The Economics of Climate Change

Lecture 8: Regulation via Prices vs. Quantities

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Previous lecture (s):

- number of policy instruments that can be used for climate change (taxes, permits, direct regulation, and so on)
- In general economic instruments tend to be preferred due to incentives it induce in polluters
- However, it is important to consider the comparisons between the two main types of instruments Prices (taxes, subsidies) and quantities (tradable permit markets)

This lecture:

- In what circumstances will a regulator prefer prices over quantities and vice versa?
- What influences this choice?

Initial assumptions

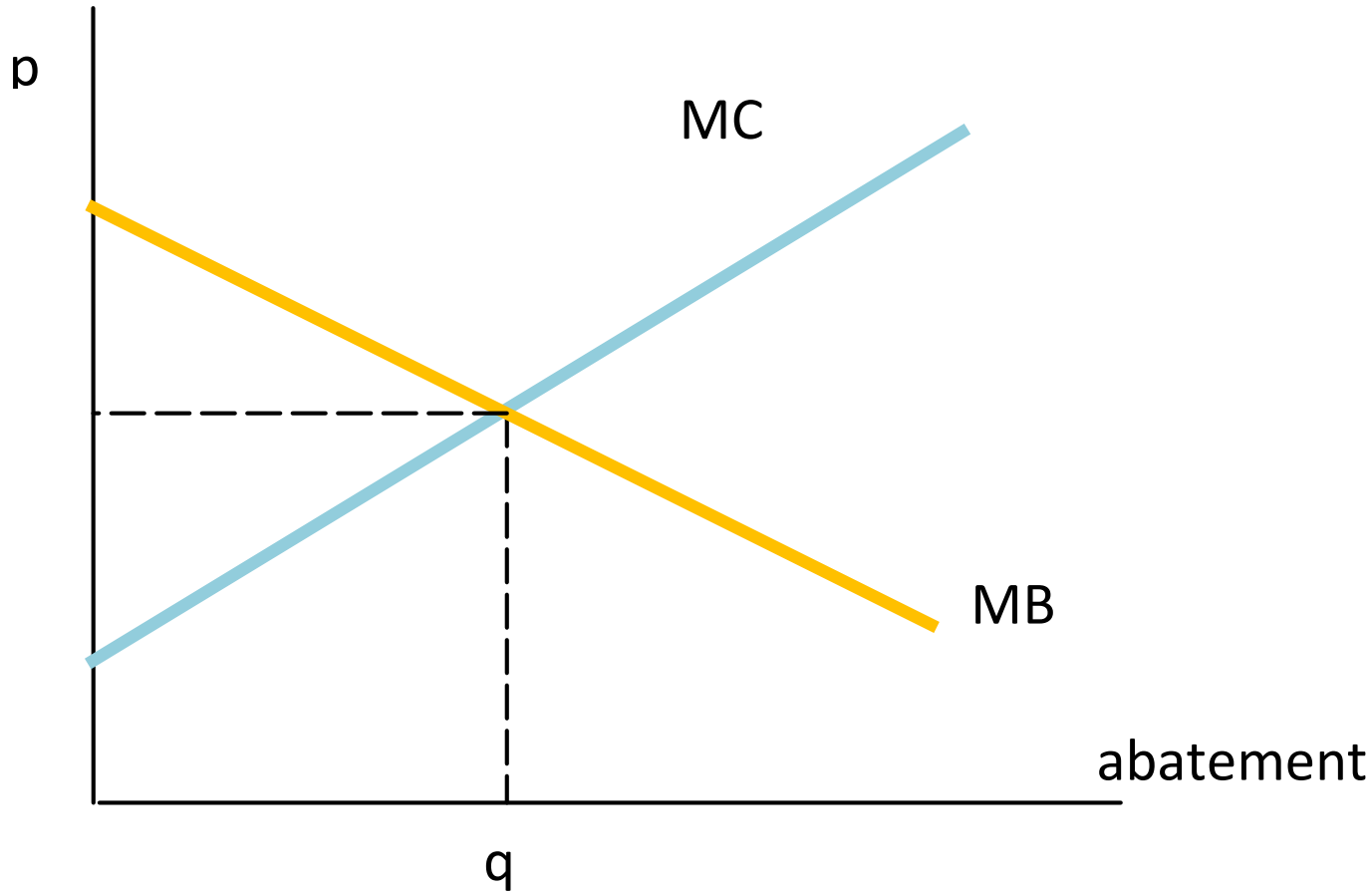
- One regulator decides on whether to use a price or quantity policy to regulate greenhouse gas emissions

In economy there is a:

- Marginal cost function (MC): the additional cost of reducing emissions (abatement) by one unit
- Marginal Social benefit function (MB): the additional benefit of reducing emissions (abatement) by one unit
- We look at the uncertainty of the functions (the regulator is uncertainty about the curves)

Under complete certainty

- Under complete certainty both instruments are equivalent, i.e. choosing a p^* will give q^* and vice versa:



