

Production Externalities

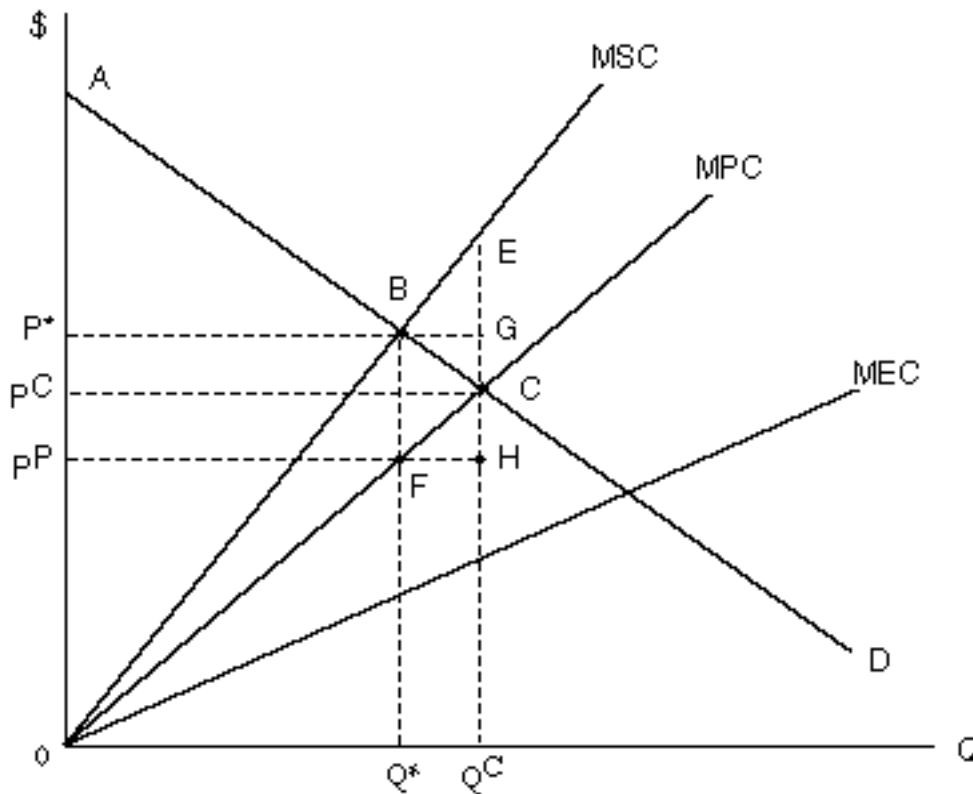
Externalities are a type of market failure.

Production externalities occur when the production activities of one individual imposes costs or benefits on other individuals that are not transmitted accurately through the market.

Example:

A farmer takes irrigation water out of a river before it reaches a wildlife refuge. The farmer's actions reduce the flow of water reaching the wetland, which reduces the amount of wetland acreage available to waterfowl. Consequently, fewer birds are attracted to the refuge, which decreases the utility of birdwatchers. If farmers had to account for the value of the lost utility to birdwatchers (i.e., there was a price associated with a reduction in birds), they would probably reduce the amount of irrigation water they pumped from the river.

Production Externalities and the Failure of Competitive Markets



MPC = marginal private cost

MEC = marginal externality cost

MSC = social cost (vertical sum of MPC and MEC)

Social optimum at B (where $MSB = MSC$)

ABQ^*O = social benefits

OBQ^* = social costs

ABO = social welfare

Free market outcome at C

ACQ^cO = social benefits

$OCQ^c + OEC = OEQ^c$ = social costs

$ABO - BEC$ = social welfare

BEC = deadweight loss

A Mathematical Representation of Production Externalities

Definitions:

- Q = output
- B(Q) = total social benefit of producing Q.
- C(Q) = total private cost of producing Q.
- E(Q) = total external cost of producing Q.
- W(Q) = social welfare function (total surplus from producing Q).

