Asymmetric Information

Environmental Economics and Policy Instruments

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Outline

1. A model of pollution with private information about abatement costs
2. Regulations: Price vs quantities
3. Contract-based environmental regulation: a mechanism design approach

Model with unknown costs

- A polluter (firm) and a polluted agent (victim)
- e: emissions/pollution by the firm
- $C(e, \theta)$: cost of reducing emission to e (abatement costs)
- $\theta \in \{L, H\}$ random parameter with $H > L$
- Prob$[\theta = L] = \nu$, Prob$[\theta = H] = 1 - \nu$ with $0 < \nu < 1$
- e^e_θ: *laissez-faire* emissions with $C(e^e_\theta, \theta) = 0$ for $= L, H$
- $C(e, \theta) > 0$, $C'(e, \theta) < 0$, $C''(e, \theta) \geq 0$, for every $e < e^e_\theta$
- Marginal abatement costs lower with L than H:
  $-C'(e, L) < -C'(e, H)$ for every $e \leq e^e_L$
- Linear marginal costs: $C'(e, \theta) = \theta(e^e - e)$ for every $e < e^e_\theta$

Assumptions

- Damage $D(e)$ with $D(e) > 0$, $D'(e) > 0$, $D''(e) > 0$ for every $e > 0$
- Linear marginal damage $D'(e) = k \times e$
- Risk-neutral agents (maximize expected payoff)
- Damage and cost function and distribution of θ are common knowledge
- Asymmetric information: θ is known only by the firm

Optimum under asymmetric information

Minimize *ex post* welfare for each "state of nature" $\theta \in \{L, H\}$

$$\min_{e} D(e) + C(e, \theta)$$

for $\theta = L, H$. Optimal pollution levels e_L^* and e_H^* contingent on the realization of θ such that:

$$D'(e_L^*) = -C'(e_L^*, L)$$

$$D'(e_H^*) = -C'(e_H^*, H)$$

Marginal damage equals marginal abatement costs in each state of nature

Optimum implemented with **non-linear** tax $\tau(e) = D(e)-$ or $+K$ with K a constant

Firm minimizes $D(e) + C(e, \theta) - K$ and therefore chooses e_θ^*

Emission standard

- Cap emissions to $\bar{e}$
- Firm chooses e_θ which minimizes $C(e_\theta, \theta)$ subject to $e_\theta \leq \bar{e}$ for $\theta = L, H$
- Firm emits $\bar{e}$ if costs are L or H
- Maximizes *ex ante* Welfare:

$$\min_{\bar{e}} E[C(\bar{e}, \theta)] + D(\bar{e})$$

- FOC: $D'(\bar{e}) = E[-C'(\bar{e}, \theta)]$
  Marginal damage equals expected marginal abatement costs
- Ex ante efficient emission level: $\bar{e} = e^*$ (if θ unknown)
- Under emissions if $\theta = L$ and over emissions if $\theta = H$

Emission fee

- Tax per unit of emissions τ
- Firm chooses e_θ that minimizes overall costs $C(e_\theta, \theta) + \tau e$
- First-order condition:

$$-C'(e_L^\tau, L) = \tau = -C'(e_H^\tau, H)$$

- Regulator minimizes $E[C(e_\theta^\tau, \theta) + D(e_\theta^\tau)]$ with respect to τ subject to firm's reply function above
- FOC:

$$E\left[\left(C'(e_\theta^\tau, \theta) + D'(e_\theta^\tau)\right) \frac{de_\theta^\tau}{d\tau}\right] = 0$$

- Since $de_\theta^\tau / d\tau = \theta$, solution:

$$E[D'(e_\theta^\tau)] = E[-C'(e_\theta^\tau, \theta)] = -C'(e_\theta^\tau, \theta) = \tau = D'(e^*)$$

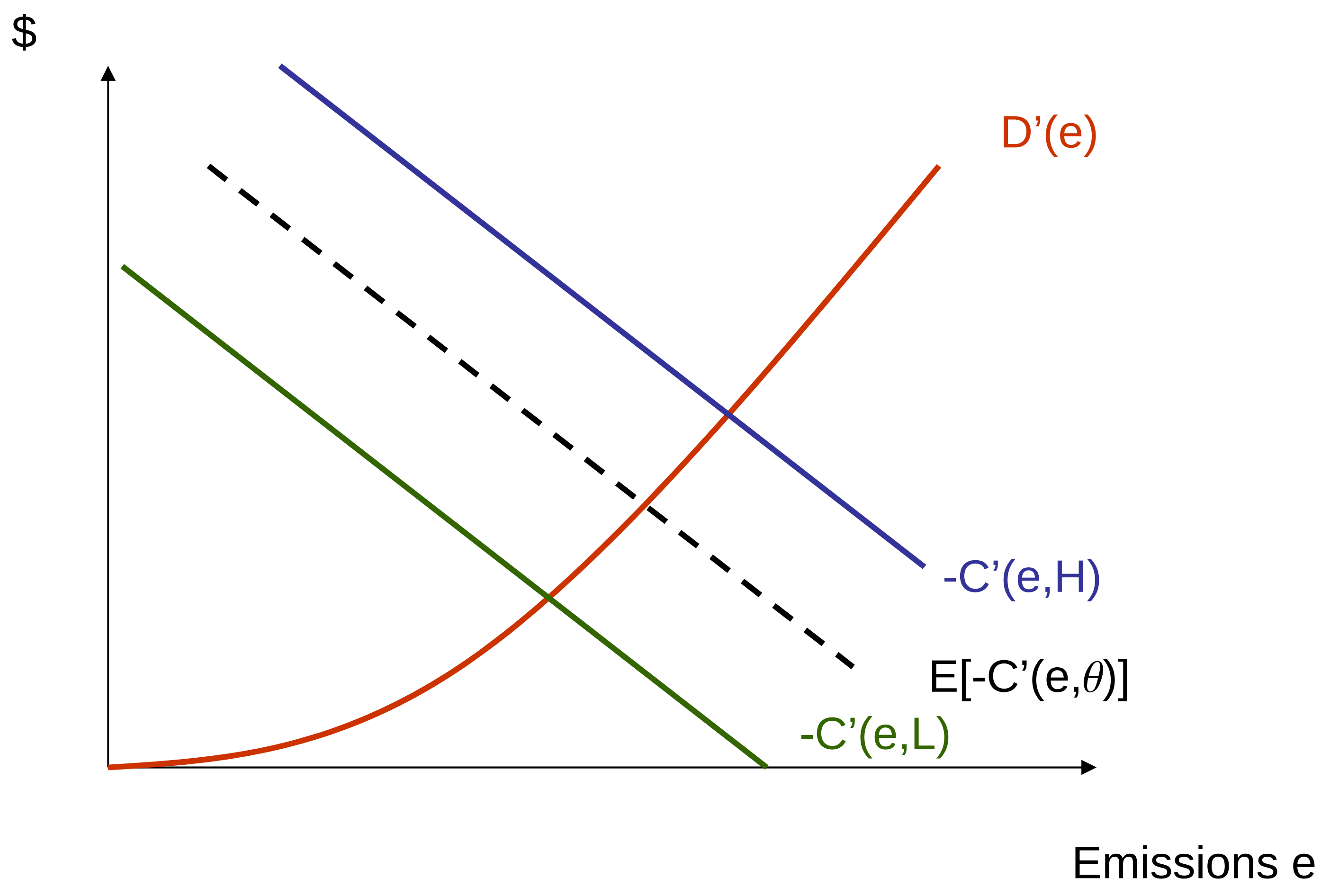
- Under emissions if $\theta = L$ and over emissions if $\theta = H$

