# MGT 621 – MICROECONOMICS

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## *7. Externalities & Regulation*

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# AGENDA

**What are externalities?**

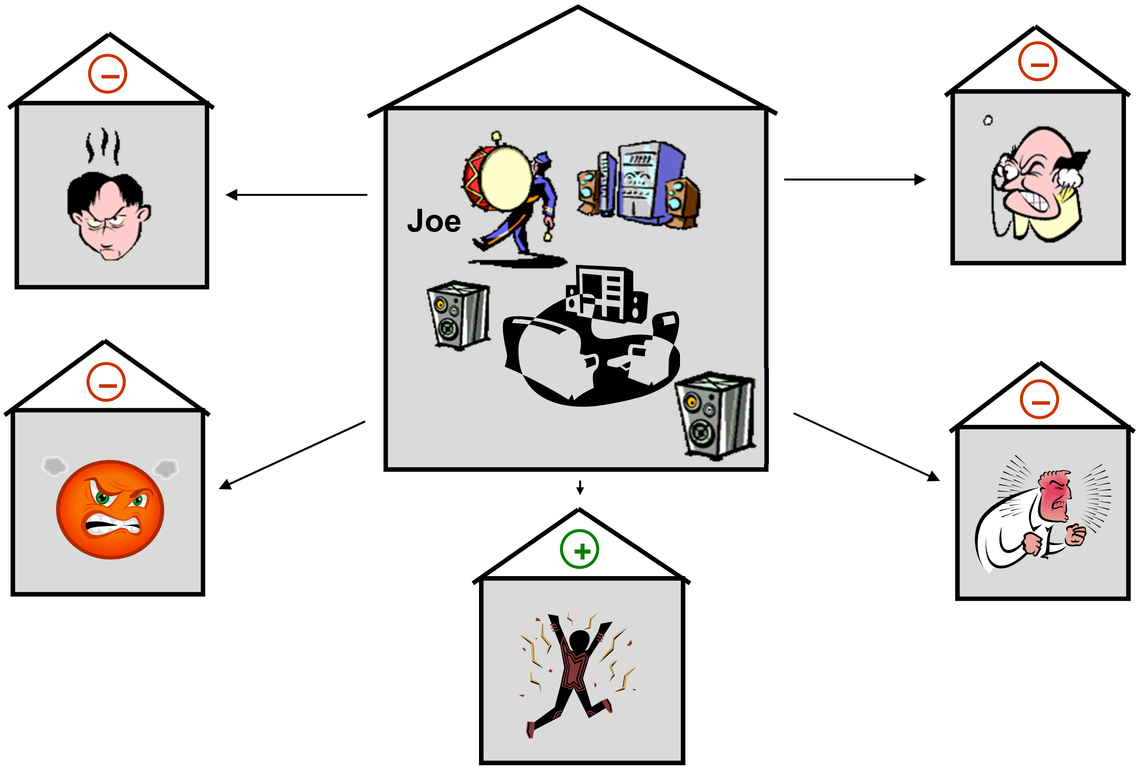
**Example: Production Externalities**

**Some Regulatory Options**

**Uncertainty Matters: Prices vs. Quantities**

**Key Concepts to Remember**

# WHAT ARE EXTERNALITIES?
## Example






# WHAT ARE EXTERNALITIES? (Cont'd)

**Definition. An externality exists whenever the well-being (utility) of a consumer or the production possibility set of a firm are *directly* affected by the action of another agent in the economy.**

**Externalities can be "positive" or "negative."**

# WHAT ARE EXTERNALITIES? (Cont'd)
## Some Examples

- **Drivers' cars release pollutants that deteriorate the air quality**
- **Cigarette smoke increases the probability of lung cancer for smokers and others**
- **Chemical plant releases wastes in river; fishing industry becomes less productive**
- **Fish caught by one fishing boat cannot be caught be another fishing boat**
- **High-tech patents lead to public disclosure of inventions that can be used by other firms (be they complementors or competitors)**



# AGENDA

**What are externalities?**

**Example: Production Externalities**

**Some Regulatory Options**

**Uncertainty Matters: Prices vs. Quantities**

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# EXAMPLE: PRODUCTION EXTERNALITIES

**One firm's decisions may have a direct impact on another firm's payoff.**

- **Our discussion of game theory shows (see, e.g., the Prisoners' Dilemma) that, in general, if each firm individually maximizes its profits, then the sum of both firms' profits may not be maximal.**

**Consider the following situation for two firms, 1 and 2:**

- **Firm 1's production produces wastewater, resulting in an externality for a downstream fishing company**
- **Firm 2, impacted by firm 1's waste production could reduce harmful effects, say by treatment of water, but at a cost**

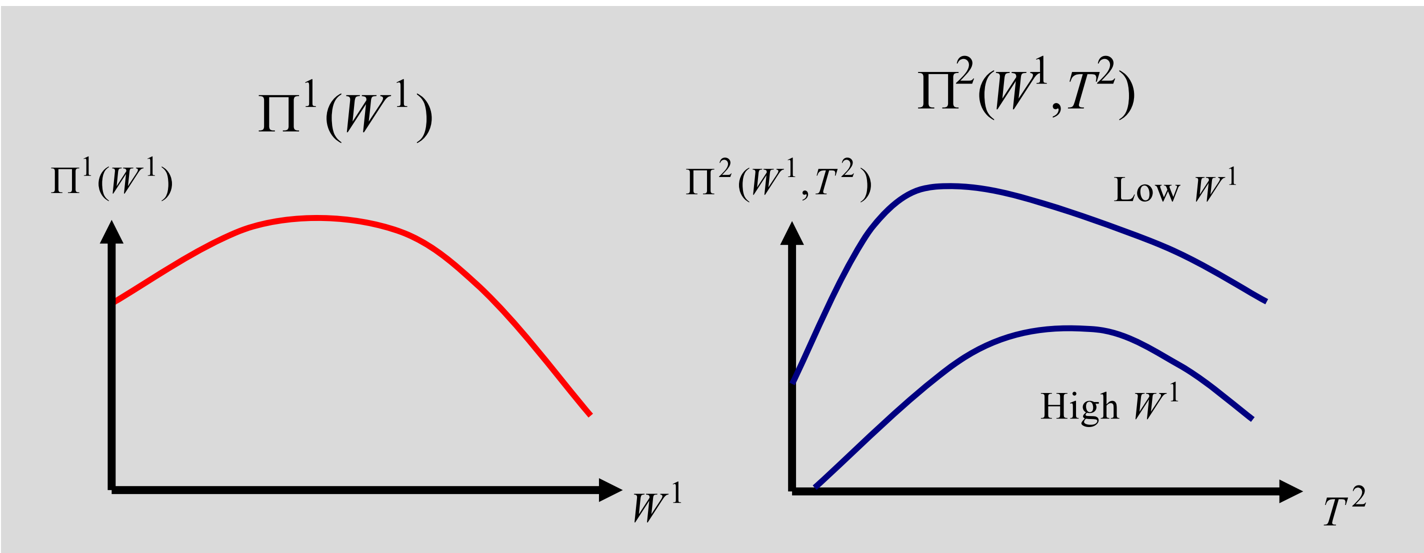


# PRODUCTION EXTERNALITIES (Cont'd)

**Firm 1 produces a nonnegative amount of waste, $W^1$**

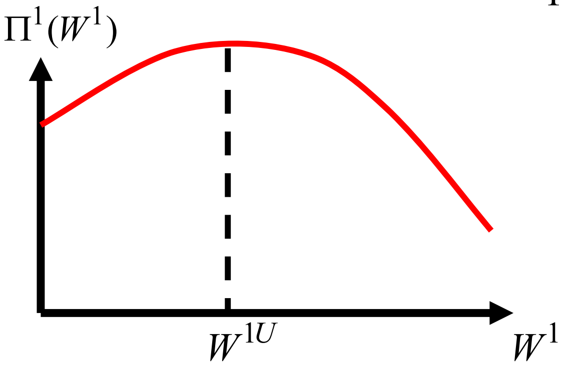
**Firm 2, negatively impacted by firm 1's waste production, could reduce the harmful effects through treatment $T^2$, which comes at a cost.**

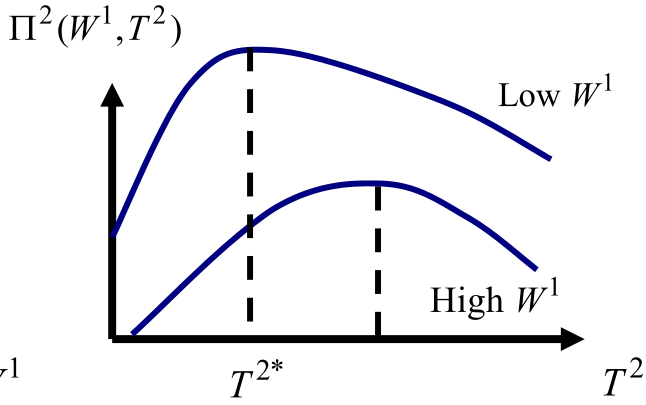
**Payoff Functions:**



# PRODUCTION EXTERNALITIES (Cont'd)

$$\frac{d\Pi^1(W^1)}{dW^1} = 0 \qquad\qquad \frac{\partial \Pi^2(W^1, T^2)}{\partial T^2} = 0$$