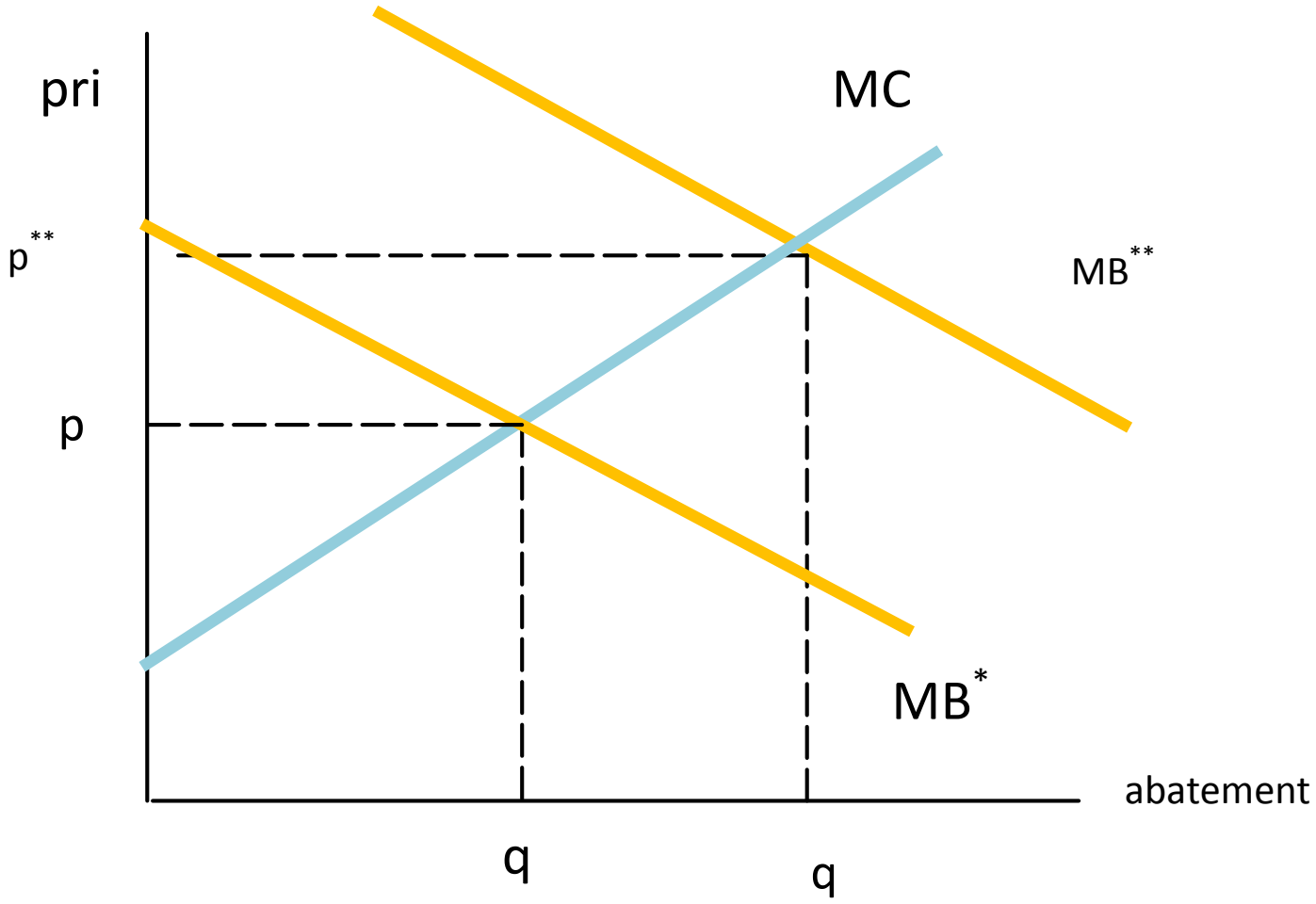
Uncertainty in the benefit function

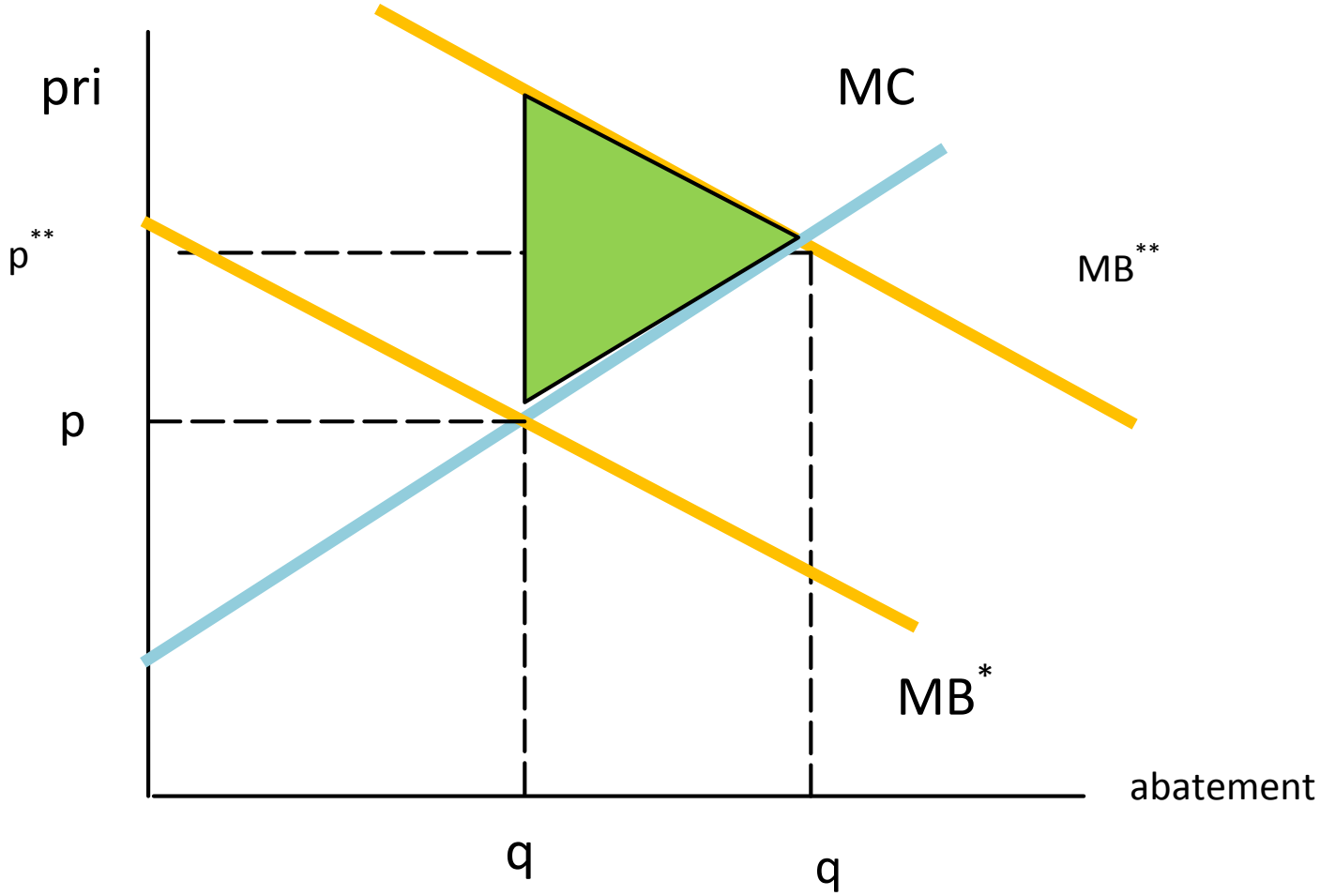
- Assume, the regulator does not know the true position of the (marginal) benefits function

