

## Externalities, Market Failure, and Government Policy

An externality can only exist when the welfare of some agent, or group of agents, depends on an activity under the control of another agent. Under these circumstances, an externality arises when the effect of one economic agent on another is not taken into account by normal market behavior.

Externalities are a type of market failure. When an externality exists, the prices in a market do not reflect the true marginal costs and/or marginal benefits associated with the goods and services traded in the market. A competitive economy will not achieve a Pareto optimum in the presence of externalities, because individuals acting in their own self interest will not have the correct incentives to maximize total surplus (i.e., the “invisible hand” of Adam Smith will not be “pushing folks in the right direction”). Because competitive markets are inefficient when externalities are present, governments often take policy action in an attempt to correct, or internalize, externalities.

Externalities may be related to production activities, consumption activities, or both. Production externalities occur when the production activities of one individual imposes costs or benefits on other individuals that are not transmitted accurately through a market. We first examine *production externalities*, for example, air pollution from burning coal, ground water pollution from fertilizer use, or food contamination and farm worker exposure to toxic chemicals from pesticide use. We will then analyze the case of consumption externalities, which occur when the consumption of an individual imposes costs or benefits on other individuals that are not accurately transmitted through a market.

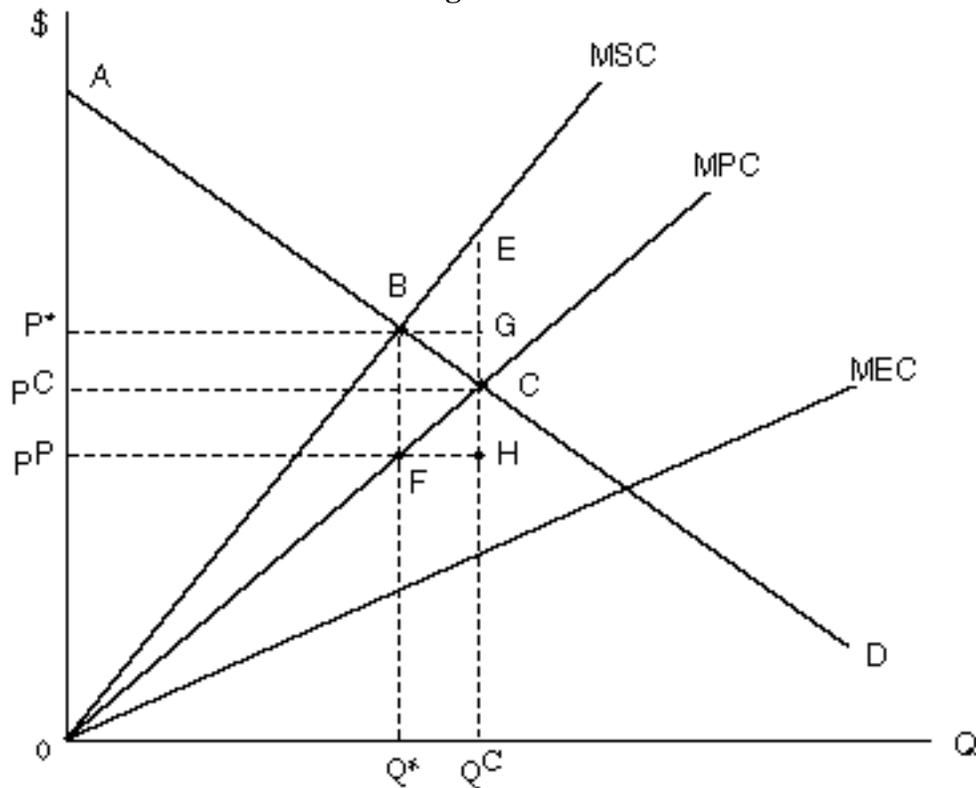
### Production Externalities

To motivate the concept of a production externality, consider the following examples:

