Econ 1661 / API-135: Final Review

April 29, 2022

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Agenda for today

1. Exam logistics and study recommendations
2. Overview of course material
3. Practice problems
4. Q&A

*** Please ask questions throughout ***

Exam logistics

- Final exam:
  - **When**: Saturday, May 7 from 9:00am – 12:00pm
  - **Where**: Science Center Lecture Hall D
- Closed book, closed notes
- Calculators, graphing tools (e.g., ruler) will be allowed
- Content: weeks/modules 1-13
- Format: like midterm exam, past final exams
  - Combination of T/F/U and qualitative/quantitative short answers
- Arrive early (~15 min.)!
- Logistics email will be sent out early next week

Office hours and study help

- I have office hours by Zoom from 3:00-5:00pm today
- Additional office hours:
  - Friday, May 6 from 1:00-3:00pm ET in Harvard Hall 105 + Zoom
- Feel free to email any TF before 5:00pm on Friday, May 6 if specific questions come up while studying
- Reminder: practice exams posted to Canvas

Study recommendations

- Prioritize the material covered in recorded lectures and (less so) sections
  - Professor Stavins' "key take-aways" are a helpful guide
  - Don't worry about papers covered in section but not on the reading list (these will help your intuition/understanding, but will not be directly tested)
- **Review problem set solutions**
- Review notes from in-person sessions
- Do practice exams posted on Canvas (2019-2021 finals + solutions)
  - **Disclaimer 1**: the 2021 final was a take-home, open-note exam
  - **Disclaimer 2**: the 2019, 2020 finals include concepts we did not cover
- If you need to prioritize your time, do not worry about the reading list for the purposes of the exam
  - If we ask about a specific reading, you should be able to answer the question based on concepts from the lectures, not knowledge only found in the reading

Tips for the exam

- Be able to reproduce the main analytical/quantitative problems
  - Know what we are asking (e.g., “efficient abatement Q?” → solve for Q such that MC=MB)
  - If applicable, be able to draw a graph: helpful even if we don’t require it
- Clearly read each question and answer all parts
- Show your work! We ***want*** to give partial credit
- If you do not know the answer, start with what you do know
- For calculations:
  - It is okay to be approximate, within reason
  - We will accept answers that write out a calculation, but do not explicitly solve
- Pay attention to the point allocations for timing
  - We hope to give more time for a given question relative to the midterm

(Rough) Outline of Course

1. *Fundamentals:* Basic science & theory (economic, ethical)
2. *Policy Analysis Methods:* Estimating costs and benefits, NPV, etc.
3. *Pollution Control:* Policy options, design, comparisons
4. *Local Air Pollution:* EJ, relationship to GHG, policy lessons
5. *National & Regional Policy:* History, lessons, policy interactions
6. *International Policy:* History, challenges, next steps

Disclaimer

- We will not cover the entire course today
- Instead, want to emphasize certain important concepts and models from each topic to help guide your studying
- Suggest that you use these slides to guide your studying – they should not be your only study resource, but these slides can help identify important topics covered so far

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Fundamentals: Science

CO_2 is a *globally mixed, stock pollutant*:

→ *Global commons problem:* local mitigation costs, global benefits

→ *Intergenerational challenge:* upfront costs, benefits accrue over time

Fundamentals: Economics

Put yourself in decision-maker's shoes:

- Producers maximize profit ($Total\ Revenue - Total\ Private\ Costs$)
- Consumers maximize utility

  ⟶ Both only care about *private benefits and private costs*

- Social planners/policy-makers maximize total net benefits (TB – TC)

  ⟶ Social planners care about *social benefits and social costs*

Fundamentals: Economics

If social and private costs or benefits differ (*externalities)*, unregulated market won't meet social planner's goal!

Put yourself in decision-maker's shoes:

- Producers maximize profit ($Total\ Revenue - Total\ Private\ Costs$)
- Consumers maximize utility

  ⟶ Both only care about *private benefits and private costs*

- Social planners/policy-makers maximize total net benefits (TB – TC)