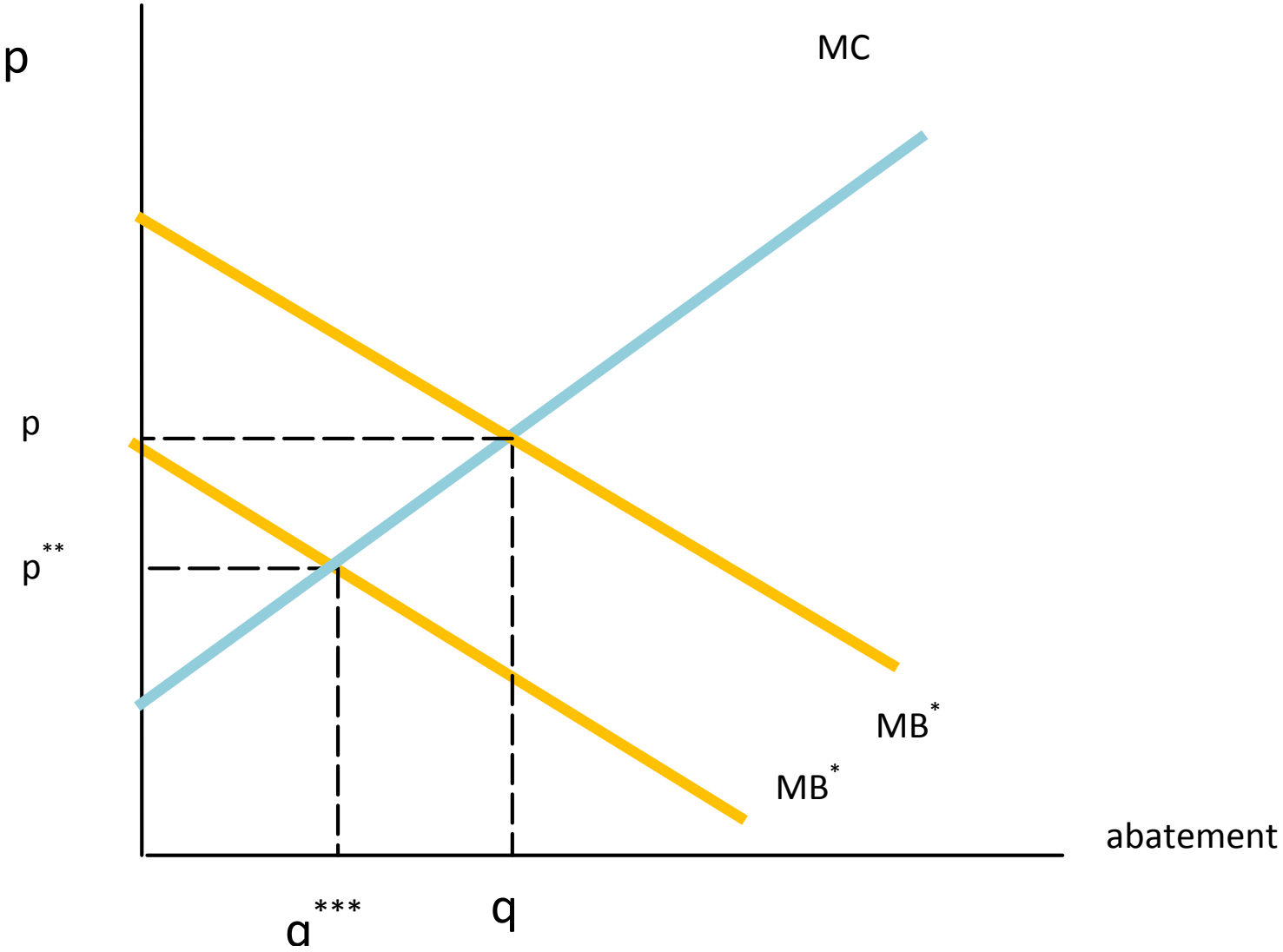
Findings:

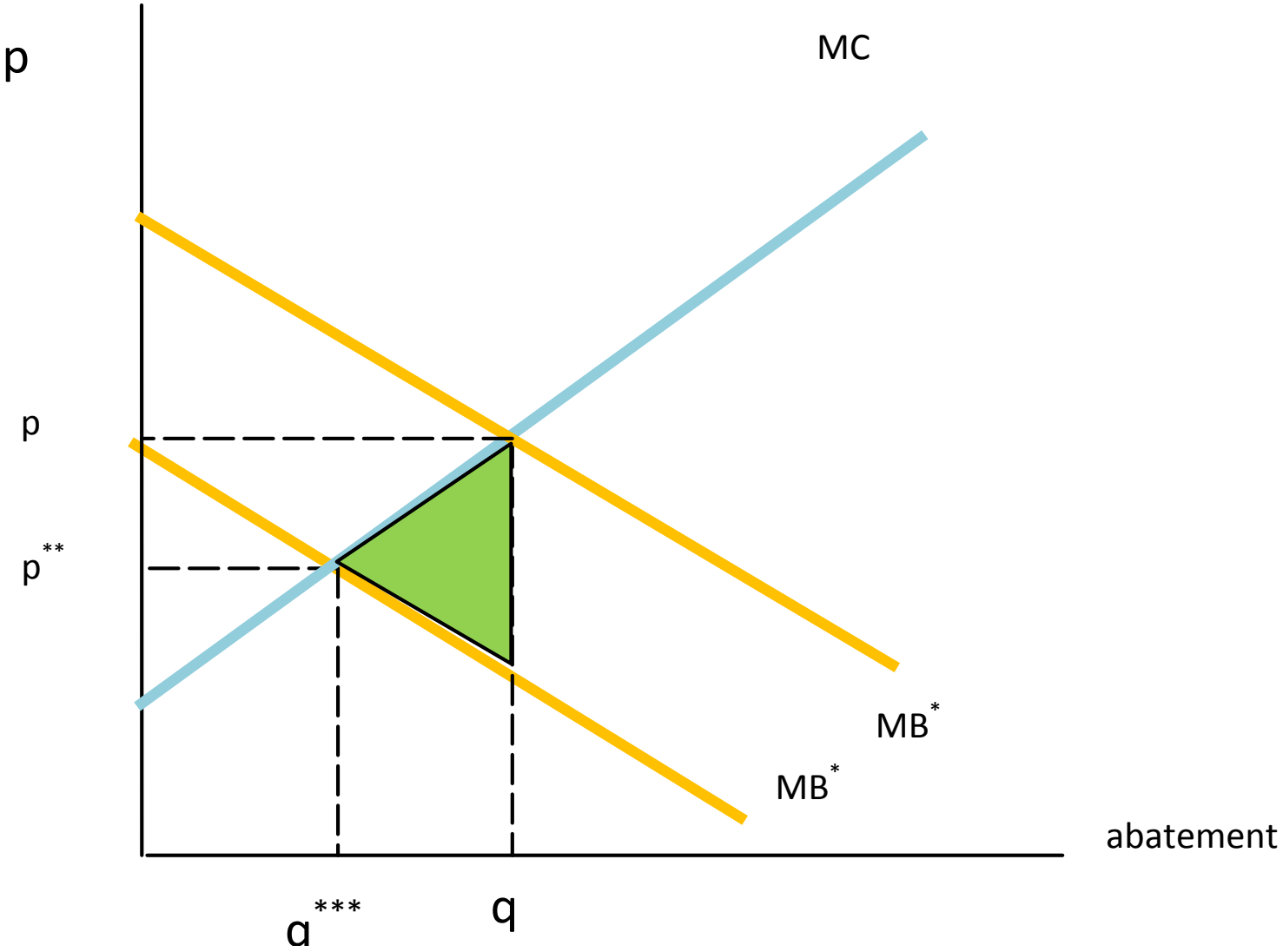
1. In general, error in estimation results in social loss
2. This social loss will be the same for both Pigouvian taxes and permits

MB is greater than originally thought




pri
MC
p**
MB**
p
MB*
abatement
q
q


p
MC
p
p**
MB*
MB*
abatement
a***
q


p
MC
p
p**
MB*
MB*
abatement
q***
q

Why is the social loss the same for both p and q?

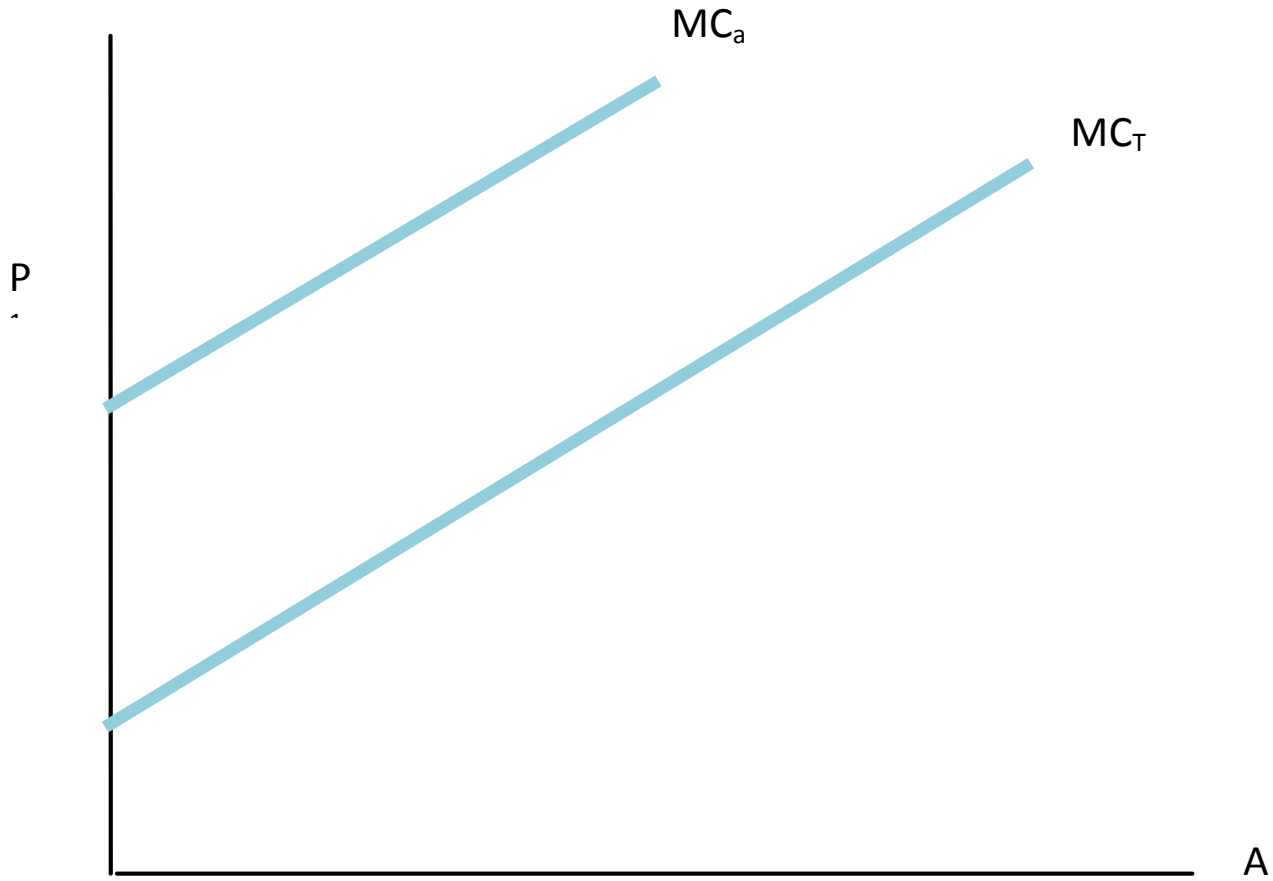
- Regulator knows, with complete certainty, the MC function
- In competitive market the following holds: $p^* = MC(q^*)$
- So given q^* can determine p^* and vice versa