- 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.
- A more common example is the case of a firm polluting an air or water source as a by-product of production. Examples here include, the production of refrigerators using CFC’s, a coal-burning electricity plant (NO<sub>x</sub> and Sox), or a paper mill which dumps chlorine bleach into a river as a by-product of producing white office paper. In the Far East of Russia, there is also a huge health issue that is created by gold mining. The mine-owners use magnesium to separate gold ore from quartz, but do not recycle the magnesium. Instead they wash it into the river, which is the source of drinking water for cities in Eastern Russia, such as Vladivostok and Khabarovsk. Partly as a result of poor water quality, the life expectancy citizens in the Russian Far East has dramatically decreased

## Production Externalities and the Failure of Competitive Markets

Figure 1.1



MPC = marginal private cost (this is the inverse of the private supply curve)  
 MEC = marginal externality cost (suffered by people damaged by pollution)  
 MSC = social cost (vertical sum of MPC and MEC)

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

Social Benefits =  $ABQ^*O$ .

Social Costs =  $OBQ^*$ .

Social Welfare =  $ABO$ .

Free market outcome at C

Social Benefits =  $ACQ^cO$ .

Social Costs =  $OCQ^c + OEC = OEQ^c$ .

Social Welfare =  $ABO - BEC$ .

Deadweight Loss =  $BEC$ .

### **An example of a case where pollution is directly related to output:**

Fertilizers: Use of fertilizers leads to nitrate / phosphate contamination of ground water. Thus, the output of fertilizer might be a good example to keep in mind.

## 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 when the following rule holds:

$$\text{MB} = \text{MPC} + \text{MEC}.$$

### How Does Unregulated Competition Perform in the Presence of Externalities?

Under unregulated competition, firms maximize profits, resulting in the FOC:

$$B_Q(Q) = C_Q(Q),$$

which is the familiar rule:  $\text{MB} = \text{MPC}$

When this FOC is solved for Q, call it  $Q_c$ , we find that  $Q_c < Q^*$ . In fact, we find that

$Q_c < Q^*$  whenever  $\text{MEC} > 0$ . Because  $Q_c < Q^*$ ,  $Q_c$  cannot be the socially optimal Q.

Thus,  $Q_c$  is inefficient.

Because a competitive economy will be inefficient (will not achieve a Pareto Optimum) in the presence of externalities, combating externalities is a legitimate arena for government policy. The policy goal is to move the economy to a socially optimal point such as point B in Figure 1.1, where MSB (i.e., Demand) equals MSC.

This social optimum may be achieved by any of several policies. We will examine three policies:

- (1) a Tax
- (2) a Subsidy
- (3) a Restriction, Standard, or Quota

We will find that the choice of policy has implications for the distribution of economic benefits among producers, consumers and government.

Before we begin our analysis, we should briefly discuss the **targeting** of externality control policies. Targeting refers to the process of deciding which economic variable (e.g. output quantity or input price) should be regulated in an attempt to control the externality. Each policy mentioned in the preceding paragraph can be targeted in several ways. Typical targets include outputs, inputs, or the externality-generating activity itself (i.e., the pollutant). In most cases, targeting the externality-generating activity itself, or its associated price, is the most efficient approach, because targeting outputs or inputs (or their prices) creates distortions in the relative prices of goods and thus generates other economic inefficiencies (in a general equilibrium).

### **Policy 1: Externality Tax ("Pollution Tax") or Output Tax**

Suppose the government establishes an Externality Tax of  $t^* = P^* - P^P$ . It is easy to show that a tax of  $t^*$  is the required market correction to achieve  $Q^*$  units of production. This fact can be seen graphically in figure 1.1 when we realize that the firm treats the tax rate as an additional component of its marginal private cost; that is, a unit tax of  $t^*$  shifts the MPC curve upwards in a parallel fashion by the distance  $t^*$ . The optimal tax (i.e. the one that achieves  $Q^*$ ) is clearly  $t^* = MEC(Q^*)$ .

The welfare implications of the Externality Tax are:

$$\begin{aligned}\text{Consumer surplus} &= ABP^* \\ \text{Producer surplus} &= OFP^P \\ \text{Government revenue} &= P^*BFPP\end{aligned}$$

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, however, the relationship between pollution and production output is often very difficult to estimate with any degree of precision.

