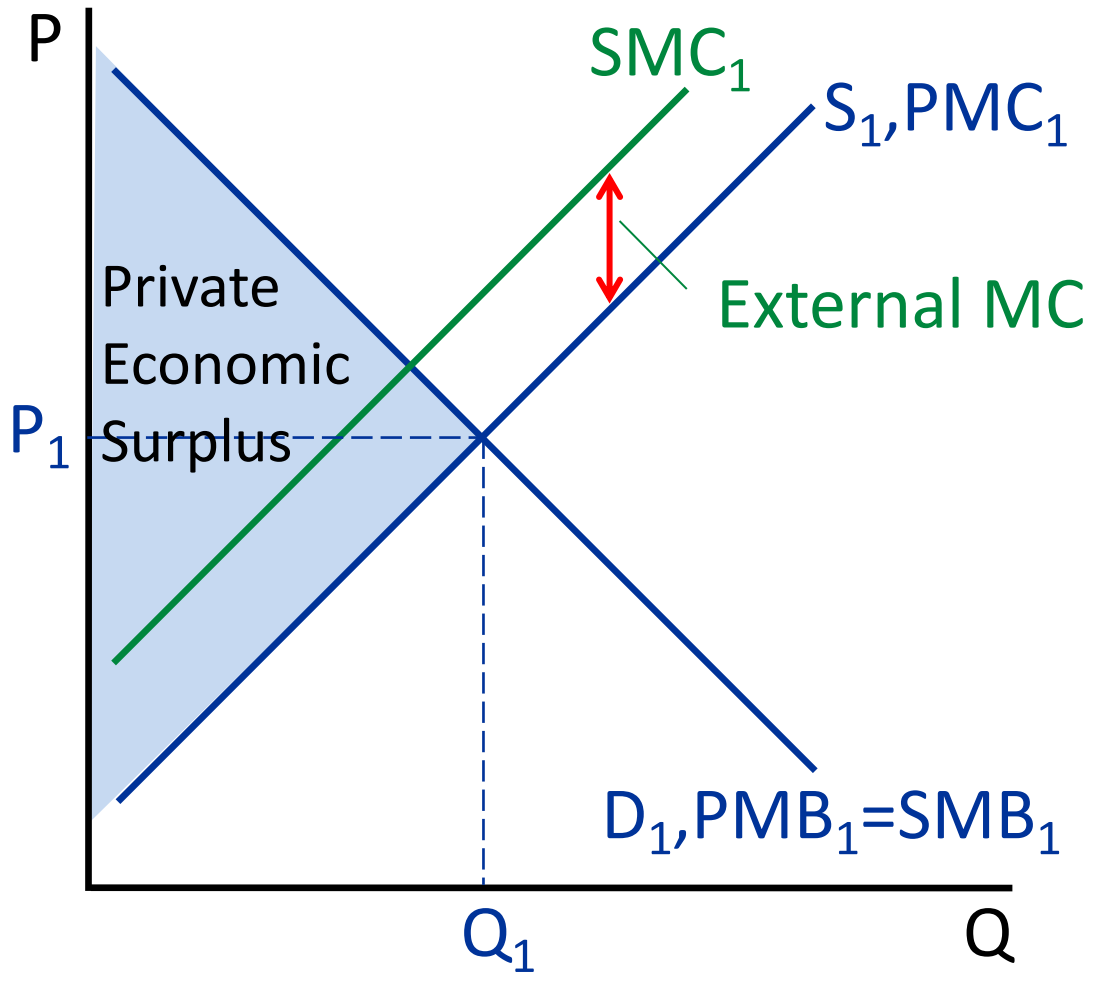
(Market for Coal Powered Electricity)



External MC is the $ measure of the external cost of producing 1 extra unit of coal powered electricity (e.g. global warming)

Negative Production Externality

(Market for Coal Powered Electricity)



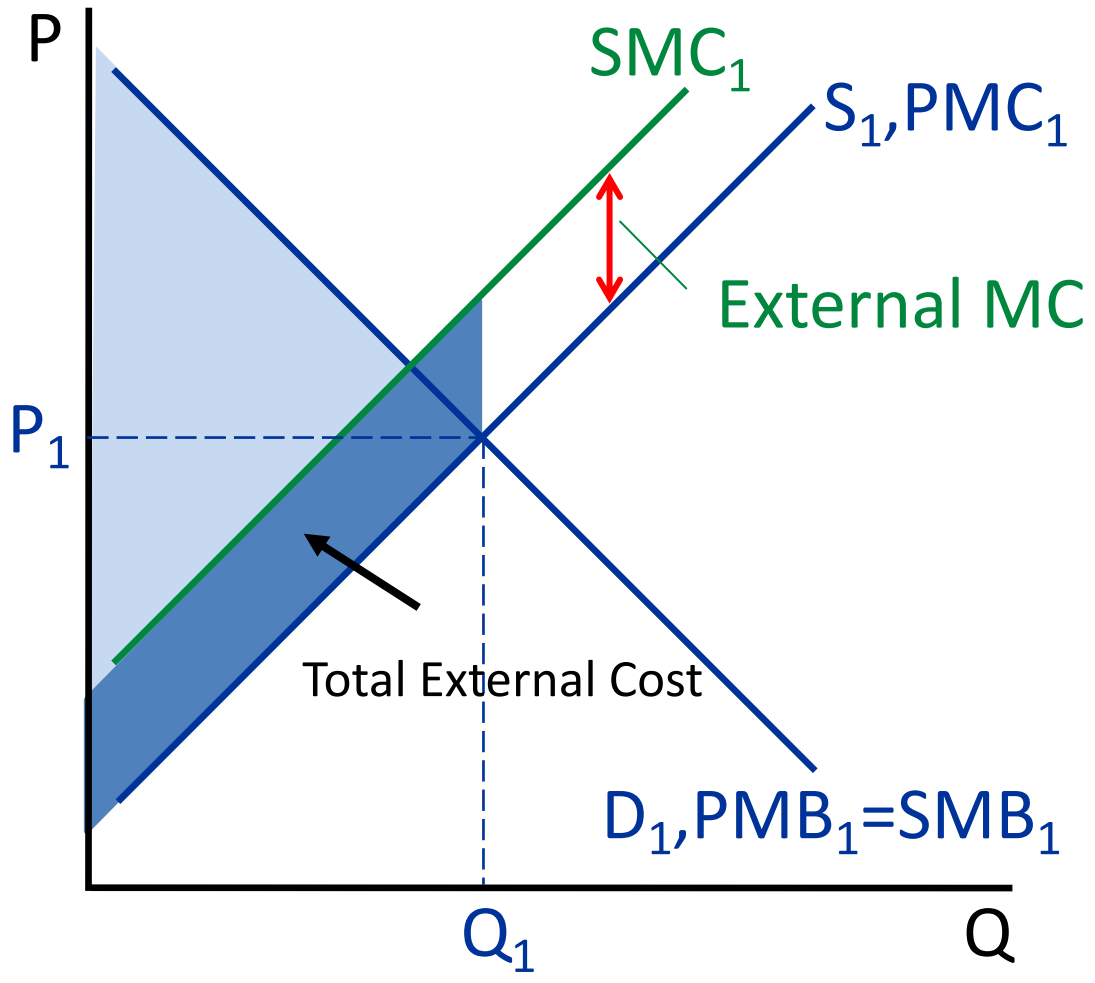
External MC is the $ measure of the external cost of producing 1 extra unit of coal powered electricity (due to climate change)

Total Social Economic Surplus

- Total private economic surplus plus external benefits minus external costs.
- It includes the welfare (measured in $) of both people in the market and outside the market.

Negative Production Externality

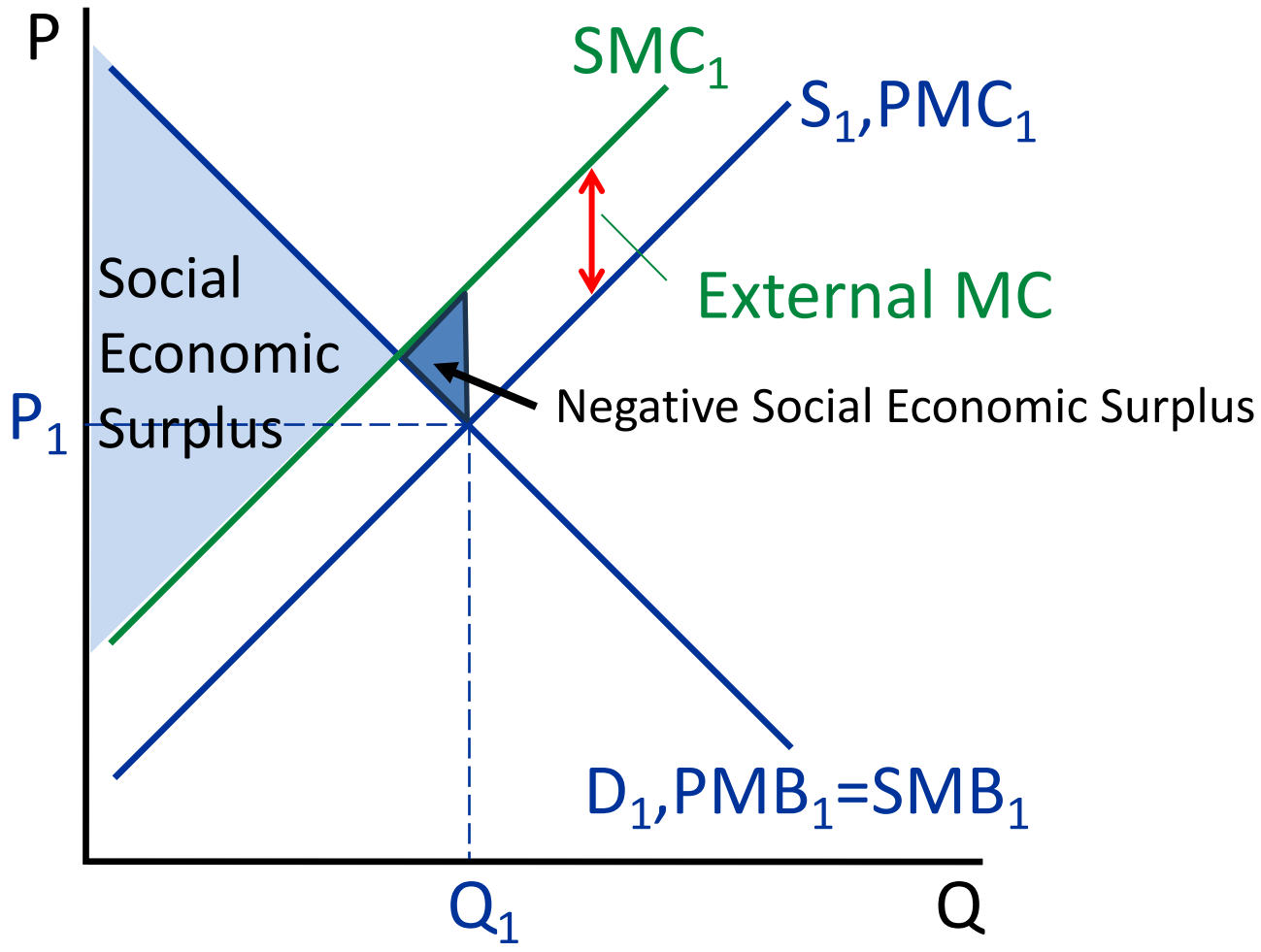
(Market for Coal Powered Electricity)



Dark blue area is the total external cost of producing Q_1: sum of external MC from 0 to Q_1

