Uncertainty and Pollution Control:

Comparing and combining market based policy instruments

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Fundamentals of Environmental Economics and Policy
Professor Robert Stavins

Agenda

- Review cap-and-trade and tax equivalence
- Compare instruments with uncertainty
- Combining policy instruments

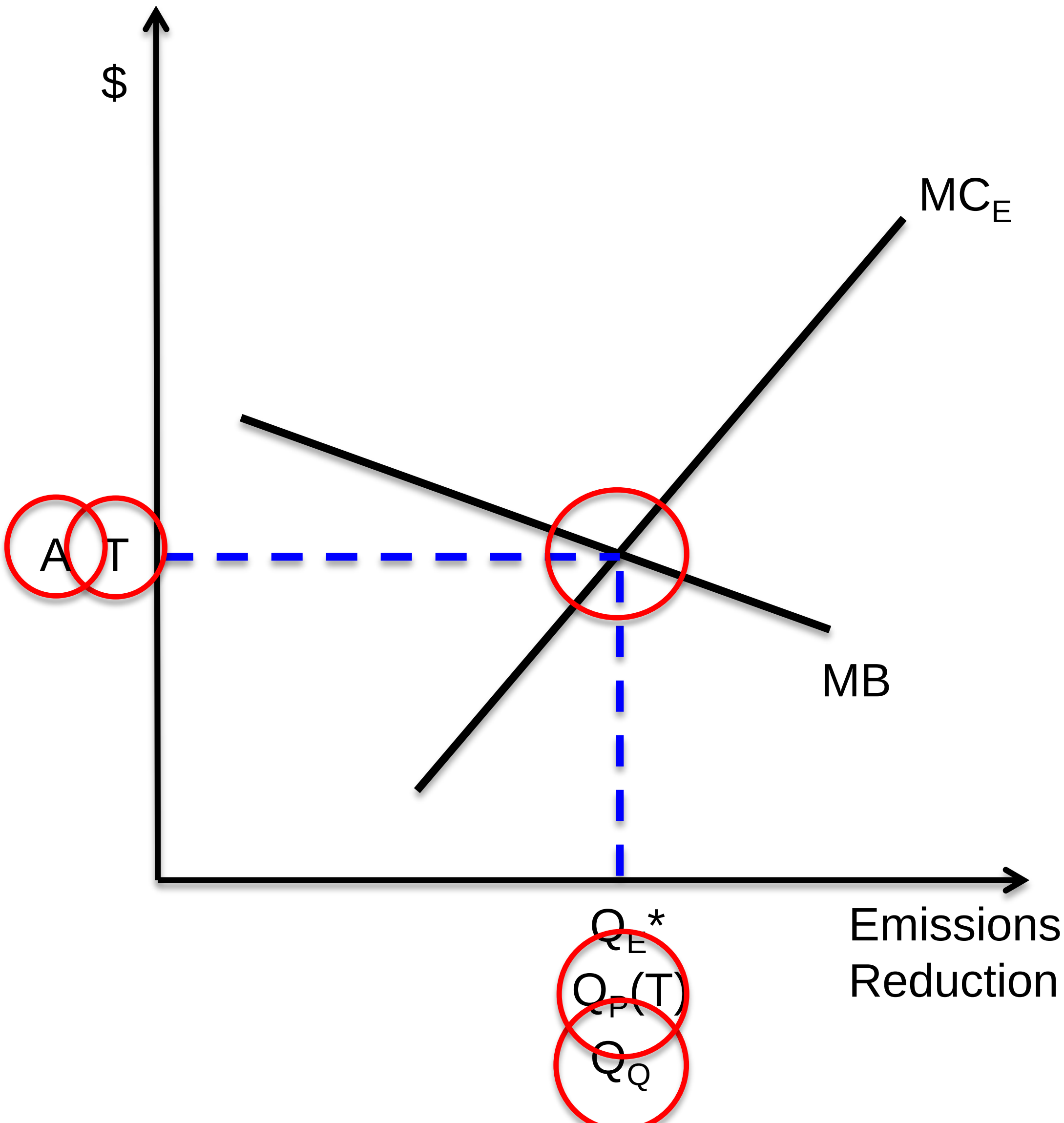
Review cap-and-trade and tax equivalence

- Firms minimize costs of complying with policy

  Total costs = Abatement costs + Tax/Permit Costs

- Under a tax, cheaper to abate if MC < T
  - This gives us emissions E(T) = U – Q(T)
- Under a cap, a maximum of E(T) emissions allowed
  - Firms with highest compliance costs by permits
  - IF we set E = E(T), we'll get Q(T) reductions
  - Permit price A = T

Price and quantity instruments are equivalent in the absence of uncertainty



Policymaker wants to achieve an efficient level of pollution

- Knows MB and the expected MC

Option 1: Price instrument (P)

- Set tax T
- Firms abate until MC=T
- $Q_P = Q_E^*$ expected reductions

Option 2: Quantity instrument (Q)

- Issue emission permits:
  # Permits = Baseline - Q_E^*
- Firms buy permits if MC > A;
  sell if MC < A
- Expected price $A = MC(Q_E^*)$

If MC_E is correct, both the tax and the tradeable permit system max net benefits

What happens if costs are uncertain?

Specifically, what if the intercept of MC is unknown?

What would cause MC to be higher or lower?