**Optimal treatment $T^{2*}$**
**Depends on $W^1$**



# PRODUCTION EXTERNALITIES (Cont'd)

**Efficient outcome maximizes total profits,**

$$\max_{W^1, T^2 \geq 0} \left\{ \Pi^1(W^1) + \Pi^2(W^1, T^2) \right\}$$

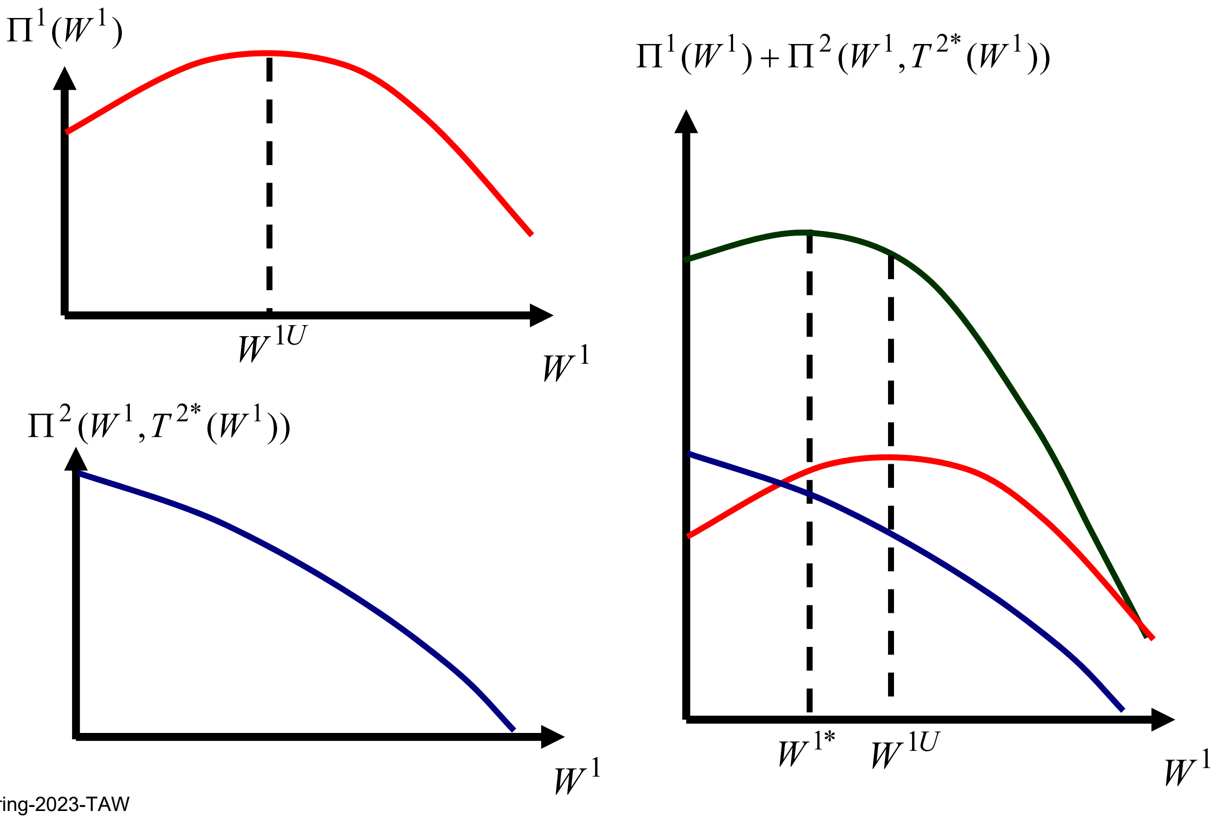
**Firm 1: optimality condition for socially optimal $W^1$ differs from the individual optimality condition,**

$$\frac{d\Pi^1(W^1)}{dW^1} + \frac{\partial \Pi^2(W^1, T^2)}{\partial W^1} = 0$$

**Firm 2: optimality condition for socially optimal $T^2$ is same as individually optimal, for any given $W^1$**

$$\frac{\partial \Pi^2(W^1, T^2)}{\partial T^2} = 0$$

# PRODUCTION EXTERNALITIES (Cont'd)






# PRODUCTION EXTERNALITIES (Cont'd)

## Define Externalities in Terms of Harm

**Define harm to firm 2 as a function of $W^1$ (corresponds to the externality that firm 1 exerts on firm 2)**

$$h(W^1) = \Pi^2(0, T^{2*}(0)) - \Pi^2(W^1, T^{2*}(W^1))$$

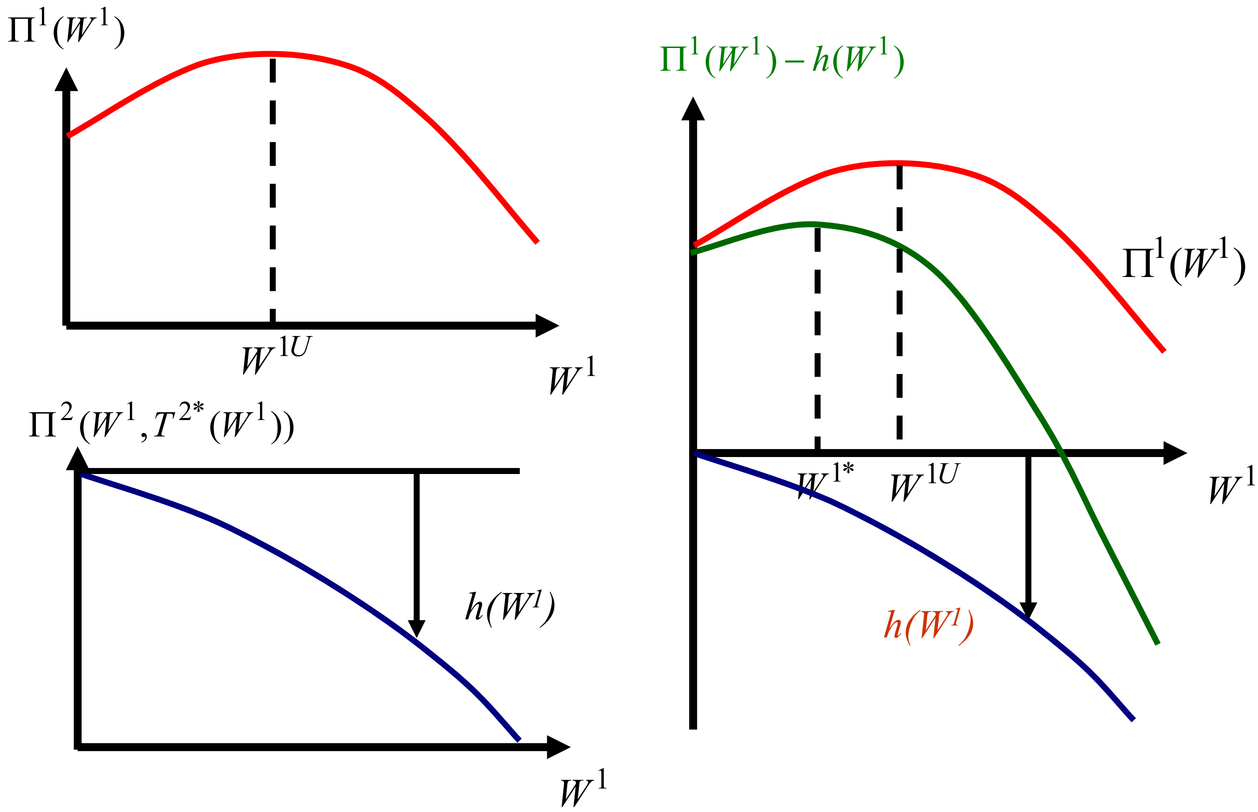
**Choose $W^1$ to maximize profit of firm 1, minus harm:**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - h(W^1) \right\}$$

**Choose $T^2$ to maximize profit of firm 2:**

$$\max_{T^2 \geq 0} \Pi^2(W^{1*}, T^2)$$

# PRODUCTION EXTERNALITIES (Cont'd)






# PRODUCTION EXTERNALITIES (Cont'd)

**Gives FOC for $T^2$ identical to optimal**

$$\frac{\partial \Pi^2(W^1, T^2)}{\partial T^2} = 0$$

**Gives FOC for $W^1$ identical to optimal**

$$\frac{d\Pi^1(W^1)}{dW^1} - \frac{\partial h(W^1)}{\partial W^1} = 0$$

$$\frac{d\Pi^1(W^1)}{dW^1} - \left\{ -\frac{\partial \Pi^2(W^1, T^{2*})}{\partial W^1} \right\} - \underbrace{\left\{ -\frac{\partial \Pi^2(W^1, T^{2*})}{\partial T^{2*}} \right\} \left\{ \frac{\partial T^{2*}}{\partial W^1} \right\}}_{0} = 0$$

$$\frac{d\Pi^1(W^1)}{dW^1} + \frac{\partial \Pi^2(W^1, T^{2*})}{\partial W^1} = 0$$