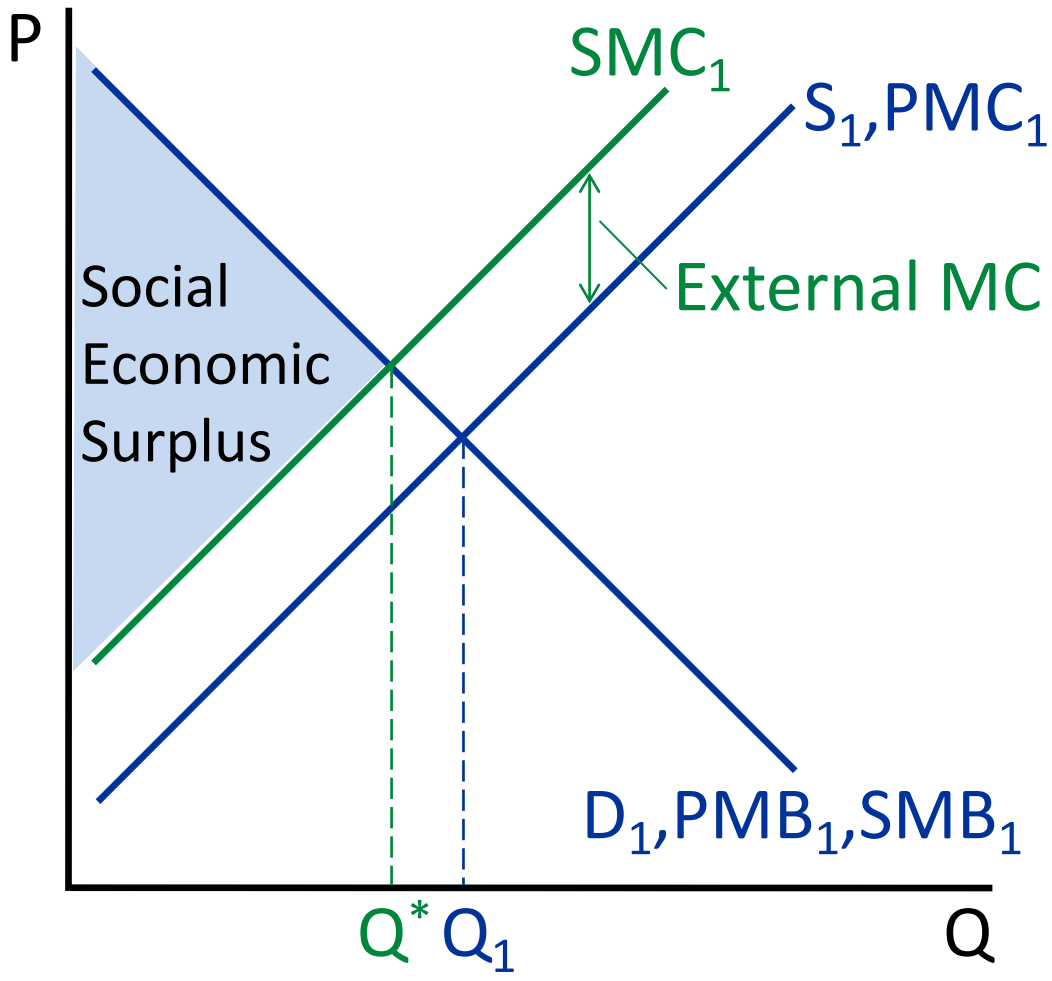
Negative Production Externality

(Market for Coal Powered Electricity)



Social Economic Surplus at Q_1 is the light blue area minus the dark blue area

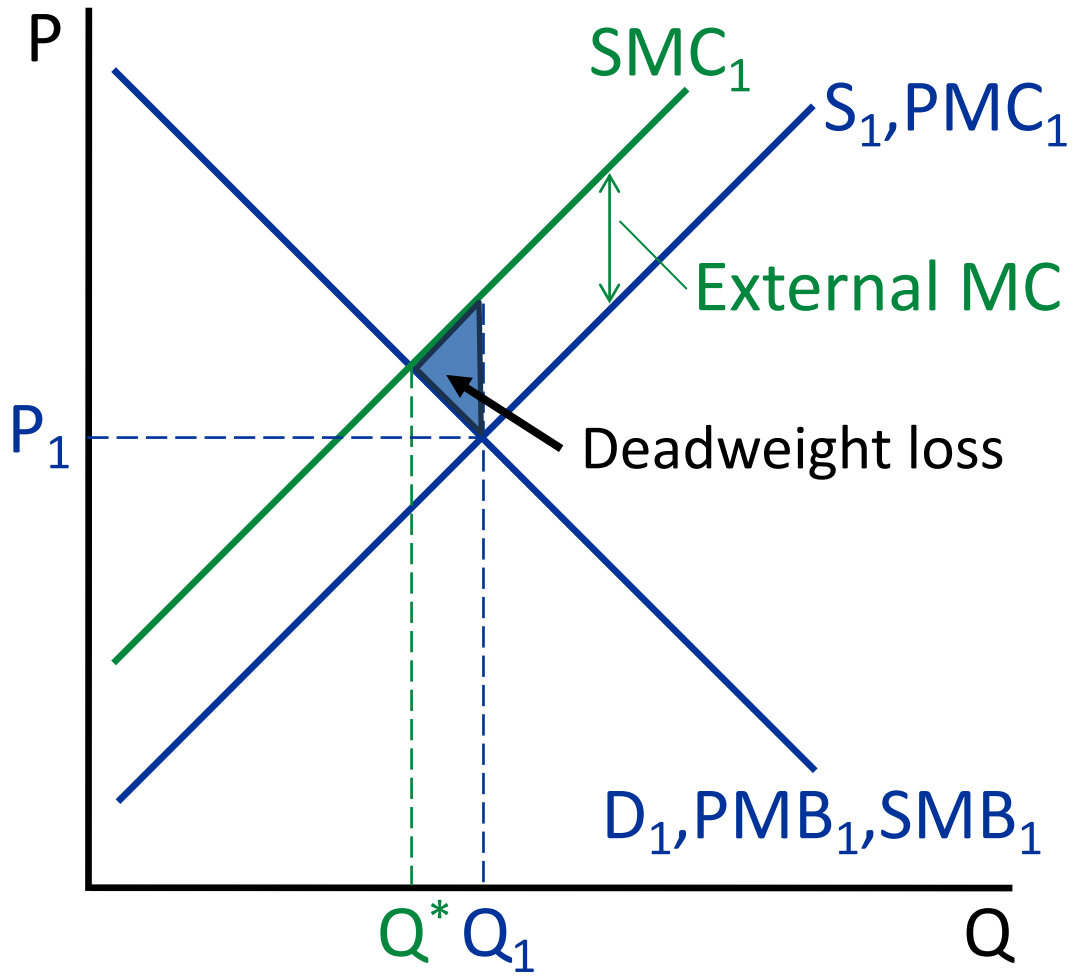
Efficient Quantity with Externality



Efficient quantity that maximizes social economic surplus is Q* (where SMC and SMB intersect)

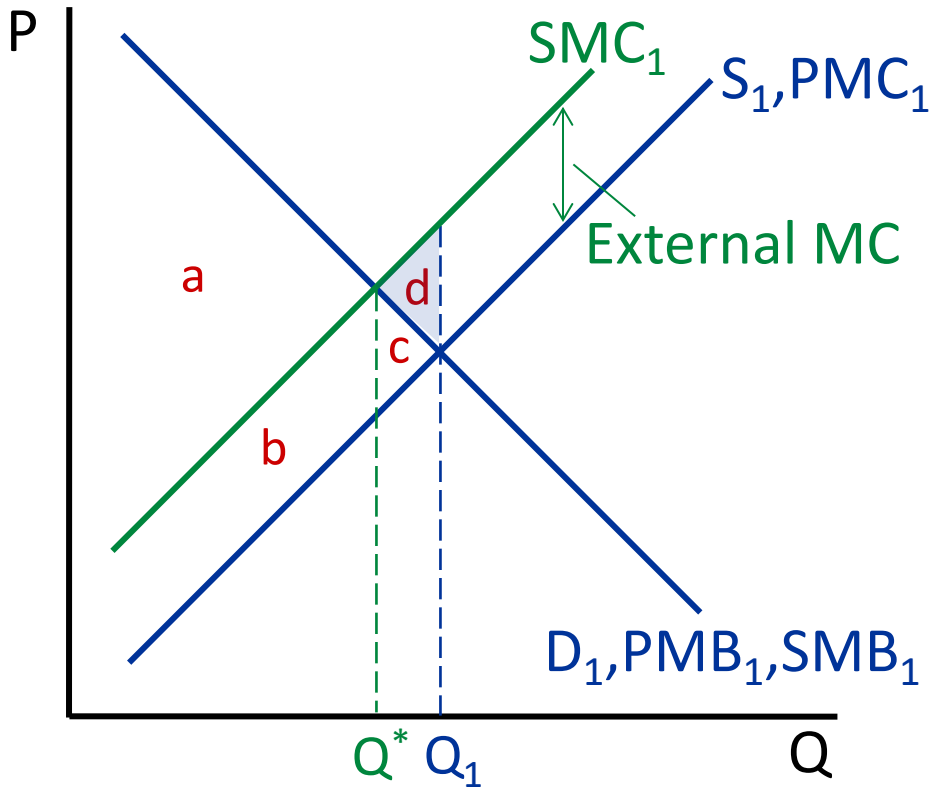
Negative Production Externality

(Market for Coal Powered Electricity)



Efficient quantity is Q* but market equilibrium quantity is Q_1:
Deadweight loss: triangle starting at Q_1 and pointing to Q*

Welfare Analysis of a Negative Production Externality



	Q_1	Q^*
Consumer and Producer Surplus	a+b+c	a+b
External Costs	−(b+c+d)	−b
Total Social Surplus	a−d	a
Deadweight Loss	d	

Deadweight Loss

- The total social surplus is largest at the quantity (Q*), where SMB=SMC.
- Why is this the case?
- Any shortfall from the largest total social surplus is the deadweight loss.

Whenever There Is a Negative Production Externality:

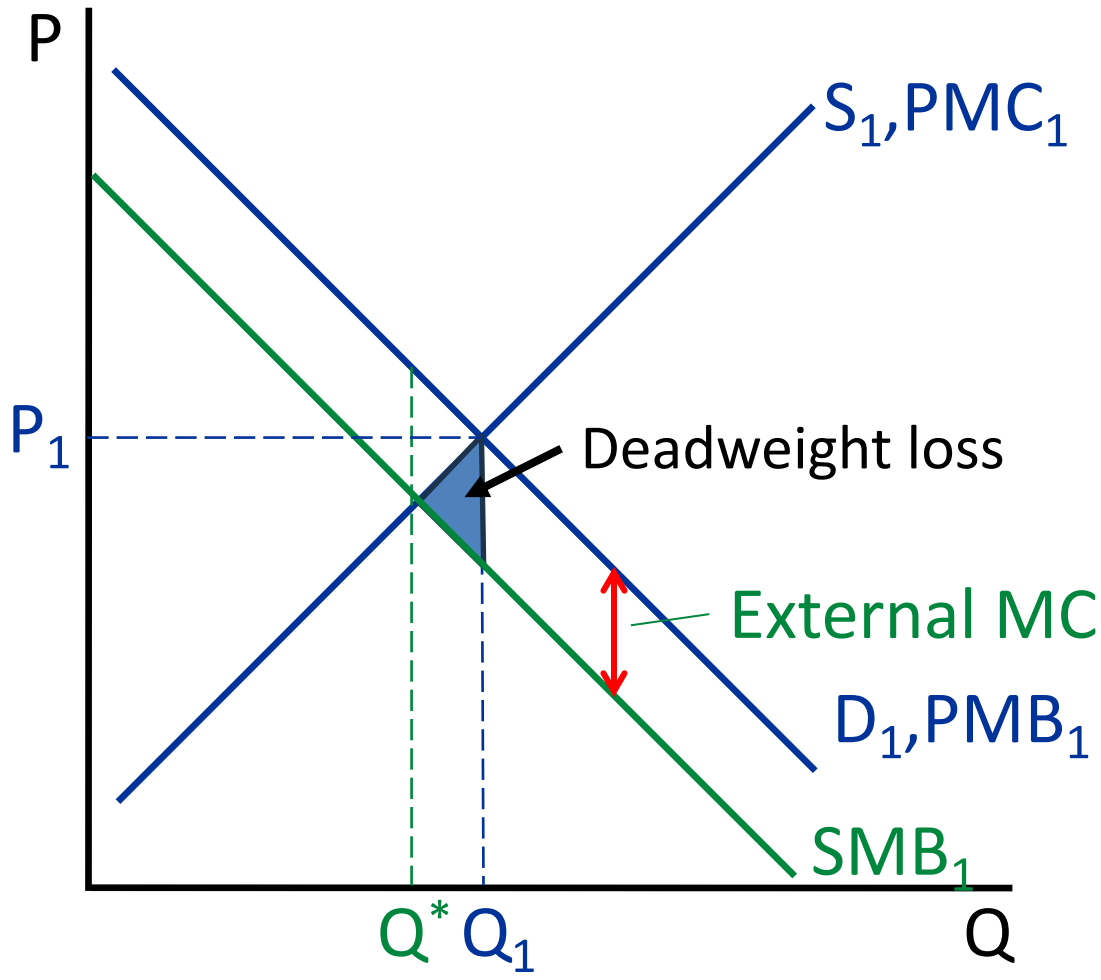
- The SMC curve lies above the PMC curve.
- The people in the market will choose to produce where PMC=PMB (or supply is equal to demand).
- But total social economic surplus higher if the market produced and consumed *less* (where SMC=SMB).

Some Points about the Welfare Analysis of a Negative Externality

- The total social surplus includes producers and consumers in the market as well as all agents affected by the externality
- Even with a negative externality, some production may still be desirable (if SMC and SMB intersect).
- When there is no externality, SMB and PMB are the same, and SMC and PMC are the same.
- Negative Consumption Externalities work the same by shifting down the PMB into the SMB

Negative Consumption Externality

(Market for Gasoline)



Efficient quantity is Q* but market equilibrium quantity is Q_1:

Deadweight loss: triangle starting at Q_1 and pointing to Q*

Quiz:

Question: Gasoline consumption generates a climate change negative externality. The market outcome is inefficient. Who is at fault?

- A. Consumers who don't take into account that gasoline contributes to global warming
- B. Producers who don't take into account that gasoline contributes to global warming
- C. Both consumers and producers
- D. Nobody is at fault

III. Positive Externalities

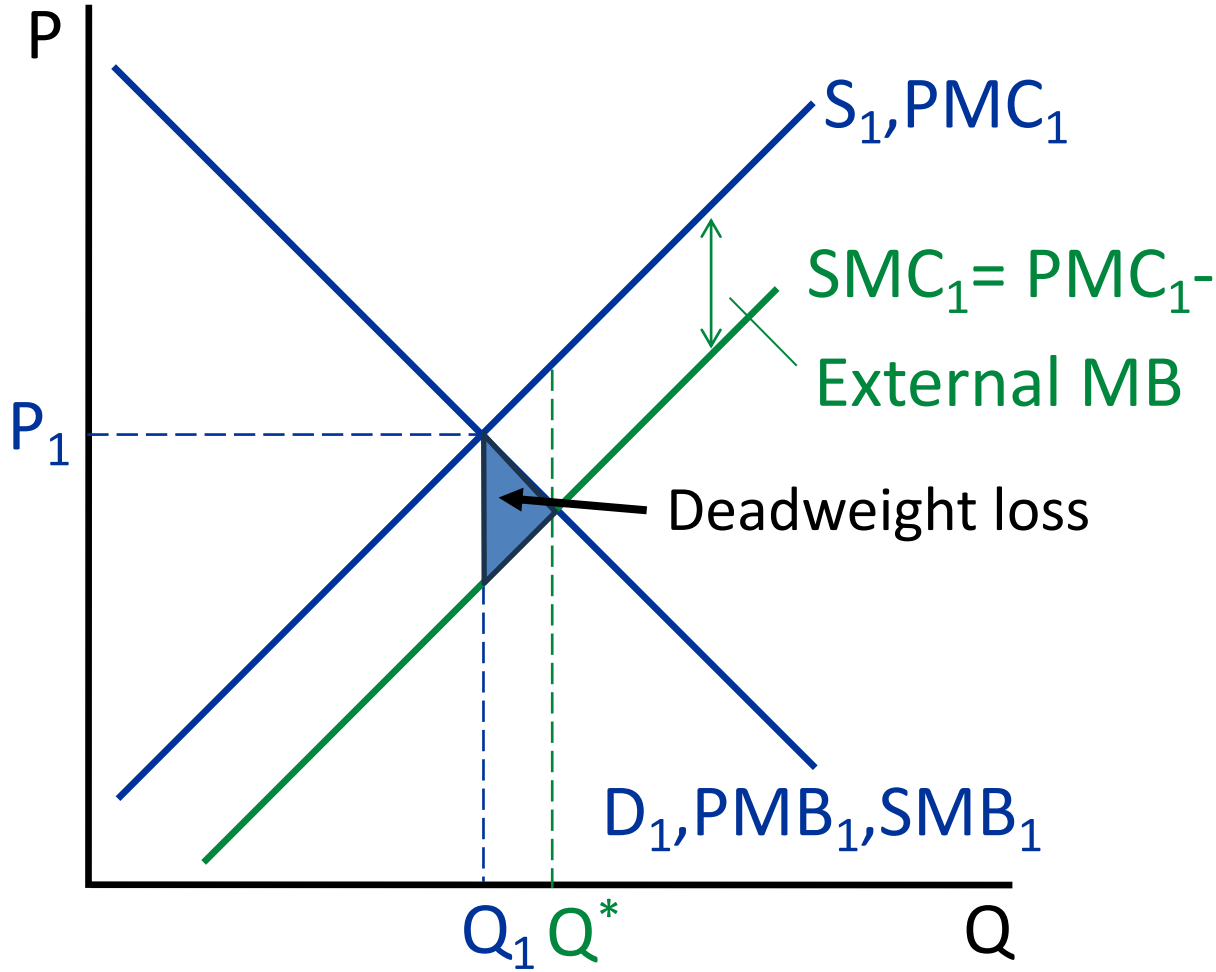
Positive Externality

- The effects on those outside the market are good.
- There is an external benefit.
- Positive externalities can result from either the consumption or the production of a good (or both).

More Terminology

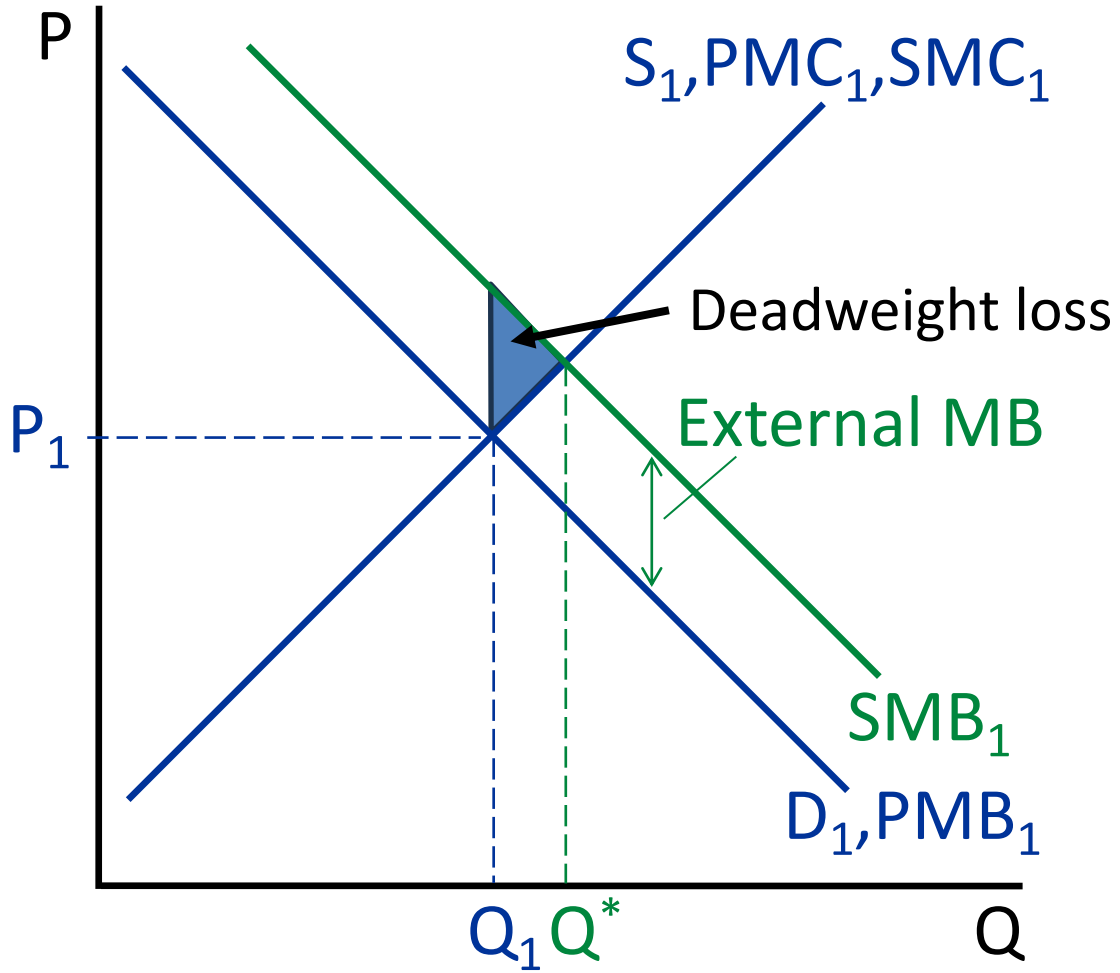
- External Marginal Benefit: The additional benefit to people outside the market when one more unit is produced and consumed.
- Mathematically: external marginal benefit is like a negative external marginal cost
- Social Marginal Cost: Private marginal cost minus external marginal benefit if positive externality in production
- Social Marginal Benefit: Private marginal benefit plus external marginal benefit if positive externality in consumption

Positive Production Externality
(Beehive honey production that helps crops)



Efficient quantity is Q* but market equilibrium quantity is Q_1:
Deadweight loss: triangle starting at Q_1 and pointing to Q*

Positive Consumption Externality
(Market for Vaccines)



Efficient quantity is Q* but market equilibrium quantity is Q_1:
Deadweight loss: triangle starting at Q_1 and pointing to Q*

Other Examples of Positive Externalities?

- **Technology spillovers:** Firms constantly invent better production processes that can then be copied and drive long-run economic growth
- **Education and research:** Fundamental knowledge taught and created also has spillovers on industry (e.g., Stanford and Silicon Valley)
- **Mundane example:** Planting flowers in your yard that neighbors enjoy. Almost everything not market mediated has externalities!