  ⟶ Social planners care about *social benefits and social costs*

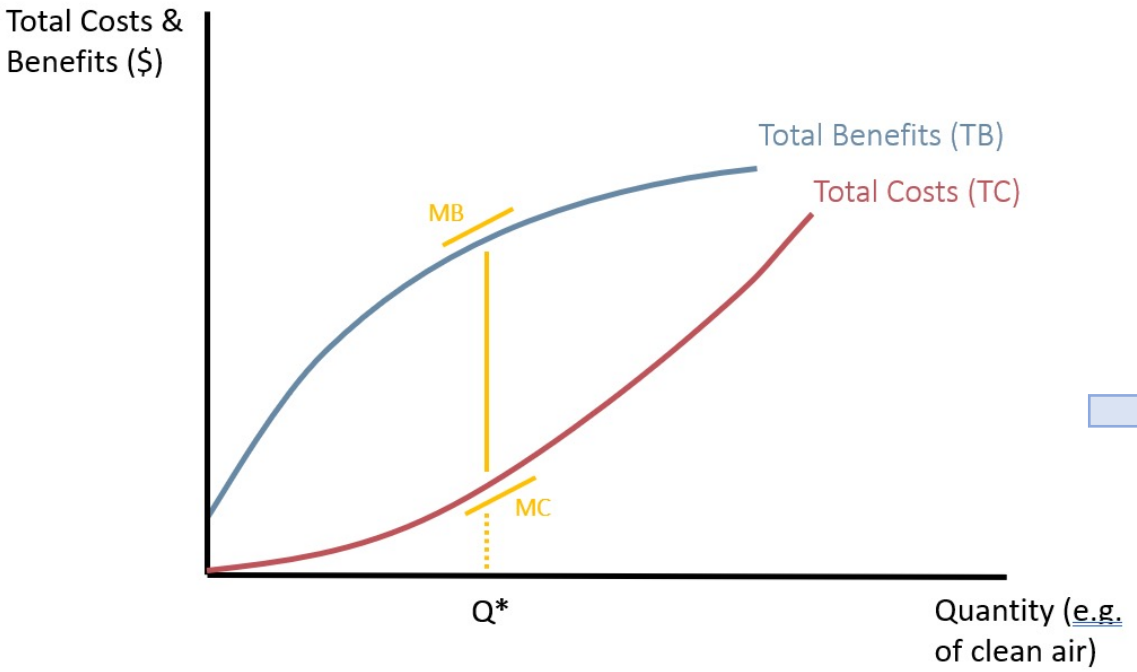
Fundamentals: Ethical Foundations

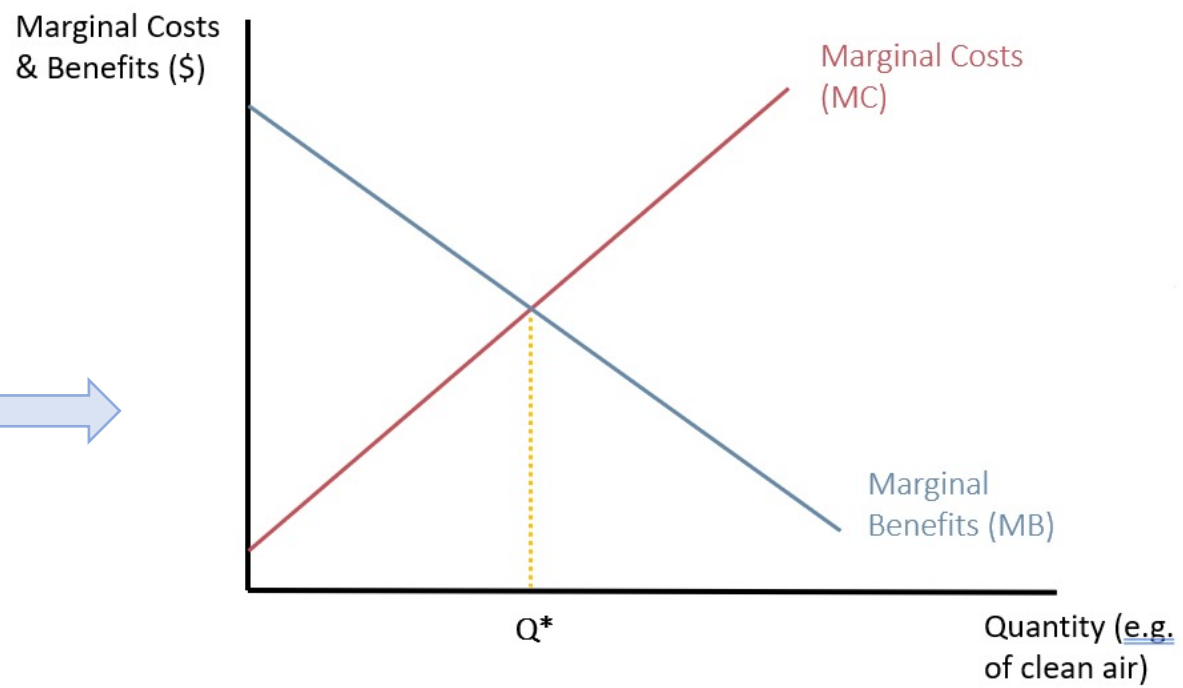
Where does this goal come from?

Pareto efficiency: only undertake policies if at least some people are made better off and no one is made worse off.

Kaldor-Hicks criterion: only undertake policies with benefits greater than costs (necessary but not sufficient for Pareto efficiency)