Deriving the Condition for a Social Optimum:

The Social Welfare Maximization Problem is:

$$\text{Max}_Q \{W(Q) = B(Q) - C(Q) - E(Q)\}.$$

Social welfare is maximized where Q satisfies the First-Order Condition (FOC):

$$W_Q = B_Q(Q) - C_Q(Q) - E_Q(Q).$$

where:

$B_Q(Q)$ = the partial derivative of B(Q) with respect to Q.
Note that $B_Q(Q)$ marginal benefit = MB

$C_Q(Q)$ = the partial derivative of C(Q) with respect to Q.
Note that $C_Q(Q)$ = marginal private cost = MPC

$E_Q(Q)$ = the partial derivative of E(Q) with respect to Q.
Note that $E_Q(Q)$ = marginal external cost = MEC

Solving the FOC for Q gives the **socially optimal output**, call it Q^* .

Notice that we can rearrange the FOC as follows:

$$B_Q(Q) = C_Q(Q) + E_Q(Q).$$

In this form, we see that the FOC implies that the social optimum, Q^* , occurs where MB = MPC + MEC.

Policies to Combat Externalities

- A competitive economy will be inefficient (will not achieve a Pareto Optimum) in the presence of externalities.
- The policy goal is to move the economy to a socially optimal point where the $MSB = MSC$.
- Policies the government can use to correct for externalities:
 - a tax
 - a subsidy
 - a restriction, standard, or quota

Externality Tax or Output Tax

- The government sets a unit tax such that the firm's MPC becomes equivalent to the MSC.
- If the government knows how much pollution is produced per unit of production output, then the government can set a tax on production output that achieves the same results as an externality tax.
 - In practice, this relationship is difficult to measure.
- The government revenue from either type of tax not only corrects the externality but also gives the government the opportunity to reduce other distortionary taxes (such as income taxes or sales taxes) in the economy, thereby eliminating other deadweight losses in the economy.

Externality Tax or Output Tax

A Mathematical Representation

We can easily show that the appropriate externality tax, t^* , needed to bring unregulated competition in line with the social optimum is:

$$t^* = E_Q(Q^*) = MEC(Q^*).$$

A unit tax of t^* results in the following private optimization problem:

$$\text{Max}_Q \{ \pi(Q) = PQ - C(Q) - t^*Q \}$$

which yields the FOC:

$$\pi'(Q) = P - C_Q(Q) - t^* = 0$$

or, $P = C_Q(Q) + t^*$.

Since $P = MB$ at all points along the demand curve, and since the regulator has set $t^* = E_Q(Q^*)$, we can express the private condition under the tax as:

$$B_Q(Q^*) = C_Q(Q^*) + E_Q(Q^*)$$

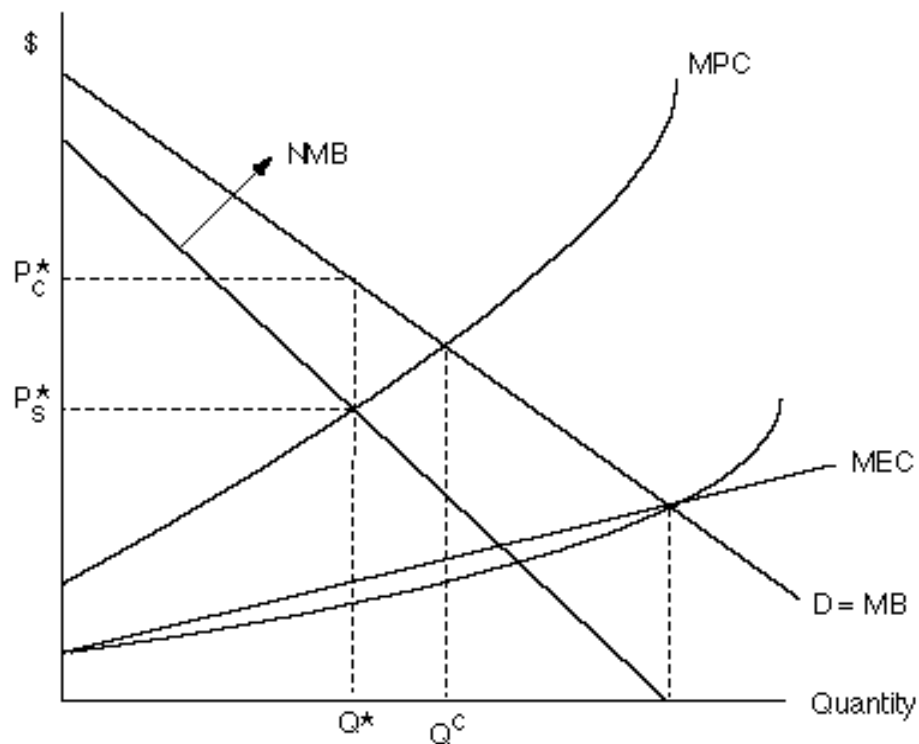
which is identical to the condition for a social optimum.