Price vs quantities

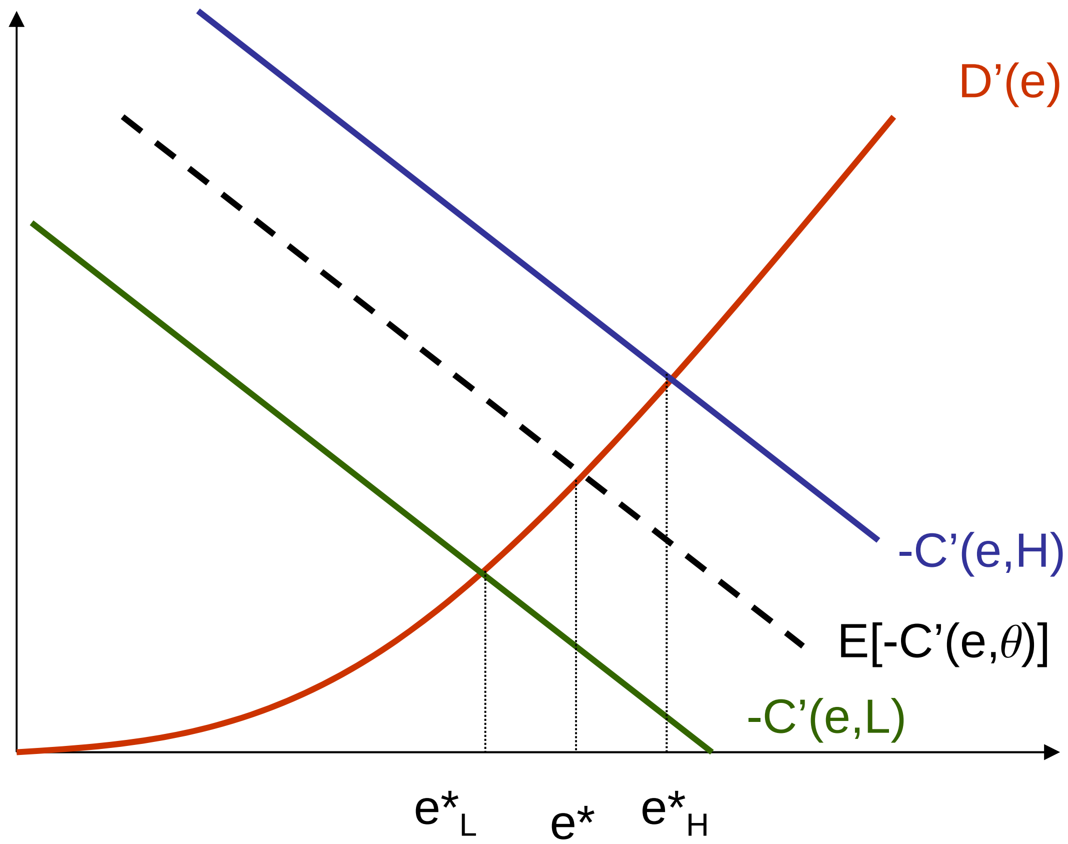
Theorem

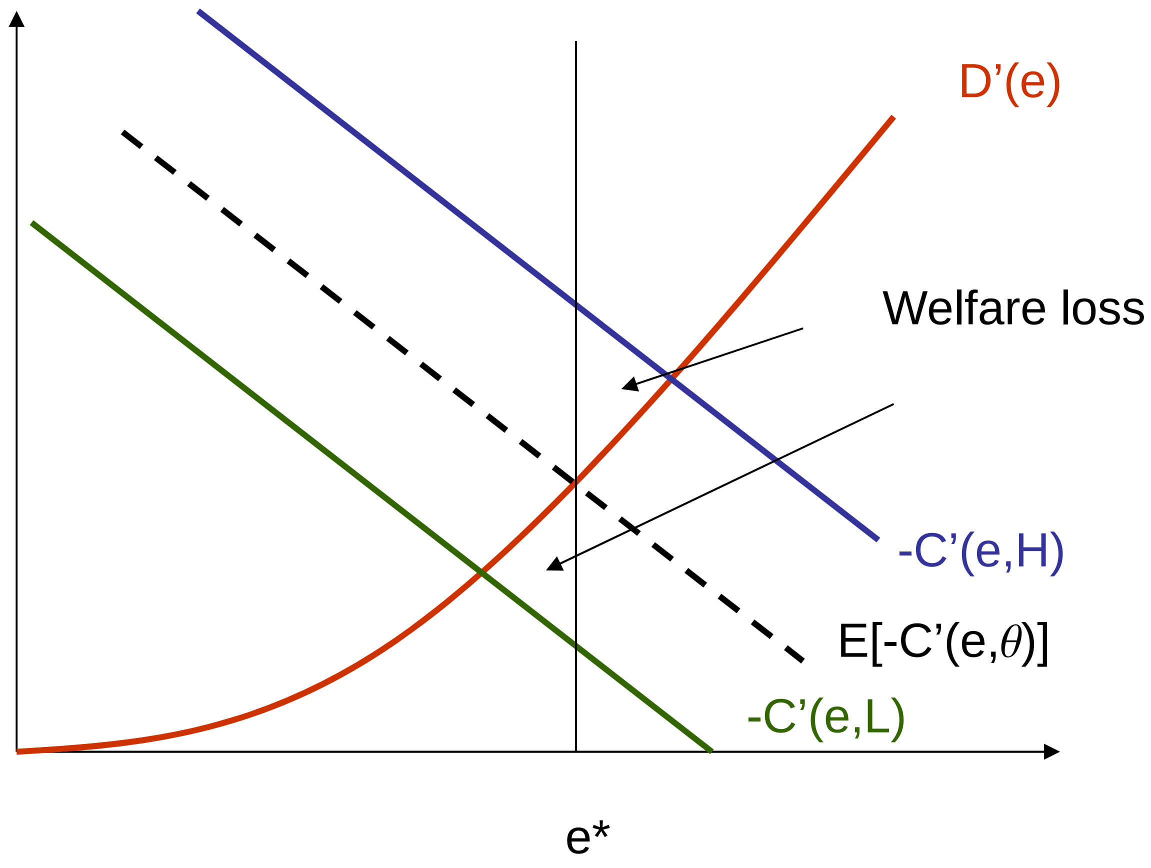
Emissions standard preferred if marginal damages are more steeply sloped than marginal abatement costs; emission fees preferred otherwise.