Fundamentals: Economics

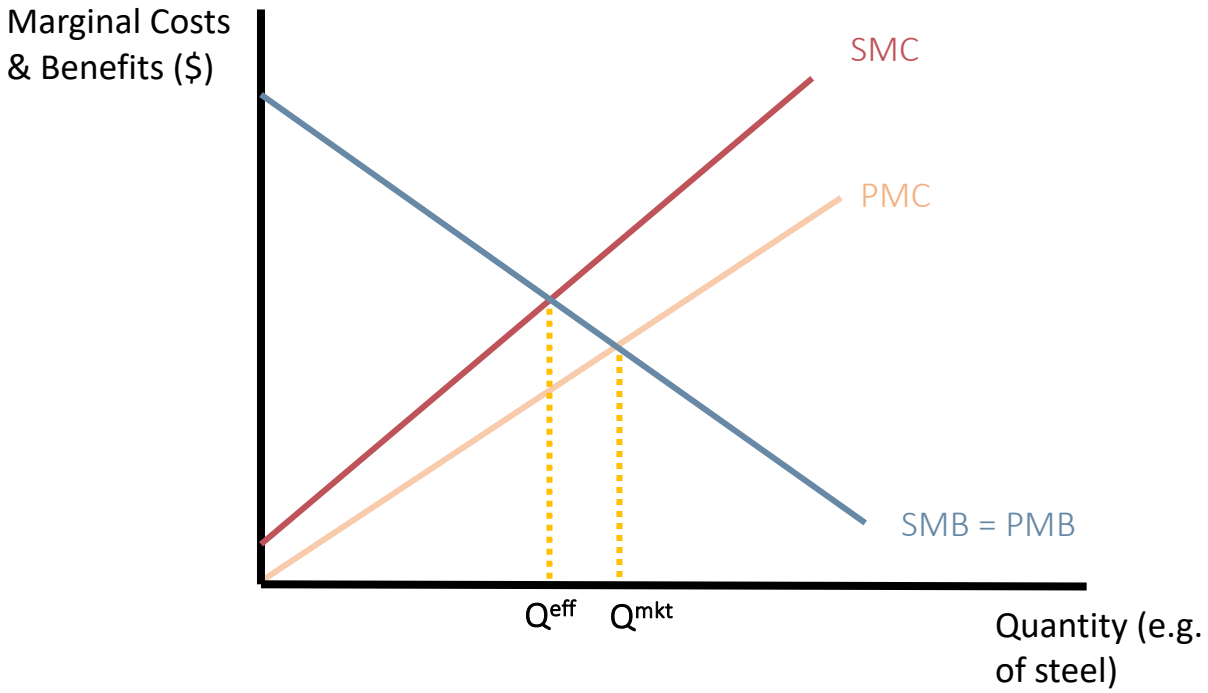




"To an economist, being efficient means maximizing net benefits"

Equimarginal rule: Efficient level of abatement (Q) occurs where MB = MC*

Fundamentals: Economics

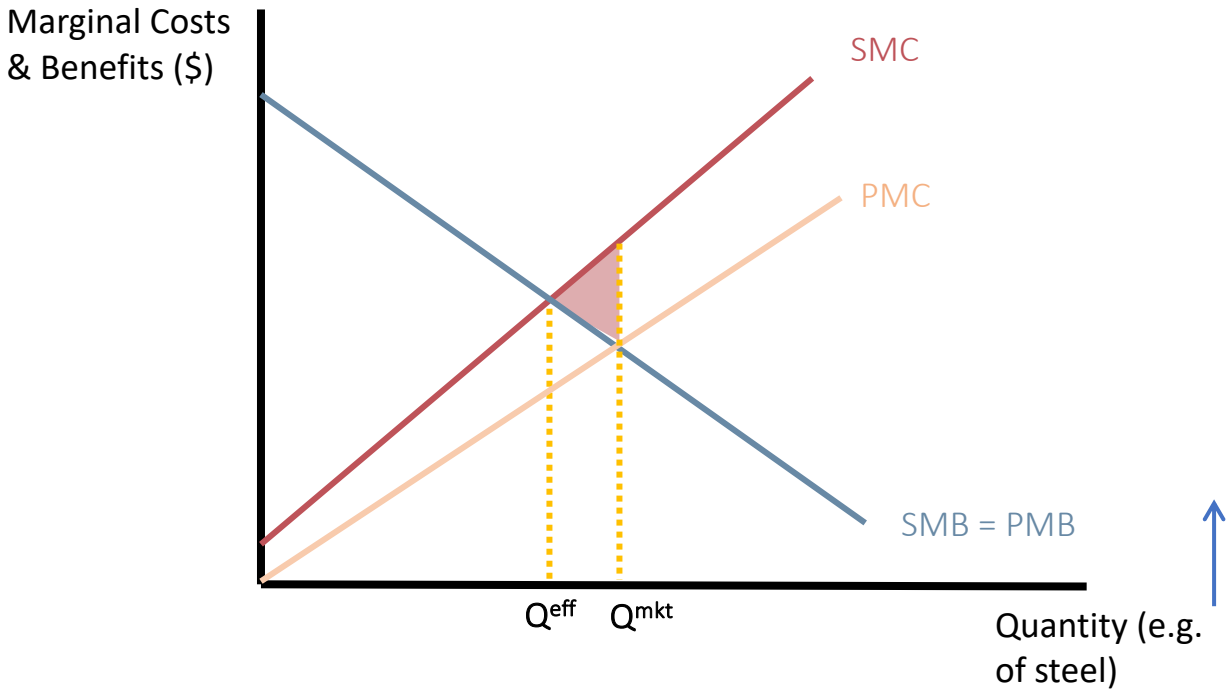


Externalities occur when private and social marginal costs (or benefits) are not equal

In these cases, intervention in the market is needed to reach the efficient outcome:

- *Exception (Coase):* Under certain conditions, bilateral negotiation can result in the efficient outcome without government intervention

Fundamentals: Economics



Externalities occur when private and social marginal costs (or benefits) are not equal

Identifying deadweight loss

- Find equilibrium quantity (given PMC, PMB, any policies in place)
- Find efficient quantity
- Calculate net benefits *you're missing out on* by not being at efficient quantity (using SMC, SMB)

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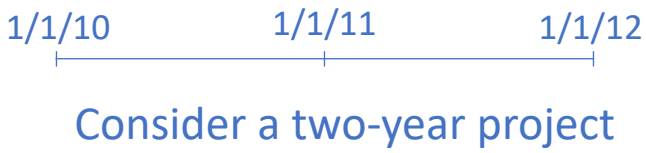
Policy Analysis: Estimating Benefits and Costs

- Review *taxonomy* and *estimation methods* of benefits and compliance costs
- If benefits and/or costs accrue over time, think about defining efficiency in a dynamic way: *maximize net present value (NPV)*
  - Net present value scales down future benefits and costs using a *discount rate*
  - Tip: Remember what the "year" used to discount actually means
    - "Start of project"
    - End of first year
    - Beginning of second year