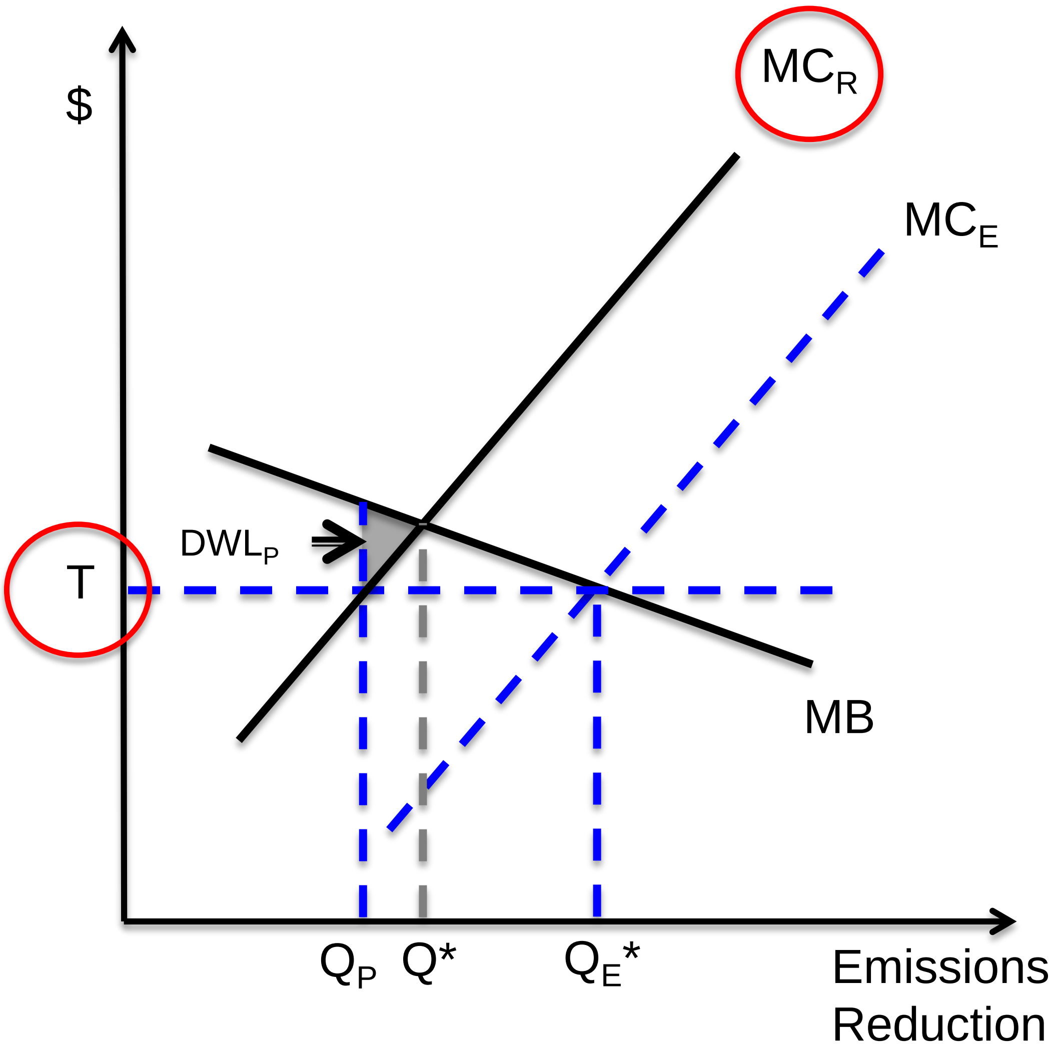
Under a tax, government locks in a *price*

- Tax (T) set before MC is known.
- Firms always abate until realized $MC_R = T$.
- Thus under at tax, government locks in the marginal **price** of emissions, and let's the quantity of emission reductions float.
  - If MC ends up being higher, then reductions will be lower than expected
  - If MC ends up being lower, then reductions will end up being higher than expected

Under tradeable permits, government locks in a quantity

- Quantity of allowable emissions set before MC is known.
  - U = Q + E, so this is same as setting emissions reductions (Q_Q)
- Firms buy and sell permits based on the realized permit price A = MC_R.
  - We showed in class that permits go to highest value (highest MC) users until MC is the same for all covered firms.
- Since there is a cap on reductions, A floats to clear the market.
  - If MC is higher than expected, A will be higher than the expected A; If MC is lower than expected, A will be lower.
- Thus under tradable permits, government locks in **quantity** of emissions, and let's the price of emission reductions float.

What happens if we set a tax and realized costs end up higher than expected?