An Alternative Externality Tax: A Tax on the Consumption Good

The government can also place a sales tax on the consumption of the polluting good.

When a sales tax is implemented in place of a production tax, the residual demand curve for firms in the market shifts downward to represent the net price of each unit sold.

The net price, or Net Marginal Benefit (NMB), is the marginal benefit of consumers less the level of the sales tax ($NMB = D - t^*$).



Q^* = social optimum output

P_c^* = optimal consumer price

P_s^* = $P_c^* - t$ = net producer price

t = externality tax

Pollution-Reduction or Output-Reduction Subsidy

Producers are subsidized for reducing pollution or output.

Example: The government pays subsidy = $P^* - P^P$ for each unit of output that is **not** produced.

If we let \bar{Q} = the current level of output, firms in a competitive industry have the following objective:

$$\text{Max.}_{Q} \{ = PQ - C(Q) + (\bar{Q} - Q)S \}$$

with FOC:

$$Q = P - C'(Q) - S = 0$$

From inspection, we see that the optimal subsidy level (i.e., the unit of subsidy that equates the optimal social and private outcomes) is: $S^* = t^* = \text{MEC}(Q^*)$.

Producers' maximum profits now occur at output level Q^* .

In the long run, subsidies for pollution reduction may actually **increase** pollution because the subsidy may attract more firms into the market.

Restrictions/Quotas/Standards on Pollution or Output

This policy is the command-and-control approach where the government restricts output to Q^* .

The welfare implications of an Output Restriction:

Producer surplus is larger than the Externality Tax

Government revenue = zero which is smaller than the Externality Tax

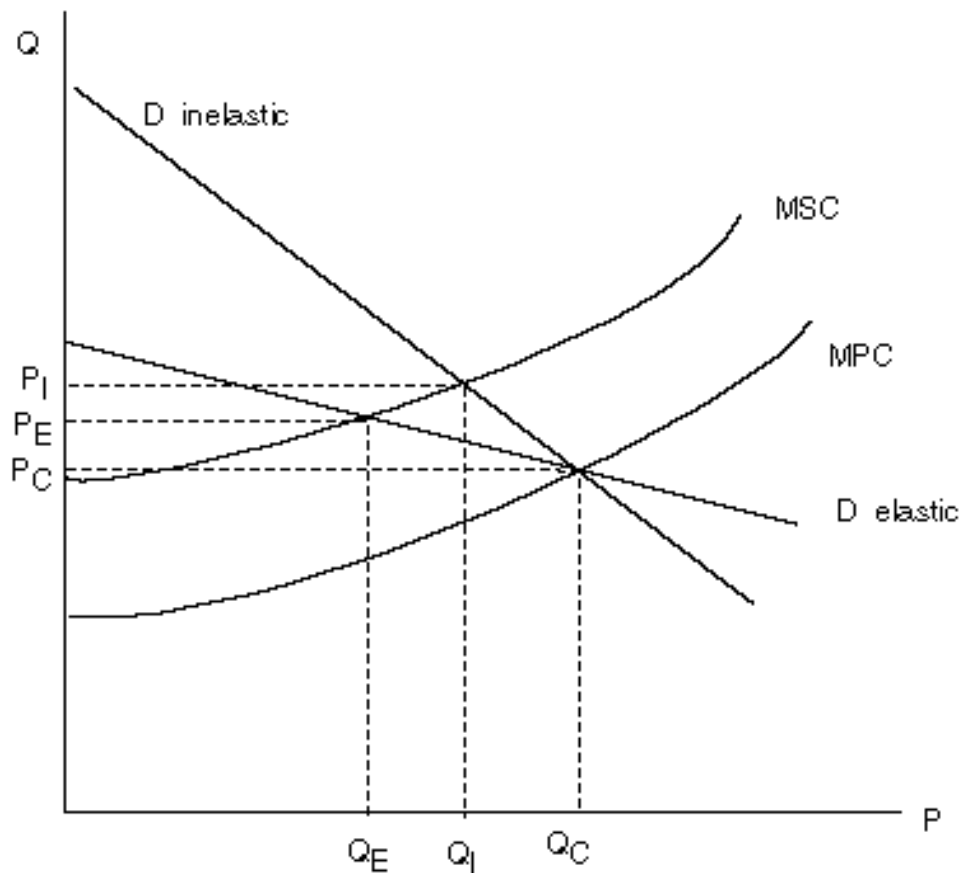
If the production quota is **transferable**, then producers will bid against each other for the quota rights until the quota price equals $P^* - P_P$.

Whoever *initially* had the legal rights to the transferable quota will earn **quota rents**.

After paying for the quota rights, producers will be left with surplus that is the same as it was under an externality tax, and the quota rents here are equal in size to Government Revenue under the externality tax.

The government can shift the quota rents from producers to other economic agents (such as consumers, poor graduate students, or even back to the government itself) by choosing who initially gets the legal rights to the transferable quota.

The Impact of Market Parameters (Elasticity Effects) on the Magnitude of Externalities



P_c, Q_c = competitive price and quantity in the market

P_i, Q_i = socially optimal price and quantity when demand is inelastic

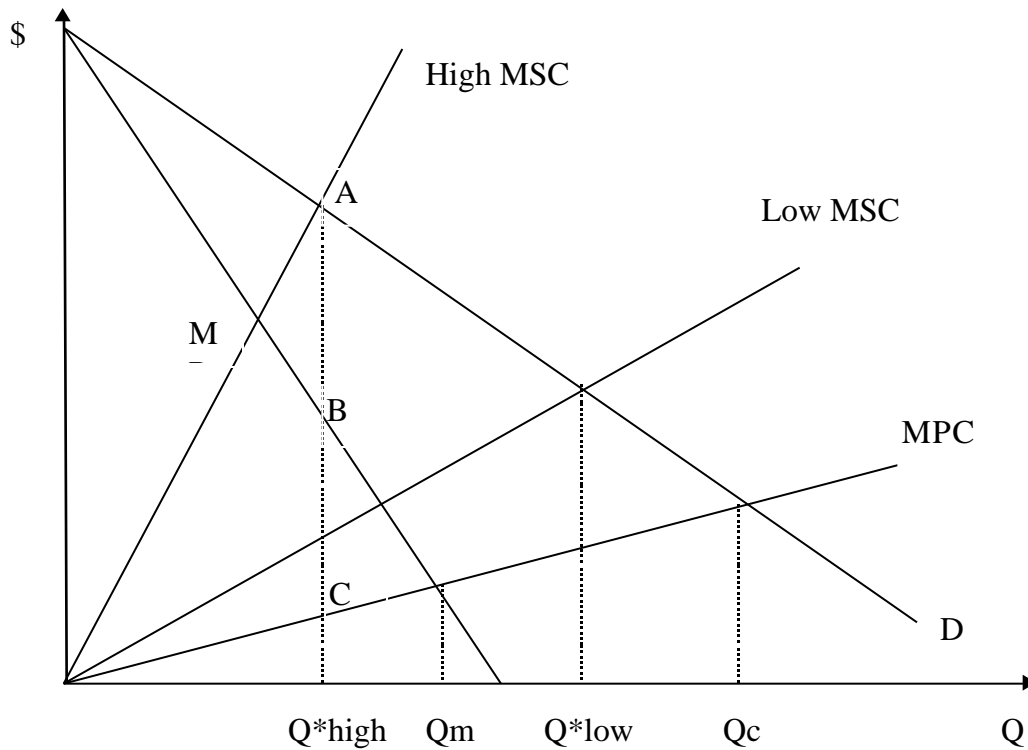
P_e, Q_e = socially optimal price and quantity when demand is elastic