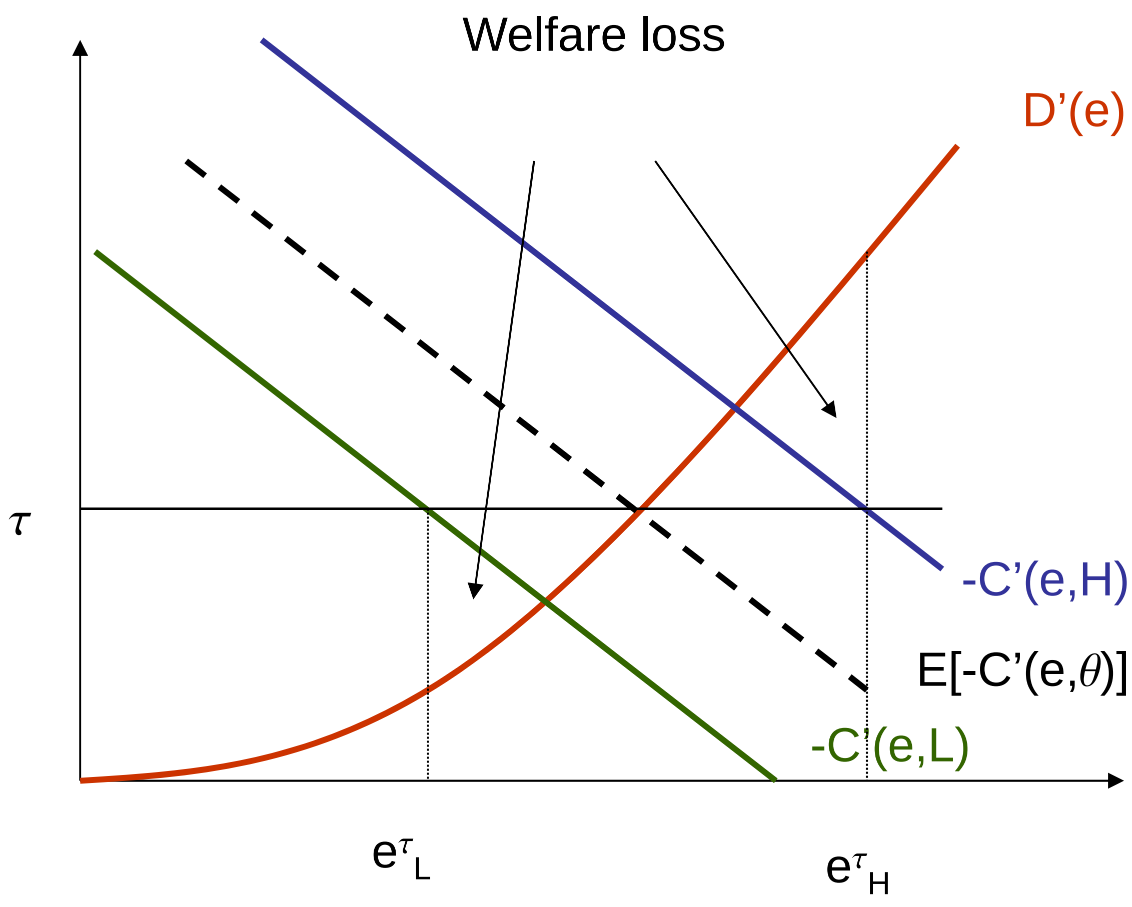
- Due to Weitzman (1974)
- Rely on a linear approximation of marginal costs and damages
- Help to choose between emission fee or standard
- Examples: Quantity regulations are used for pollution problems with dramatic impacts if exceed a threshold (eg poisoning, irreversible damages, species extinction,...), Price regulation if "flat" marginal damage