New social optimum Q*

- $MB = MC_R$

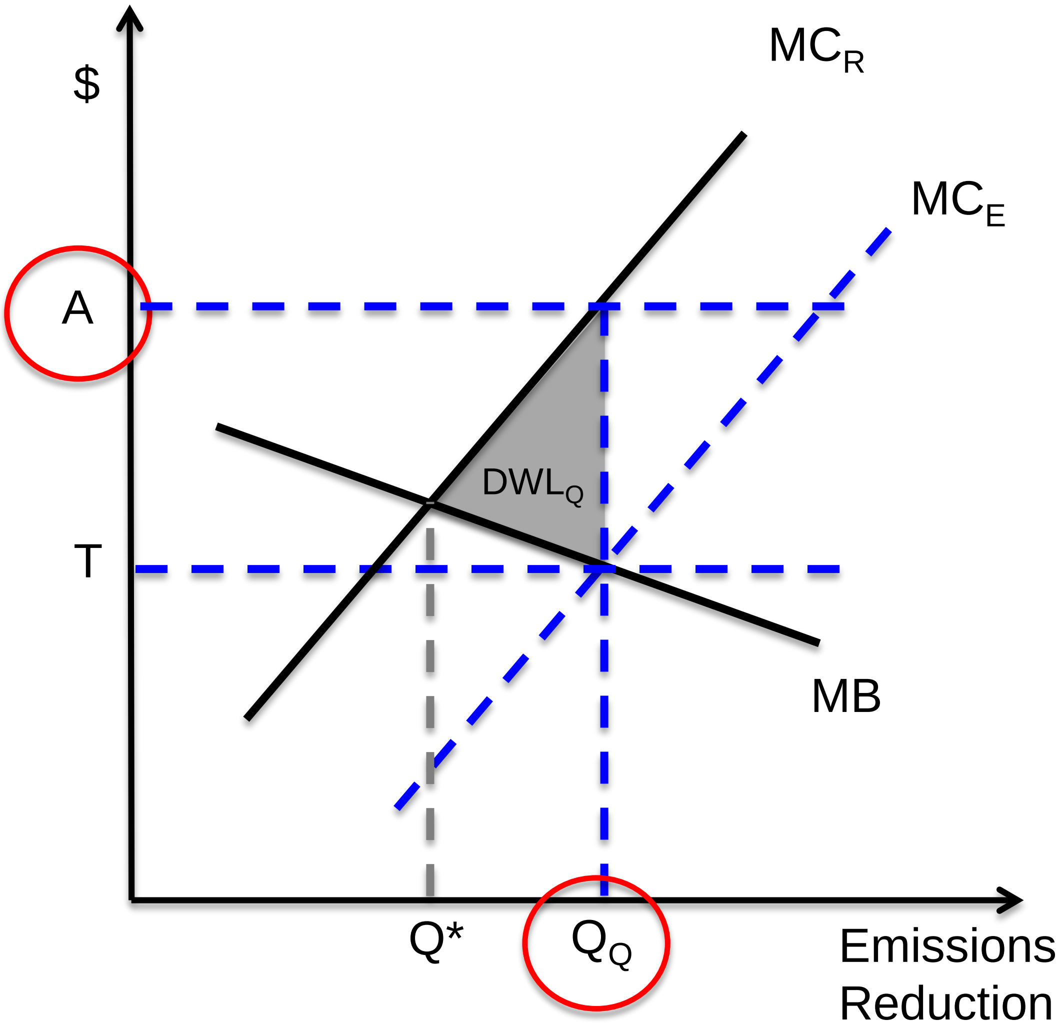
If the government chose to use a tax, firms still abate until $MC_R = T$

Since T was chosen under $MC_E < MC_R$, this will result in too few emission reductions

What DWL here?

- Since Q < Q*, DWL is the social value of beneficial emissions reductions not achieved by the policy

What happens if we set an emissions cap and realized costs end up higher than expected?



New social optimum Q*

- $MB = MC_R$

Since the government set a cap, the quantity of emissions reduction is still fixed at $Q_Q = Q_E^*$

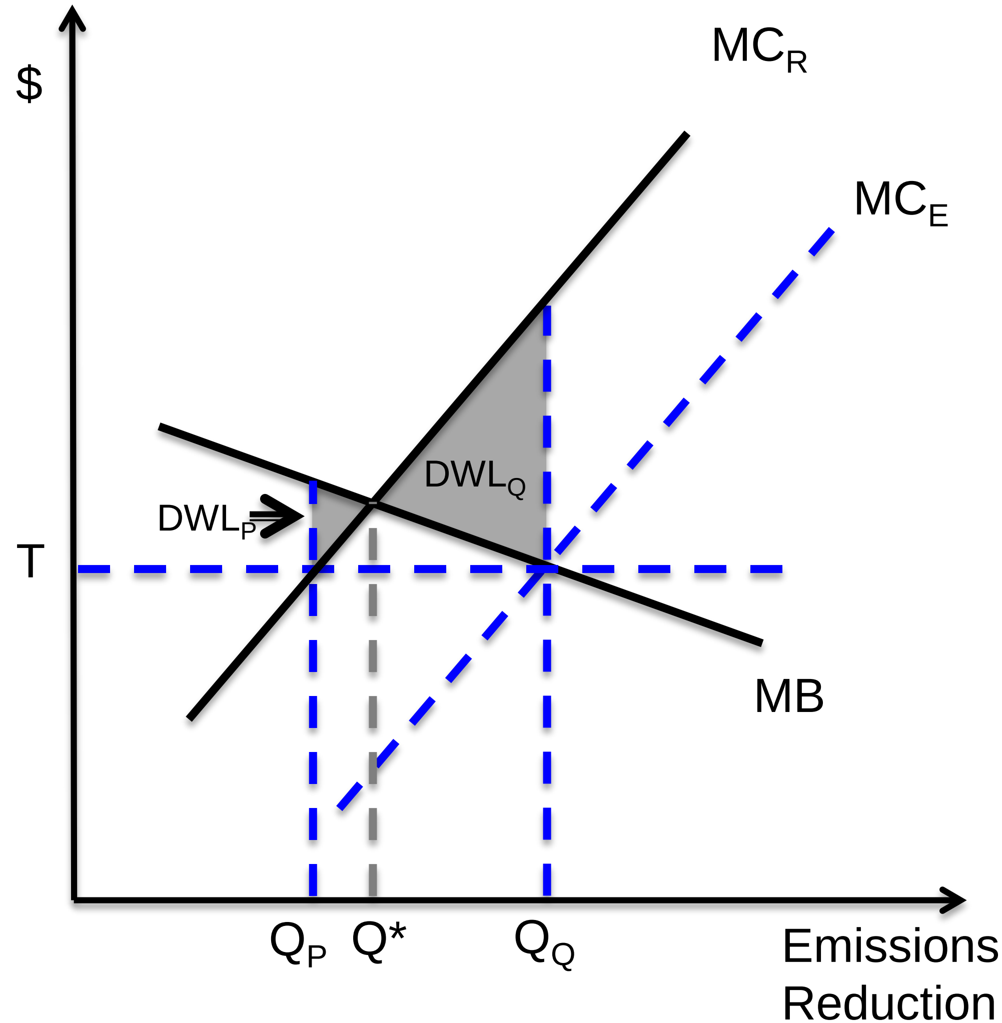
But since costs are higher, $Q_E^* > Q^*$