The elasticity of demand affects the degree of inefficiency associated with a production externality.

When demand is highly inelastic, the inefficiency will be small, so it may not be worth regulating the externality.

When demand is highly elastic, the inefficiency will be large, so regulation may be desirable.

Imperfectly Competitive Market Structure and externality Policy



We consider two cases:

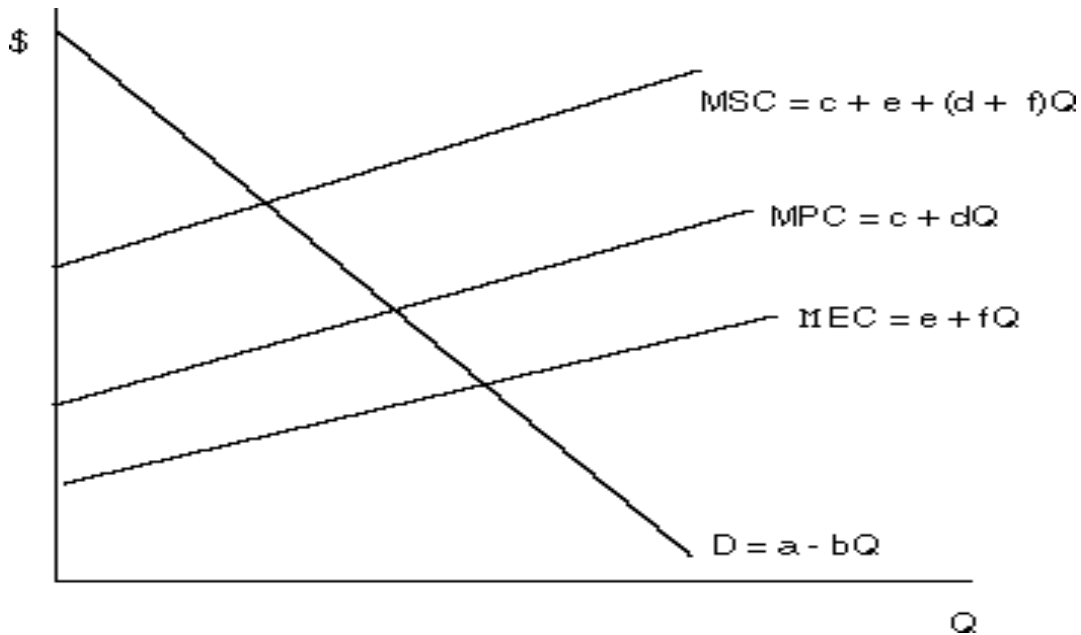
- MSC is relatively low (i.e., MEC is small).
- MSC is relatively high (i.e., MEC is large).

In both cases, unregulated competition produces too much output at point Q_c .

In the case of “low MSC,” the optimal output, Q^*_{low} , is larger than the monopoly output, Q_m . Control regulation may not be warranted.

In the case of “high MSC,” the monopolist produces “too much” output from a social perspective because $Q^*_{high} < Q_m$. The optimal tax policy for monopoly in this case is $t^* = \text{the distance } BC$. The monopolist will compare $MPC + \text{the tax } (t^*)$ with MR in order to determine its Q . At Q^* , $MR = \text{tax} + MPC$.

Production Externalities: An Example



Output: Q .