Keep in mind that the government revenue from either type of tax not only corrects the externality, it 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. Such spillover benefits from one market to another can be computed in general equilibrium models.

## A Mathematical Representation Continued:

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:

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

which yield the FOC:

$$Q(Q) = P - C_Q(Q) - t^* = 0$$

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:

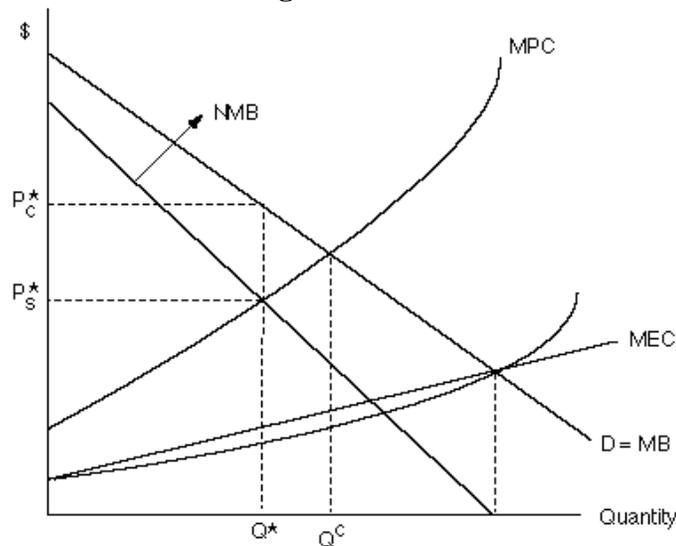
$$B_Q(Q^*) = C_Q(Q^*) + E_Q(Q^*)$$

which is identical to the condition for a social optimum.

## An Alternative Presentation of Production Externalities: A Tax on the Consumption Good

It is also useful to show the equivalence of a tax on production and 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 ( $NMB = D - t^*$ ).

**Figure 1.2**



$Q^*$  = social optimum output,  
 $P_S^* = P_C^* - t =$  net producer price,

$P_C^*$  = optimal consumer price  
 $t$  = externality tax

## Policy 2: Pollution-Reduction or Output-Reduction Subsidy

The second policy consists of a subsidy to producers for reducing pollution or for reducing output. Example: 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 first-order condition:  $Q = P - C'(Q) - S = 0$

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

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

Consumer surplus =  $ABP^*$ .

Producer surplus =  $OFBP^* + BGHF$ , [where  $BGHF = (P^* - P^P) \cdot (Q^C - Q^*)$ ].

Government expenditure =  $BGHF$ .

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

## Policy 3: Restrictions/Quotas/Standards on Pollution or Output

This policy is the command-and-control approach. The government restricts output to  $Q^*$ . Output restrictions can be implemented rather simply through **production quotas**.

The welfare implications of an Output Restriction:

Consumer surplus =  $ABP^*$

Producer surplus =  $OFBP^*$  (larger than for Externality Tax, as we will see)