Uncertainty in the marginal cost

- Assume that due to a random shock (uncertainty) the regulator has an anticipated marginal cost function instead of the real marginal cost function
- Under this a regulator can choose Q but be surprised by the associated cost of it
- Regulator can choose P and be confident of the marginal costs no matter how uncertain the cost function is

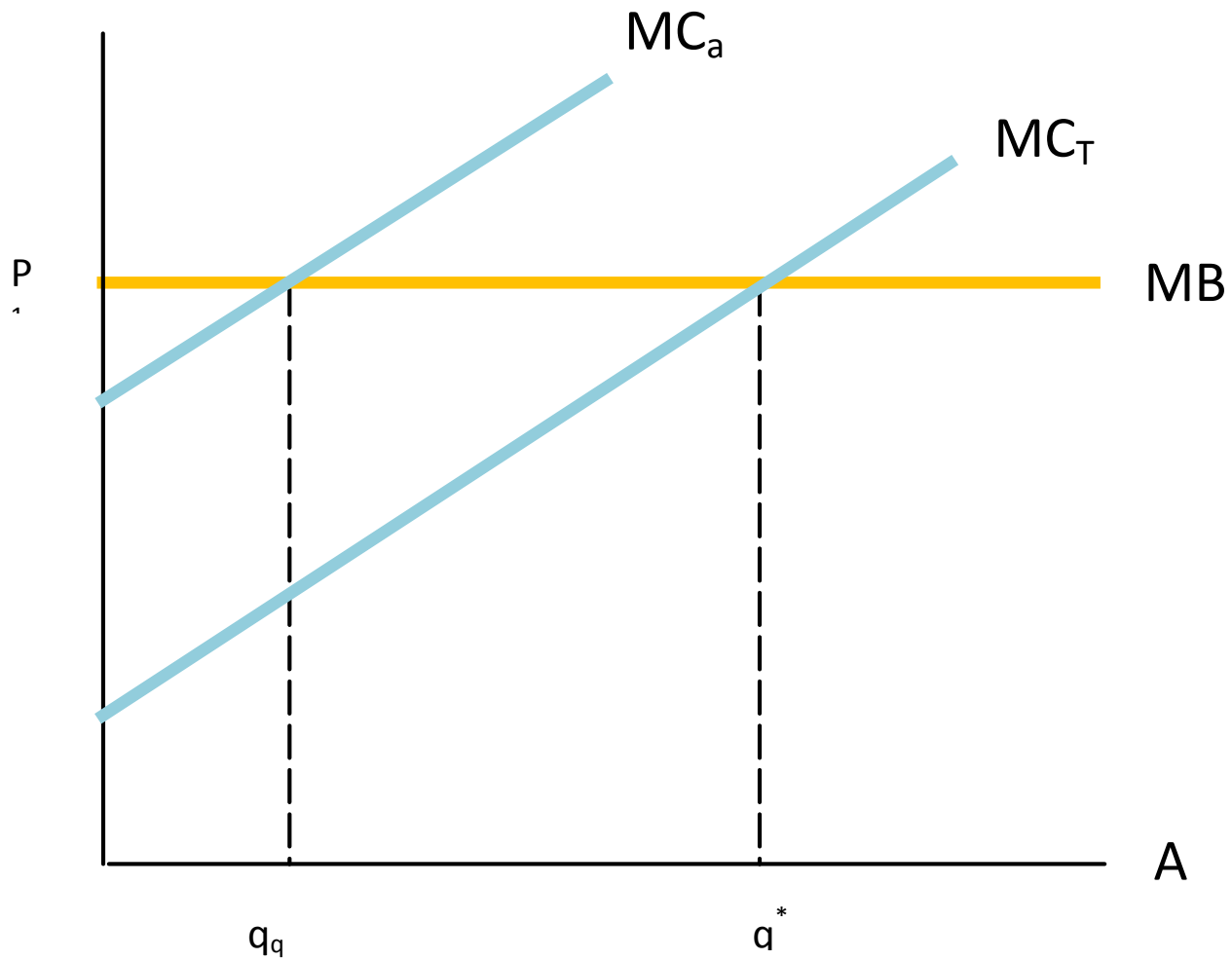
many interesting things:

1. Steepness of MB curve with uncertain MC
2. Steepness of MC with uncertain MC
3. Relative steepness of both MB and MC with uncertain MC