Total consumer benefit = area under demand: $B(Q)$.

Total private cost: $C(Q)$.

Total externality cost: $E(Q)$.

Inverse demand (D) = Marginal Benefit (MB):

$$(1) \quad P = a - bQ.$$

Marginal private cost (MPC):

$$(2) \quad C(Q) = c + dQ.$$

Marginal externality cost (MEC):

$$(3) \quad MEC = e + fQ.$$

Marginal social cost (MSC):

$$(4) \quad MSC = MPC + MEC = c + dQ + e + fQ = c + e + (d + f)Q$$

Production Externalities: An Example (cont.)

The Social Optimum:

The social optimum occurs where $MB = MSC$.

In terms of the figure, this condition is met at:

$$c + e + dQ + fQ = a - bQ$$

which implies:

$$Q^* = \frac{a - c - e}{d + f + b} .$$

We also know that:

$$P^* = a - bQ$$

so substitution yields:

$$P^* = a - \frac{ba - bc - be}{d + f + b} .$$

Production Externalities: An Example (cont.)

Unregulated vs. Regulated Competition:

Unregulated competition will result in:

$$B_Q(Q) = C_Q(Q) \quad (\text{MB} = \text{MPC}),$$

or, in terms of the figure,

$$a - bQ = c + dQ \quad Q^C = \frac{a - c}{b + d}$$

$$P = a - bQ \quad P^C = a - \frac{ba - bc}{b + d}$$

which is not the socially optimal allocation.

The appropriate externality tax, t^* , needed to bring unregulated competition in line with the social optimum is:

$$t^* = E_Q(Q^*) = \text{MEC}(Q^*).$$

So that the result of *regulated competition*,

$$B_Q(Q^*) = C_Q(Q^*) + t^*,$$

where:

$$t^* = \text{MEC}(Q^*) = e + f \frac{a - c - e}{d + f + b} = \frac{e(d + b) + f(a - c)}{d + f + b}$$

produces the socially optimal allocation.

Production Externalities: An Example (cont.)

Unregulated Monopoly:

A profit-maximizing monopolist sets $MPC = MR$, where MR (marginal revenue) is the derivative of R (total revenue) and total revenue is $R = P(Q)Q$

$$R = (a - bQ)Q$$

or,

$$R = aQ - bQ^2$$

which implies,

$$MR = a - 2bQ$$

Then, setting $MPC = MR$:

$$c + dQ = a - 2bQ$$

which implies,

$$Q^M = \frac{a - c}{d + 2b}$$

and, we know from before,

$$P = a - bQ$$

so substitution yields:

$$P^M = a - \frac{ba - bc}{d + 2b}$$

Production Externalities: An Example (cont.)

Unregulated Middleman:

The unregulated middleman seeks to set $MR = MO$, where MO (marginal outlay) is the derivative of Outlay, which is defined as: $Outlay = MPC(Q)Q$.

Thus, the objective function of the middleman is:

$$Max_Q \{ (a - bQ)Q - (c + dQ)Q \}$$

which has the following FOC:

$$Q = a - 2bQ - c - 2dQ = 0$$

Note: This can also be solved by calculating the marginal outlay:

$$Outlay = (c + dQ)Q \implies MO = c + 2dQ,$$

then, setting $MR = MO$:

$$MR = a - 2bQ = c + 2dQ \quad Q^D = \frac{a - c}{2(b + d)}.$$

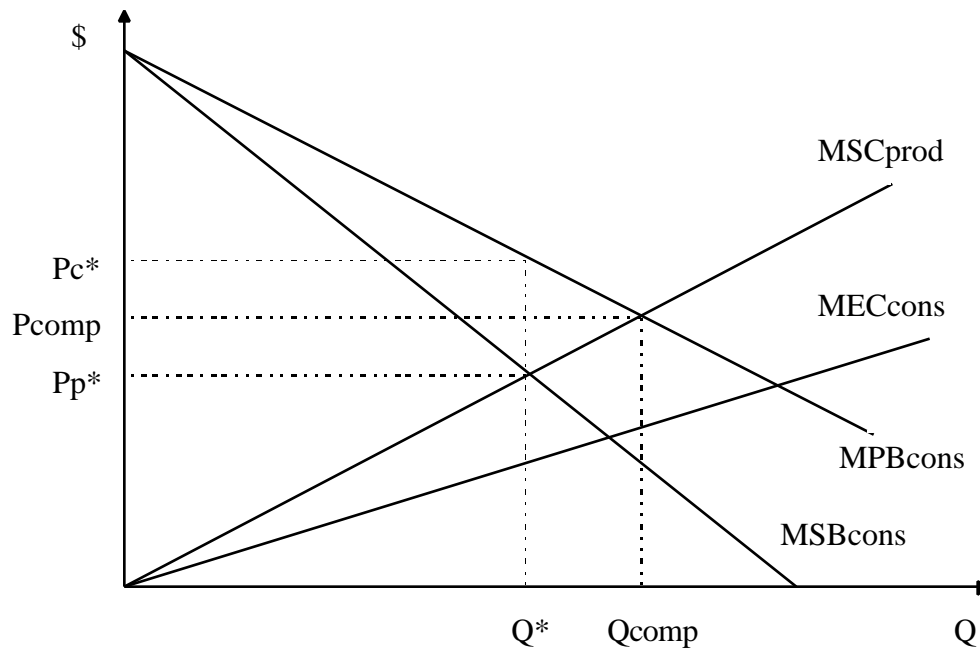
The middleman finds the price (s)he will pay producers by substituting Q^D into the equation for MPC :

$$P^P = c + dQ \quad P^P = c + \frac{d}{2} \frac{a - c}{b + d}.$$

The middleman finds the price (s)he will charge consumers by substituting Q^D into the equation for inverse demand (D):

$$P^C = a - bQ \quad P^C = a - \frac{b}{2} \frac{a - c}{b + d}$$

Consumption Externalities



MSC = Marginal Social Cost of producing the product (no production externalities)

MECcons = Marginal External Cost **of consumption**

MPBcons = Marginal Private Benefit = individual demand

MSBcons = Marginal Social Benefit = $MPBcons - MECcons$

Inefficient Outcome Under Unregulated Competition:

Q_{comp} = output under unregulated competition

P_{comp} = price under unregulated competition

Socially Optimal Outcome = Q^* :

Optimal tax on consumption externality: $t^* = MEC(Q^*)$

P^*_{cons} = optimal consumer price

$P^*_{prod} = P^*_{cons} - t^* =$ net price received by producers at production quantity Q^*

Externalities from Cigarette Smoking:

Health Costs Associated with Smoking:

- Smokers' health costs shared by society.
- Cost of family support (in case of early death).
- Risk to nonsmokers (second-hand smoke).

Estimated Death Toll (1989):

Activity	Annual Deaths
Cigarettes	400,000
Alcohol	150,000
Drugs	30,000

- Approximately 30 billion packs of cigarettes are smoked annually.

Estimated Annual External Costs of Smoking:

\$ 35 billion (medical cost)
\$ 20 billion (lost work)
\$ 5 billion (fires, smoke, odor damage)
\$ 60 billion (total cost)