Consider a two-year project

Policy Analysis: Estimating Benefits and Costs

- Review *taxonomy* and *estimation methods* of benefits and compliance costs
- If benefits and/or costs accrue over time, think about defining efficiency in a dynamic way: *maximize net present value (NPV)*
  - Net present value scales down future benefits and costs using a *discount rate*
  - Tip: Remember what the "year" used to discount actually means
    - "Start of project" ⟶ No discounting: Year 0
    - End of first year ⟶ 12 months after "start": Year 1
    - Beginning of second year ⟶ 12 months after "start": Year 1

Cost and Benefit Concepts

- Taxonomy of compliance costs
  - Resource compliance costs
  - Government regulatory costs
  - Social welfare costs
  - Transitional costs
  - Indirect costs
- Taxonomy of environmental values:
  - Use values
  - Non-use values (including option and existence values)

Cost and Benefit Estimation

- Cost estimation methods: covered on midterm
- Benefit estimation methods:
  - Revealed preference (e.g., hedonic property model, hedonic wage model)
  - Stated preference
- Benefit transfer: taking existing benefit estimates from another context and using them to analyze policy
- Benefit estimation methods to avoid:
  - Avoided-cost measure of benefits
  - Societal revealed preference
  - Cost of illness
- VSL: translates estimates of mortality risk reduction ***from RP/SP methods*** into a standard unit

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Pollution Control Options

Standards (e.g. technology, performance):

→ Are not cost-effective or are only cost-effective given perfect information about individual marginal costs curves

Market-based instruments (e.g. CAT, taxes):

→ Take advantage of firms' own incentives to reach cost-effective outcomes

Pollution Control Options

Efficient policies maximize net benefits (or NPV if multiple periods) by equating *aggregate* marginal benefits and *aggregate* marginal costs

- Not always feasible (due to info requirements, etc.)

⟶ Gives us policy goal that maximizes net benefits

Cost-effective policies achieve *a given goal* at minimum total cost

- This equates the marginal costs of reducing pollution for each firm

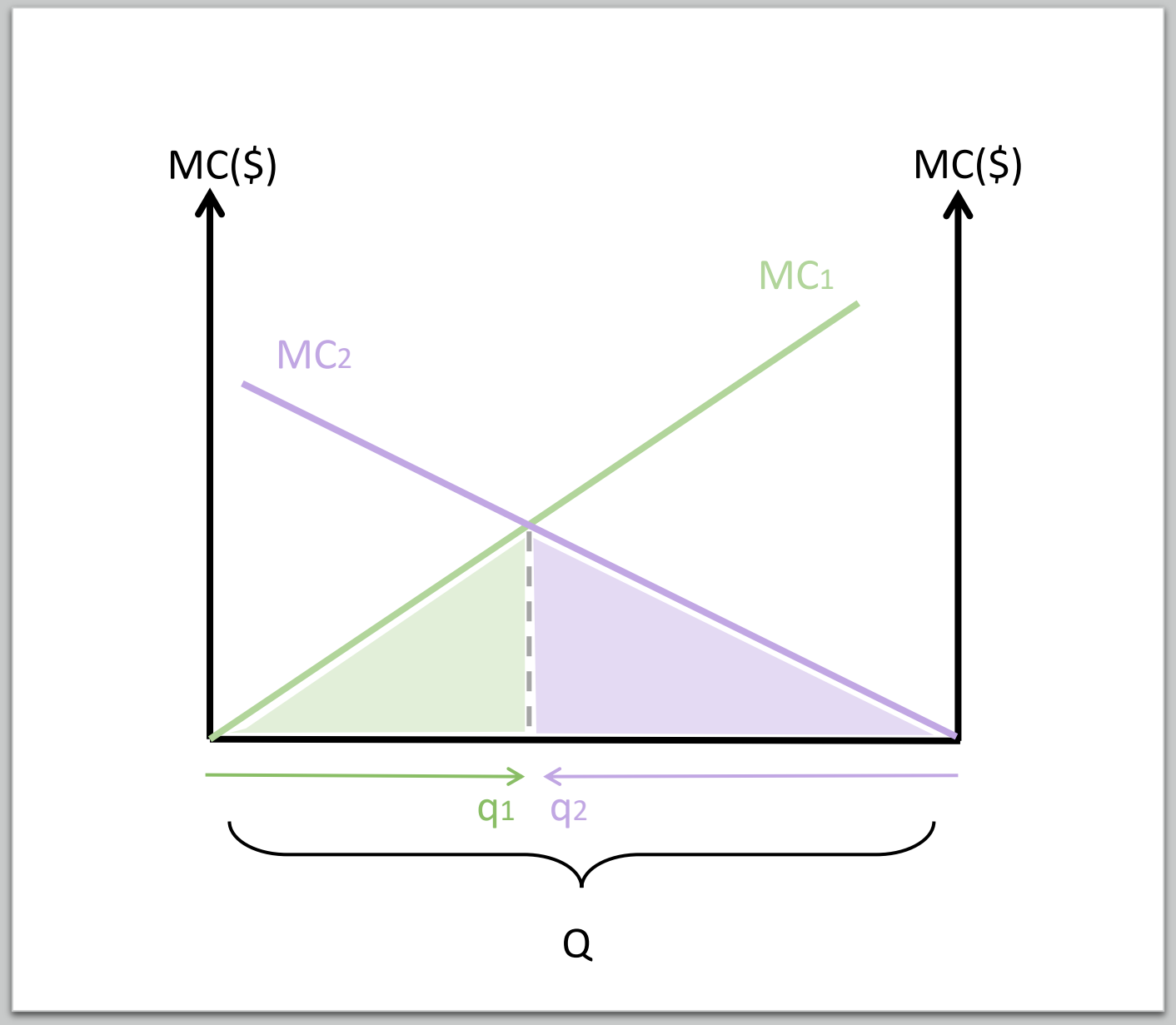
⟶ Helps us achieve *any given* goal in lowest-cost way

Pollution Control Options

Necessary condition for C/E:

MC1(q1*) = MC2(q2*).