MC_a
MC_T
P
A

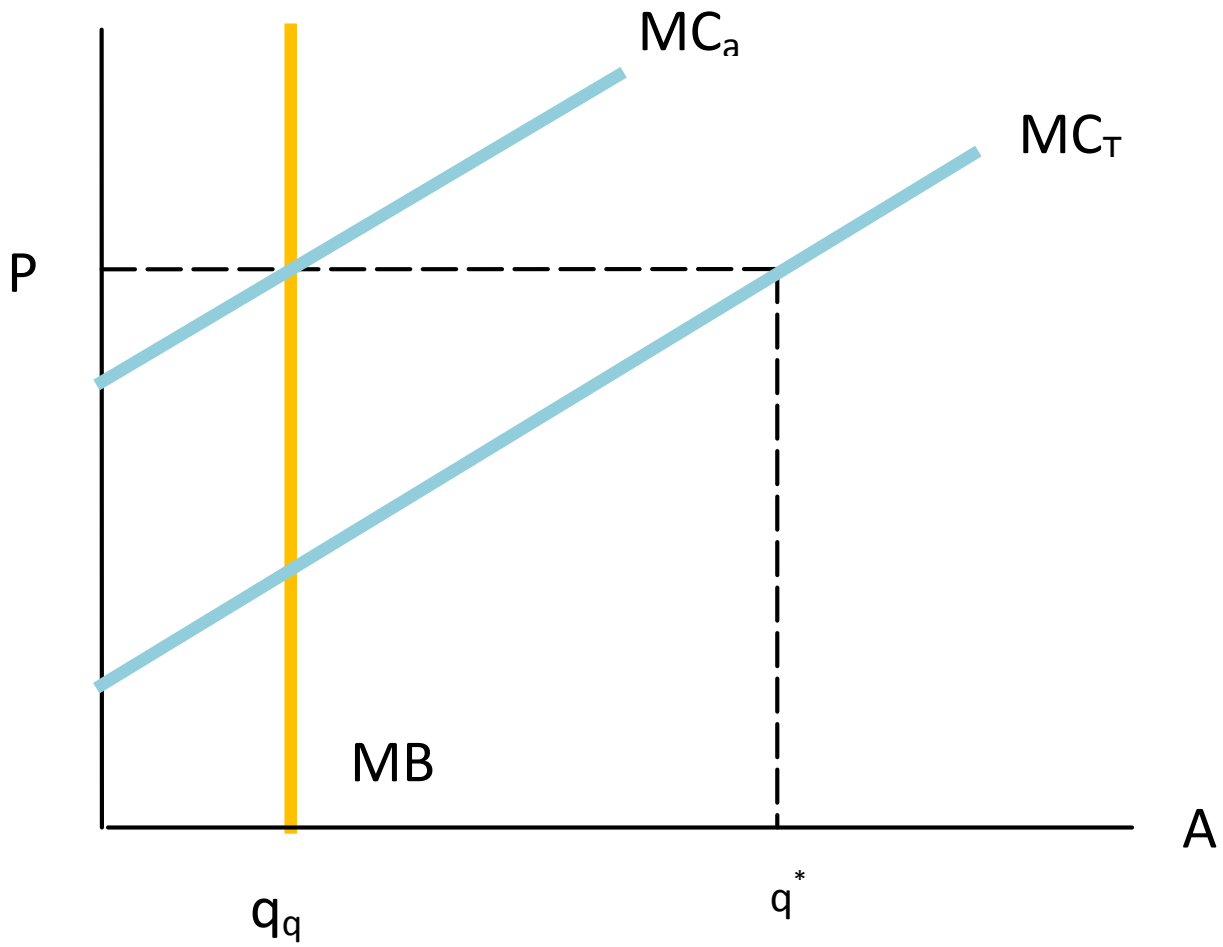
Horizontal MB function

Price (tax) reaches socially optimal level
Quantities has distortion $(q^* - q_q)$