Whenever There Is a Positive Externality:

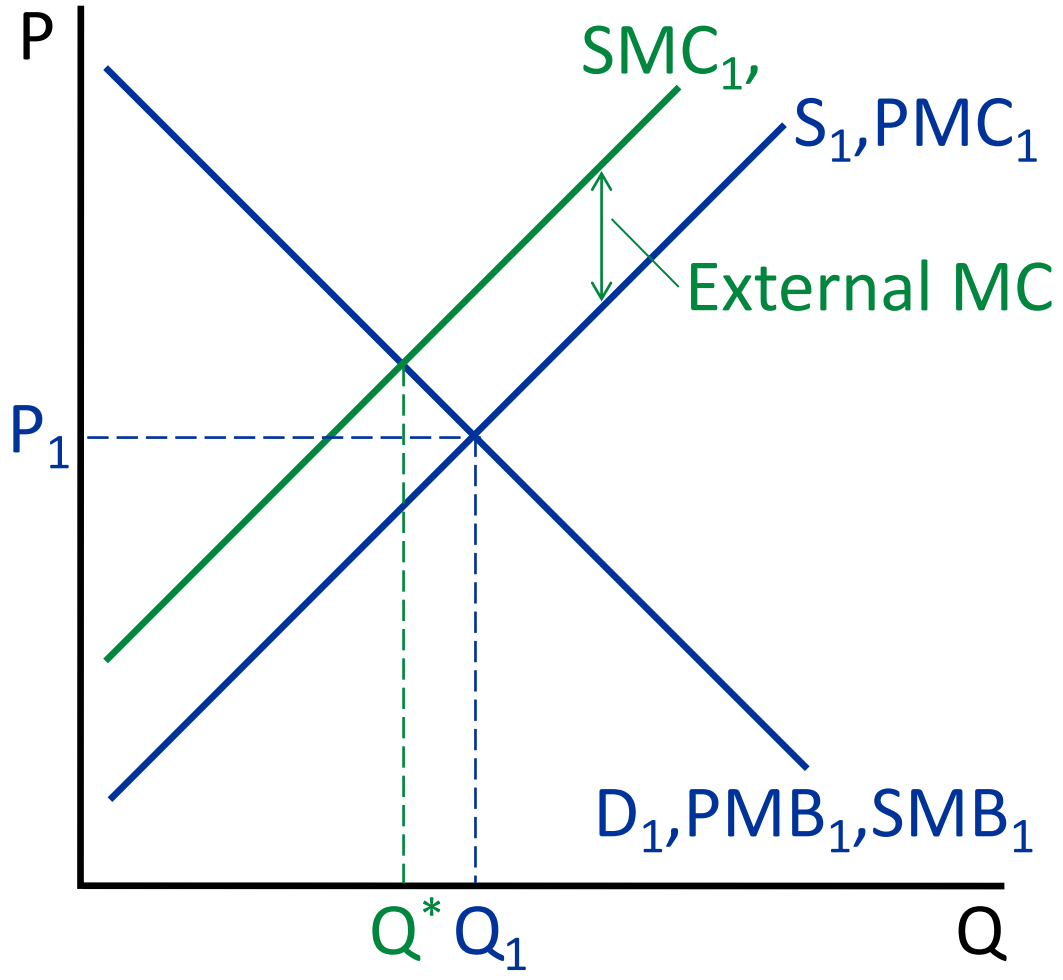
- The SMC curve lies below the PMC curve.
- The people in the market will choose to produce where PMC=PMB (or supply is equal to demand).
- But society would be better off if the market produced and consumed *more* (where SMC=SMB).

IV. Remedies for Externalities

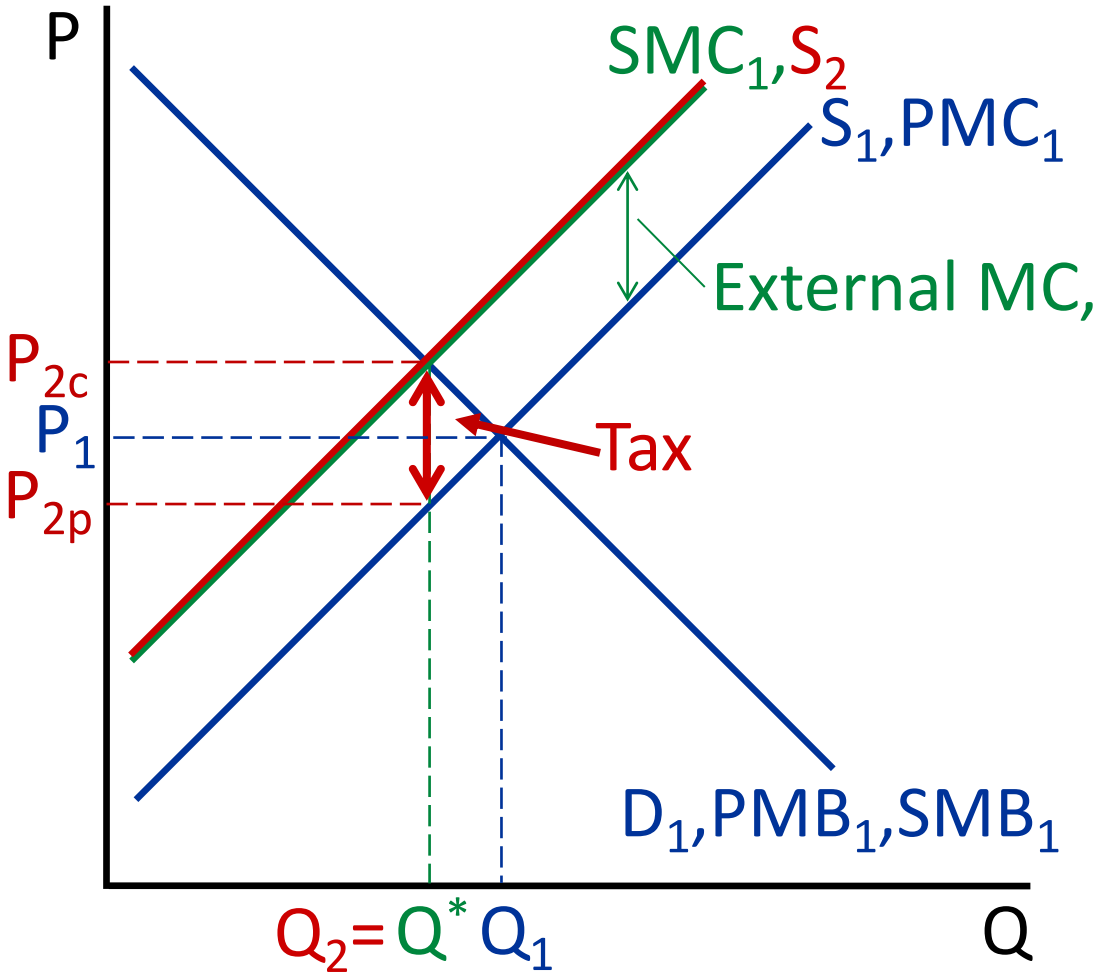
Remedies for Externalities

- Private Solution:
  - Negotiation and compensation
  - Social sanctions
- Government Regulation
  - Some externality generating actions are regulated or prohibited
- Taxes and Subsidies
  - Taxes can discourage negative externalities and subsidies encourage positive externalities