At the cost-effective allocation, any movement away from that allocation would increase costs.



Pollution Control Options

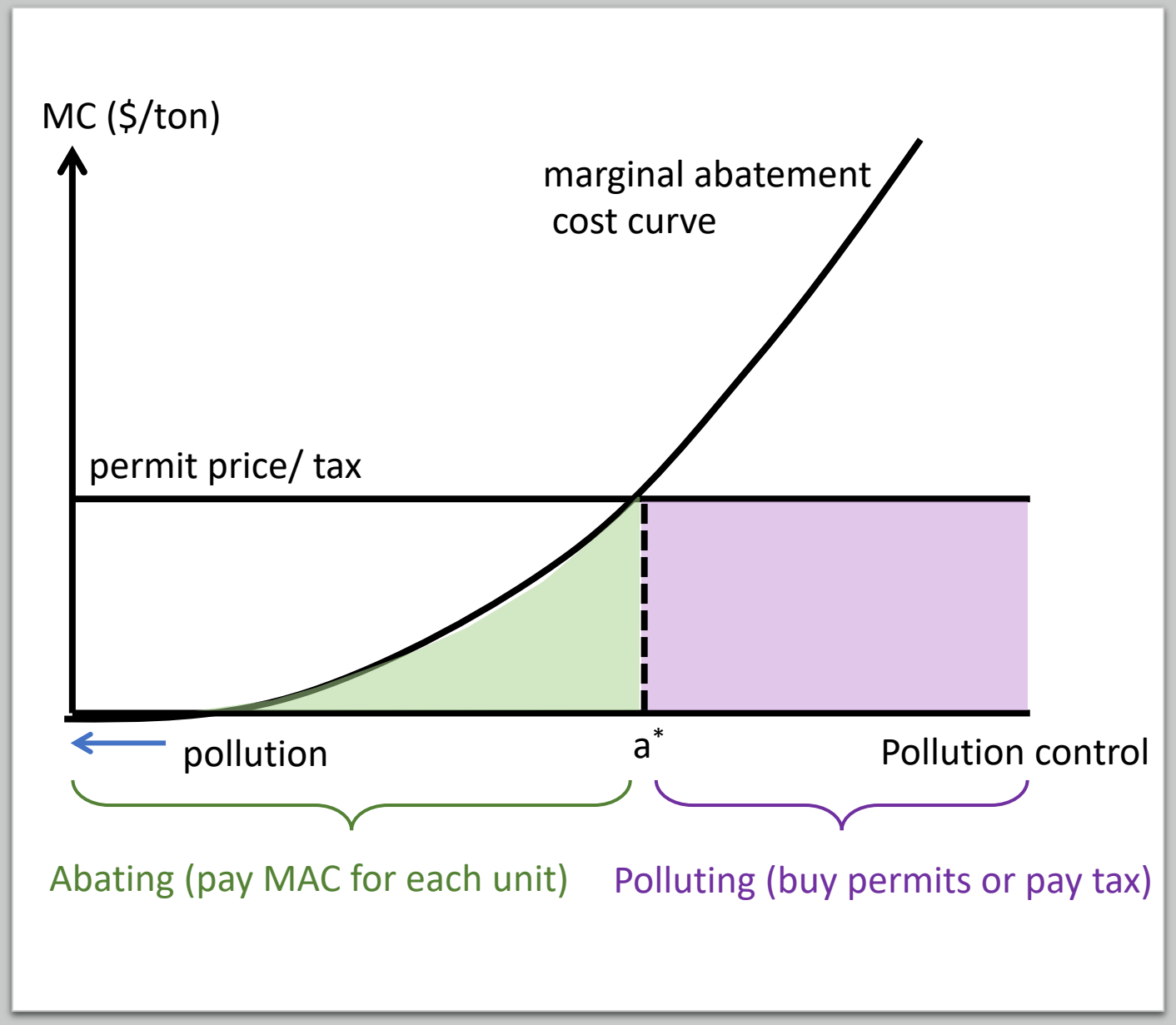
Why do CAT/taxes achieve the cost-effective allocation?

Firms choose cost-minimizing level of abatement. Under CAT/taxes, pay:

- MAC for each unit they abate
- Permit price/tax for each unit they continue to pollute

Firm abates until:
MAC = permit price
MAC = tax

This causes $MAC_1 = MAC_2 = \ldots = MAC_n$



Pollution Control Options: Uncertainty

Without uncertainty, P & Q instrument are equally cost-effective and can be designed to be efficient

With uncertainty in MC, the relative slopes determine the preferred policy instrument (to max. net benefits).