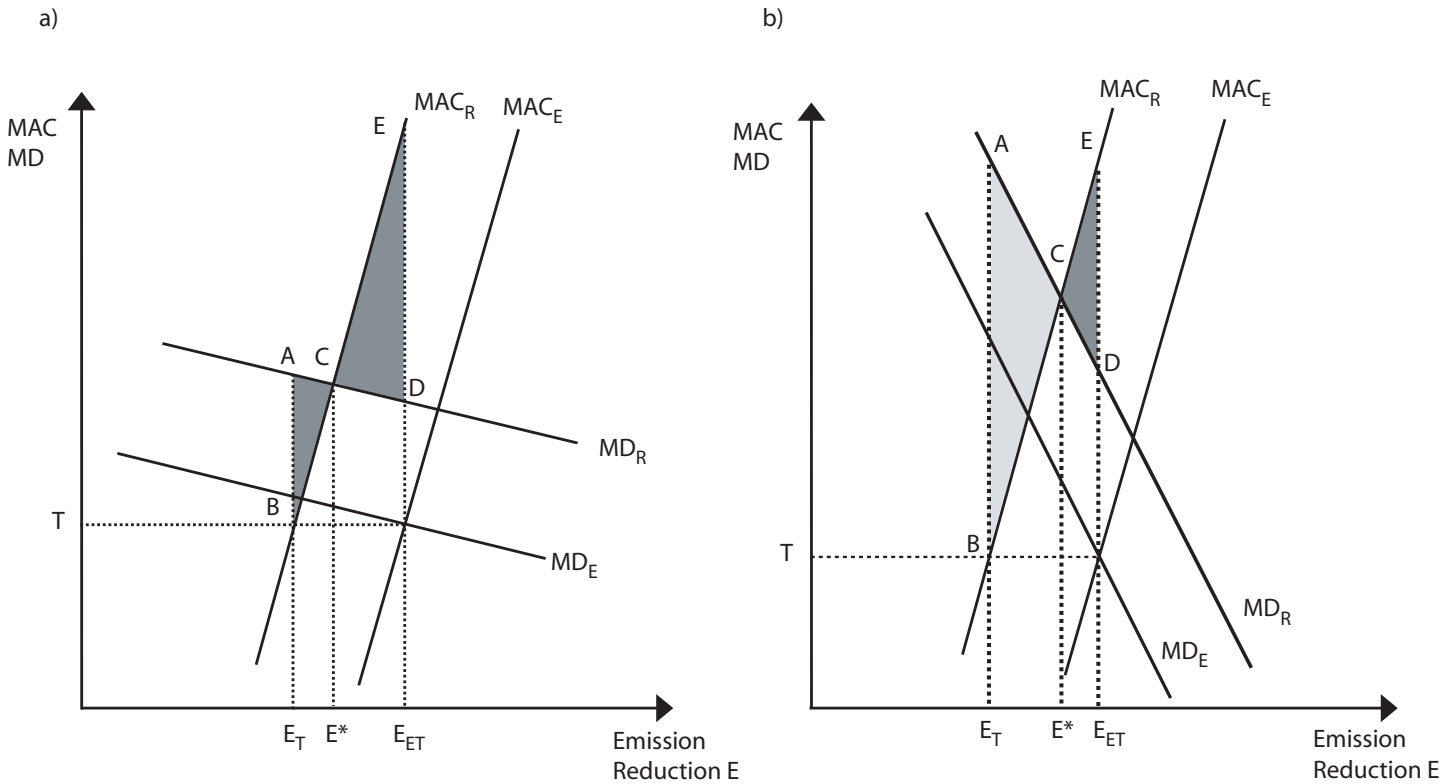


Vertical MB function

Price causes distortion $(q^* - q_q)$
Quantity instruments optimal



Changes in the slope of MDs



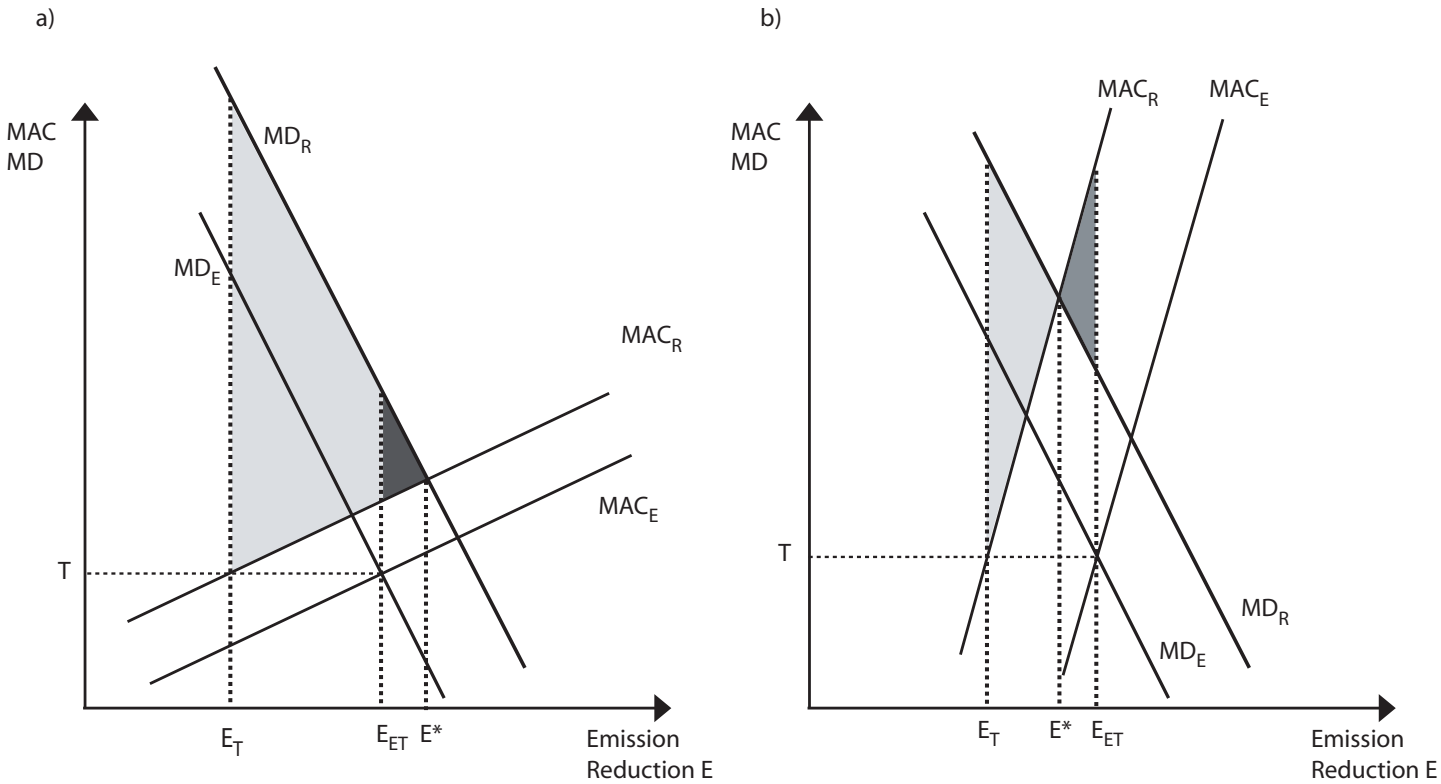
MAC_E: Expected MAC
MAC_R: Realized MAC
MD_E: Expected MD
MD_R: Realized MD
E_T: Emission Reduction with Tax solution
E_{ET}: Emission Reduction with Emissions Trading

Summary of effects of MB slope

Flatter marginal benefit function $\Longrightarrow$ *favours price instruments*

Steeper marginal benefit function $\Longrightarrow$ *favours quantity instruments*

Changes in the slope of MACs



MAC_E: Expected MAC
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MD_E: Expected MD
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Summary of effects of MAC slope

The slope of the marginal cost function matters in determining the preferred policy instrument:

Steeper marginal cost function $\Longrightarrow$ *favours price instruments*

Flatter marginal cost function $\Longrightarrow$ *favours quantity instruments*

A price instrument is more (less) efficient than a quantity mechanism when marginal benefits are relatively flat (steep) compared to the marginal costs

Weitzman (1972) Main result

Assume quadratic cost functions:

$$B(q,\eta) = (I+\eta)q + \frac{b}{2}q^2$$
$$C(q,\theta) = (\theta)q + \frac{c}{2}q^2$$

Price instruments are relative more efficient than quantity instruments when:

$$\Delta = \frac{\sigma^2}{2c}(c-b)$$

where σ^2 is variance of cost shock, c slope of MC and b is slope of MB
Important points:

1. When $c > b$ prices preferred
2. When $c < b$ quantity preferred
3. When $c = b$, effectively the same
4. Variance of cost shock alter magnitude of relative efficiency

Compliance and Enforcement on the International Level

Note: Regulated actors are sovereign countries not firms or other private entities