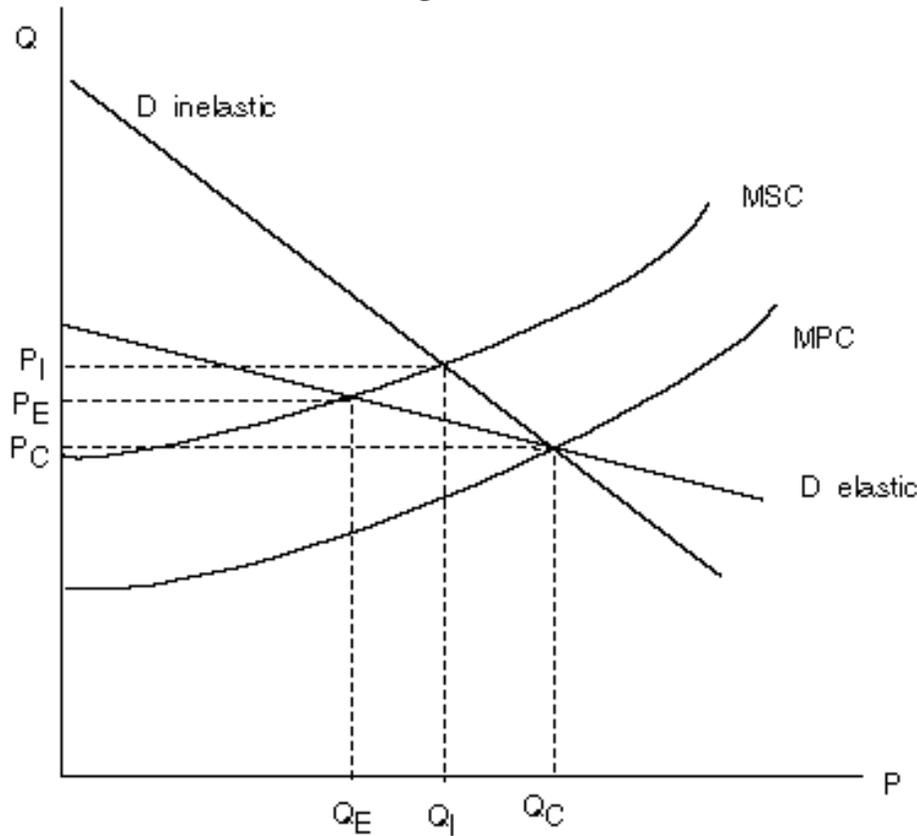
Government revenue = zero (smaller than for Externality Tax)

Producers prefer output restrictions to externality taxes (as we will show next), because producers gain a larger share of the total social surplus under output restrictions. (The Government gets less, which means taxes must remain higher elsewhere in a general equilibrium formulation of the economy).

If the legal rights to the production quota can be bought and sold (i.e., 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** equal to  $P^* \cdot BFP^P$  by *selling* the quota rights to producers. After paying for the quota rights, producers will be left with surplus =  $P^P \cdot FO$ . Note that the producer surplus is now the same, as it was under an externality tax and that the quota rents here are equal in size to Government Revenue under the externality tax. Thus, 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

Figure 1.3



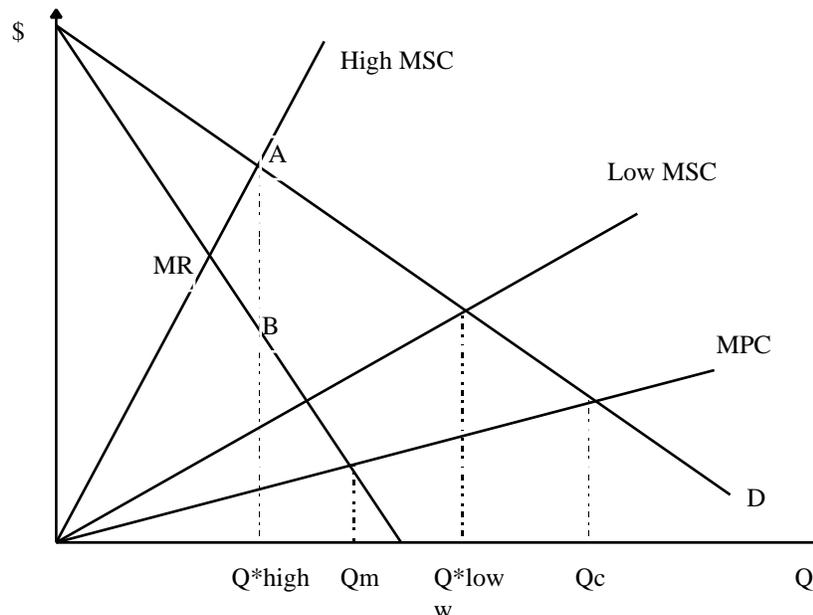
$P_c, Q_c$  = Competitive price and quantity in the market  
 $P_i, Q_i$  = socially optimal price and quantity when demand is inelastic  
 $P_e, Q_e$  = socially optimal price and quantity when demand is elastic