⟶ *Weitzman Rule:*

- Relatively steep MB: Favor Q instrument (CAT)
- Relatively flat MB: Favor P instrument (tax)

If MB is uncertain & that uncertainty is correlated with uncertainty in MC

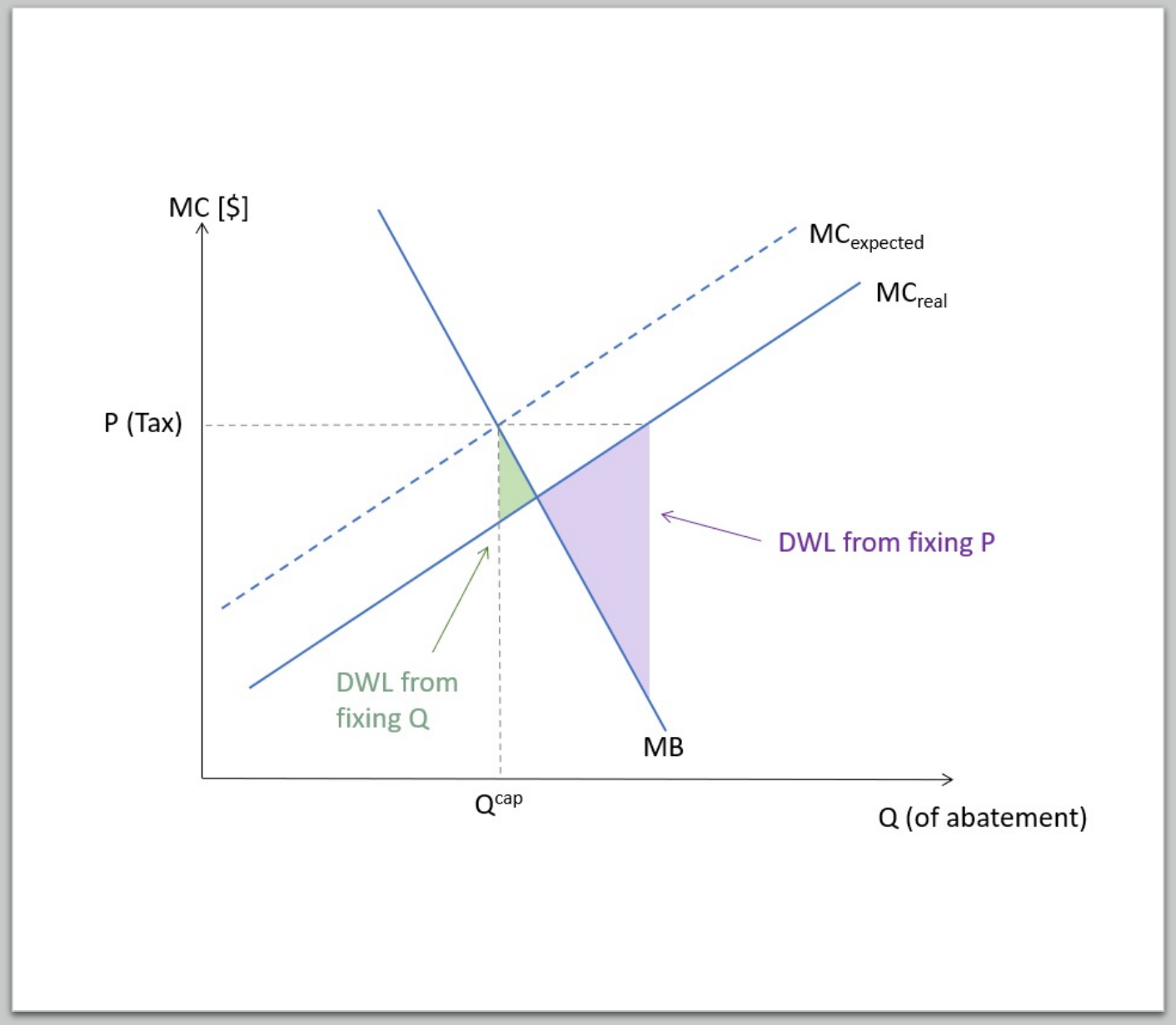
⟶ *Stavins Rule:*

- Positive correlation: Push towards favoring Q instrument (CAT)
- Negative correlation: Push towards favoring P instrument (tax)

Pollution Control Options: Uncertainty

Graphing tips:

1) Policy-makers set the level of the tax or cap based on ***expected*** costs and benefits
2) The efficiency of the tax or CAT program is determined by ***actual*** costs and benefits



Pollution Control Options: Considerations

Also consider *"real world"* comparison

- Equivalent:
  - emissions reductions
  - aggregate abatement costs
  - effects on competitiveness
  - revenue raising ("nearly equivalent")
- Similar:
  - costs to regulated firms
  - distributional impacts
- Subtle Differences:
  - transactions costs ("some differences)
  - performance in presence of uncertainty
  - linkage between jurisdictions
- Significant differences:
  - carbon price volatility
  - complementary policy interactions
  - potential for market manipulation
  - administrative complexity

Pollution Control Options: Considerations

Rather than thinking about choice of tax vs. CAT as a dichotomous choice. *Design elements* can be more important than this choice

- Hybrid policies (e.g. price collar)
- Banking and borrowing
- Allowance allocation decision & use of revenue

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Local Air Pollution & Climate Change

What's the connection to climate change?

1. GHGs are often co-emitted with pollutants impacting local air quality (and reduction in GHGs can have substantial co-benefits)
2. Improvements in local air pollution can be important in garnering political support for domestic (state or local) climate action

Disproportionate exposure is a major environmental justice concern, with many possible causes
For local air pollutants, the location of emissions abatement *affects the overall quantity of benefits and to whom they are distributed*

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2. Improvements in local air pollution can be important in garnering political support for domestic (state or local) climate action
3. Policy lessons from environmental policy & continuing legal and administrative structure
   - Example: Acid Rain Program (flexible and responsive policies, be wary of long-term projections, etc.)