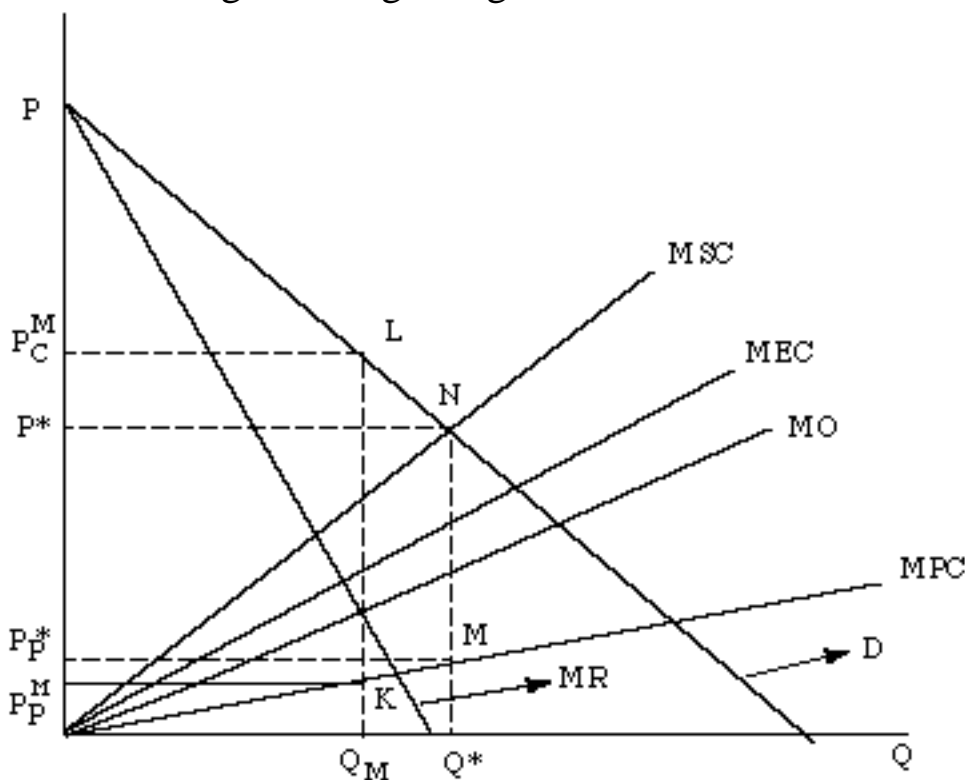
Policy Alternatives to Control Cigarettes:

- (1) A cigarette tax or tobacco tax.
- (2) A standard/quota to restrict quantities of cigarettes and tobacco.

If marginal externality cost = average externality cost, then the tax should be \$2.00 per pack (\$60 billion / 30 billion packs).

Modeling the Economics of Illicit Drugs

When drugs are illegal, organized crime is the middleman.



- D = demand
- MR = marginal resource
- MO = marginal outlay
- Q_M = middlemen quantity
- P_P^M = producer price under middlemen
- P_C^M = consumer price under middlemen
- MPC = marginal private cost
- MEC = marginal externality cost
- MSC = marginal social cost
- Q^* = social optimum
- P^* = consumer price under social optimum
- P_P^* = producer price under social optimum.

A drug tax may increase consumption from Q_M to Q^* . It will generate revenue $P_P^* M N P^*$.

Consumption of drugs causes “consumption externalities.” Addicts “waste their lives,” causing pain and suffering to their family and friends. There is an issue of “cognitive dissonance,” as victims behave against their self-interest, and that is one reason for compulsory actions. There is disagreement about social cost of drug use. It may be exorbitant and result in a very high tax. Enforcing this tax will not prevent illegal supply. The “workable tax” that enables “legal market” may lead to a large increase in consumption that is socially suboptimal.

The Economics of Illicit Drugs

Some economists propose drug legalization:

- (1) Legalize illicit drugs.
- (2) Ban advertisement and sale to minors.
- (3) Institute a tax on drugs.

Benefits:

- Increased government revenue.
- Reduced government costs (fewer prisoners and less drug enforcement).
- Reduced crime.

Costs:

- Increased addiction.
- Legalization may induce more to try.

Economic Impacts:

1. Shift income from drug traffickers to government (taxes) and legal marketers (pharmacies).
2. Eliminating drug trafficker middlemen may result in increased quantity and higher producer prices.
 - Poor coca farmers may benefit from legalization.
3. The costs of crime enforcement may go down.
4. Consumer prices (inclusive of taxes) may go down and quantity may go up.

Economic analysis requires the assessment of:

- (1) Market structure under current arrangements.
- (2) Market structure after legalization.
- (3) Externality cost of health and crime.
- (4) Demand for drugs when they are legal and illegal.