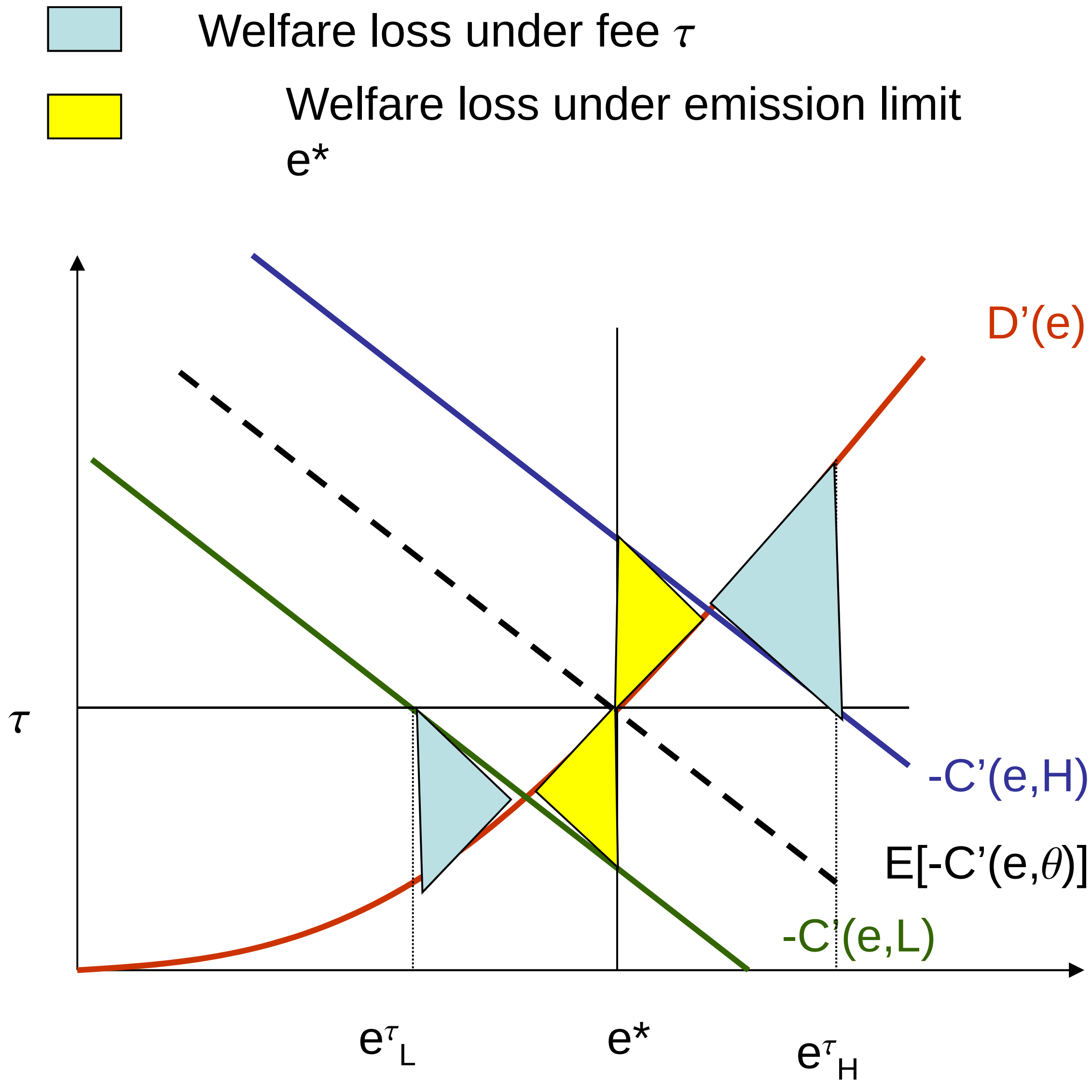

$
D'(e)
-C'(e,H)
E[-C'(e,θ)]
-C'(e,L)
Emissions e

First-best emissions

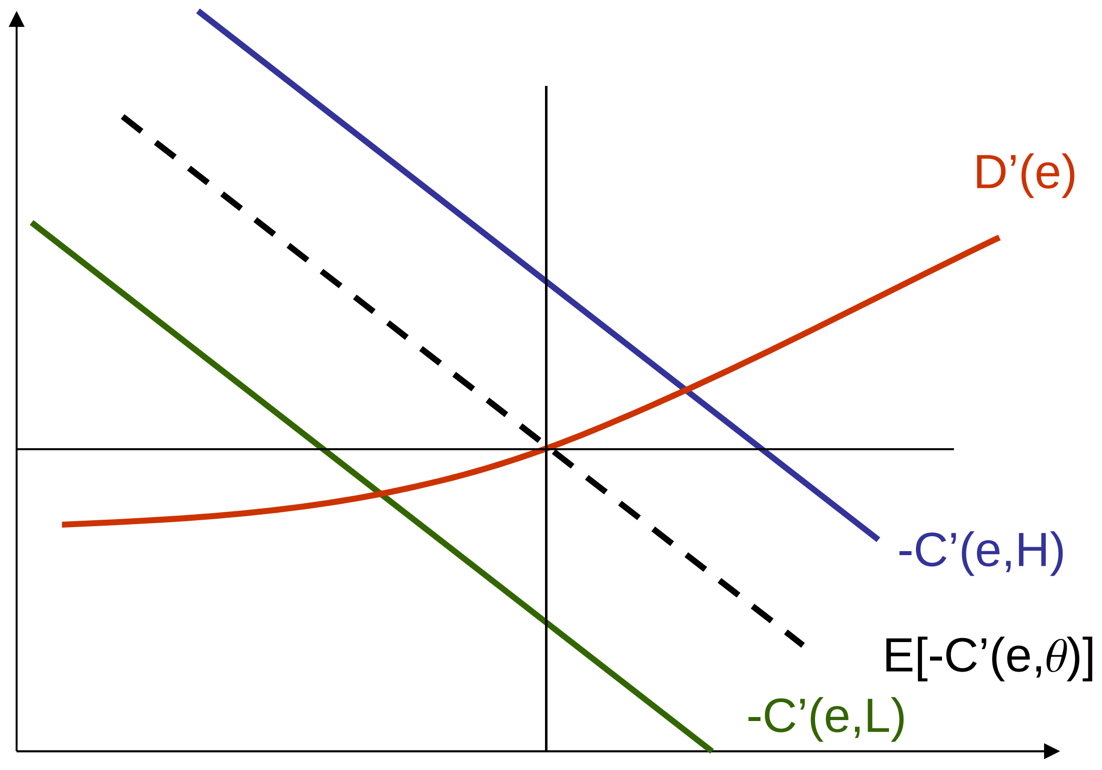



D’(e)
Welfare loss
-C’(e,H)
E[-C’(e,θ)]
-C’(e,L)
e*

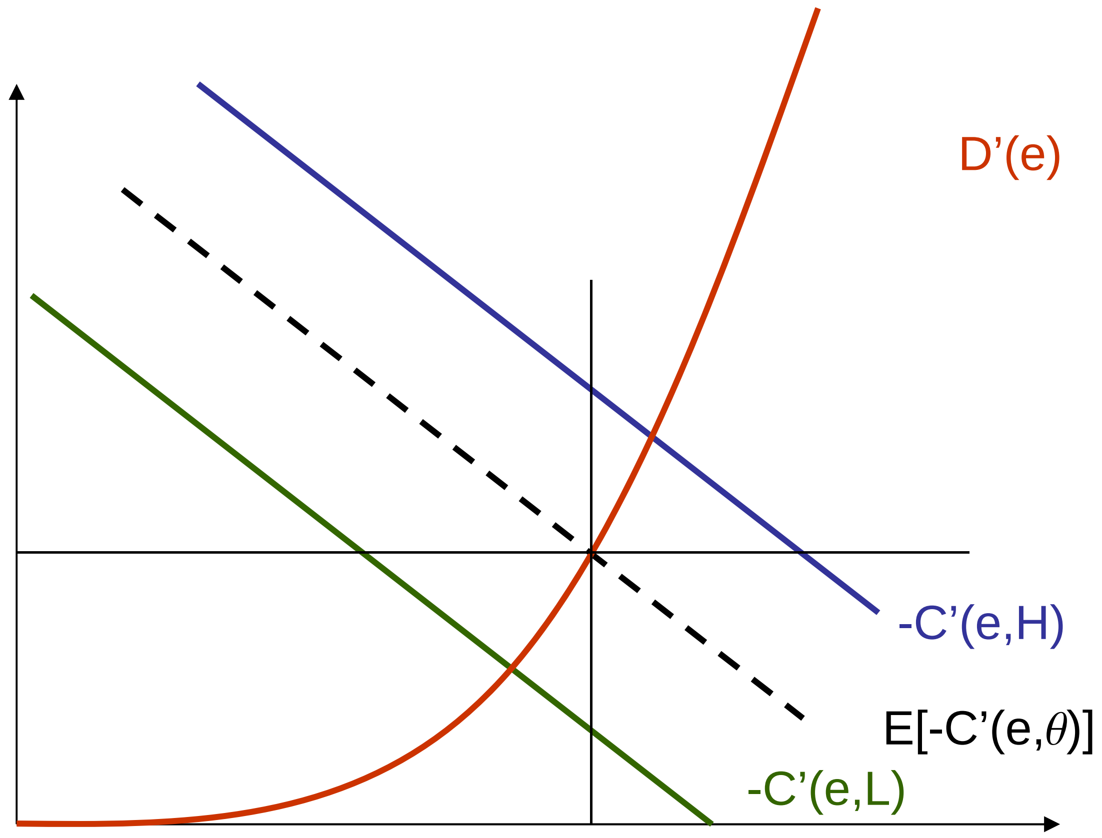

Welfare loss
D'(e)
τ
-C'(e,H)
E[-C'(e,θ)]
-C'(e,L)
e^τ_L
e^τ_H


Welfare loss under fee τ
Welfare loss under emission limit e*
D'(e)
τ
-C'(e,H)
E[-C'(e,θ)]
-C'(e,L)
e^τ_L
e*
e^τ_H