# AGENDA

**What are externalities?**

**Example: Production Externalities**

**Some Regulatory Options**

**Uncertainty Matters: Prices vs. Quantities**

**Key Concepts to Remember**



# REMEDIES FOR MARKET FAILURE

**Idea: How can we correct market to move back toward competitive norm?**

- **"Polluter Pays" Principle**
- **Litigation to recover harms: "damages"**
- **Tax per unit on externality: "pollution tax"**
- **Marketable emissions rights**
  - **Create market for rights to produce the externality**
- **Regulation of emissions or other waste**
  - **Restriction against hazardous waste**
  - **Limits on emissions rate**
- **Assign property rights and allow negotiation (Coase Theorem)**

# “POLLUTER PAYS” PRINCIPLE

**Polluter may be required to pay a fee to the government, offsetting the entire damage. In that case, the polluter (firm 1) solves the problem**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - h(W^1) \right\}$$

**If firm 1 maximizes its profit minus harm, it will choose optimal waste ($W^1$). No money paid to harmed firm (firm 2), who solves the following problem:**

$$\max_{T^2 \geq 0} \Pi^2(W^{1*}, T^2)$$

**If firm 2 is not compensated for damages, it will choose optimal treatment.**



# LITIGATION RECOVERS DAMAGES

**Polluter may be required to pay fee to harmed firm equal to the damage. Then the polluter solves problem:**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - h(W^1) \right\}$$

**If firm 1 maximizes its profit minus harm, it will choose optimal waste ($W^1$) for whatever is the level of $T^2$.**

**Firm 1 has an incentive to select a socially efficient waste level.**

# LITIGATION RECOVERS DAMAGES

**Damages paid to harmed firm, with damages determined for <u>optimal level of $T^2$</u>. Then firm 2 chooses $T^2$ to solve problem:**

$$\max_{T^2 \geq 0} \left\{ \Pi^2(W^1, T^2) + h(W^1) \right\}$$

**Monetary damages – harm – do not depend on actual choice of $T^2$, so $h(W^1)$ is a constant, from perspective of firm 2.**

**If firm 2 is compensated a <u>fixed amount</u> for damages, it will maximize its before-harm-payment profit and will choose optimal treatment.**

$$h(W^1) = \Pi^2(0, T^{2*}(0)) - \Pi^2(W^1, T^{2*}(W^1))$$



# LITIGATION RECOVERS DAMAGES (Cont'd)

**Damages paid to harmed firm, with damages determined for <u>actual level of $T^2$</u>. Then firm 2 solves the problem:**

$$\max_{T^2 \geq 0} \left\{ \Pi^2(W^1, T^2) + h(W^1) \right\}$$

**Monetary damages – harm – do depend on actual choice of $T^2$, so $h(W^1)$ is not a constant, from perspective of firm 2, in this case.**

$$h(W^1) = \Pi^2(0, T^2(0)) - \Pi^2(W^1, T^2)$$

$$\max \underbrace{\left\{ \Pi^2(W^1, T^2) - \Pi^2(W^1, T^2) \right\}}_{0} + \Pi^2(0, T^2(0))$$

**Profit after damage payment is independent of $T^2$; firm 2 has no incentive to choose optimal treatment.**

# POLLUTION TAX

**The polluter may be required to pay a fee to government equal to a fixed amount t <u>per unit</u> of pollution. Per-unit amount is set equal to the marginal harm. Then polluter solves problem:**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - t\,W^1 \right\}$$

**Firm 1, maximizing its own after-tax profit, leads to efficient level of waste (**$W^1 = W^{1*}$**) :**

$$t = \left. \frac{\partial h(W^1)}{\partial W^1} \right|_{W^1 = W^{1*}}$$

$$\frac{d\Pi^1(W^1)}{dW^1} = \frac{\partial h(W^{1*})}{\partial W^1}$$



# MARKETABLE EMISSIONS RIGHTS

**Government determines optimal total waste, and issues emissions rights. The number of rights equal to optimal waste. Rights can be bought and sold. Market clearing price will equal marginal cost of waste reduction. Thus, if the optimal total waste is produced, then the price will be equal to marginal harm,**

$$p_{pr} = \frac{\partial h(W^1)}{\partial W^1}$$

**Firm 1's optimization problem:**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - p_{pr}\ W^1 \right\}$$

**Profit maximization condition leads Firm 1, maximizing its own after-tax profit, to an efficient level of waste:**

$$\frac{d\Pi^1(W^1)}{dW^1} = p_{pr} = \frac{\partial h(W^1)}{\partial W^1}$$

# DIRECT REGULATIONS OF EMISSIONS

**Government sets maximum allowable waste regulation, after determining the solution of the problem:**

$$\max_{W^1 \geq 0} \left\{ \Pi^1(W^1) - h(W^1) \right\}$$

**Firm required to meet regulation or else face a penalty higher than the cost of meeting the regulation. Incentive to just meet the regulation.**



# PROPERTY RIGHTS AND RENEGOTIATION

**Generally applicable only with a very small number of firms**

**General approach**

- **Assign property rights to either party**
  - **Right to pollute or Right to no pollution**
- **Allow negotiation**
- **Efficient outcome either way**
- **Distribution of profits differs**

**Coase Theorem**

# PROPERTY RIGHTS AND RENEGOTIATION

**Give property rights to either (→ Case 1 and 2)**

**Case 1. Assume give right to polluter for some high pollution level. Then impacted firm will pay to firm 1 some amount of money, B, to reduce pollution.**

$$\Pi^1(W^{1*}) + \Pi^2(W^{1*}, T^{2*}) > \Pi^1(W^{1U}) + \Pi^2(W^{1U}, T^{2U})$$

$$\Pi^2(W^{1*}, T^{2*}) - \Pi^2(W^{1U}, T^{2U}) > \Pi^1(W^{1U}) - \Pi^1(W^{1*}) > 0$$

**Then B can be chosen such that**

$$\Pi^2(W^{1*}, T^{2*}) - \Pi^2(W^{1U}, T^{2U}) > B > \Pi^1(W^{1U}) - \Pi^1(W^{1*}) > 0$$

**whence**

$$\Pi^2(W^{1*}, T^{2*}) - \Pi^2(W^{1U}, T^{2U}) - B > 0$$ **Firm 2 increases profit**

$$\Pi^1(W^{1*}) - \Pi^1(W^{1U}) + B > 0$$ **Firm 1 increases profit**



# PROPERTY RIGHTS AND RENEGOTIATION

**Case 2. Assume give to affected firm right to face no pollution. Then polluting firm will pay firm 2 some amount of money, F, to allow pollution. (Assume no abatement, i.e., $T^2 = 0$, when there is no pollution)**

$$\Pi^1(W^{1*}) + \Pi^2(W^{1*}, T^{2*}) > \Pi^1(0) + \Pi^2(0,0)$$

$$0 > \Pi^2(W^{1*}, T^{2*}) - \Pi^2(0,0) > \Pi^1(0) - \Pi^1(W^{1*})$$

**Then F can be chosen such that**

$$0 > \Pi^2(W^{1*}, T^{2*}) - \Pi^2(0,0) > -F > \Pi^1(0) - \Pi^1(W^{1*})$$

**whence**

$$\Pi^2(W^{1*}, T^{2*}) - \Pi^2(0,0) + F > 0$$ **Firm 2 increases profit**

$$\Pi^1(W^{1*}) - \Pi^1(0) - F > 0$$ **Firm 1 increases profit**

# COASE THEOREM

Coase Theorem. If all parties can negotiate with each other costlessly and with perfect information, then bargaining will lead to an efficient outcome.

The outcome will be efficient, no matter how the initial property rights are determined.

**A Caveat**

If property rights are not firmly established, so that agents spend resources trying to reallocate property rights, then the final outcome, including the costs of reallocating property rights, will not be efficient.