Under these costs, the marginal cost at $MC(Q_E^*) = A > T$

What DWL now?

- Since $Q_Q > Q^*$, DWL is the social cost of excessive emissions reductions achieved by the policy

We want to choose the policy with the lowest expected DWL

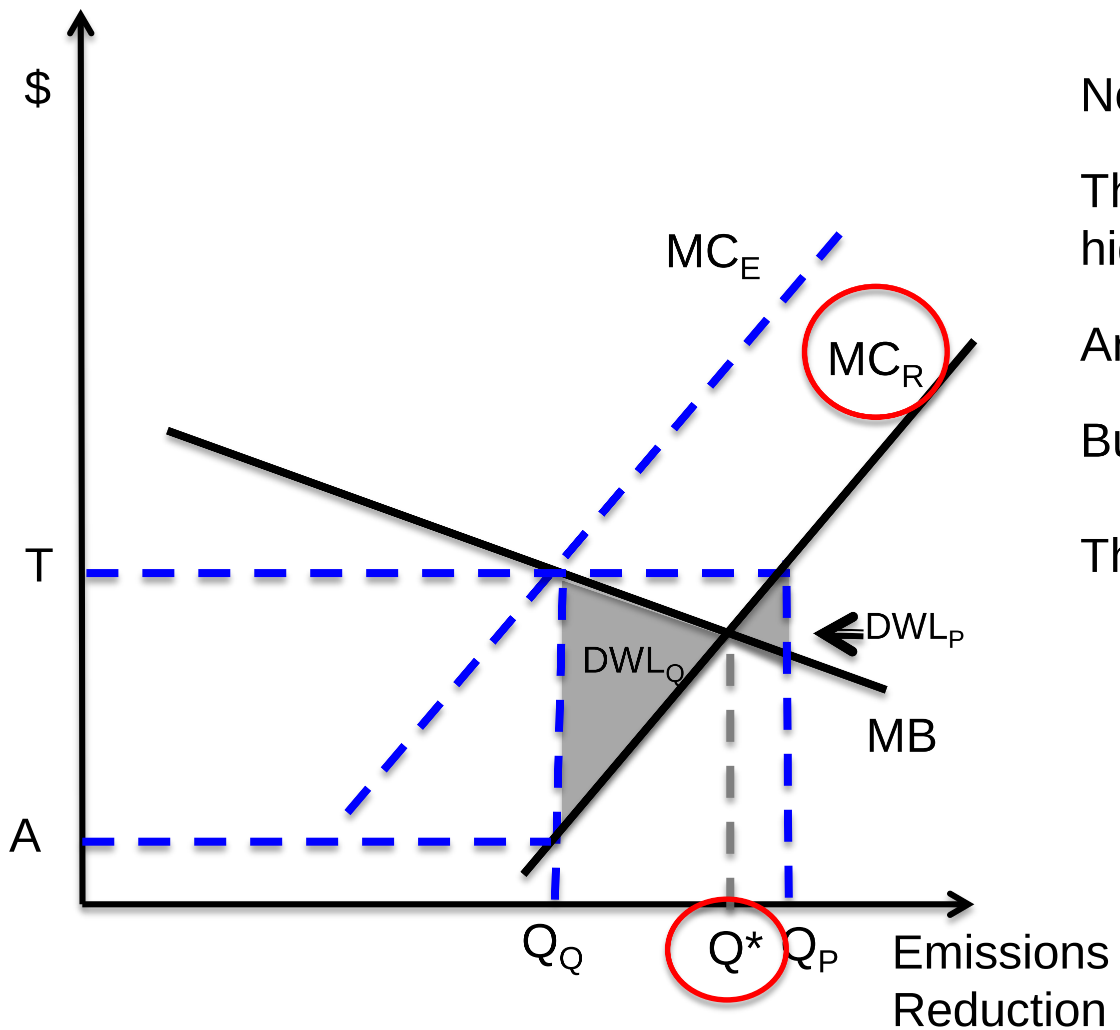


In this example, $DWL_P < DWL_Q$

Since MB and MC are linear: Can see this by simply noticing that Q_P is closer to Q* than Q_Q

So a tax is preferable in this example

What if costs ended up being lower than expected?