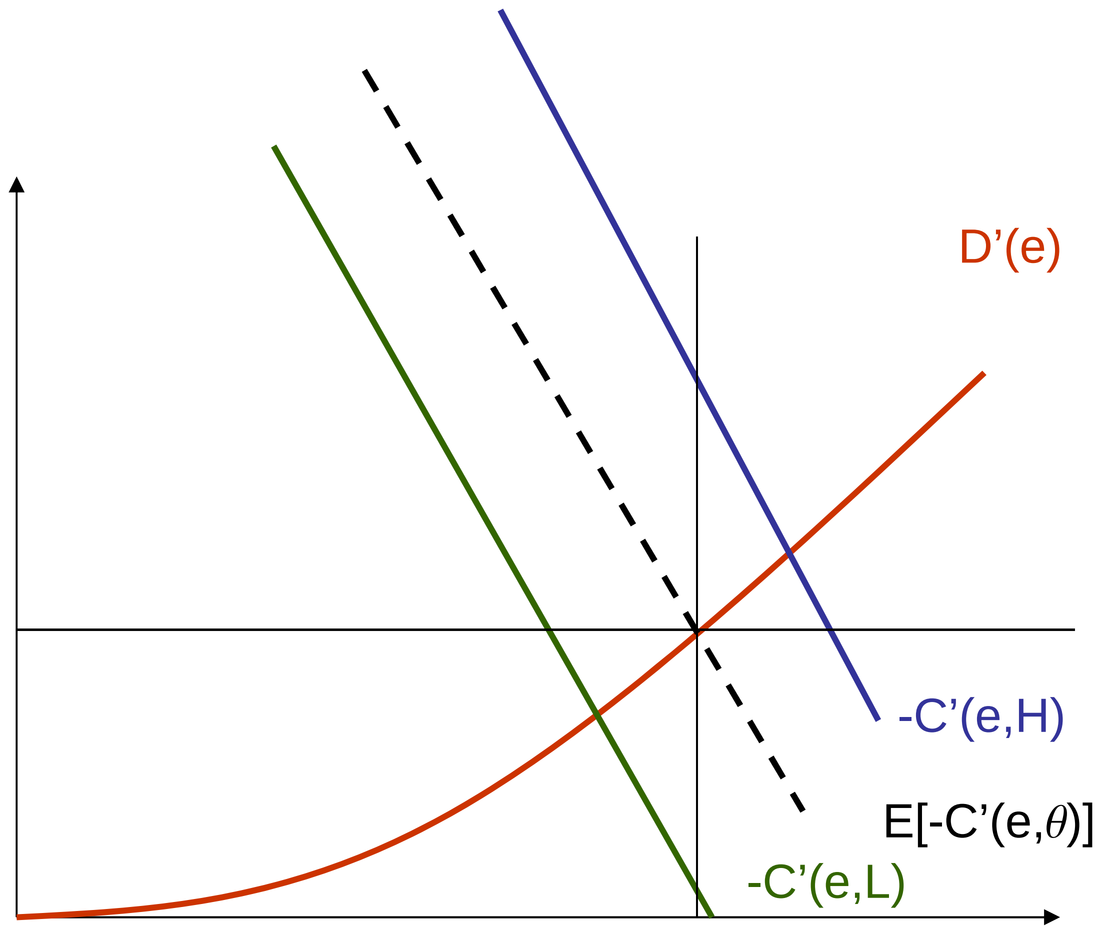
Price dominates quantities



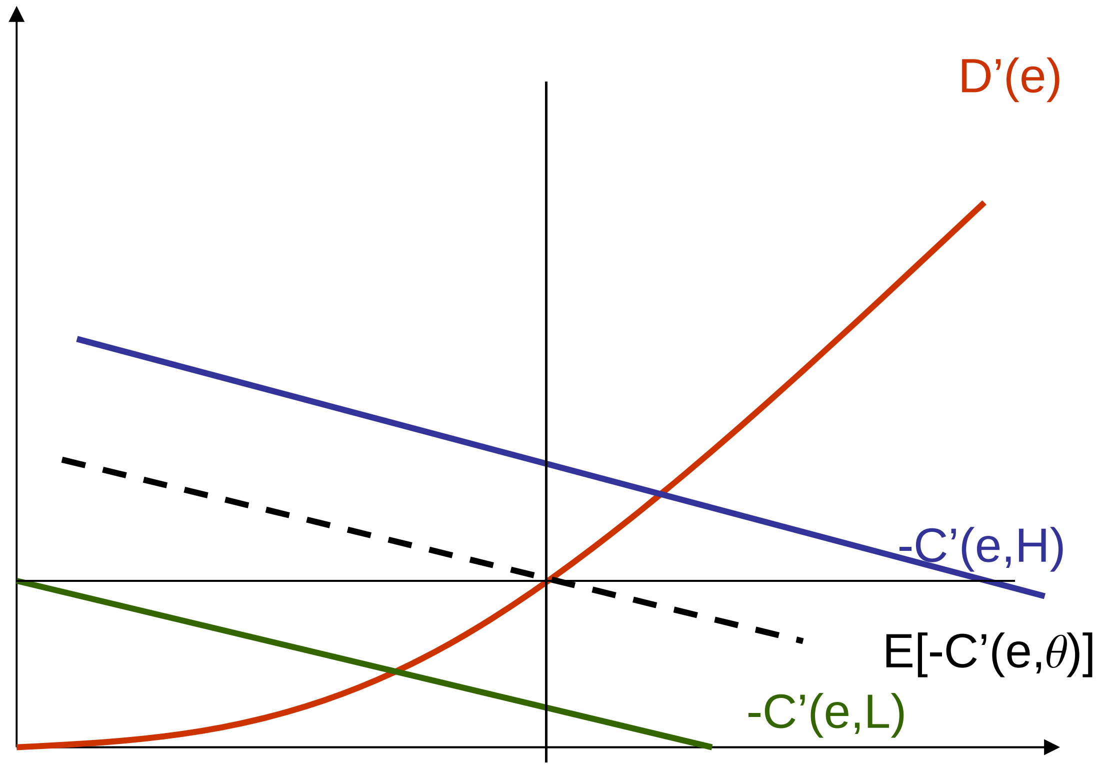
Quantities dominate price



Price dominates quantities



Quantities dominate prices



Proof

From Baumol and Oates (1988), page 71 with

- Abatement $a = e^e - e$
- Linear marginal abatement cost $c'(a) = K + c \times a + \theta$ with $K \geq 0$, $c > 0$ and θ distributed according to cumulative F, density f and $E[\theta] = 0$
- Linear marginal benefit from abatement $B'(a) = \alpha - \beta \times a$ with $\alpha > \beta > 0$

Extensions

- Hybrid policy: standard + tax + penalty ....
  Improvement because closer to the damage function
- Stock pollutant or resource (Weitzman, JEEM 2002)
- Multiple pollutants (Ambec and Coria, JEEM 2013)
  - Complementarity and substitutability among pollutants matters the same way than the slope of marginal costs
  - Sometime optimal to tax one pollutant and set a standard on the other even if they exhibit same costs and damages

Contract-based regulations

- Contract-based regulation: the polluting firm is free to accept or not the regulation
- Menu of regulations with subsidies and abatement levels
- Examples:
  - Purchase of land for biodiversity conservation and carbon sequestration (Mason and Plantinga JEEM 2013)
  - Agro-environmental schemes: subsidies to reduce pesticide and fertilizer uses, to turn to organic farming (Chabé-Ferret and Subervie, JEEM 2013)
  - Voluntary agreements to some extend (Lyon and Maxwell)

Example: Purchase of land for carbon sequestration

- Mason and Plantinga JEEM 2013
- x share of land in forest
- Benefit to the regulator but opportunity cost $C(x-\theta)$ for farmers
- θ share of costless forest = private information
- $C(x-\theta)$ increasing convex in x
- Which share of $x(\theta)$ to implement with subsidy $T(\theta)$?
- Subsidy contingent on "abatement"

Mechanism design approach to contract-based regulation

- Adverse selection problem (ex ante asymmetric information)
- Revelation Principle:
  Without loss of generality we can rely on direct revelation mechanisms
- Second-best emissions are (Bayesian Nash subgame perfect) equilibrium emissions of a "message" game in which the firm reveals its "type" L or H truthfully
- The contract regulation $\{(e_L, t_L), (e_H, t_H)\}$ maximizes total welfare under participation and incentive-compatibility constraints

Full information

- Recall $-C'(e, L) < -C'(e, H)$ for every $e \leq e^e$
- The regulator minimizes $D(e_\theta) + t_\theta$ subject to $t_\theta - C(e_\theta, \theta) \geq 0$ (Participation or Individual Rationality constraint)
- Solution e^*_θ and $t^*_\theta = C(e^*_\theta, \theta)$ for $\theta = L, H$
- First-best emissions with no rent to firm (cost reimbursed)
- If a low cost firm pretend to be a high cost then obtains $t^*_H - C(e^*_H, L) = C(e^*_H, H) - C(e^*_H, L) > 0$
- Low cost firms have incentive to "mimic" high cost firms

Regulator maximization program under adverse selection

$$
\begin{array}{lll}
\min_{\{e_\theta, t_\theta\}_{\theta=L,H}} & E[D(e_\theta) + t_\theta] \text{ subject to} & \\
& t_L - C(e_L, L) \geq 0 & IR_L \\
& t_H - C(e_H, H) \geq 0 & IR_H \\
& t_L - C(e_L, L) \geq t_H - C(e_H, L) & IC_L \\
& t_H - C(e_H, H) \geq t_L - C(e_L, H) & IC_H
\end{array}
$$

IR=Individual-Rationality (or Participation) constraints
IC=Incentive-Compatibility constraints

Solving the program 1/2

IR_H and IC_L are binding constraints therefore

$$t_H^{sb} = C(e_H, H)$$

and

$$t_L^{sb} = C(e_L, L) + C(e_H, H) - C(e_H, L)$$

Define $\Delta(e) \equiv C(e, H) - C(e, L) > 0$ for $0 < e < e_\theta^e$

Solving the program 2/2

The regulator's objective becomes

$$\min_{\{e_\theta\}_{\theta=L,H}} \nu(D(e_L)+C(e_L,L)+\Delta(e_H))+(1-\nu)(D(e_H)+C(e_H,H))$$