The answers to important policy questions often depend on the magnitudes of key elasticities. Figure 1.3 shows that the elasticity of demand affects the degree of inefficiency associated with a production externality. When demand is inelastic, the socially optimal level of production,  $Q_i$ , is not too far from the competitive level of production,  $Q_c$ . In the extreme case of infinitely inelastic demand, demand may be vertical at the point  $Q_c$ , so that the unregulated and regulated outcomes coincide. Under conditions of highly inelastic demand, the inefficiency associated with a production externality may be small, so that it may not be worth regulating the externality. Under highly elastic demand conditions, however, the socially optimal level of production,  $Q_e$ , is farther away from the competitive level,  $Q_c$ . In this case, the inefficiency associated with the production externality may be relatively large, so that regulation may be desirable.

In some cases, depending on the value of the demand elasticity, producer profit may actually increase under pollution regulation. In figure 1.3, if demand for the final product is inelastic, then a regulation that decreases production, such as a quota/standard designed to reduce pollution, will move producers towards the monopoly level of output. In such a case, producers may actually *desire* regulation, because the increase in market price associated with a lower level of production may actually increase producer surplus! The more inelastic is demand, the higher are producer revenues under regulation and firms are more likely to gain increased profit under pollution regulation.

## Imperfectly Competitive Market Structure and Externality Policy

**Figure 1.4**



In figure 1.4, we can consider two cases:

- one in which MSC is relatively low (i.e. MEC is small);  
“low MSC”
- one in which MSC is relatively high (i.e. MEC is large);  
“high MSC”

In both cases, unregulated competition produces too much output, at point  $Q_c$ . Under a monopoly, however, the unregulated monopolist may produce either too much or too little from a social perspective. In the case of “low MSC”, the optimal output,  $Q^*_{low}$ , is larger than the monopoly output,  $Q_m$ . Hence, under a monopolistic market structure, externality control regulation may not be warranted. In fact, the optimal policy may be to subsidize the polluting monopolist to produce more of the polluting good.

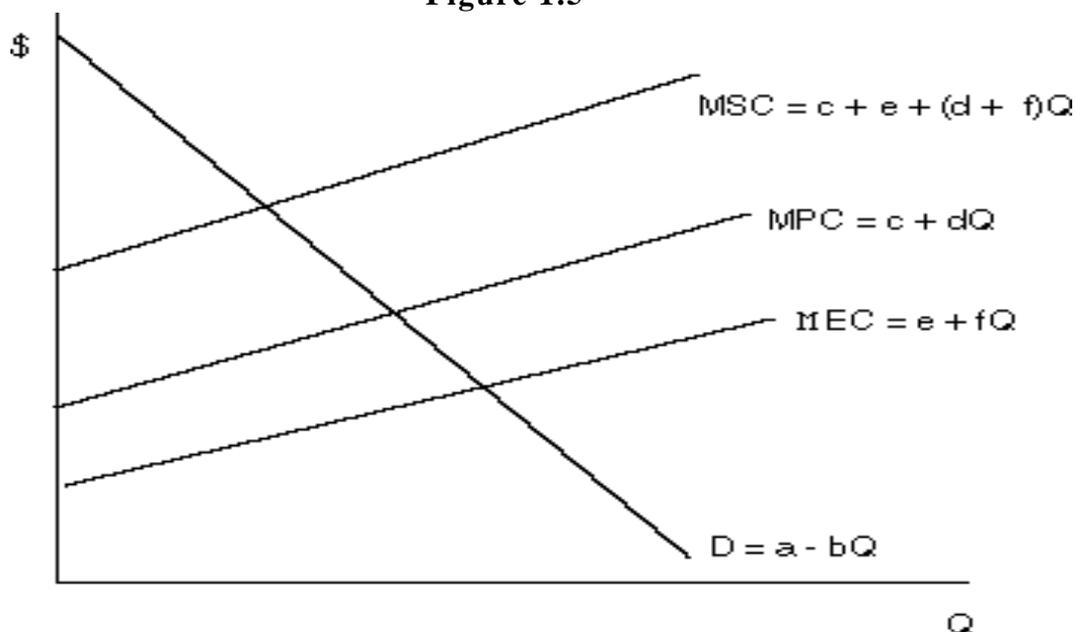
In the case of “high MSC”, the monopolist produces “too much” output from a social perspective, because  $Q^*_{high} < Q_m$ . The optimal tax policy for monopoly, in this case is  $t^*$  = the distance AB. In that case,  $MPC + t^*$  will intersect the Marginal Revenue curve at point B, which causes the monopolist to produce the optimal amount.