$MC_E > MC_R$

Now $Q^* > Q_E^*$

This means that Q_P is now too high

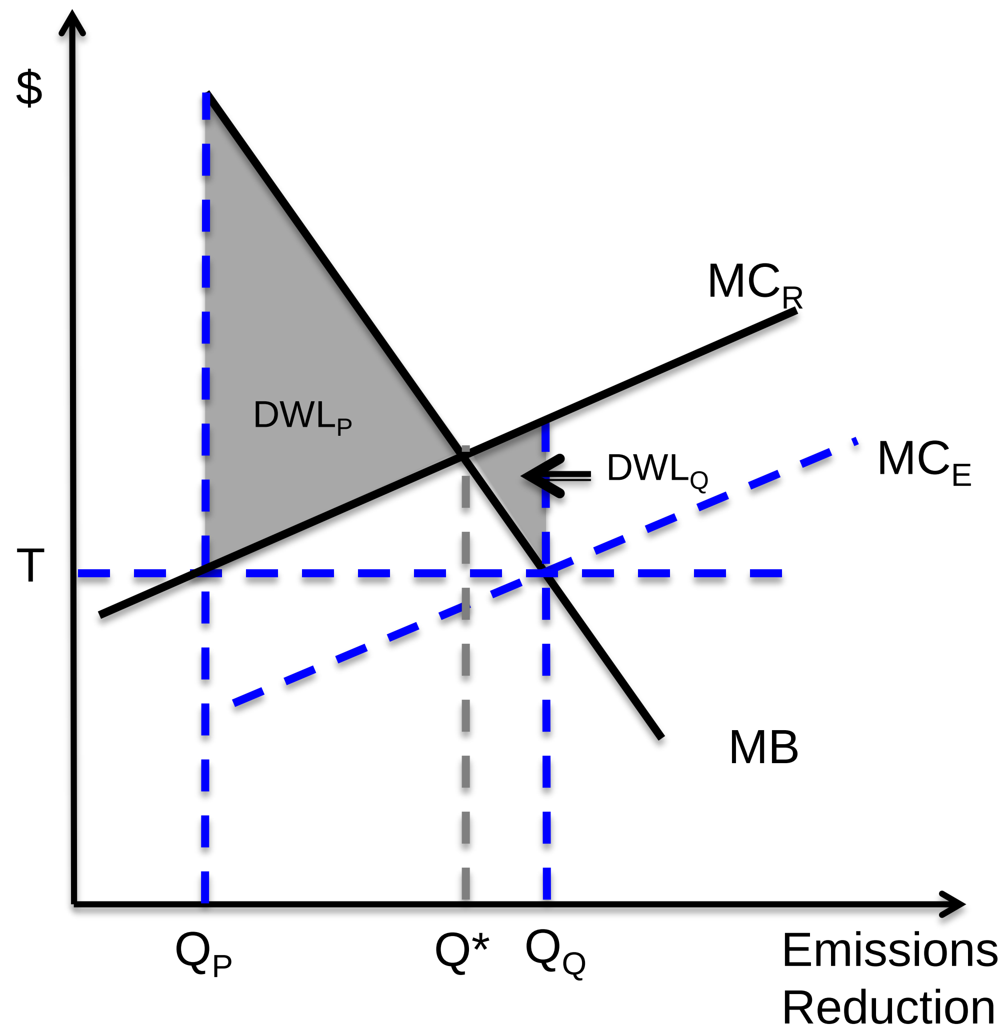
And Q_Q is now too low

But Q_P is still closer to Q^* than Q_Q

This tells us that $DWL_P < DWL_Q$

Why does the tax perform better here?

What matters is the relative slopes of MB and MC



In the previous example, MC was steeper than MB

Here we show that the situation is reversed if MC is flatter than MB

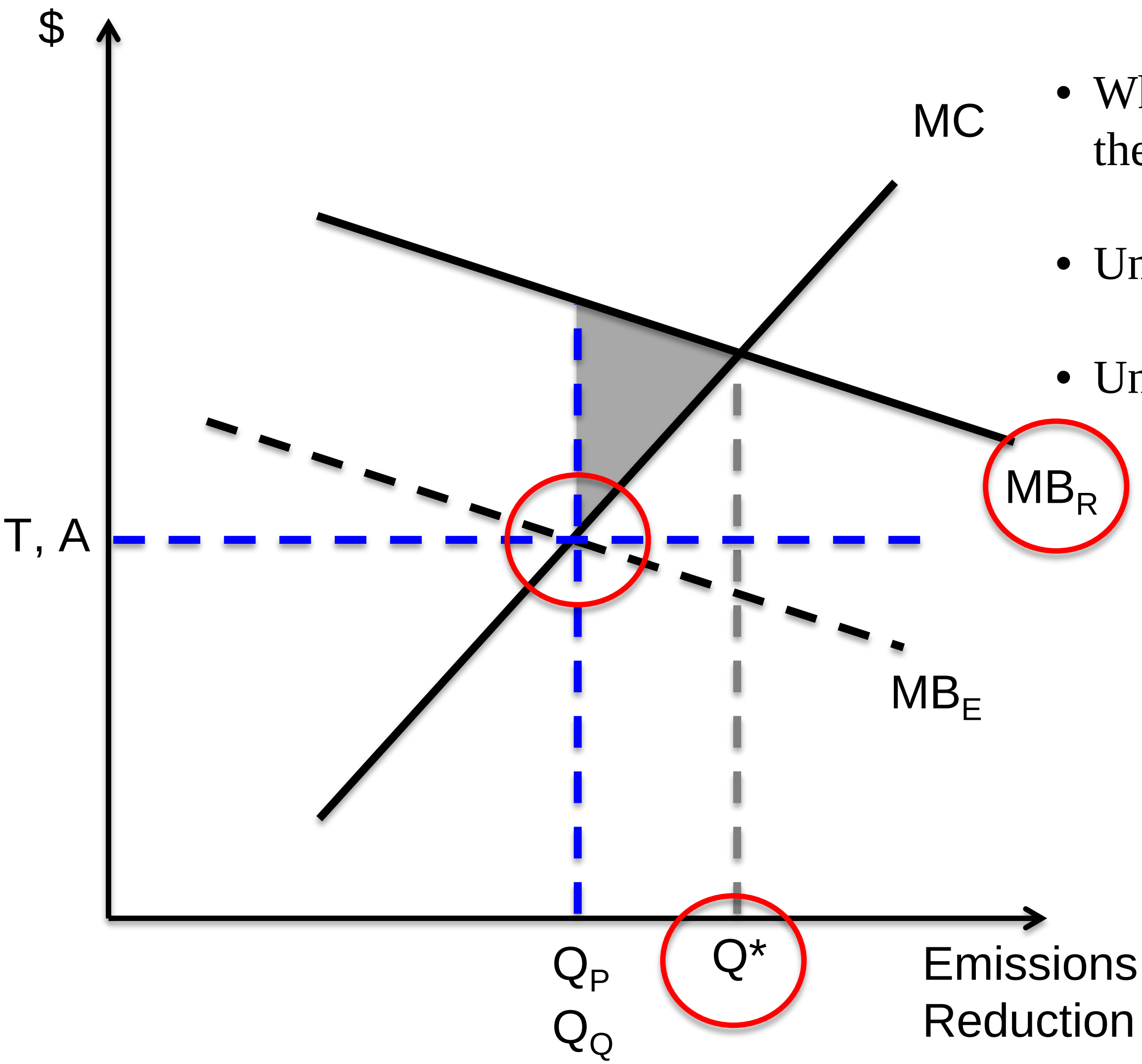
Now the tradeable permit approach is more efficient than the tax: $DWL_P > DWL_Q$