# AGENDA

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# PRACTICAL PROBLEM: REDUCING GLOBAL CARBON OUTPUT

**To bound global warming to less than 2 degrees Celsius by 2050, worldwide carbon emissions need to be reduced by 50% in that timeframe (IPCC 2008).**

**Hence, need to provide incentives for …**

- **carbon abatement by implementing an efficient carbon pricing policy**
- **technological innovation by encouraging the necessary investments**

**Question: Design a simple (i.e., implementable) regulatory scheme which *jointly* accounts for innovation and abatement.**

Remark: For details on the material in the following slides, see Weber, T.A., Neuhoff, K. (2010) "Carbon Markets and Technological Innovation," *Journal of Environmental Economics and Management*, Vol. 60, No. 2, pp. 115—132; an earlier version is also available at http://ssrn.com/abstract=1333244



# THE MODEL
## Primitives

- **Unit mass of firms, indexed by $\theta \in \Theta$ , distributed on type space $\Theta$ such that**

$$\mu = \int_{\Theta} \theta dF(\theta) < \infty \quad \textbf{and} \quad \sigma_{\theta}^2 = \int_{\Theta} (\theta - \mu)^2 dF(\theta) < \infty$$

- **Each firm $\theta$ has business-as-usual (BAU) level of emissions $e_0(\theta) > 0$**
- **BAU emissions levels of all firms are subject to a common macroeconomic shocks, modeled by the additive zero-mean noise $\tilde{\varepsilon}$ such that**

$$\sigma_{\varepsilon}^2 = \int_{\Theta} \varepsilon^2 dG(\varepsilon) < \infty$$

- **Expected total emissions:**

$$e_0 = E[\int_{\Theta} (e_0(\theta) + \tilde{\varepsilon}) dF(\theta)] < \infty$$

# THE MODEL (Cont'd)
## Timing

**The actions take place in three periods, indexed by** $t \in \{0,1,2\}$

- **Regulation Stage (t=0)**
  - **Regulator commits to a regulatory policy in the form of a cap-and-trade scheme with price controls, denoted by** $R = (E, L, U)$

    $E$ **: Emissions cap (e.g., set by number of issued emissions permits)**

    $L$ **: Price floor in market for emissions permits**

    $U$ **: Price cap in market for emissions permits**

- **Innovation Stage (t=1)**
  - **Each firm** $\theta$ **decides about its innovation activity** $y \geq 0$ **at the cost of** $K(y) = cy^2/2$ **where** $c \geq 0$ **determines the slope of the marginal cost**
  - **An innovation activity of** $y$ **results in the realization** $\rho$ **of a random cost improvement** $\tilde{\rho}(y) > 0$**, where** $y = E[\max\{\tilde{\rho}(y),1\} \mid y] - 1$

    $\rho \leq 1$ **: Innovation unsuccessful – current practice is (weakly) better**

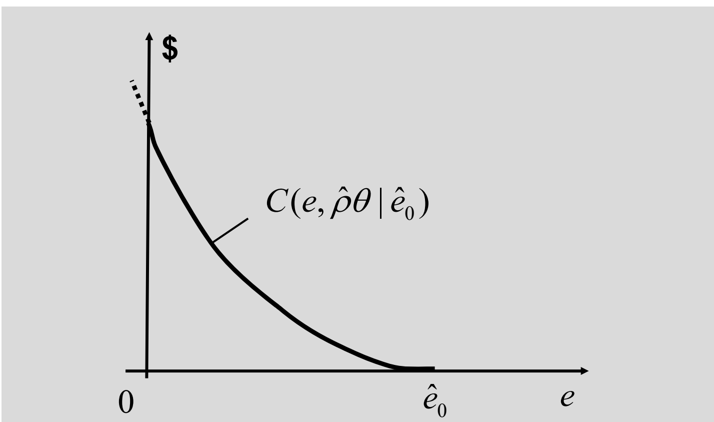
    $\rho > 1$ **: Innovation successful – firm exercises option of using it**



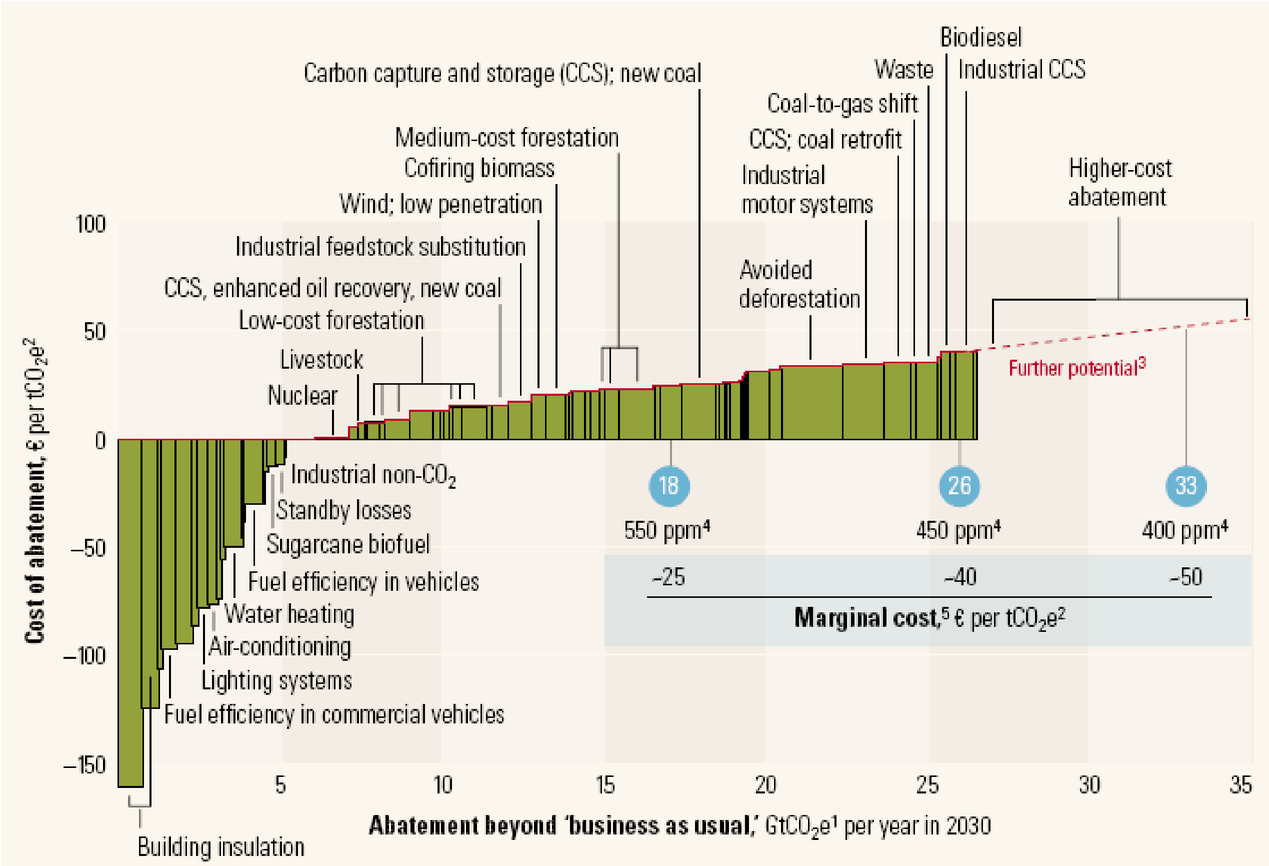
# THE MODEL (Cont'd)
## Timing

- **Implementation Stage (t=2)**
  - **The macroeconomic uncertainty** $\varepsilon$ **realizes**
  - **Each firm** $\theta$**, based on the outcome** $\hat{\rho} = \max\{\rho,1\}$ **of its innovation activity in the last stage and the current price** $p$ **for carbon emissions, decides about its emission level** $e(p,\hat{\theta}) = e(p,\hat{\rho}\theta) \geq 0$
  - **Firm** $\theta$**'s total cost of abating its emissions to a level** $e \leq \hat{e}_0 = e_0(\theta) + \varepsilon$ **is**

$$TC(e, p, \hat{\rho}\theta \mid \hat{e}_0) = C(e, \hat{\rho}\theta \mid \hat{e}_0) + pe = \frac{(\hat{e}_0 - e)^2}{2\hat{\rho}\theta} + pe$$



# MARGINAL ABATEMENT COST ALMOST LINEAR

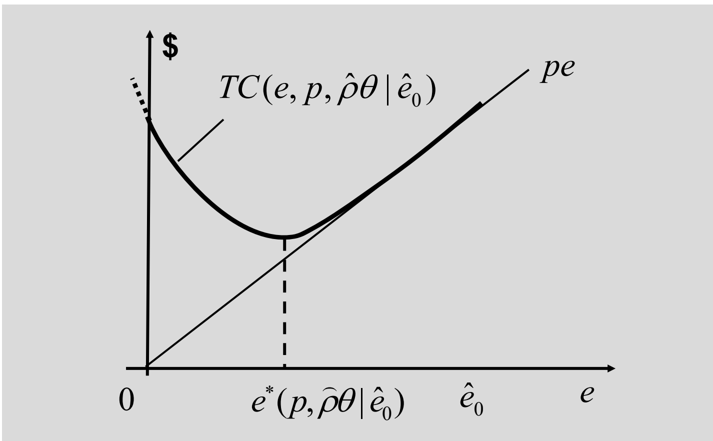



Source: Enkvist et al. (2007)