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National & Regional Policy

Lessons from experience: Carbon pricing

1. Emissions leakage: carbon pricing can lead to increased emissions in regions not covered by the policy, reducing policy effectiveness
   - Border adjustments, output-based free allocation?
2. Banking: potentially large percent of gains from trade, especially in thin markets
3. Allowance allocation is important distributional, political issue & affects benefit of program

National & Regional Policy

Policy Interactions (examples)

- *Perverse interactions*: Federal CAT, strict subnational CAT system causes 100% leakage, higher cost
- *Benign interactions*: Federal tax, subnational CAT system (or Federal CAT, less stringent CAT system)
- *Positive interactions*: Subnational "laboratories", pressure for federal action, corrections for insufficient action

Multiple market failures justify multiple policy tools

National & Regional Policy

- Private gap / "*energy paradox*": some energy efficient technology that would pay off for adopters are not adopted
- Social gap / "*energy efficiency gap*" : some energy efficient technology that would be socially efficient (i.e., pay off for society) are not adopted

National & Regional Policy

- Private gap / "*energy paradox*": some energy efficient technology that would pay off for adopters are not adopted
- Social gap / "*energy efficiency gap*" : some energy efficient technology that would be socially efficient (i.e., pay off for society) are not adopted

Explanations: market failure (information & liquidity constraints, externalities, etc.), behavioral explanations (salience, heuristics), model/measurement explanations (unobserved costs or product attributes)

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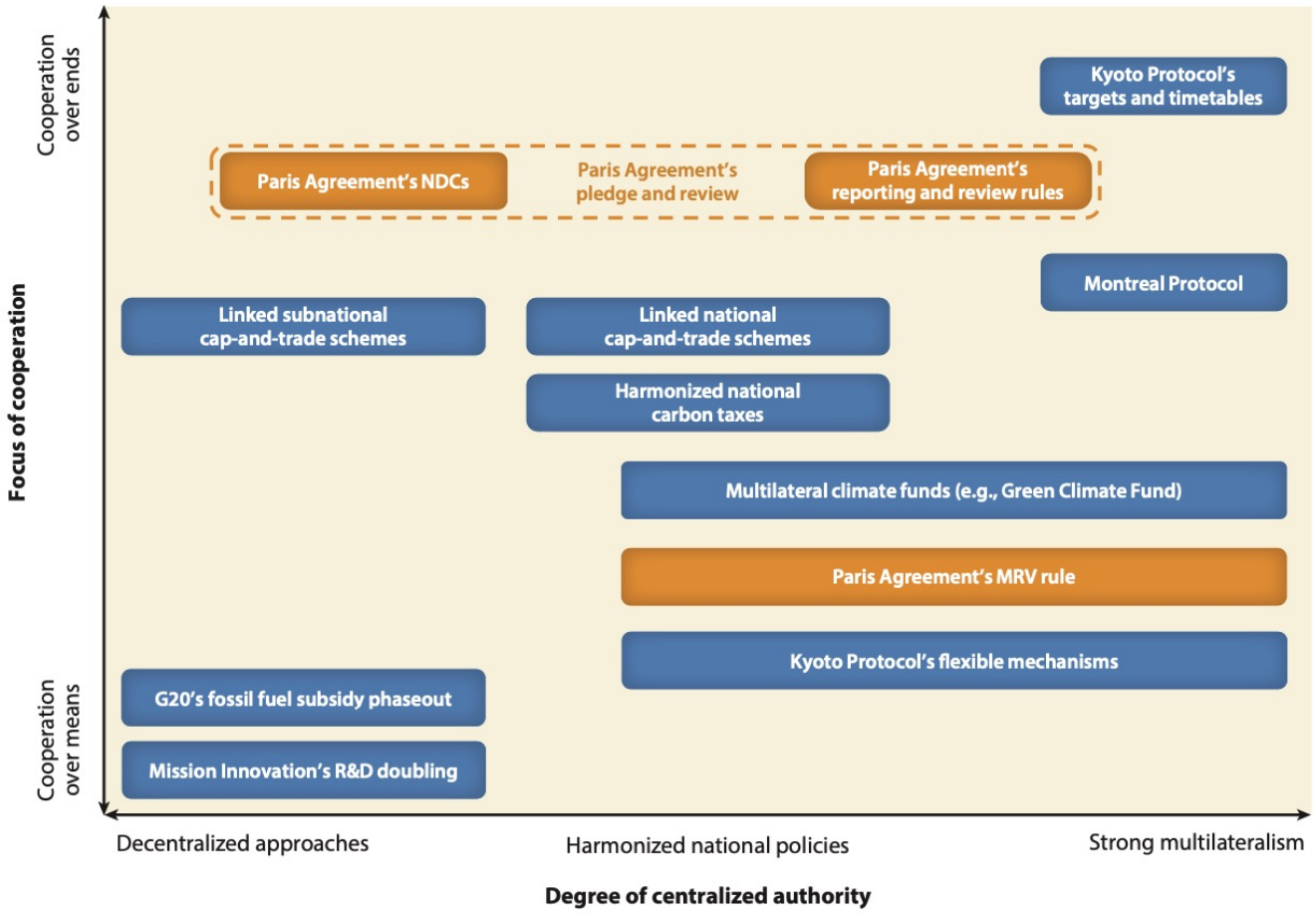
International Climate Policy

Very (very) brief history—see Week 12 review session**:**

- 1992: UNFCCC Article 3: common but differentiated responsibility
- 1997: COP-3 Kyoto: didn't constrain largest emitters
- 2009-10: COP15/16: blurred Annex 1 & non-Annex 1 distinction
- 2011: COP-17 Durban: long-term participation of all parties, broke from Berlin Mandate
- 2015: COP-21 Paris: pledge and review, NDCs, ratchet mechanism, linkage

Necessary conditions for success: adequate scope of participation (achieved more or less), adequate ambition of individual regional contributions (how can we encourage increased ambition over time?)