Tax Remedy for a Negative Producer Externality

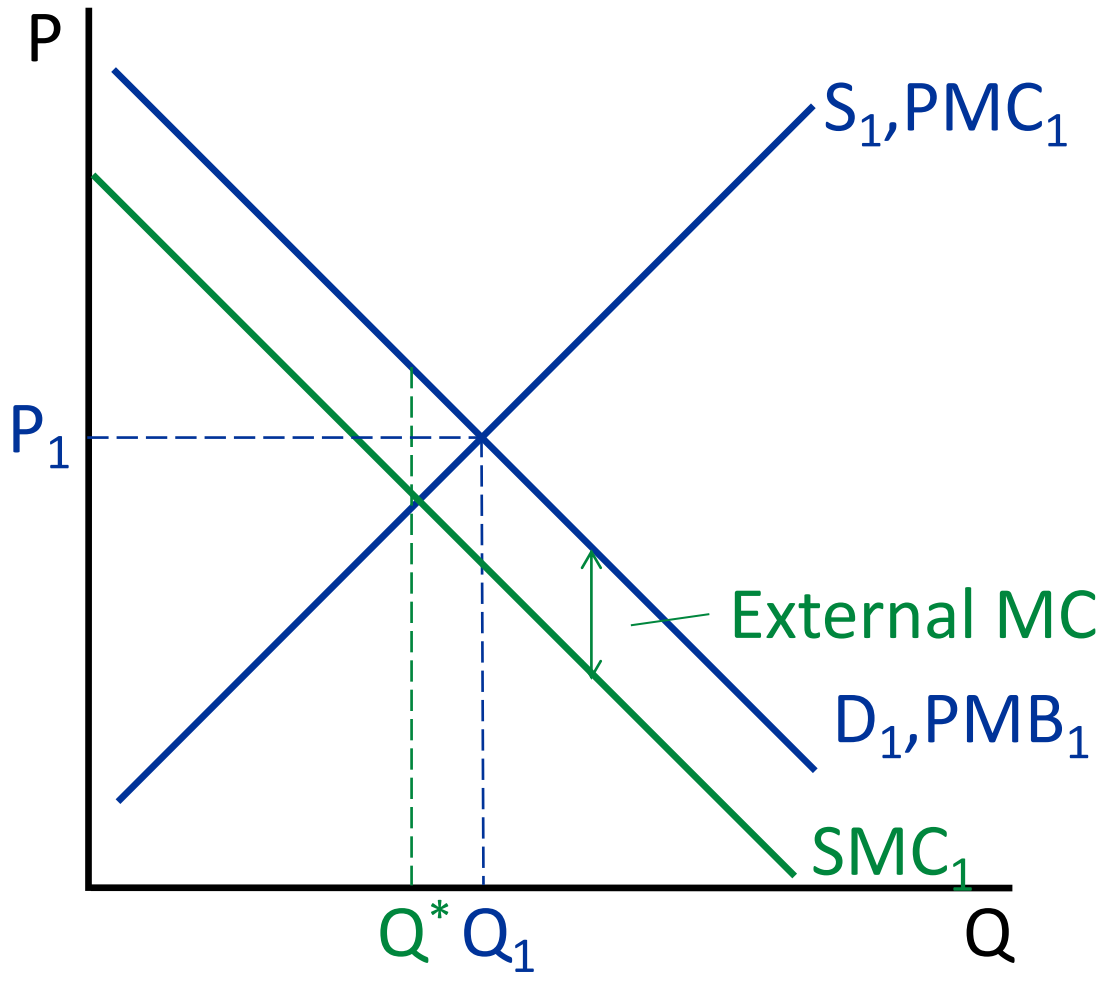


Tax Remedy for a Negative Producer Externality

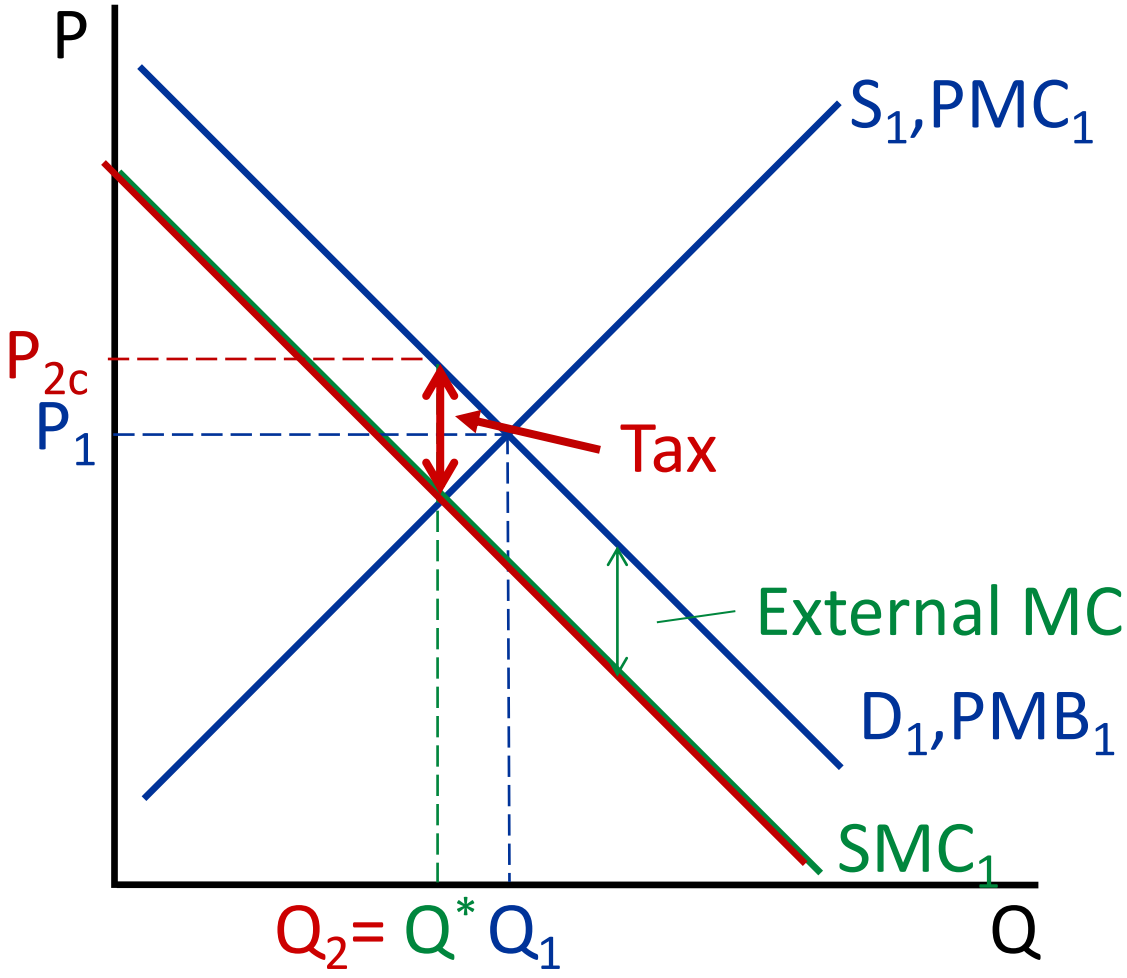


A tax on producers equal to the external MC shifts PMC up to SMC and moves equil. from Q_1 to $Q_2=Q^*$. P_{2c} is consumer price, P_{2p} producer price

Tax Remedy for a Negative Consumption Externality



Tax Remedy for a Negative Consumption Externality



A tax on consumers equal to the external MC shifts PMB down to SMB and moves equilibrium from Q_1 to Q_2=Q*.

Quiz:

Question: Suppose the externality is on consumer side (like gasoline for driving). Which tax remedy works?

- A. A gas tax on consumers
- B. A gas tax on producers
- C. Both A. and B.
- D. None

Quiz:

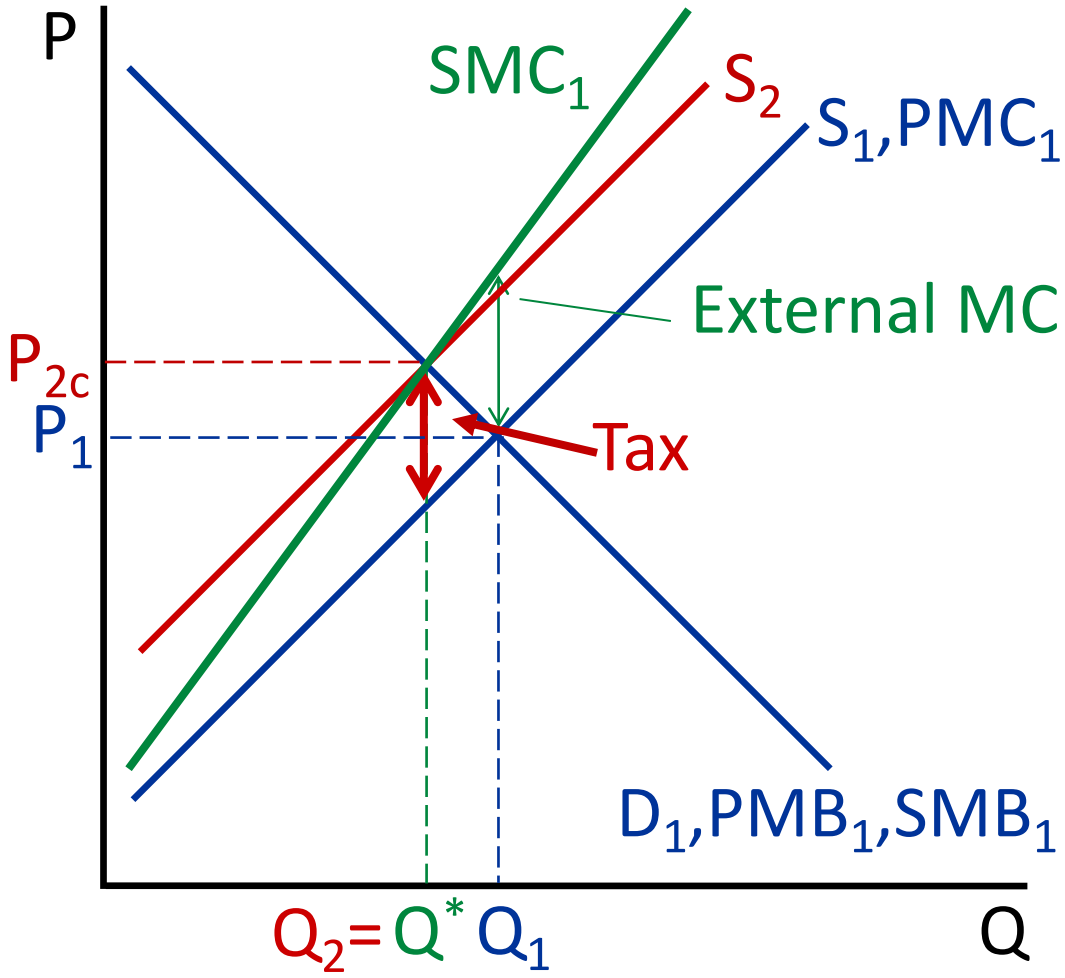
Question: Gasoline consumption generates a climate change negative externality with marginal cost $2 per gallon. What is the correct remedy?

- A. $2 tax per gallon charged on consumers
- B. $2 tax per gallon charged on producers
- C. Either A. or B.
- D. Phase-out gas cars

Tax Remedy for Negative Externality

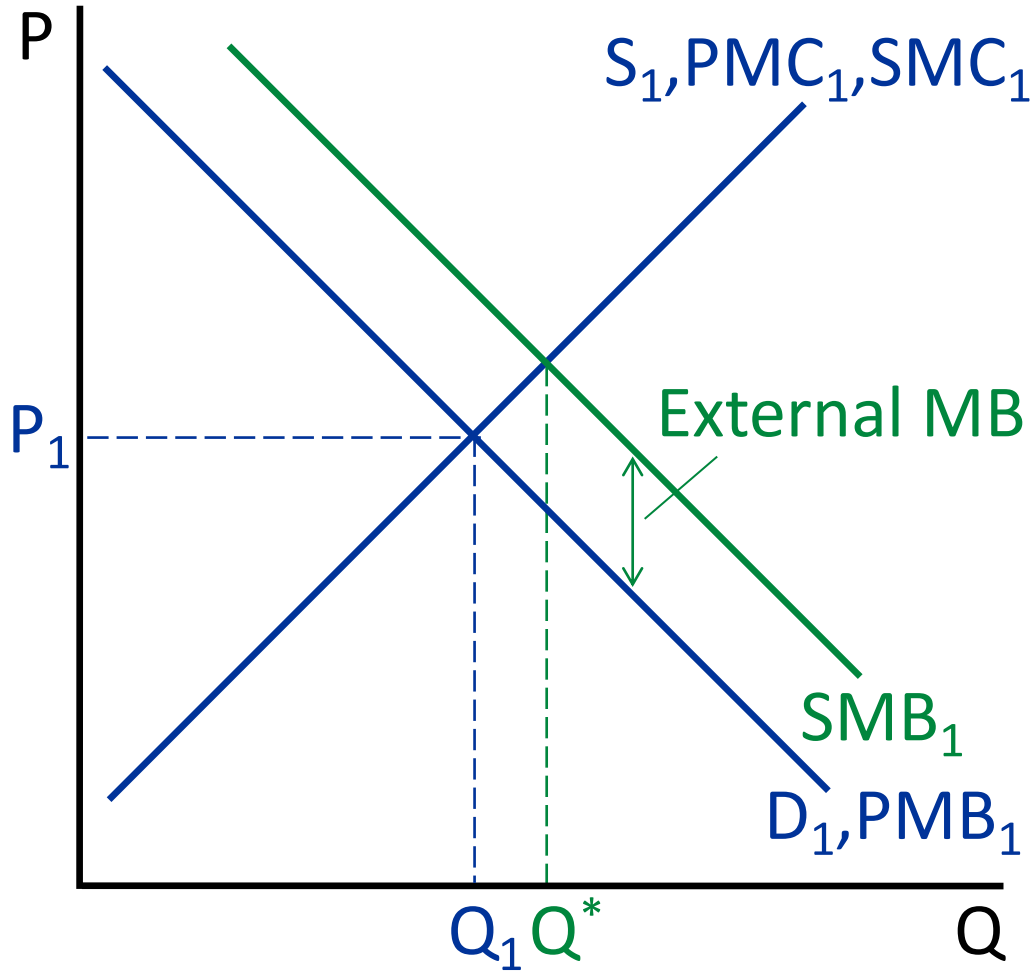
- A tax per unit equal to the external MC moves the market equilibrium to efficiency.
- It does not matter whether the tax is charged to consumers or producers (see earlier lecture)
- It does not matter whether the externality is created by producers or consumers
- If external MC varies with Q: The right tax is the marginal external effect at the **socially efficient point**