Weitzman (1974) Rule:

$$|\text{MC Slope}| > |\text{MB Slope}| \Rightarrow \text{Price Instrument}$$

$$|\text{MC Slope}| < |\text{MB Slope}| \Rightarrow \text{Quantity Instrument}$$

What if the benefits are uncertain, not the costs?



- Now $MB_R > MB_E$
- What matters for determining outcome of the policy is the marginal cost curve:
- Under a tax, MC determines Q
- Under a cap, MC determines P

- If only benefits are uncertain, then both instruments are **equally** inefficient
- So, benefit uncertainty has **no effect** on which instrument is more efficient

The Weitzman Rule

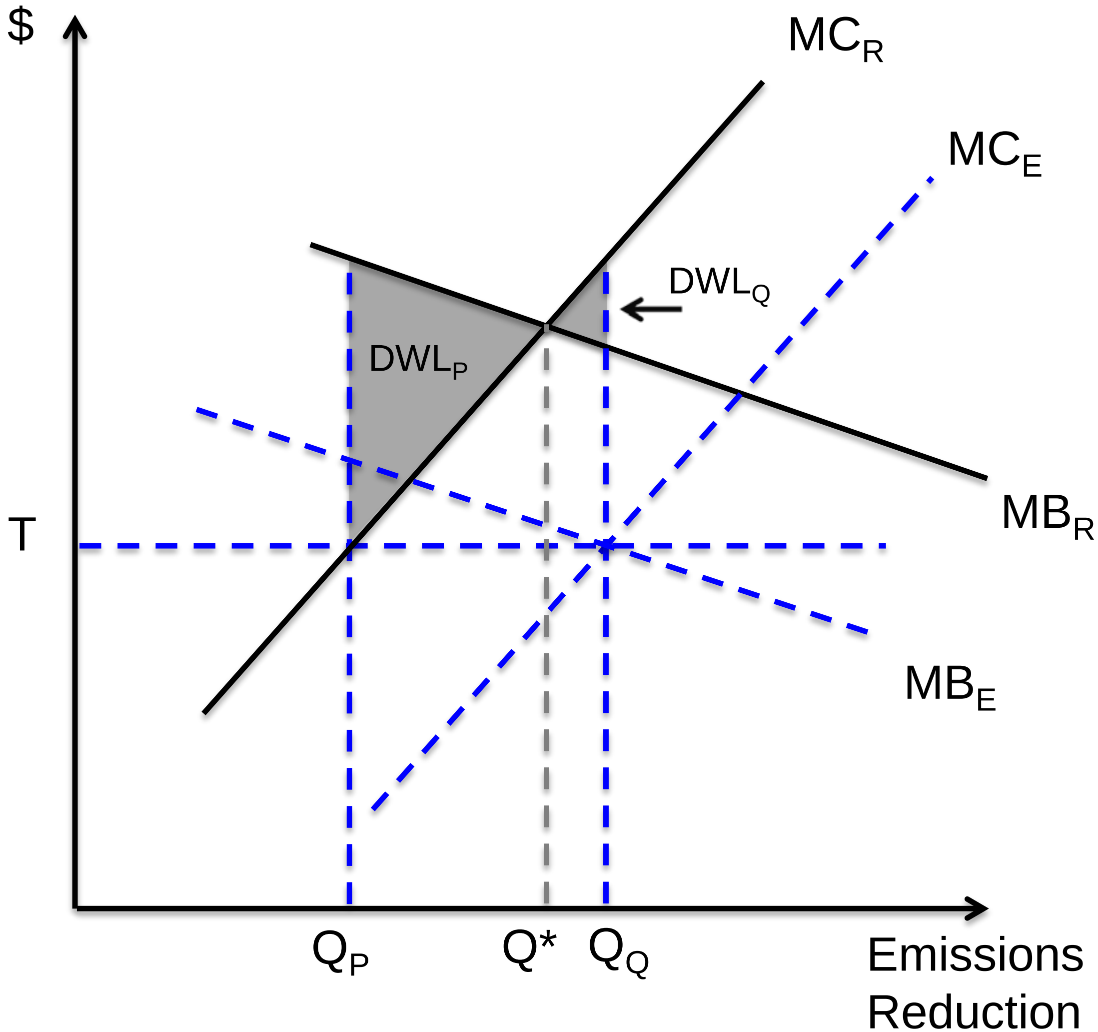
- **Coasean logic suggests that defining property rights should be equivalent to Pigouvian taxation**