# MODEL SOLUTION
## Implementation (t = 2)

**Each firm $\theta$ chooses emissions so as to minimize its total emissions cost.**




$$e^*(p, \hat{\rho}\theta \mid \hat{e}_0) = \hat{e}_0 - \hat{\rho}\theta p$$

$$TC^*(p, \hat{\rho}\theta \mid \hat{e}_0) = \hat{e}_0 p - \frac{\hat{\rho}\theta p^2}{2}$$

# MODEL SOLUTION (Cont'd)
## Innovation (t = 1)

**Each firm $\theta$ chooses a level of innovation $y$ to maximize its expected net payoff,**

$$\pi(p,y,\theta)=\frac{\theta y p^2}{2}-K(y)=\frac{\theta y p^2}{2}-\frac{cy^2}{2}$$

**resulting in the optimal innovation of**

$$y^*(p,\theta)=\frac{\theta p^2}{2c}$$

**and the positive expected payoff**

$$\pi^*(p,\theta)=\frac{\theta^2 p^4}{8c}$$



# MODEL SOLUTION (Cont'd)
## Regulation (t = 0)

**The set of feasible cap-and-trade schemes is**

$$\Re=\{(E,L,U)\in\mathbf{R}_+^3 : L\le U\}$$

**The total carbon emissions output in the economy conditional on the market price for carbon and the macroeconomic condition is**

$$Q(p,\varepsilon)=\int_\Theta e^*(p,(1+y^*(p,\theta))\theta\,|\,e_0(\theta)+\varepsilon)dF(\theta)=e_0+\varepsilon-\mu p(1+\underbrace{\frac{\mu^2+\sigma_\theta^2}{2\mu c}}_{\beta}p^2)$$

**describes innovation (for $\beta=0$: no innovation)**

**Environmental damages (measured in \$) are assumed to be quadratic in total emissions,**

$$D(Q)=\frac{dQ^2}{2}$$

# MODEL SOLUTION (Cont'd)
## Regulation (t = 0)

**Given a feasible cap-and-trade scheme $R = (E, L, U)$, the market-clearing condition set by the regulator,**

$$H(p, \varepsilon, R) = (U - p)(p - L)(E - Q(p, \varepsilon)) = 0$$

**determines the price $p \in [L, U]$ for carbon**

**Hence, <u>expected environmental damages</u> are**

$$\overline{D}(R) = E[D(Q(\tilde{p}, \tilde{\varepsilon})) \mid H(\tilde{p}, \tilde{\varepsilon}, R) = 0]$$

**Similarly, <u>expected abatement cost</u> are**

$$\overline{C}(R) = E[C(e^*(\tilde{p}, (1 + y^*(\tilde{p}, \tilde{\theta}))\tilde{\theta}) \mid e_0 + \tilde{\varepsilon}) \mid H(\tilde{p}, \tilde{\varepsilon}, R) = 0]$$



# MODEL SOLUTION (Cont'd)
## Regulation (t = 0)

**In addition, the regulator may want to consider the firms' cost of innovation**

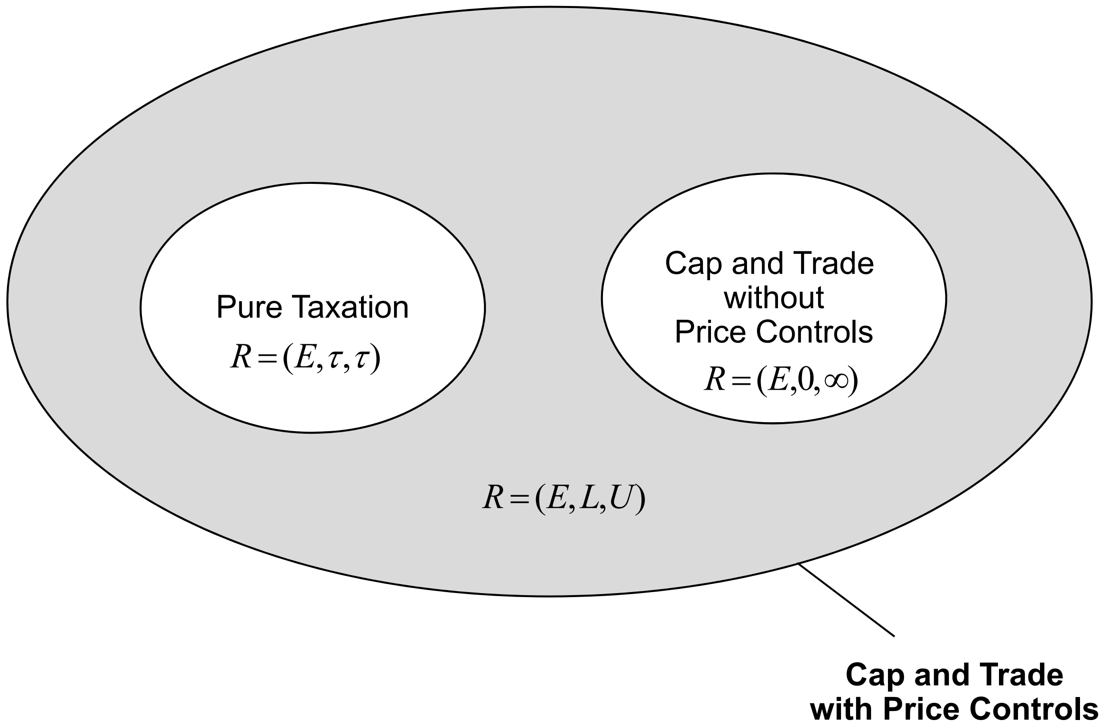
$$\overline{K}(R) = E[\lambda K(y^*(\tilde{p}, \tilde{\theta})) \mid H(\tilde{p}, \tilde{\varepsilon}, R) = 0]$$

**The regulator's objective function is**

$$\overline{W}(R) = -\left(\overline{C}(R) + \overline{D}(R) + \overline{K}(R)\right) = -\overline{SC}(R)$$

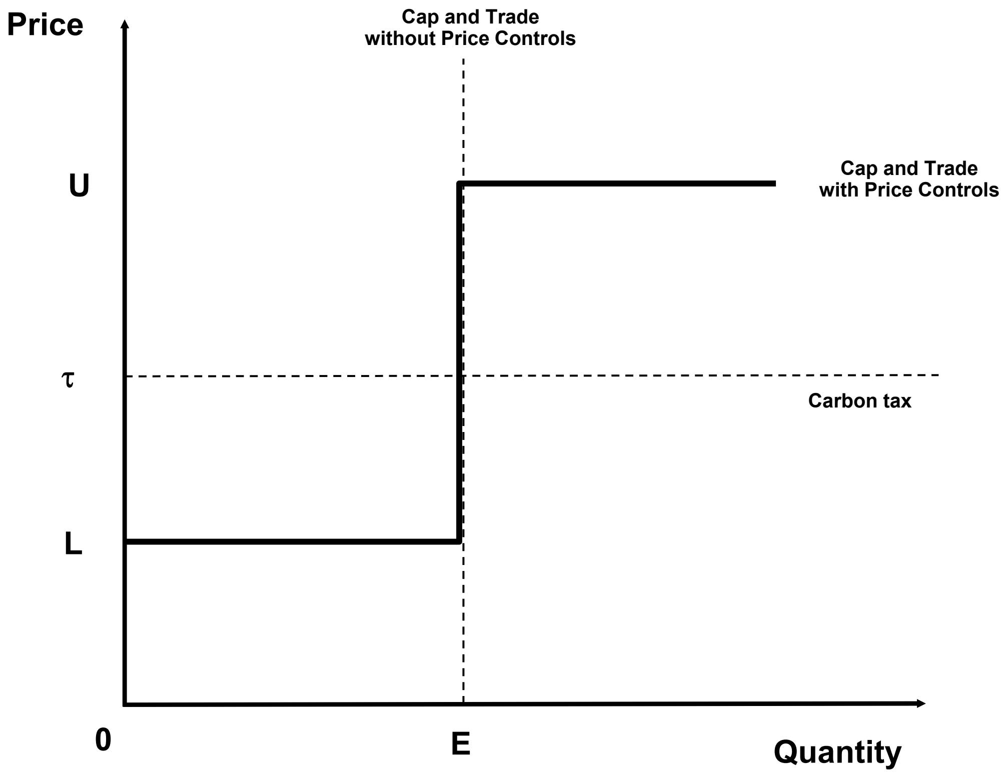
**<u>Problem</u>: Find optimal $R^* \in \Re$**

# RELATION BETWEEN COMMON REGULATORY SCHEMES
## Cap and Trade with Price Control = True Generalization






# COMMON REGULATORY SCHEMES (Cont'd)



# PURE TAXATION

**Under pure taxation, there is no price uncertainty, but there is uncertainty about the environmental damage.**

**Let** $\overline{W}(\tau)$ **be the planner's objective function;**

$$\overline{W}(\tau) = -\frac{\tau^2}{2} - \frac{d}{2}(\sigma_\varepsilon^2 + (e_0 - \tau)^2)$$