International climate policy



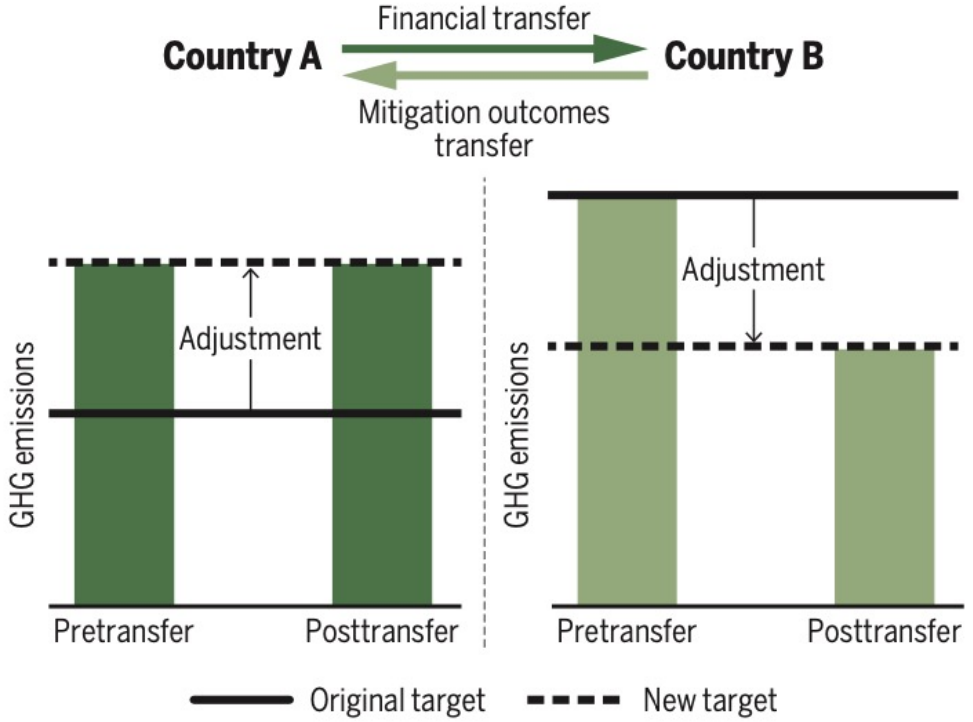
- Should be able to discuss the various potential types of climate architecture
- Important distinction: top-down, bottom-up, hybrid
  - Which would Kyoto be?
  - Which would Paris be?

International Climate Policy

Linkage: emission reductions in one jurisdiction counted toward abatement commitments of another

- *Benefits*: cost savings, improved market functioning, political benefits, administrative economies of scale
- *Concerns*: distribution on correlated pollutants, decreased policy autonomy
- Can be relatively straight-forward (California and Quebec) or very complex

Article 6.2: Parties can use internationally transferred mitigation outcomes (ITMOs) to comply with emissions targets in NDCs, allows bottom-up, heterogeneous linkage, serves as unit of accounting



“What kinds of questions can we ask from weeks 7-13?”

- “Define the ‘energy paradox’ from an economic perspective. List three possible explanations for this apparent anomaly. For each explanation, identify whether the anomaly is based on a traditional economic market failure, a behavioral-based market failure, or a model or measurement explanation.” *(2013 Final)*
- “Most economists would argue that carbon-pricing is a necessary but not a sufficient component of a sensible climate policy. Why would they argue that carbon pricing is not sufficient for a sensible climate policy?” *(2016 Final)*
- “Briefly explain why Professor Stavins says that the acid rain program achieved the right result for the wrong reason.” *(2017 Final)*
- “What is ‘linkage’ in the context of international agreements to combat climate change? Briefly describe one advantage of linkage and one disadvantage.” *(2017 Final)*

(non-exhaustive) List of quantitative questions

- Externality problems (e.g., PSET 1)
- NPV problems (e.g., PSET 1)
- Pollution control problems (e.g., PSET 2)
  - Mandates
  - Taxes
  - Cap-and-trade, w/ and w/o price-collar (e.g., PSET 3)
  - Prices vs. quantities (e.g., PSET 3)
  - Innovation incentives (e.g., PSET 5)

Pollution control example: 2018 Final Exam

There are two electricity plants that emit CO_2. They have the following marginal costs of abatement (emissions reductions):

$$MC_1 = 4q_1 \text{ and } MC_2 = 2q_2$$

What is the cost-effective allocation of control when a total of 6 units of abatement is required?

- Cost-effectiveness → $MC_1 = MC_2$
- We know that $q_1 + q_2 = 6$, so

$$4q_1 = 2q_2$$
$$4q_1 = 2(6 - q_1)$$
$$6q_1 = 12$$
$$q_1 = 2$$

- And as a result, we know that $q_2 = 4$
- Important distinction: cost-effectiveness vs. efficiency!!

Pollution control example: 2018 Final Exam

If the marginal benefits of abatement are given by $MB = 10 - Q$, what is the efficient allocation of pollution control?

- First we need the aggregate industry MC curve: horizontal aggregation.
  - $MC_1 = 4q_1 \rightarrow q_1 = \frac{1}{4}MC_1$
  - $MC_2 = 2q_2 \rightarrow q_2 = \frac{1}{2}MC_2$
  - We know that at efficient level, $MC_1 = MC_2 = MC_{industry}$
  - Since $q_1 + q_2 = Q$, can sum the above inverse MC curves to get Q as a function of $MC_{industry}$. Rearranging gives:

$$MC_{industry} = \frac{4}{3}Q$$

- Next, equate MB and $MC_{industry}$: $Q^* = \frac{30}{7}$

Thank You!