Tax Remedy for Negative Externality with non constant MC

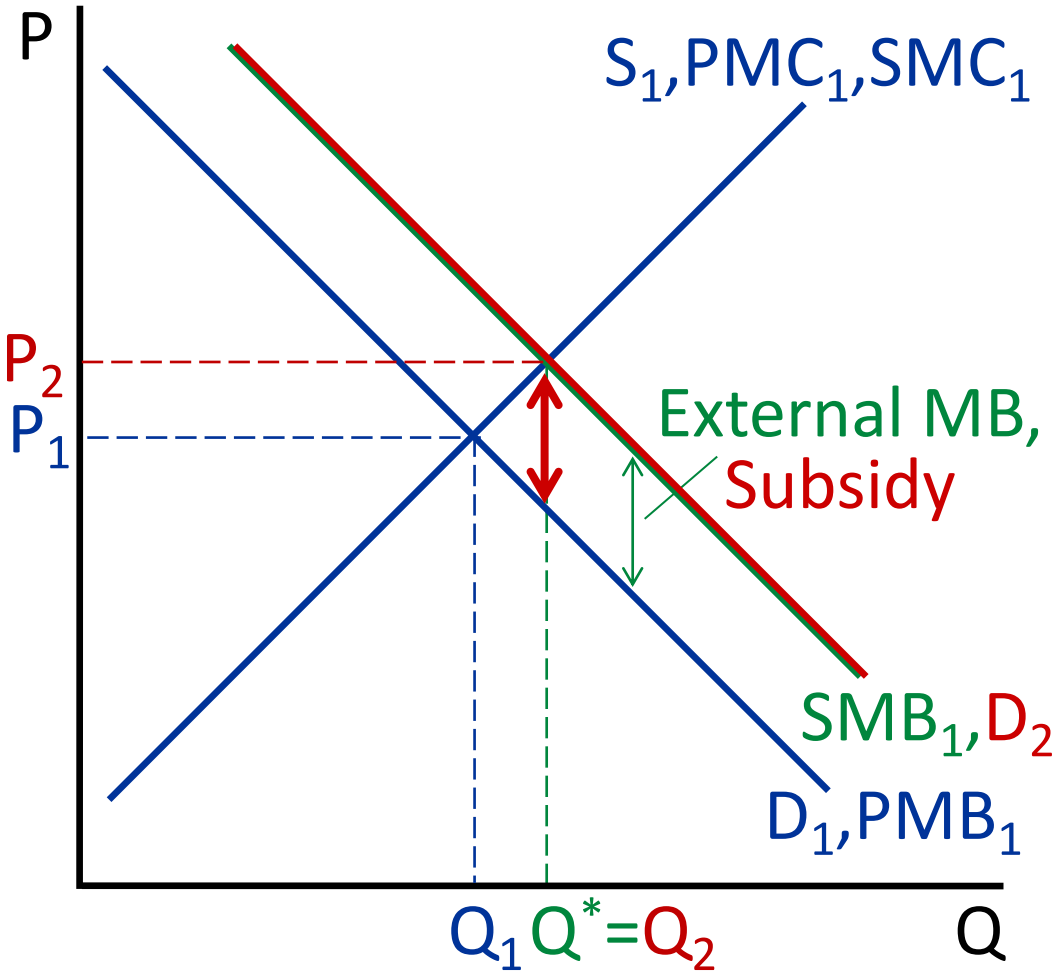


A tax per unit equal to the external MC at Q* shifts PMC up and moves equilibrium from Q_1 to Q_2=Q*

Remedy for a Positive Externality (Subsidy)



Remedy for a Positive Externality (Subsidy)



A producer subsidy equal to the external MB shifts PMB up to SMB and moves equilibrium from Q_1 to Q_2=Q*

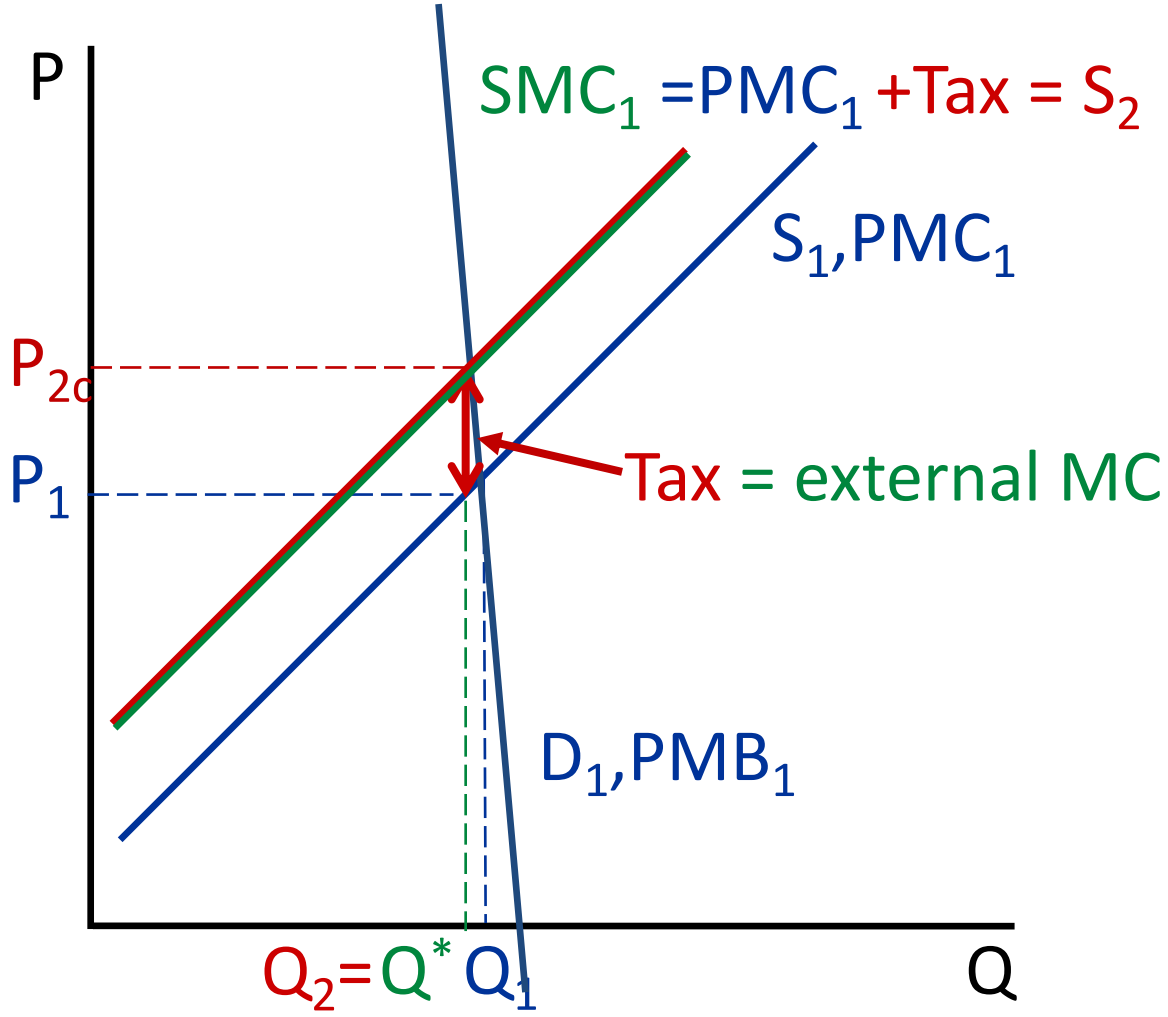
Quiz:

Question: Gasoline consumption generates a climate change marginal external cost of $2 per gallon. But suppose gasoline consumption is completely inelastic to price. What is the correct remedy for efficiency?

- A. A $2 tax per gallon
- B. Nothing
- C. Either A. or B.
- D. Phase-out gas cars

Tax Remedy with inelastic demand

(Tax and externality on producer side for visibility)



With inelastic demand, Q_1 is very close $Q_2=Q^*$ (identical with totally inelastic demand). Corrective tax does not change Q. It just reduces consumer surplus and is not needed.

Quiz:

Question: Suppose ag industry invent a powerful new pesticide that helps grow coffee in poor countries more cheaply but is toxic. Marginal damage is $10/unit as locals are poor (would be $100/unit in the US). What is the correct remedy?

- A. A $10 tax per unit
- B. A $100 tax per unit
- C. Nothing
- D. The pesticide should be entirely prohibited

Corrective (or Pigouvian) Taxes/Subsidies

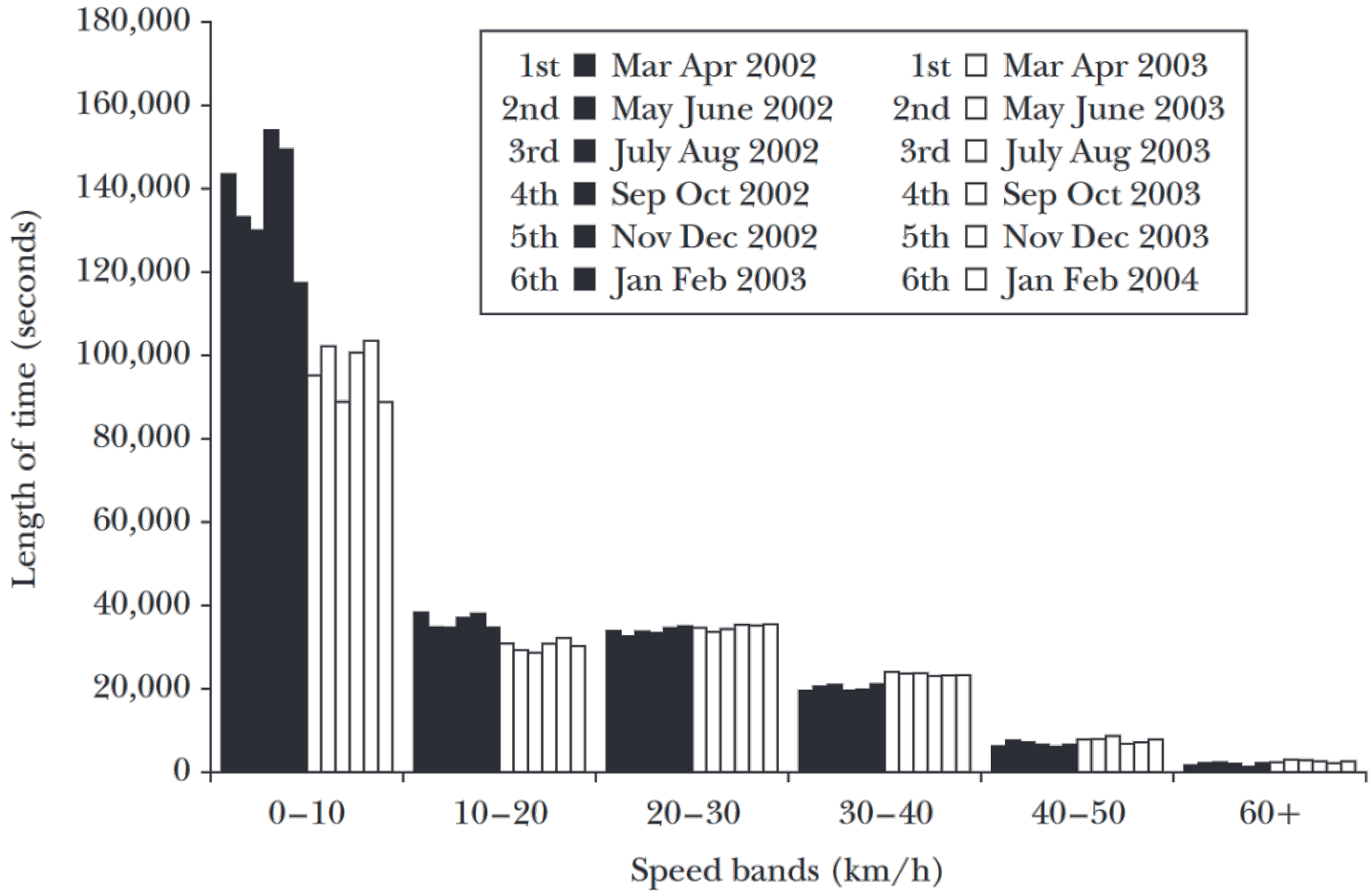
- Named after economist Arthur Pigou (1877-1959)
- The idea to make economic agents internalize the externality by incorporating it in the price
- For a negative externality: charge you a per-unit tax equal to the amount that others suffer from your action
- For a positive externality: award you a per-unit subsidy equal to the amount that others benefit from your action
- If you get the amount of the tax or subsidy right, this brings private incentives in line with social incentives
- The right amount is the amount of marginal external effect at the **socially efficient point**

Do taxes/subsidies work in practice?

- Examples where the idea is currently used:
  - Gas tax: in the US, gas taxes are earmarked for road maintenance (deals with the wear and tear externality only, not global warming)
  - Congestion pricing: some cities have imposed taxes on cars coming in crowded cities (London £15 daily) to fight congestion externalities
  - Research and Development (R&D) tax credits for firms: subsidy to encourage innovation (but not tied explicitly to size of positive externality)

Impact of London congestion charge starting in March 2003 (Leape 2006)

Impact of the Congestion Charge on Time Spent Traveling at Different Speeds in the Charging Zone during Charging Hours



Source: Transport for London. Data provided to the author, May 2006.