**and the optimal tax becomes**

$$\tau^* = \frac{de_0}{1+d}$$



# Optimal carbon tax – numerical example

**Assume:**

**Without innovation** $\tau$ **=40\$/t$CO_2$**

**$E_0$ = 13.5 GT (OECD)**

**10% reduction from existing technologies:** $\mu$ **= 33 $10^6$ t$CO_2^2$/\$$^2$**

**Innovation delivers additional 33% reductions: c = 100\$ * $10^9$**

**Result**

$(\lambda = 0)$ $\tau$ **= 46 \$/t $CO_2$**

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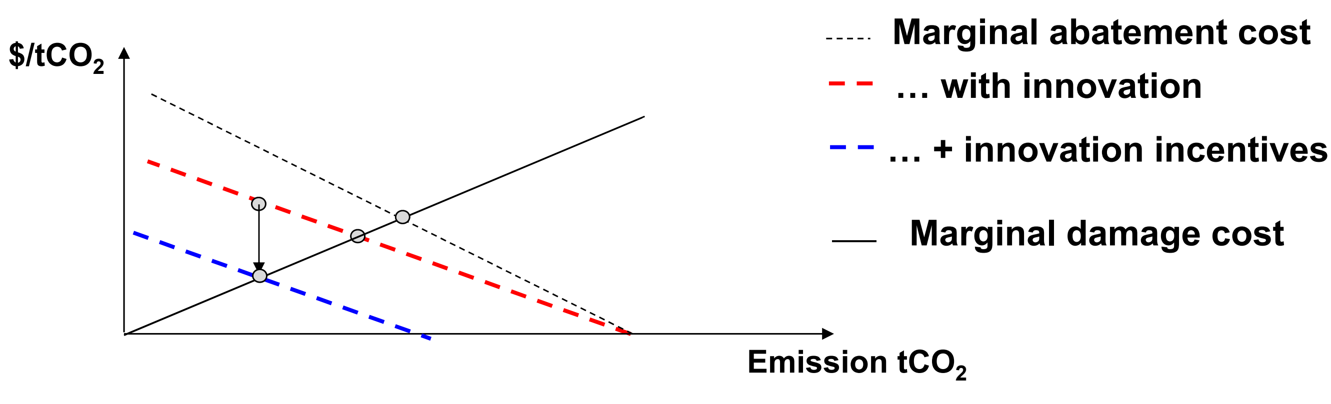
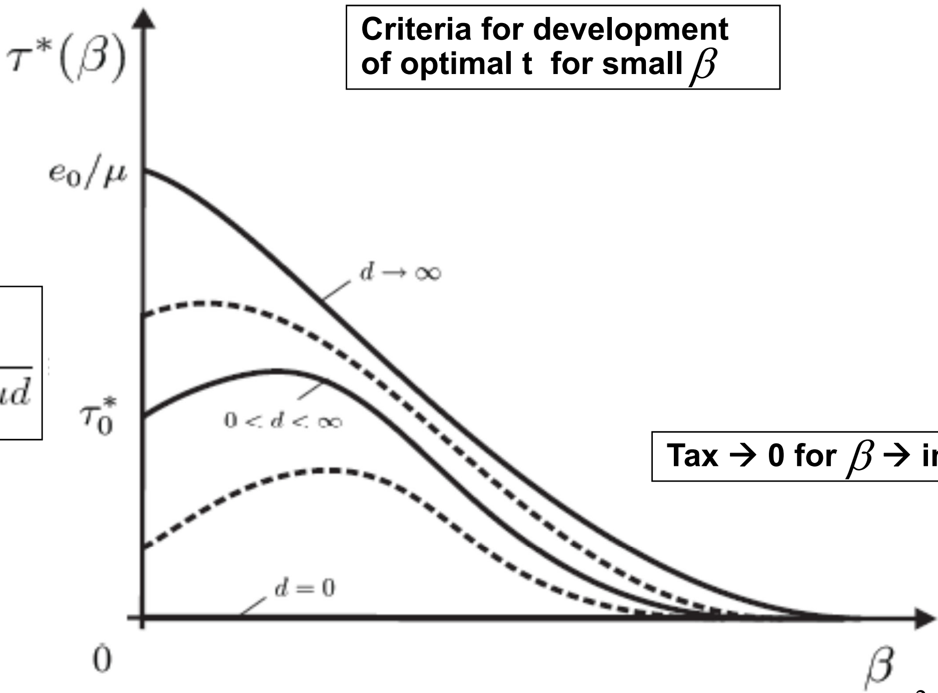


# Optimal Carbon Tax




**Criteria for development of optimal t for small $\beta$**

$$\tau^*(0) = \frac{de_0}{1+\mu d}$$

**Tax → 0 for $\beta$ → inf**

**Innovation effectiveness**

$$\beta = \frac{\mu^2 + \sigma_\theta^2}{2\mu c}$$



# BASIC CAP AND TRADE (WITHOUT PRICE CONTROLS)

**Under basic cap and trade, there is no output uncertainty, but there is price uncertainty.**

**Let** $\overline{W}(E)$ **be the planner's objective function;**

$$\overline{W}(E) = -\frac{(e_0 - E)^2 + \sigma_\varepsilon^2}{2} - \frac{dE^2}{2}$$

**and the optimal emissions cap becomes**

$$E^* = \frac{e_0}{1+d}$$

**Note that expected price under this cap is the same as the optimal tax, i.e.,**

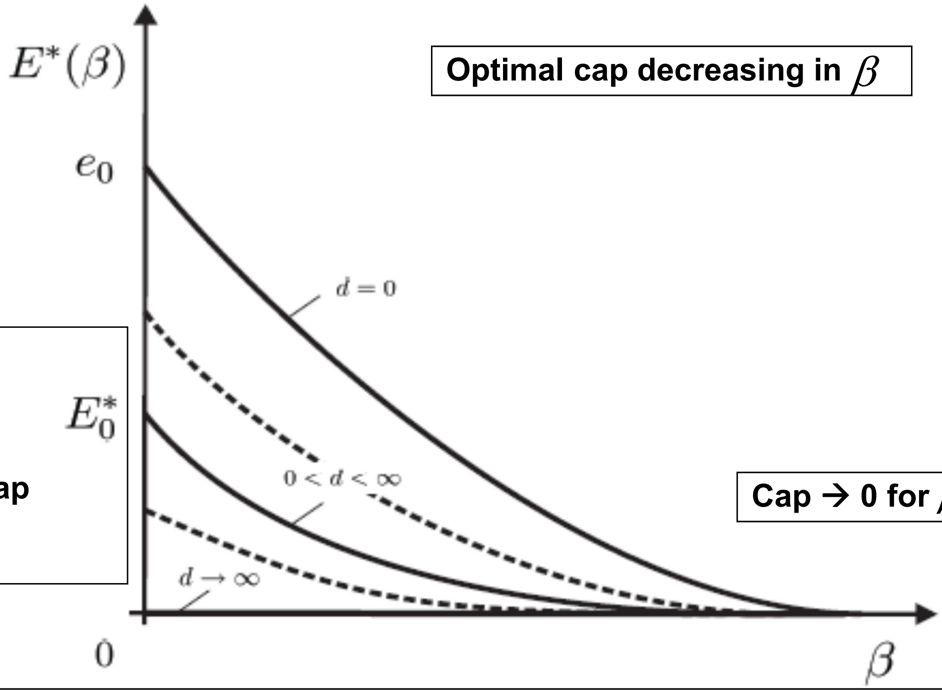
$$\overline{p}^* = E[p(\widetilde{\varepsilon}, E^*) \mid E^*] = \tau^*$$

**BUT, this does not mean that the two are equivalent!**

# OPTIMAL CAP

Optimal cap decreasing in $\beta$

Analytic solution optimal cap




Cap → 0 for $\beta$→inf

Increase in $\beta$ increases relative attractiveness of quantity based regulation



# PRICES (TAXES) VS. QUANTITIES (EMISSIONS CAP)
## Weitzman (1974)

**Depending on the relative magnitude of the marginal abatement cost (1) and the environmental damages (d), it may be better to either impose a pure tax or a basic cap-and-trade scheme:**

$$\overline{W}^*_{Tax} - \overline{W}^*_{Basic\ C\&T} = (1-d)\frac{\sigma_\varepsilon^2}{2}$$

**Tax is strictly better if and only if** $d < 1$

| | | |
|---|---|---|
| **Small damage cost d** | → | **Pure Tax** |
| **Large damage cost d** | → | **Basic Cap and Trade** |

# CAP AND TRADE WITH PRICE CONTROLS
## A Simple Example

**Example. Assume that the macroeconomic shock $\tilde{\varepsilon}$ is uniformly distributed on $[-\delta, \delta]$ , where $\delta > 0$ . Then,**