- Noncompliance under price-based regulation
  - Fiscal Sovereignty always lies with the state
  - Fiscal Cushioning:
    Individual countries can use fiscal revenues to reduce fees which indirectly tax carbon (e.g. fuel duty) or increase subsidies for carbon/energy intense production processes (e.g. coal subsidies) $\rightarrow$ effective tax rate is reduced
    $\rightarrow$ individual countries can undermine the incentive effect of a global price-based regulation

Compliance and Enforcement on the International Level

- Noncompliance under a quantity-based regulation
  - Countries misrepresent their emission budget
  - Individual countries cannot influence the scarcity of certificates

  $\rightarrow$ Enforcement of quantity-based instruments on the international level is stricter than that of price-based instruments, $\alpha_t < \alpha_q$.
- Next we present the expected difference in social welfare of Prices over Quantities when;
  - marginal costs and benefits are uncertain
  - enforcement of Quantities is stricter than that of Prices

Prices vs. Quantities under Fiscal Cushioning

Expected difference in social welfare of Prices over Quantities Δ_{pq}:

$$\Delta_{pq} = \underbrace{\frac{\sigma^2 \alpha_q (1-(2-\alpha_q)\beta)}{2C''}}_{Uncertainty\ Effect} + \underbrace{\frac{\alpha_q(1-k)}{2C''}\left[\frac{F^2}{(1-\alpha_q)(1-k\alpha_q)} - \frac{(F+\underline{b})^2}{(1+\alpha_q\beta)(1+k\alpha_q\beta)}\right]}_{Differentiated\ Enforceability\ Effect}$$

- α_q: enforcement probability of quantity-based regulations
- $\alpha_t = k\alpha_q$; $k \in]0,1[$ measure for the difference in enforceability
- F: sanction for noncompliance
- $\underline{b}$: level of the marginal benefit curve
- Assumption for incomplete enforcement: $F < \frac{1-\alpha_q}{\alpha_q} p = \frac{(1-\alpha_q)\underline{b}}{\alpha_q(1+\beta)}$
- p: permit price

Strict dominance of Quantity-based Instruments

Quantity-based regulation ought to be always preferred if

$$\sigma^2 < \overline{\sigma}^2$$

where

$$\overline{\sigma}^2 = (1-k)\left(\frac{(F+\underline{b})^2(2-\alpha_q)^2}{2(2-\alpha_q(1-k)} - \frac{F^2}{(1-\alpha_q)(1-k\alpha_q)}\right)$$

- α_q: enforcement probability of quantity-based regulation
- k: measure for the difference in enforceability
- F: sanction for noncompliance
- $\underline{b}$: level of the marginal benefit curve

Instrument Choice - Analytical Results

- Institutional variables and the level of the marginal benefit curve which were irrelevant in Weitzman's (1974) approach, now determine instrument choice
- Relative Slope Criterion is no longer valid!
- The threshold level $\overline{\sigma}^2$
  - increases with the level of the marginal benefit curve
  - decreases when prices are stricter enforceable
- Quantity-based instruments ought to be always preferred if $\sigma^2 < \overline{\sigma}^2$

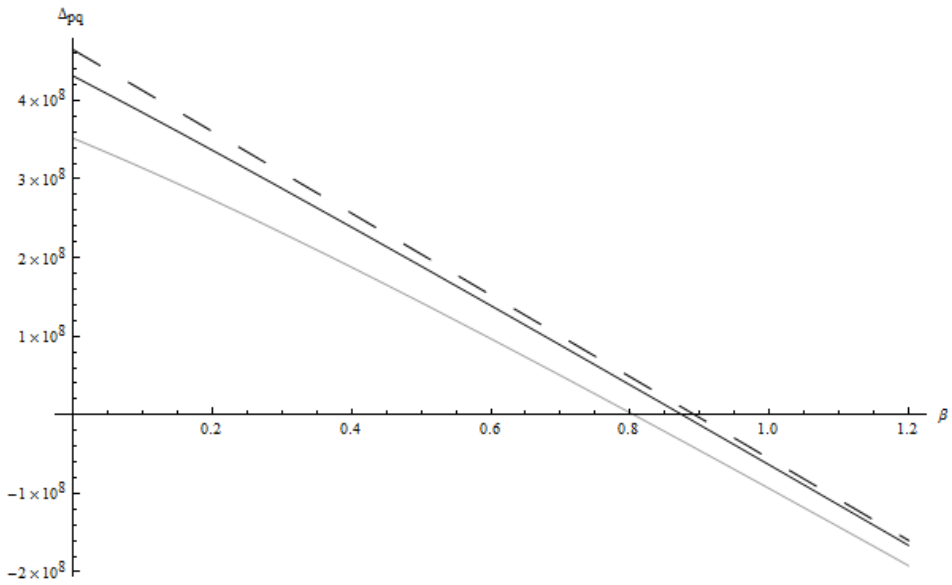
Numerical Simulations in the Context of Climate Change

- Conventional perspective: Newell and Pizer (2003) suggest the use of price instruments (e.g. carbon tax) to regulate GHG emission
- The results of our numerical calculations give insights into the impact of both effects
- Application of our model to the case of regulating CO_2 emissions, based on data presented in Newell and Pizer (2003)

Table: Parameter values

Parameter	Value
Slope of marginal costs (C'')	$1.6 * 10^{-7} \$/t^2$
Slope of marginal benefits (B'')	$-8.7 * 10^{-13} \$/t^2$
Cost uncertainty (σ)	$13\$/t$
b	$9\$/t$
Sanction (F)	$0.98\$/t$
Enforcement probability of Quantities (α_q)	0.8

Numerical Simulations



- More recent studies estimate much higher $\underline{b}$-values
- Quantities ought to be strictly preferred if $\underline{b} = 30\$/t$ is assumed
  $\rightarrow$ variance of costs $\sigma^2 < \overline{\sigma}^2$

- The estimated slopes of the marginal curves yield $\beta \approx 5.4 * 10^{-6} \rightarrow$ differentiated enforceability effect is too weak in order to render quantity instruments preferable