In markets with externalities, a monopoly market structure is preferable to unregulated competition whenever the monopolist produces “too much” output

- competitive markets always produce more than a monopolist. Therefore, if the monopolist produces too much, perfectly competitive firms produce *way* too much.

## Production Externalities: An Example

Figure 1.5



### Definitions:

Output:  $Q$ .

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

Total private cost:  $C(Q)$ .

Total externality cost:  $E(Q)$ .

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

$$(1) P = a - bQ$$

Marginal private cost ( $MPC$ ):

$$(2) C(Q) = c + dQ$$

Marginal externality cost ( $MEC$ ):

$$(3) MEC = e + fQ$$

Marginal social cost ( $MSC$ ):

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

### The Social Optimum:

As we derived in class, the social optimum occurs where  $MB = MSC$ . In terms of figure 1.5, this condition is met at:

$$c + e + dQ + fQ = a - bQ \qquad Q^* = \frac{a - c - e}{d + f + b}$$

$$P^* = a - bQ$$

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

### Unregulated vs. Regulated Competition:

*Unregulated competition* will result in:

$$B_Q(Q) = C_Q(Q), \quad \text{or, } MB = MPC, \quad \text{or, in terms of Figure 1.5:}$$

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

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

which is not the socially optimal allocation. The appropriate externality tax,  $t^*$ , needed to bring unregulated competition in line with the social optimum is:

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

So that the result of *regulated competition*,

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

where:

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

produces the socially optimal allocation.

### Unregulated Monopoly

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

$$R = (a - bQ)Q \quad R = aQ - bQ^2 \quad MR = a - 2bQ$$

Then, setting  $MPC = MR$ :

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

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

Compare the monopoly solution with the social optimum. Under what conditions will the monopoly solution coincide with the social optimum?

### 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):

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

Compare the middleman solution with the social optimum. Under what conditions will the middleman solution coincide with the social optimum?

### Practice Problem 1.1:

Assume an econometrician provides you with the following parameter estimates for the economic model presented in this example:

$$\begin{aligned} a &= 50 \\ b &= 1 \\ c &= 0 \\ d &= 1 \\ e &= 0 \\ f &= 1.5 \end{aligned}$$

Find (1) the social optimum, (2) the unregulated competition result, (3) the unregulated monopoly result, and (4) the unregulated middleman result.

### Answers to Practice Problem 1.1:

Assume an econometrician provides you with the following parameter estimates for the economic model presented in Example 1.1:

$$\begin{aligned}a &= 50 \\b &= 1 \\c &= 0 \\d &= 1 \\e &= 0 \\f &= 1.5\end{aligned}$$

Find (1) the social optimum, (2) the unregulated competition result, (3) the unregulated monopoly result, and (4) the unregulated middleman result.

(1) Social Optimum:

$$Q^* = \frac{a - c - e}{d + f + b} \Rightarrow Q = 14.28, \quad P^* = a - \frac{ba - bc - be}{d + f + b} \Rightarrow P = \$35.71$$

(2) Unregulated Competition:

$$Q^c = \frac{a - c}{d + b} \Rightarrow Q = 25, \quad P^c = a - \frac{ba - bc}{b + d} \Rightarrow P = \$25$$

(3) Unregulated Monopoly:

$$Q^M = \frac{a - c}{d + 2b} \Rightarrow Q = 16.66, \quad P^c = a - \frac{ba - bc}{d + 2d} \Rightarrow P = \$33.33$$

(4) Unregulated Middleman:

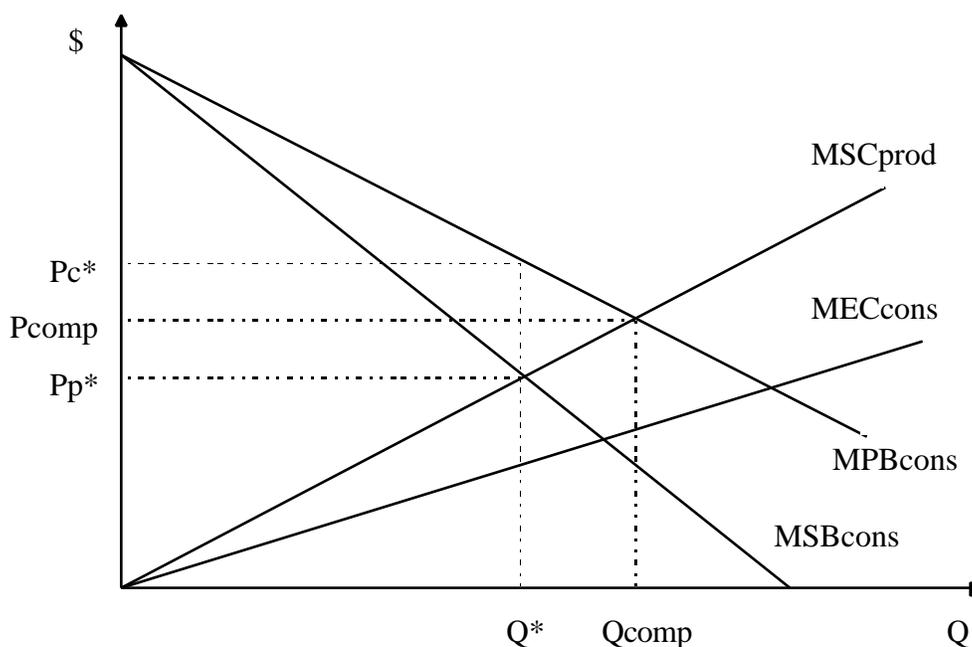
$$Q^D = \frac{a - c}{2b + 2d} \Rightarrow Q = 12.5, \quad P^P = c + \frac{da - dc}{2b + 2d} \Rightarrow PP = \$12.5$$

$$P^c = a - \frac{ba - bc}{2b + 2c} \Rightarrow PC = \$37.5$$

## Consumption Externalities

In the preceding examples, we had *production* externalities in mind. We now turn to examples of goods associated with *consumption* externalities. A consumption externality exists when one individual's consumption imposes costs on other individuals that are not transmitted through a market.

**Figure 1.5. 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)
<u>\$ 5 billion</u>	(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).

### Policy consequences:

- (1) Producers: Restriction on quantities may benefit producers or distributors if elasticity of demand is smaller than 1.
- (2) Tax Shifts Benefit the Government: Tax revenues can be used to compensate victims of smoking damages, or it can be used in lieu of other, distortionary taxes (such as income taxes, sales taxes, etc.) to support government programs.
- (3) Unintended Consequences: May strengthen the case for the legalization of drugs.

## **The Economics of Illicit Drugs**

If cigarette smoking is legal, why should illegal drugs not be legal? It is interesting to many economists that our society has chosen to regulate illicit drugs differently than cigarettes. Some economists, including Milton Friedman and Gary Becker, have argued for a drug legalization policy similar to the policy for cigarettes.

### **The Proposal is the Following:**

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

### **Benefits:**

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

### **Costs:**

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

### **Economic Impacts:**

1. Legalization of drugs would shift income from the illegal network of drug traffickers to government (taxes) and legal marketers (pharmacies).
2. Drug producers may be better off if drug cartels behave like the middlemen, since eliminating drug trafficker middlemen may result in increased quantity and higher producer prices. Hence, poor coca farmers in developing countries, for example, 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. There may be higher health costs associated with drug addiction.

### **Economic analysis of the proposal requires 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.

We can assess these items by developing answers to questions such as: Is the current marketing network competitive? monopolistic? monopolistic competitive? middlemen? Analytical tools we have developed in this lecture may help us to answer these questions.