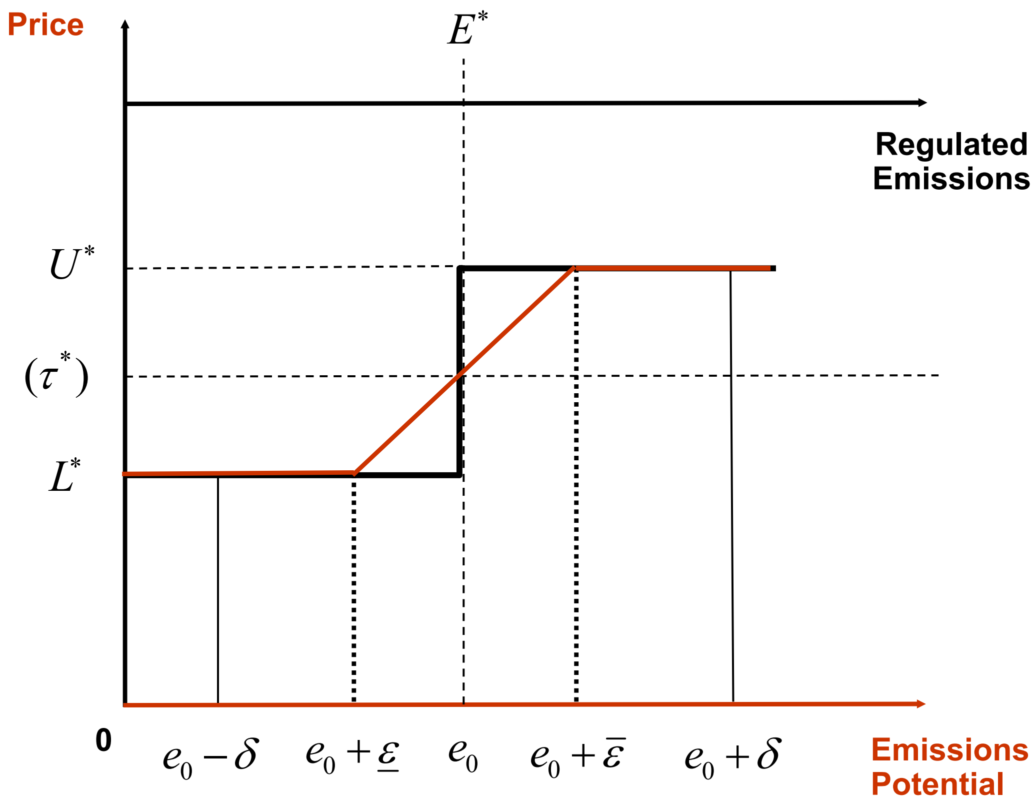
$$E^* = \frac{e_0}{1+d}$$

$$L^* = d\left(\frac{e_0}{1+d} - \frac{\delta}{2+d}\right)$$

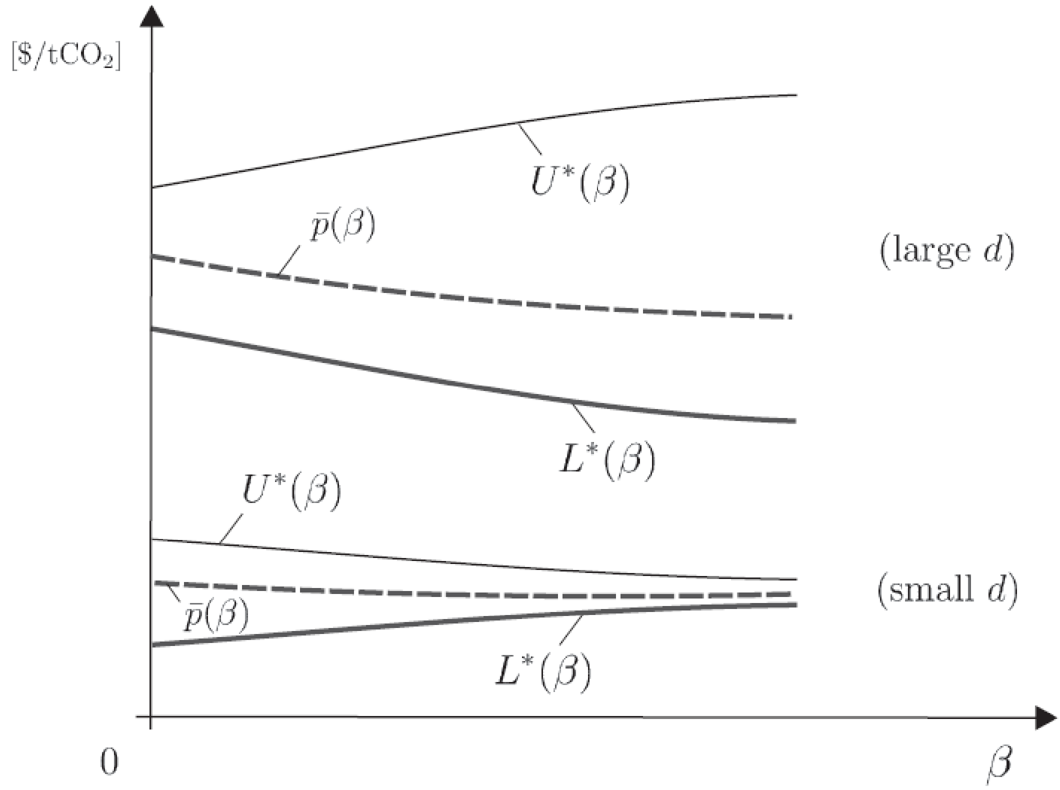
$$U^* = d\left(\frac{e_0}{1+d} + \frac{\delta}{2+d}\right)$$