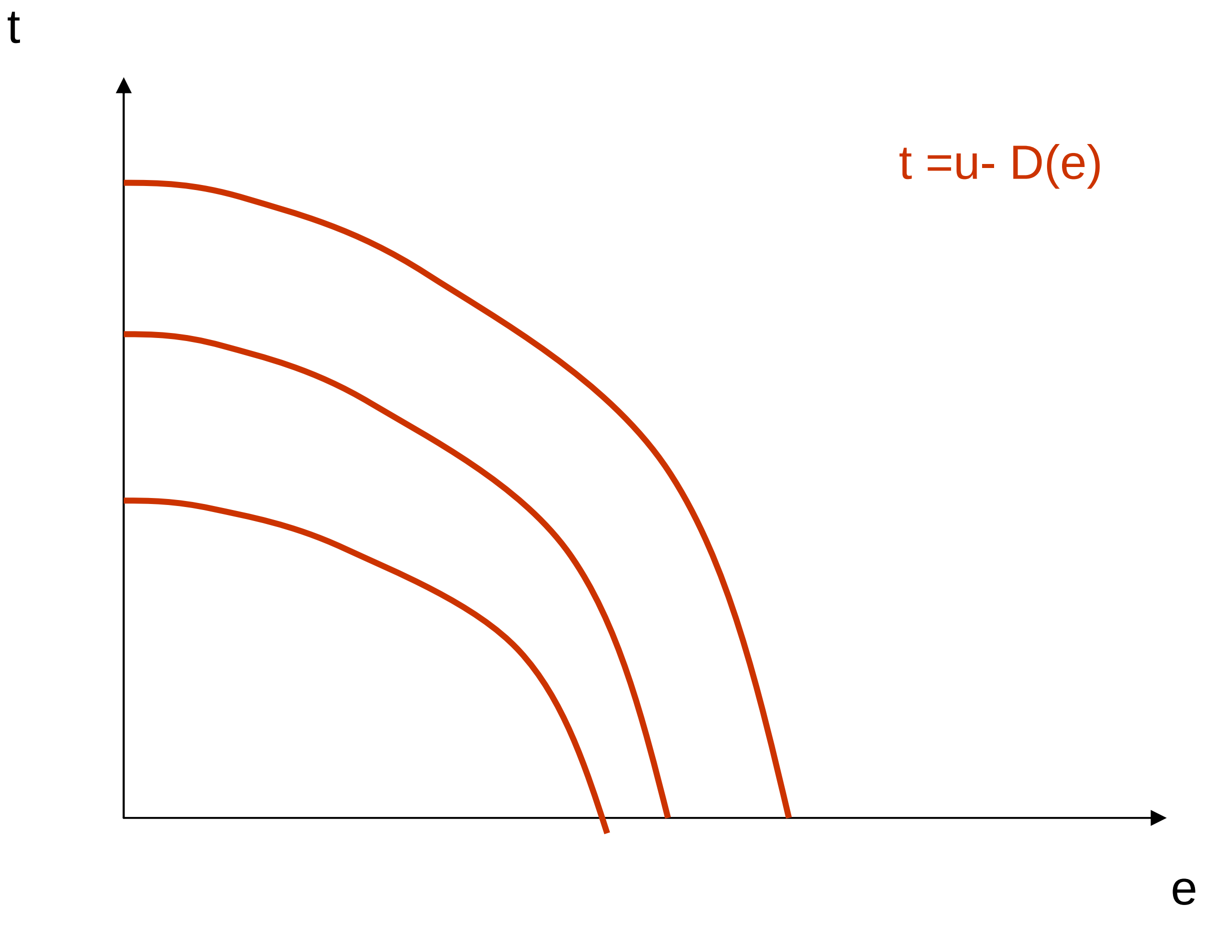
First-order conditions:

$$D'(e_L^{sb})+C'(e_L^{sb},L)=0$$

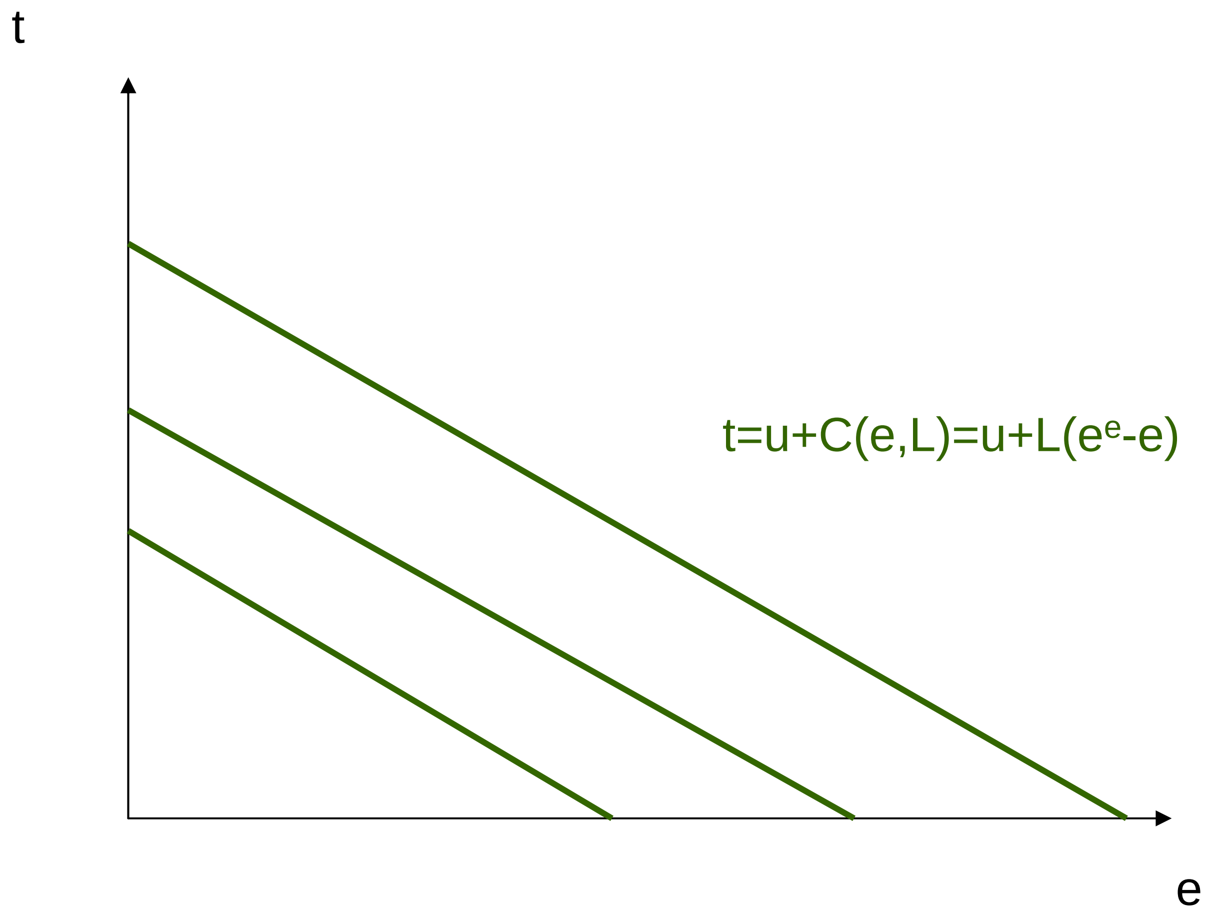
$$D'(e_H^{sb})+C'(e_H^{sb},H)=-\frac{\nu}{1-\nu}\Delta'(e_H^{sb})$$

$e_L^{sb}=e_L^*$ and $e_H^{sb}>e_H^*$
$t_L^{sb}=C(e_L^{sb},L)+\Delta(e_H^{sb})$ and $t_H^{sb}=C(e_H^{sb},H)$
No rent for high cost firms and informational rent for low cost firms