  [absent transaction costs & market power]

- **Weitzman (1974) showed that the instruments are no longer equivalent in the face of cost uncertainty**
  - If |Slope MC| > |Slope MB|, a price instrument (tax) will have lower expected DWL
  - If |Slope MC| < |Slope MB|, a quantity instrument (cap and trade) will have lower expected DWL
  - What's the intuition for this?

- **Benefit uncertainty does not matter**
  - Since it's the marginal cost curve that determines outcomes under market based instruments

Simultaneous Benefit and Cost Uncertainty and the Choice of Policy Instrument



- Same MC_E, MC_R, MB_E, and MB_R as before
- Set policies at **T** and $\mathbf{Q_Q}$ where $MB_E = MC_E$
- Positive correlation: $MB_R > MB_E \rightarrow MC_R > MC_E$
- **Q*** now closer to $\mathbf{Q_P}$ than $\mathbf{Q_Q}$
- So, result has *switched:* deadweight loss with tax is now *greater* than with permits

Stavins (1992) Rule:

- **Positive Correlation** *favors* Quantity Instrument (Q)
- **Negative Correlation** *favors* Price Instrument (P)

Can combine price and quantity instruments into a hybrid instrument

For example, in the context of a cap-and-trade system:

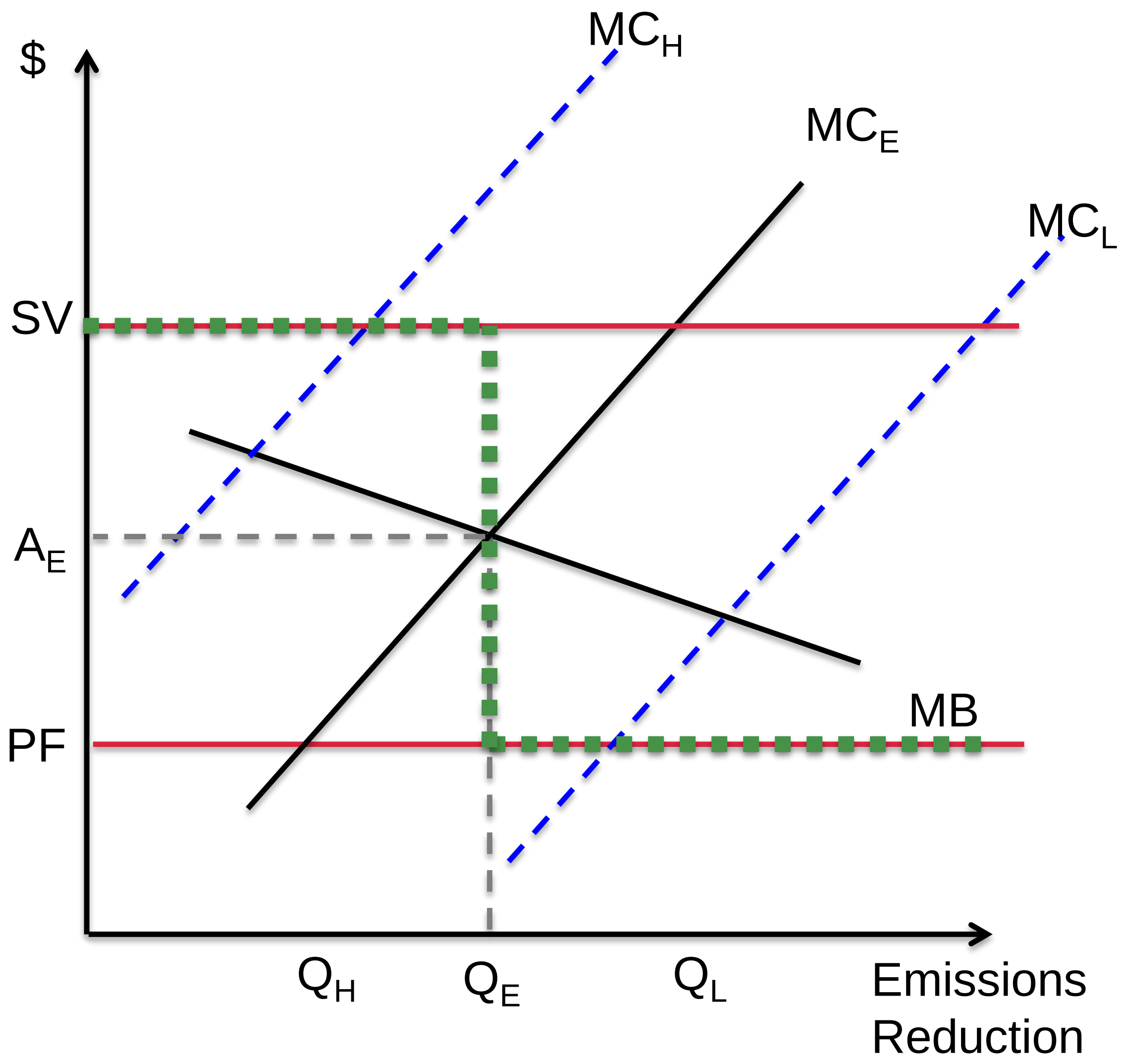
- Imagine the government announces in advance that it is willing to sell (an unlimited number of) additional allowances at a specific price **SV** (the trigger price).
    - Sometimes referred to as a “safety-valve”

- This effectively caps the allowance price A <= SV

- Once it is reached, this trigger price acts like a tax on additional pollution, fixing marginal abatement costs but expanding the original cap on aggregate emissions.