# CAP AND TRADE WITH PRICE CONTROLS
## A Simple Example (Cont'd)

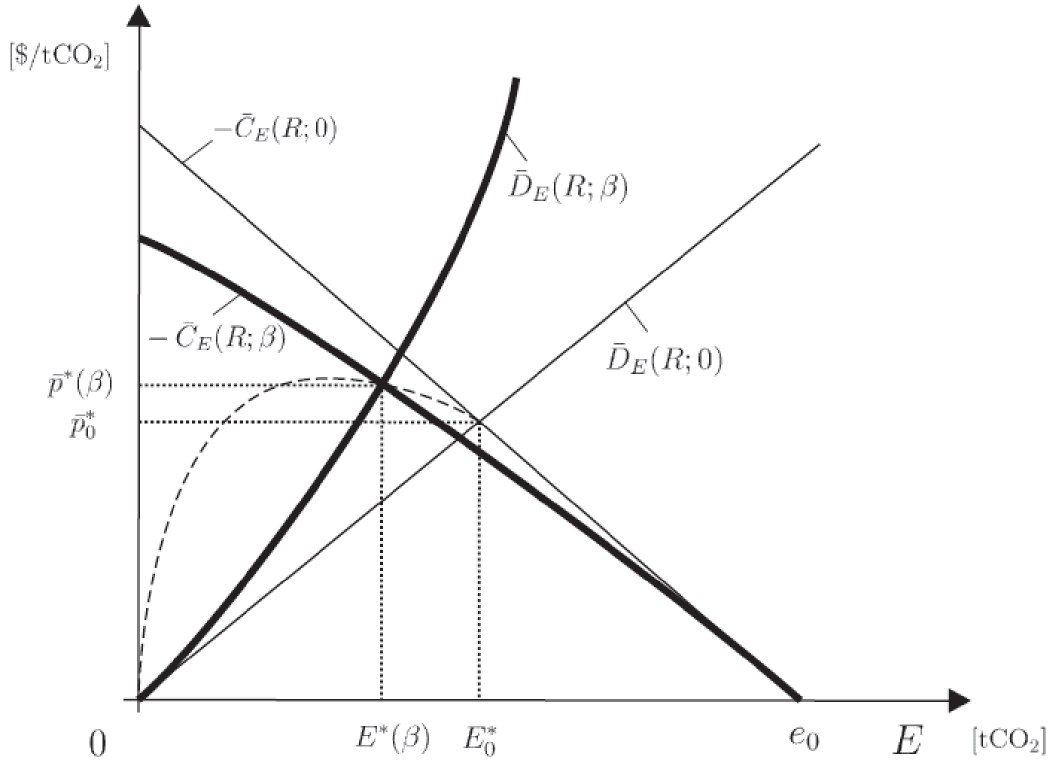


# OPTIMAL HYBRID SCHEME

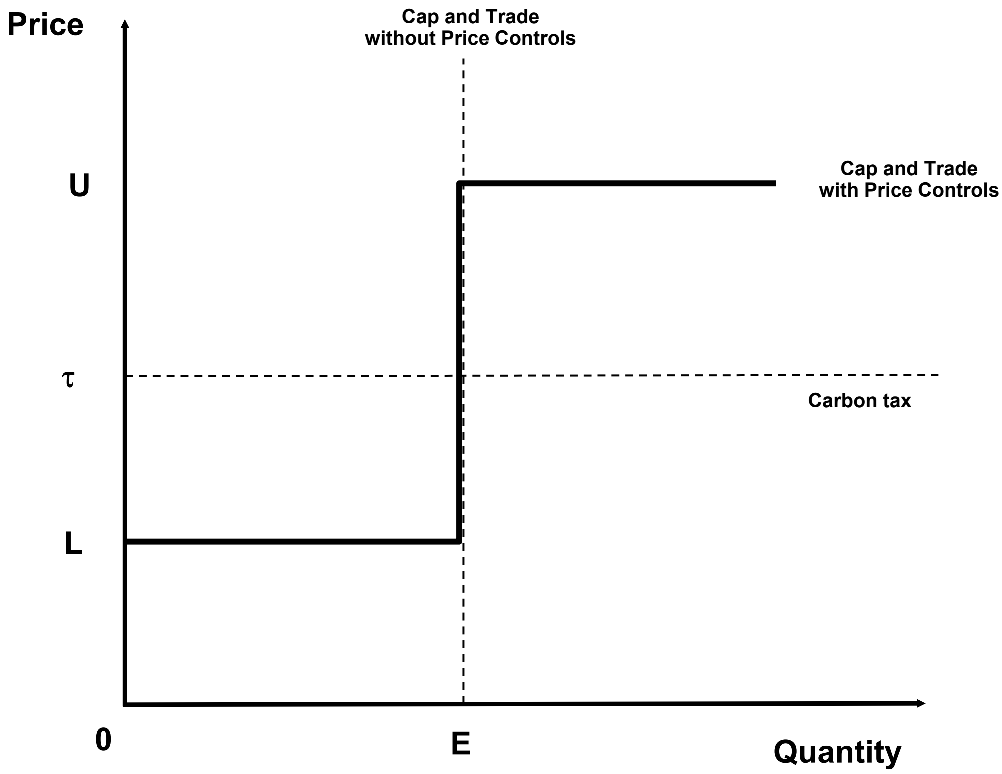





# EXPECTED MARKET PRICE VARIES WITH INNOVATION EFFECTIVENESS

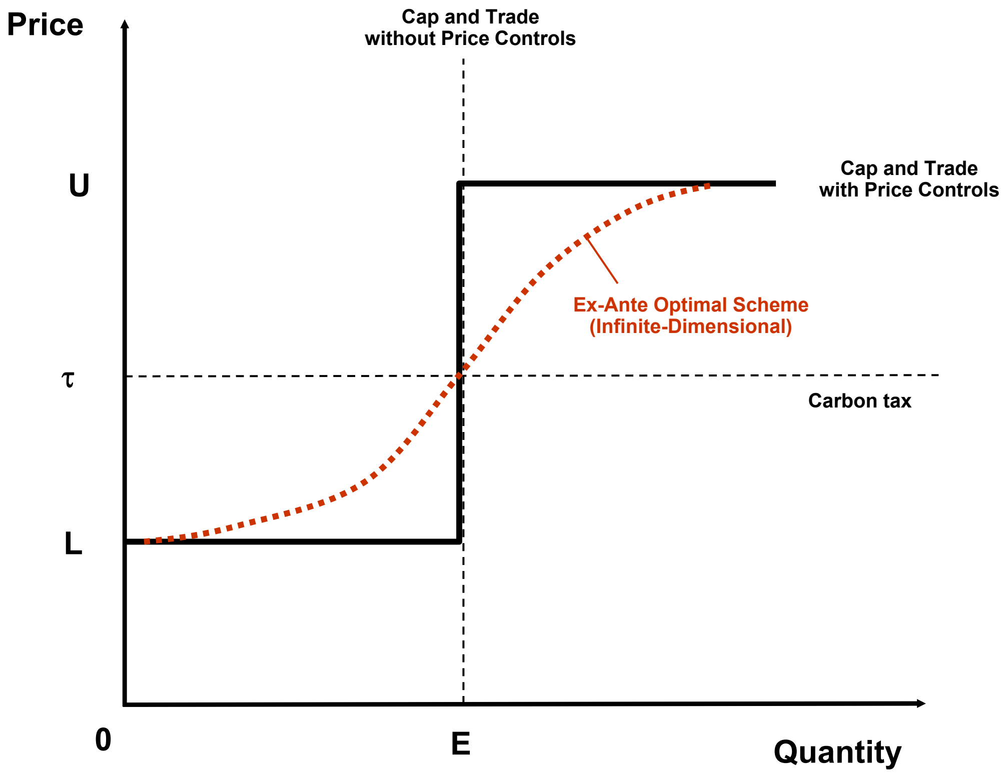


# OPTIMAL REGULATION
## Is Cap and Trade with Price Controls Really the Best One Can Do?



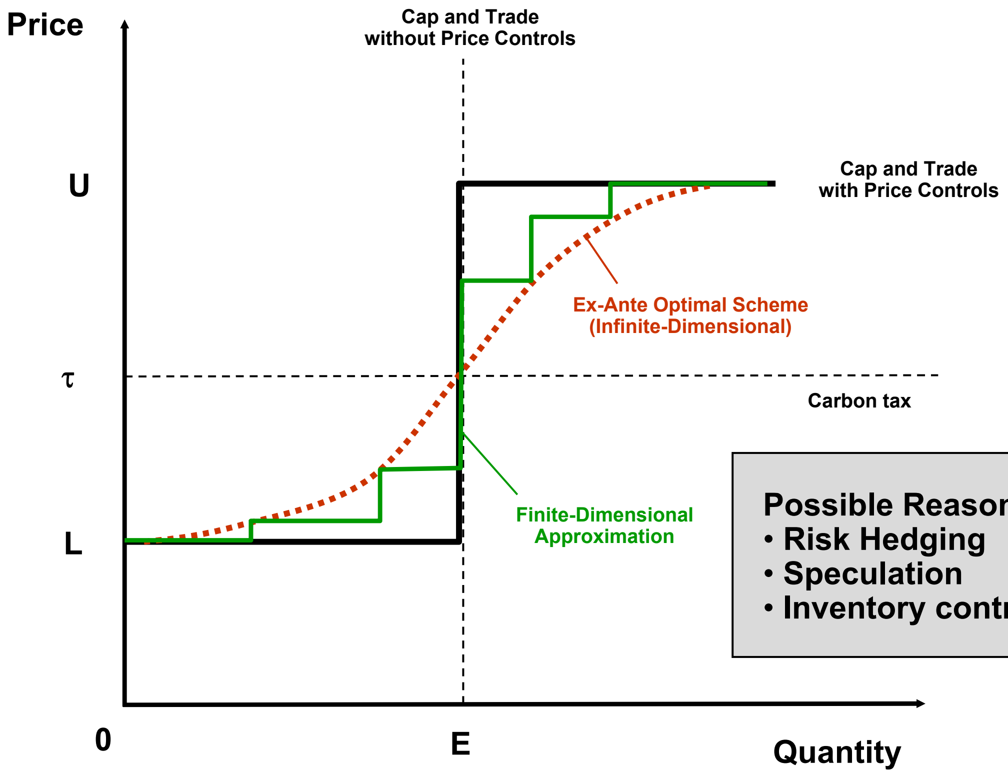



# OPTIMAL REGULATION
## Ex-Ante (Infinite-Dimensional) Solution Might Be Quite Different



# MULTI-CAP AND TRADE

## Implementation (e.g.) via Derivative Securities such as Options




**Possible Reasons:**
- **Risk Hedging**
- **Speculation**
- **Inventory control**



# ANOTHER IMPORTANT QUESTION: REGULATORY COMMITMENT

**When the macroeconomic uncertainty has realized the regulator may want to deviate from his announced regulatory policy R and deviate to R'**

- **Is it good for a regulator to commit *ex ante* to a scheme R?**
- **What are *credible* commitment devices?**
- **What *degree* of commitment is optimal?**

**Additional policy instruments available at the implementation stage**

- **Incentives**
- **Supplementary regulation**
- **Emissions banking**
- **Mode of permit allocation**

# DYNAMIC POLICY ISSUES
## A consistent policy mix is credible

**Carbon pricing**

- **Short-term – address risk from extreme carbon prices (e.g., via price controls)**
- **Medium-term – flexible price response to deliver target (e.g., national targets, minimize leakage)**
- **Long-term – global mechanism with joint carbon price, where equity can be implemented via "green fund" (e.g., on per-capita-emission basis)**

**Complementary policies**

- **Common trajectory to ensure action across governments**
- **Fairness in the design of regional and global mechanism**

**Technology policy**

- **Innovation incentives (e.g., provided by law, technology competitions)**
- **Aggressive standard setting**
- **Certification (e.g., green labelling)**



# AGENDA

**What are externalities?**

**Example: Production Externalities**

**Some Regulatory Options**

**Uncertainty Matters: Prices vs. Quantities**

**Key Concepts to Remember**

# KEY CONCEPTS TO REMEMBER

- Positive/Negative Externalities
- Production Externalities
- Market Failure
- Regulatory options to deal with market failure due to externalities
- Coase Theorem
- Prices vs. Quantities, and how to regulate both!