Quiz:

Question: The state of Texas funds roads with its gas tax—to correct for wear and tear produced by driving. What is the correct tax policy for electric vehicles (EVs) for Texas?

- A. No tax as EVs don't use gas
- B. An extra specific tax as EVs also use the road
- C. A subsidy as EVs mitigate global warming
- D. Texas should phase out gas cars like California

How do we deal with externalities in practice?

- Most common response is regulation:
  - Products/actions that generate negative externalities are forbidden by law (Harmful pollutants, dangerous consumer goods, littering, speeding, criminal behavior)
  - The penalty starts with a fine: economically equivalent to a tax but psychologically/socially very different [goal is to prohibit not price externality]
  - Limit (=allowance) on pollutant emissions. Example: smog check for gas cars in California

- Issue with regulation (for economists):

  - Issue: cheap to reduce pollutant in some cases but not others. Example: electric cars exist but not electric planes => CO2 allowance could kill high value aviation industry

Taxes and regulation combination: Cap&Trade

- Emission permits and trading (=cap&trade):
  - Pollutant emitters are given emission permits
  - Pollutant emitters can trade their emission allowances.
  - Price of emissions is the same for all. If total allowances set such that price=external MC then efficient
- Cap&trade has been used in transitions:
  - SO_2 emissions creating acid rain, CFCs depleting ozone layer: costly to prohibit immediately as time is needed to develop substitutes
  - phased-out over years through cap&trade system with shrinking allowances

Quiz:

Question: Suppose the US adopts a cap&trade policy for carbon emissions where each industry gets permits equal to 50% of their 2024 emissions. What would happen to aviation industry?

- A. Aviation industry would shrink a lot as they can't fly planes without fossil fuels
- B. Aviation industry would buy permits from other industries and just charge the extra cost on flyers.
- C. Aviation industry would invent quickly E-planes.
- D. All of A, B, C.

IV. Dealing with Global Warming

Main Costs of Global Warming

Great variation across areas and economic development. Pace of change is what makes adaptation particularly daunting:

- Extreme weather makes many populated places less livable (sea rise, heatwaves, droughts, smoke from fires)
  - Could lead to mass migration movements that are disruptive in our world of independent nations
- Agricultural production disruptions and food security risks:
  - demand for food inelastic in the short-run. Spikes in prices if agricultural output falls => Famines in low-income countries
- Impact on bio-diversity (mass extinctions)

Quiz:

Question: Suppose extreme weather shock reduces vegetables production globally by 20% which makes prices go up 200%. Which mitigating policy is most **efficient**?

- A. Nothing: Let poor people in poor countries starve and let others pay more for food
- B. Regulation: Prohibit meat so that everybody can survive with vegetarian diet.
- C. Tax: Impose a high tax on meat to discourage wasteful use of cereals to grow meat.
- D. Universal basic income so that everybody can afford food funded by tax on rich people/countries

Carbon tax: Economists' Narrow Solution

- CO2 emissions impose a global warming externality ⇒ Solution is to impose a carbon tax equal to the marginal damage of CO2 [economists carbon tax letter]

- But what is the marginal damage of CO2? Costs hard to evaluate and depend greatly on how you discount the future as most of the damage is (used to be) in the future

  - If future is discounted heavily (individual humans are impatient), CO2 damage cost is small and it is desirable to let global warming happen and civilization collapse!

  - If future not discounted heavily, then big but unpopular carbon tax is called for

- Economists have probably slowed down the process on net by underestimating costs (comparing Florida to Minnesota)

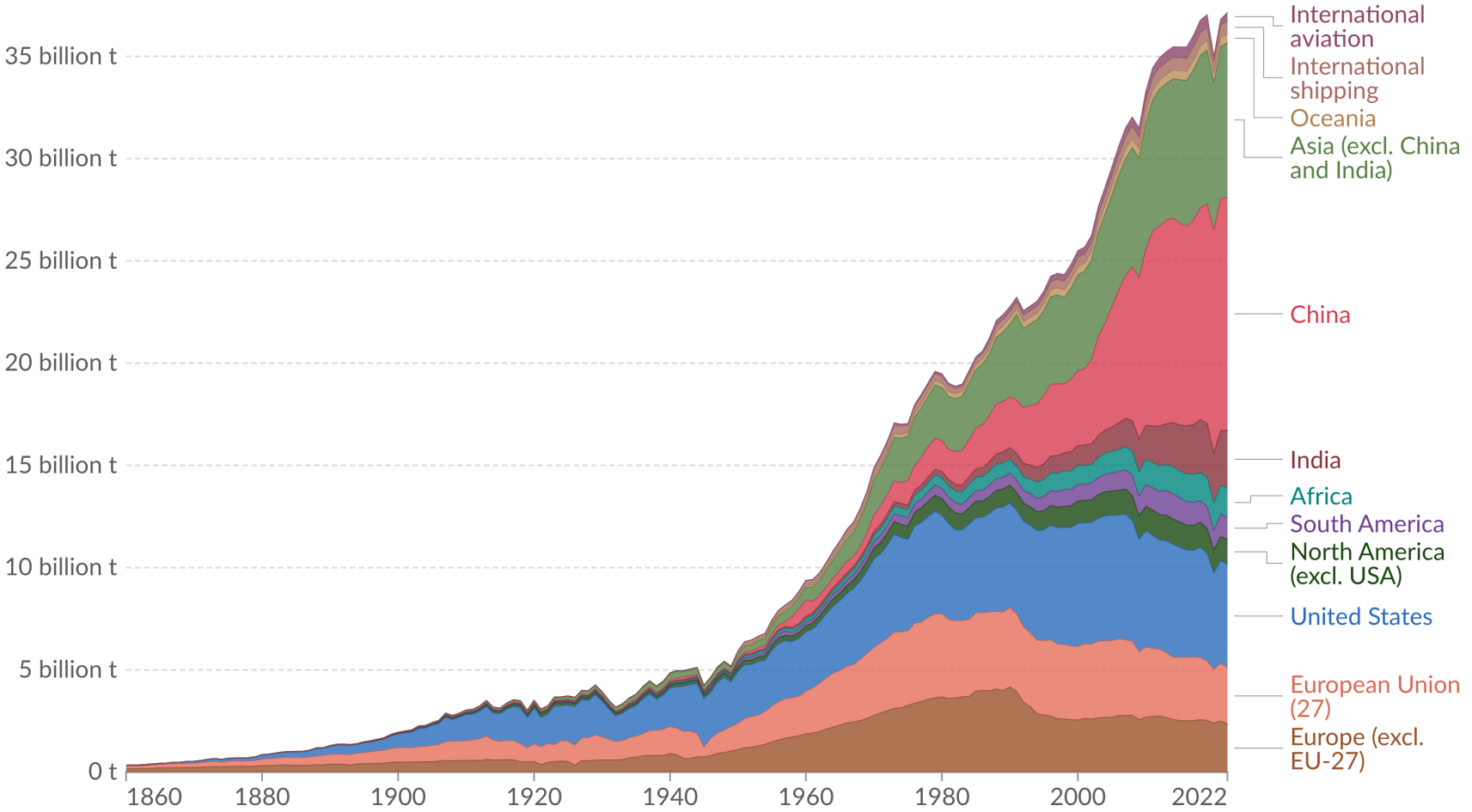
Gas taxes are generally very unpopular

Gas taxes are the go-to solution for economists. In practice, many gas users are inelastic and low income and get upset. Gas taxes tend to generate “tax revolts” as in the Yellow Vest movement in France in 2022.

Annual CO_2 emissions by world region

Our World in Data

Emissions from fossil fuels and industry[1] are included, but not land-use change emissions. International aviation and shipping are included as separate entities, as they are not included in any country's emissions.



Data source: Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

Broader View on Reducing Emissions

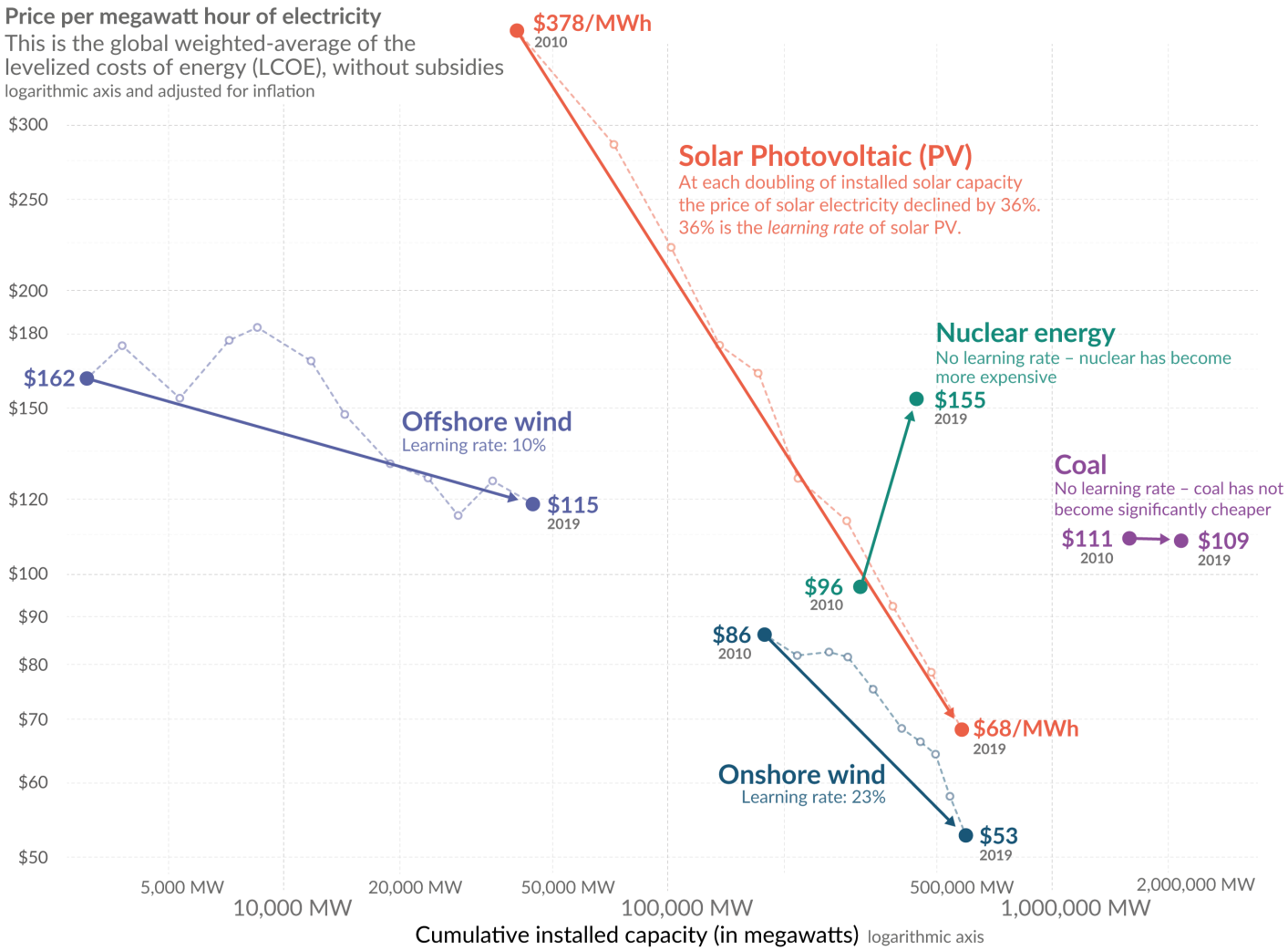
- Massive CO2 emissions pose existential civilizational risk (like CFCs destroying vital ozone layer)
- Solution is to decarbonize as a social choice and we need to do it fast (within decades not centuries)
- Economists' obsession about estimating the Marginal Cost of CO2 emissions is a distraction. Shows the limitation of marginal analysis dear to economists:
  - Getting the exact price/quantity right at the margin is 2nd order
  - The 1st order problem is to decarbonize