- The government can also institute a price floor **(PF) ---** ie the government commits to buy permits at a fixed minimum price.

Price path with a hybrid instrument



- If $A(Q_Q)$ > safety valve, the government issues more permits
  - $Q < Q_Q$
- If $A(Q_Q)$ < price floor, the government buys back permits
  - $Q > Q_Q$
- The set of possible prices under this hybrid policy is
- PF< A<SV
- [green line]

Do hybrids improve efficiency?

- Advantage: cost containment
- Disadvantage: emissions no longer capped
- Roberts & Spence (1976) showed that the ex post efficiency loss from imperfect MC estimation is smaller using a hybrid instrument than using either prices or quantities alone.
- Safety valves and price floors are very common:
  - Bingaman-Specter (2007), Waxman-Markey, etc

Safety-Valve Example – Setup

Congress is considering a policy to reduce emissions of gunk. Although this pollutant is currently unregulated, an independent review of the issue has found that marginal costs and marginal benefits of pollution control follow the following schedule:

- $MC = 3 + Q$
- $MB = 9 - .5Q$

Where Q is the quantity of gunk emission **reductions**.

Safety-Valve Problem – Part A

Calculate the statically efficient level of emissions reductions, Q*, and the marginal cost of emissions reductions at this level, P*. What are the static net benefits of this policy if the regulator chooses this level?

- *Efficient policy sets MC = MB. So,*
- $3+Q = 9 - .5Q$
- $Q^* = 4$
- $P^*=7$.

- *Net benefits are the area under the MB curve and above the MC curve up to the point of the policy.*
- *Total benefits =* $9Q + .25*(Q)^2 = 32$.
- *Total costs =* $3Q + .5*(Q)^2 = 20$.
- *So, net benefits, NB =12.*

Safety-Valve Problem – Part B

It turns out that the estimated marginal cost schedule is actually an average of two competing reports, a high cost estimate and a low cost estimate, which the independent agency considers equally likely.

- $MC^H = 6 + Q$

- $MC^L = Q$

Given this uncertainty in costs, would you recommend that the regulator use a price or a quantity instrument to regulation gunk? Explain the intuition for your answer.

Safety-Valve Problem – Part C

Congress chooses to use a quantity instrument, mandating emissions reductions equal to the efficient level, Q*. Calculate the expected net benefits of this policy, taking into consideration the fact that marginal costs are uncertain. Assume that there is a 50% chance $MC = MC^L$, and a 50% chance $MC = MC^H$.

- *At Q*=4*
- *In both cases: Total benefits = 9Q + .25*(Q)^2= 32.*

- *Start with the* $MC^L = Q$.
- *Total costs = .5*(Q)^2 = 8*
- *NB = 24.*

- *Now take the* MC^H. = 6 + Q
- *Total costs = 6Q + .5*(Q)^2 = 32*
- *NB = 0.*

- *So, expected net benefits, ENB = .5*24 +.5*0 = 12*

Safety-Valve Problem – Part D

Industry is worried about price spikes if emission reductions turn out to be expensive. In order to allay these fears, Congress writes a "safety valve" in to the law. As an alternative to purchasing permits for their emissions, polluters can pay a penalty of $8 for each unit of gunk that they emit.

Calculate the expected emissions reductions and net benefits.

Safety-Valve Problem – Part D (Solution)

- *First check the prices at Q* to see if either case binds*
  - $MC^H = 6 + Q = 10 > 8$
  - $MC^L = Q = 4 < 8$

- *The low case is unaffected (P=4, is below the safety valve).*

- *In the high case, P=10, so the safety valve will bind in this case.*
  - *i.e. polluters will prefer to pay the penalty of 8 instead of buying permits at 10*

- *At the safety valve price, emissions reductions are less than 4*
  - $MC^H(Q) = 8 = 6 + Q$, *so* $Q = 2$.
  - *Total benefits = 9Q + .25*(Q)^2 = 17.*
  - *Gross costs are 6Q + .5Q^2 + 6*2 = 14. So Net Benefits = 3.*

- *So, under the safety valve, expected net benefits, ENB = .5*24 + .5*3 = 13.5.*
- *Expected emissions reductions are .5*2 + .5*4 = 3.*

Banking and Borrowing

- What happens if firms can bank/ borrow permits across years?

- With dynamic decisions (saving or borrowing), firms equate **discounted** marginal profits from each dynamic in put across years
  - Single year: FV=(1+r)PV
- **Hotelling rule:** Permit prices will rise by the interest rate
  - Absent uncertainty
- Price volatility will be mitigated by private incentives
  - If costs are high this year, they will borrow permits from future and abate less
  - If costs are low they will do more abatement and save permits for future high cost years

Why do we care about permit price uncertainty?

- Uncertain prices make it very difficult for firms to make investment decisions
- This may cause them to delay investments
- If risk averse, could reduce investments
- Carbon tax eliminates price risk…
- Which type of pollutants does it make sense to smooth prices over time for?