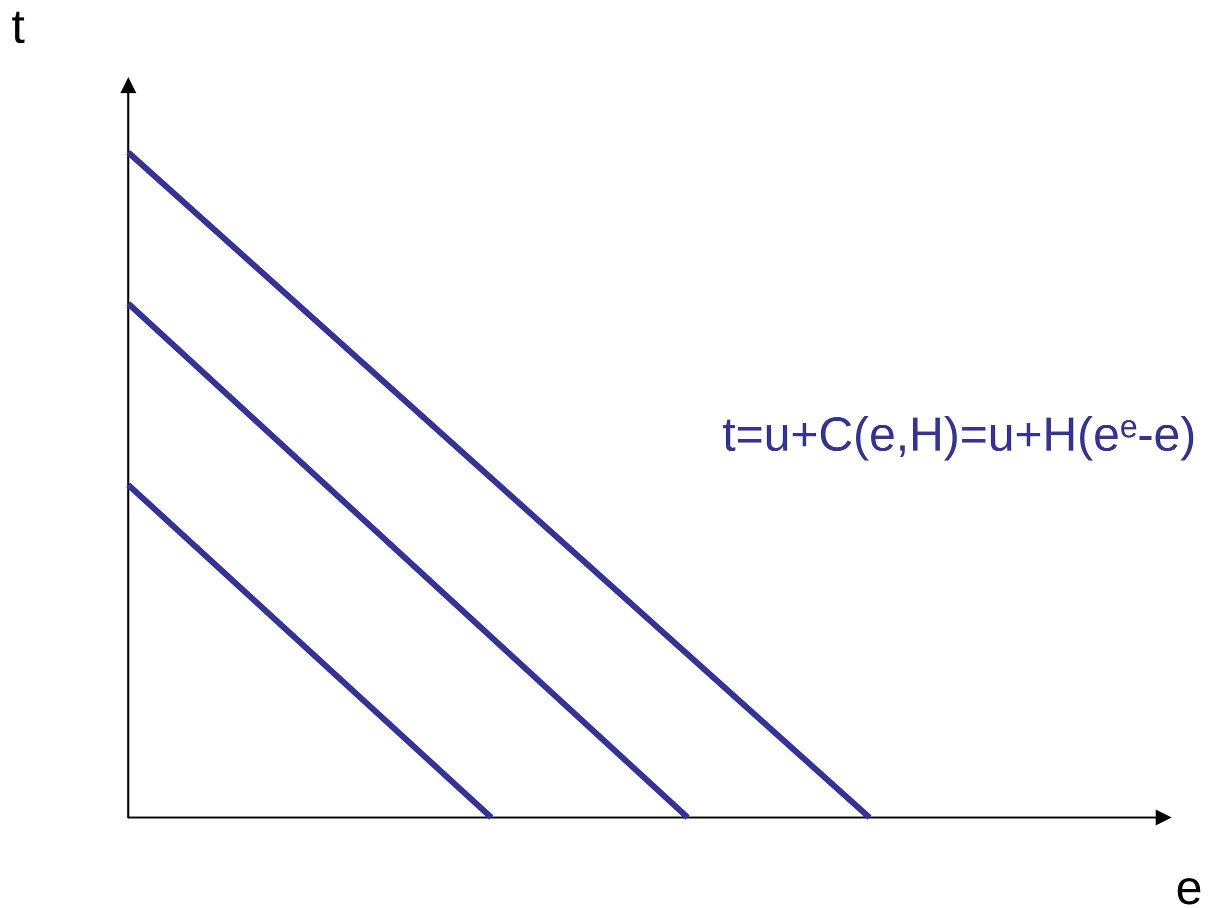
Indifference curves for regulator



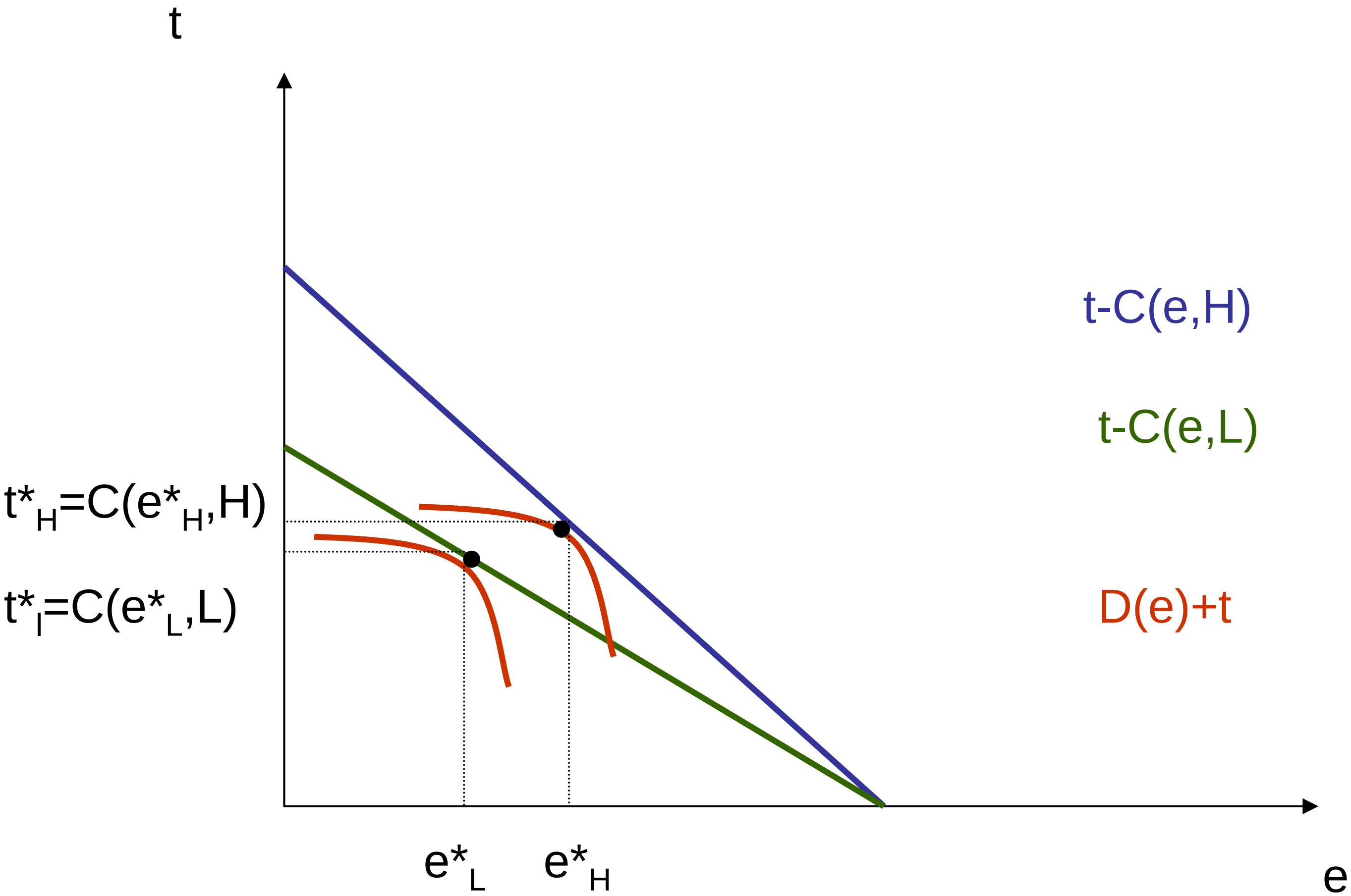
Indifference curve for low cost firm L



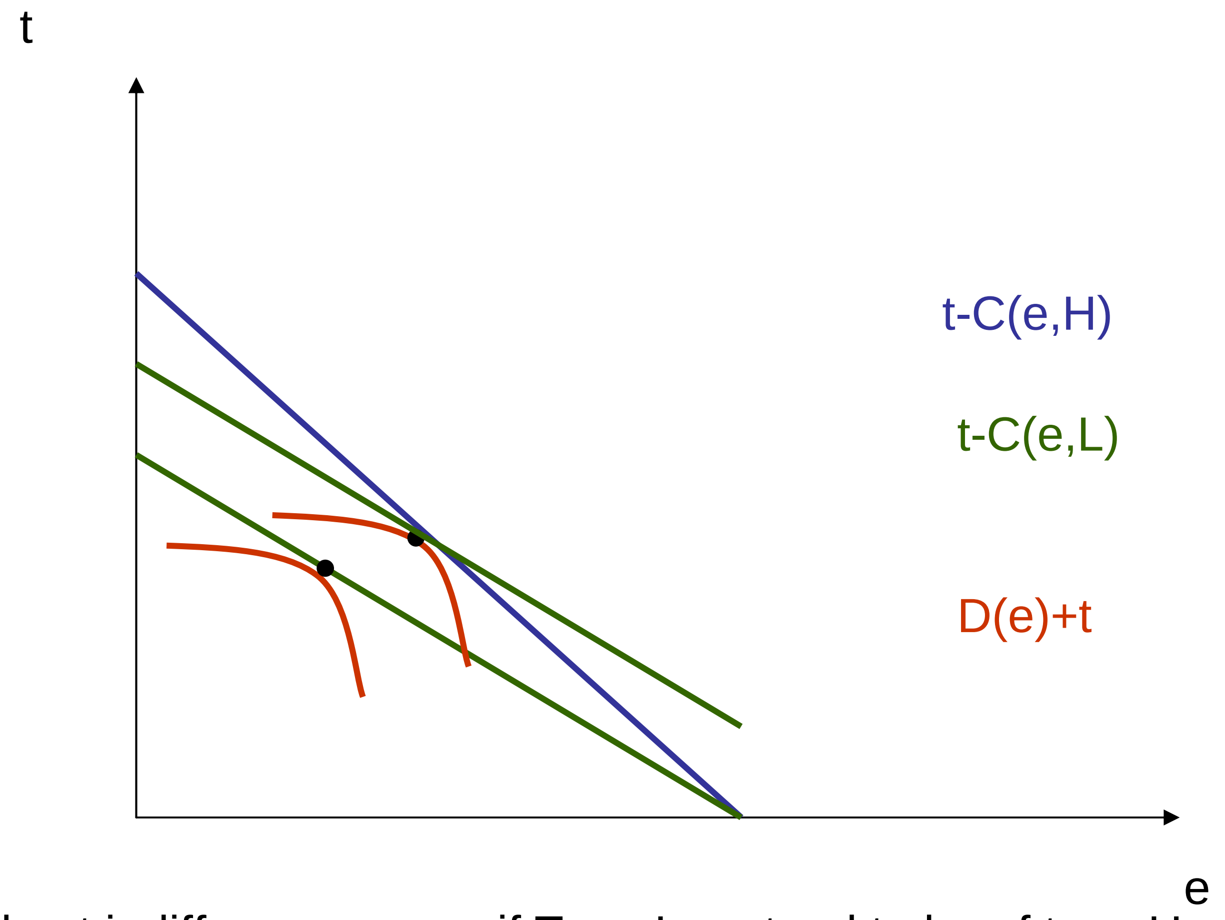
Indifference curve for high cost firm H



First-Best

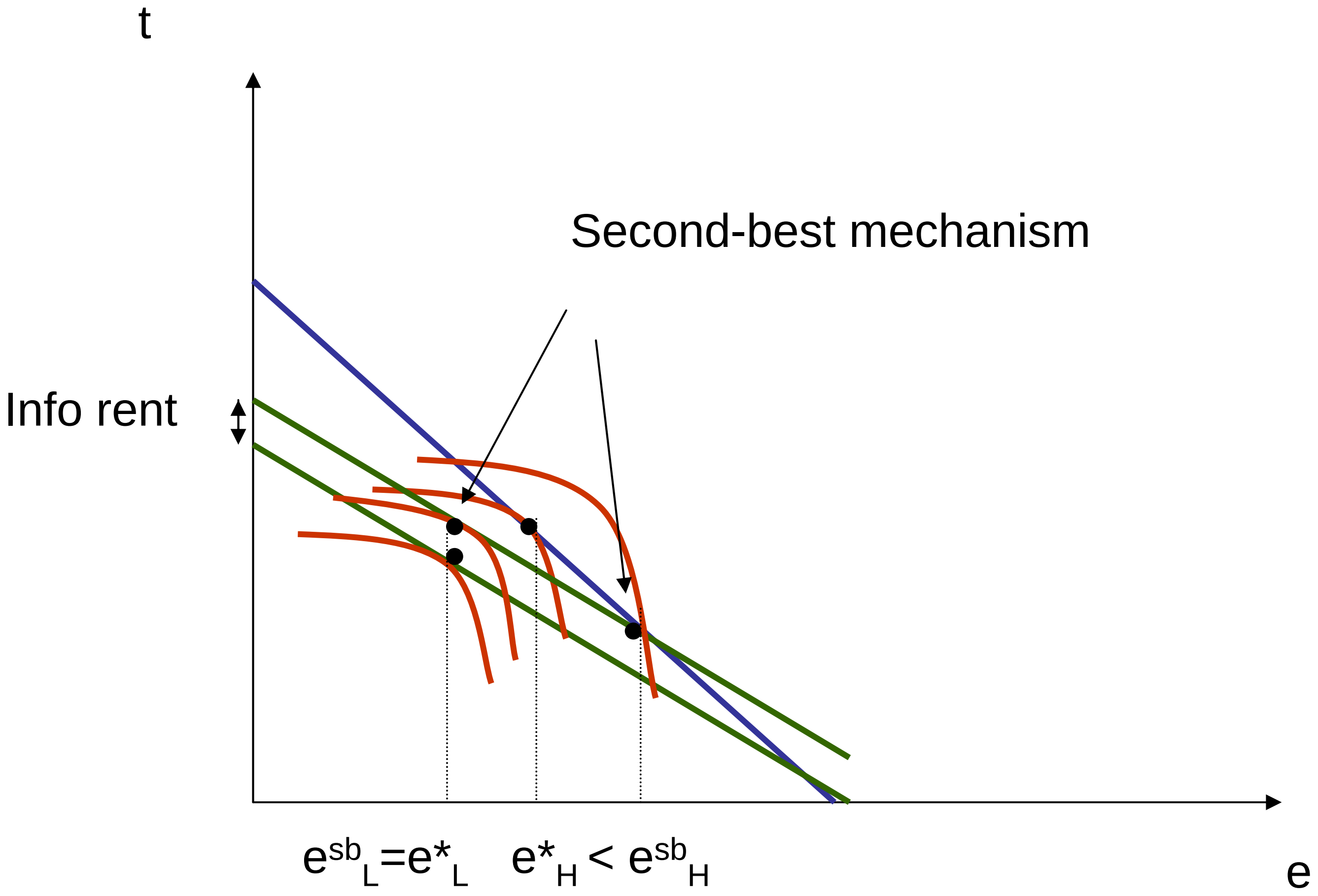


First-Best



Highest indifference curve if Type L pretend to be of type H

Second-Best



Implementing the second-best with a regulation

- Command-and-control with emissions e_θ^{sb} contingent on subsidies t_θ^{sb} for $\theta = L, H$
- Emission standard e_H^{sb} and subsidy $\Delta(e_H^{sb})$ for emitting $e_L^{sb} < e_H^{sb}$
- In general with more than two types, there exists a non-linear scheme that implements the second-best (but not the first-best)

Example: Purchase of land for carbon sequestration (Mason and Plantinga 2013)

- Which share of the forest preserved $x(\theta)$ to implement with subsidy $T(\theta)$?
- Informational rent depending on θ
- Comparison with an uniform subsidy
- Estimation: for a benefit of $ 100 per acre, increase forest area in US by 61 million acres at annual cost of $4.36 billion with this scheme compared to $9.64 billion with uniform subsidy

Concluding summary

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- A couple of problems for you!