Broader View on Reducing Emissions: Solutions

- Costs of climate change have already surpassed the cost of transition, we moved too slowly.
- Decarbonization is within sight: renewable electricity (solar/wind) + grid + big batteries could replace most fossil fuels. Renewable energy cost dropping fast.
- Could be done without killing economic growth and without huge short-term disruptions. COVID response likely cost more
- Economists' useful point: some sectors are cheaper to decarbonize than others (cars easier than planes): tradeable allowances can make sense in a transition

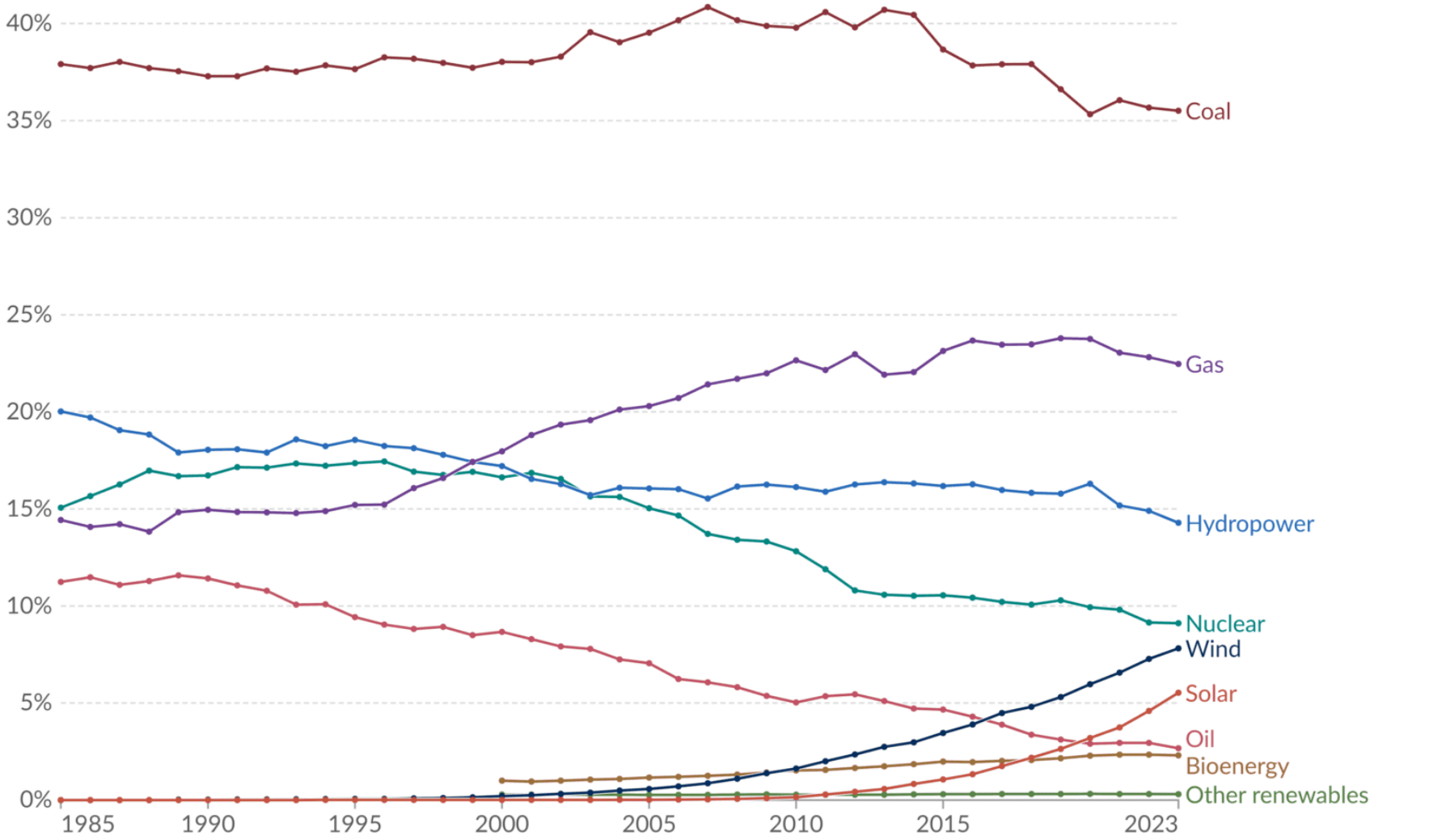
Electricity from renewables became cheaper as we increased capacity – electricity from nuclear and coal did not

Our World in Data



Source: IRENA 2020 for all data on renewable sources; Lazard for the price of electricity from nuclear and coal – IAEA for nuclear capacity and Global Energy Monitor for coal capacity. Gas is not shown because the price between gas peaker and combined cycles differs signficantly, and global data on the capacity of each of these sources is not available. The price of electricity from gas has fallen over this decade, but over the longer run it is not following a learning curve.

Share of electricity production by source, World



Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2024)

OurWorldinData.org/energy | CC BY

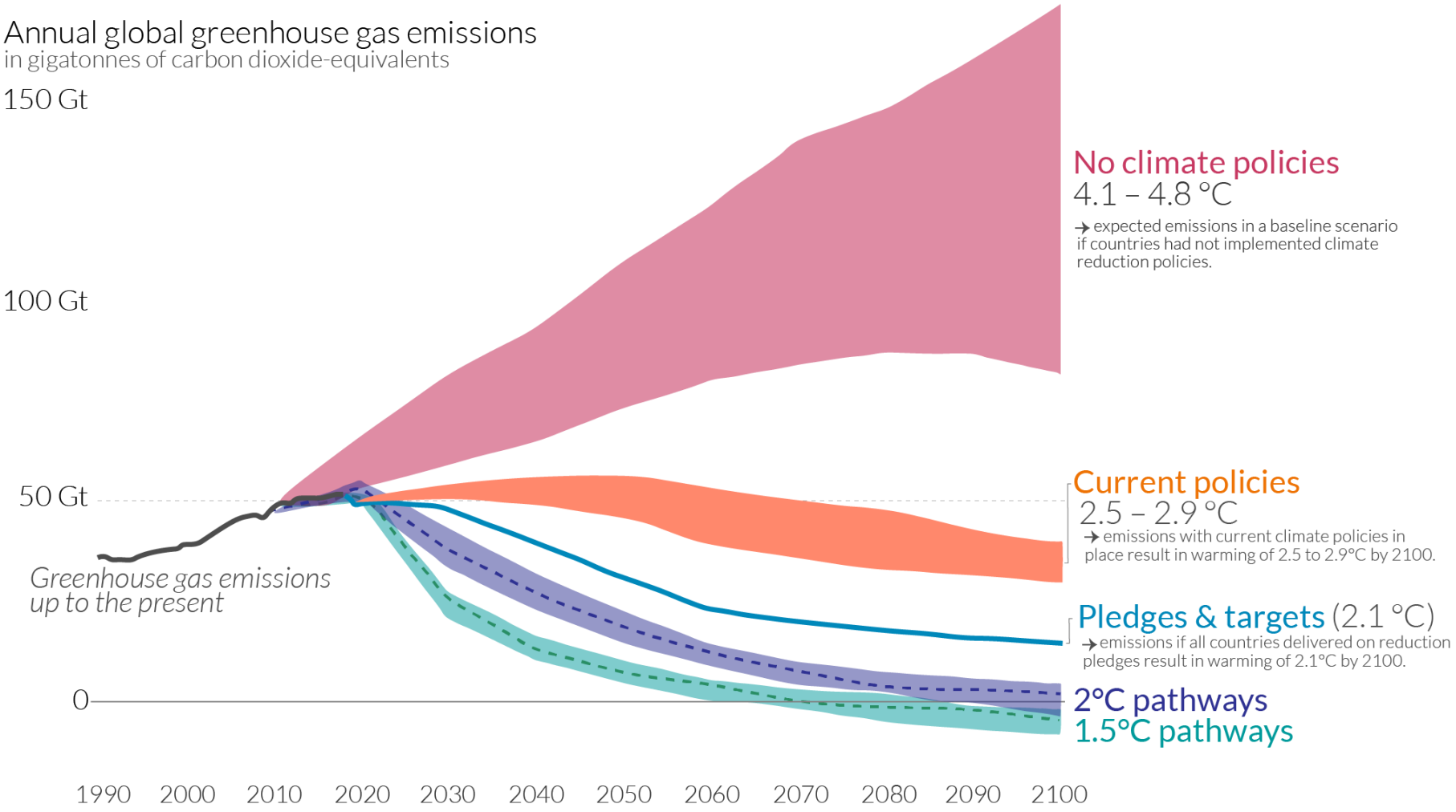
Tools actually used for decarbonization

- Government support for (a) fundamental research in clean energy, (b) clean energy industry subsidies (for producers or consumers: e.g., EV credits in the US)
- Government development of infrastructure for clean energy: clean energy power plants, grid, etc.
- Government regulations to decarbonize: phase-out coal power plants and gas powered-cars, land management, ..
- Carbon tax (or equivalent cap-and-trade carbon emission pricing) has been at best a minor tool, because it raises prices of energy and generates protests
- 2022 Inflation Reduction Act is largest US federal response to climate change to date and has no carbon tax

Global greenhouse gas emissions and warming scenarios

Our World in Data

– Each pathway comes with uncertainty, marked by the shading from low to high emissions under each scenario.
– Warming refers to the expected global temperature rise by 2100, relative to pre-industrial temperatures.



Data source: Climate Action Tracker (based on national policies and pledges as of November 2021).
OurWorldinData.org – Research and data to make progress against the world's largest problems.

Last updated: April 2022.

Quiz:

Question: Would you support spending more through government to decarbonize the economy for good in coming decades?

- A. Yes, that's the right thing to do for humanity
- B. No, because future generations get most of the benefit while current generation would pay the cost
- C. No, because I am upset previous generations did not do it already (don't want to pay to clean up their mess)
- D. No, because there are more pressing issues to address with government spending than climate change
- E. No, because markets on their own will do best to invent the new clean technologies of the future

International Coordination

- From one country perspective, decarbonizing is costly and benefit is modest (as global emissions is what matters)
- Economists: countries need to make a coordinated binding agreement to decarbonize together
- Reality: Series of international agreements: Kyoto 1997, …, Paris 2015 where countries make non-binding pledges
- Reality: leader countries can have dramatic impact:
  - Provide model that others can follow later on: California has 100% renewable electricity mandate by 2045, no new gas cars by 2035
  - Rich countries want to develop and control future renewable tech (US, EU vs. China competition for renewables is good)

Quiz:

Question: Richer countries (US+Europe) produced 2/3 of emissions to date. What seems the best moving forward?

- A. Richer countries should invent and adopt the new technologies, and help other countries adopt them.
- B. Richer countries should lead but also force other countries to transition with carbon content tariffs or sanctions.
- C. An international agreement where countries with the highest benefits from preventing climate change contribute the most.
- D. Let each country chart its own course and do what's best for its own national interest.
- E. We just need a global carbon tax equal to marginal damage.

References

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- Principles of Economics, Chapter 11.
- Leape, Jonathan, The London Congestion Charge, Journal of Economic Perspectives—Volume 20, Number 4—Fall 2006