1. Which of the following describes an externality and which does not? Explain the difference.

a. A policy of restricted coffee exports in Brazil causes the U.S. price of coffee to rise, which in turn also causes the price of tea to rise.

Externalities cause market inefficiencies because the price of the good does not reflect the true social value of the good. A policy of restricting coffee exports in Brazil causes the U.S. price of coffee to rise, because supply is reduced. As the price of coffee rises, consumers switch to tea, thereby increasing the demand for tea, and hence, increasing the price of tea. These are market effects, not externalities.

b. An advertising blimp distracts a motorist who then hits a telephone pole.

An advertising blimp is producing information by announcing the availability of some good or service. However, its method of supplying this information can be distracting for some consumers, especially those consumers who happen to be driving near telephone poles. The blimp is creating a negative externality that influences the drivers’ safety. Since the price charged by the advertising firm does not incorporate the externality of distracting drivers, too much of this type of advertising is produced from the point of view of society as a whole.

2. Compare and contrast the following three mechanisms for treating pollution externalities when the costs and benefits of abatement are uncertain: (a) an emissions fee, (b) an emissions standard, and (c) a system of transferable emissions permits.

Since pollution creates an external cost that is not reflected in the marginal cost of production, its emission creates an externality. Three policy tools can be used to reduce pollution: an emissions fee, an emissions standard, and a system of transferable permits. The choice between a fee and a standard will depend on the marginal cost and marginal benefit of reducing pollution. If small changes in abatement yield large benefits while adding little to cost, the cost of not reducing emissions is high. Thus, standards should be used. However, if small changes in abatement yield little benefit while adding greatly to cost, the cost of reducing emissions is high. Thus, fees should be used.

A system of transferable emissions permits combines the features of fees and standards to reduce pollution. Under this system, a standard is set and fees are used to transfer permits to the firm that values them the most (i.e., a firm with high abatement costs). However, the total number of permits can be incorrectly chosen. Too few permits will create excess demand, increasing price and inefficiently diverting resources to owners of the permits. Typically, pollution control agencies implement one of three mechanisms, measure the results, reassess the success of their choice, then reset new levels of fees or standards or select a new policy tool.

3. When do externalities require government intervention? When is such intervention unlikely to be necessary?

Economic efficiency can be achieved without government intervention when the externality affects a small number of people and when property rights are well specified. When the number of parties is small, the cost of negotiating an agreement among the parties is small. Further, the amount of required information (i.e., the costs of and benefits to each party) is small. When property rights are not well specified, uncertainty regarding costs and benefits increases and efficient choices might not be made. The costs of coming to an agreement, including the cost of delaying such an
agreement, could be greater than the cost of government intervention, including the expected cost of choosing the wrong policy instrument.

4. Consider a market in which a firm has monopoly power. Suppose in addition that the firm produces under the presence of (i) a positive or (ii) a negative externality. Does the externality necessarily lead to a greater misallocation of resources?

In the presence of a negative externality the market will produce too much output, as compared to the socially optimal solution. The monopolist will however produce too little output. It is possible therefore that the monopolist by himself will produce closer to the socially optimal solution than the competitive firms would. For the case of the positive externality the competitive firms will produce too little output, the monopolist will produce even less, and the monopolist is therefore leading to a greater misallocation of resources.

5. Externalities arise solely because individuals are unaware of the consequences of their actions. Agree or disagree? Explain.

This is not a true statement. It is not that people are unaware but that they are not forced to consider and account for all of the consequences of their actions. If a firm dumps waste into a river that affects a swimming area downstream it is generating an externality given it is not forced to consider the cost it is imposing on users of the swimming area. This is true whether the firm is aware of these costs or not.

6. To encourage an industry to produce at the socially optimal level the government should impose a unit tax on output that is equal to the marginal cost of production. True or false? Explain.

This statement is false. While a tax can encourage firms to produce at the socially optimal level, the tax should be set equal to the marginal external cost and not the marginal private cost. Firms will maximize profit by producing at the point where price is equal to marginal cost. When there are external costs involved the marginal cost of the firm is too low from society's point of view, and as a result too much output is produced. By setting a tax equal to the additional cost not being realized by the firm (the marginal external cost) the firm will be encouraged to consider all costs and will reduce output because the tax will increase the overall marginal cost.

7. George and Stan live next door to each other. George likes to plant flowers in his garden, but every time he does, Stan's dog comes over and digs them up. Since it is Stan's dog that is causing the damage, if economic efficiency is to be achieved, it is necessary that Stan pay to put up a fence around his yard to keep the dog in. Agree or disagree? Explain.

If there are leash laws then this would be true. Stan would either need to keep his dog on a leash or put up a fence. In general, it is possible for the two parties to bargain and come up with a solution that will benefit both of them. They could for example split the cost of the fence. Economic efficiency does not require that Stan pay for the fence. It merely requires that Stan and George negotiate over how best to address the problem and come up with a solution that will work for both of them.

8. An emissions fee is paid to the government, whereas an injurer who is sued and held liable pays damages directly to the party harmed by an externality. What differences in the behavior of victims might you expect to arise under these two arrangements?

When victims can receive the damages directly, they are more likely to file a claim, initiate a suit, and try to overstate their damages. When victims are not able to receive the damages directly, they are less likely to report violations and are less likely to overstate their damages. In theory, emissions fees paid to the government require the polluting firm to pay compensation for any damage inflicted and hence to move towards the socially optimal level of production. An individual who is injured by a firm's polluting behavior is again less likely to file a complaint if they do not feel they can directly receive the compensation.
9. Why does free access to a common property resource generate an inefficient outcome?

Free access to a resource means that the marginal cost to the user is less than the social cost because each user has no incentive to consider how his use of the resource will affect the use of the resource by other users. The use of a common property resource by a person or firm excludes others from using it. For example, the use of water by one consumer restricts its use by another. Since private marginal cost is below social marginal cost, too much of the resource is consumed by the individual user, creating an inefficient outcome. Each individual using the common property resource considers only his own actions and does not consider how all of the users collectively are impacting the resource.

10. Public goods are both nonrival and nonexclusive. Explain each of these terms and show clearly how they differ from each other.

A good is nonrival if, for any level of production, the marginal cost of providing the good to an additional consumer is zero (although the production cost of an additional unit could be greater than zero). A good is nonexclusive if it is impossible or very expensive to exclude individuals from consuming it. Public goods are nonrival and nonexclusive. Commodities can be (1) exclusive and rival, (2) exclusive and nonrival, (3) nonexclusive and rival, or (4) nonexclusive and nonrival. Most of the commodities discussed in the text to this point have been of the first type. In this chapter, we focus on commodities of the last type.

Nonrival refers to the production of a good or service for one more customer. It usually involves a production process with high fixed costs, such as the cost of building a highway or lighthouse. (Remember that fixed cost depends on the period under consideration: the cost of lighting the lamp at the lighthouse can vary over time, but does not vary with the number of consumers.) Nonexclusive refers to exchange, where the cost of charging consumers is prohibitive. Incurring the cost of identifying consumers and collecting from them would result in losses. Some economists focus on the nonexclusion property of public goods because it is this characteristic that poses the most significant problems for efficient provision.

11. A village is located next to 1000 acres of prime grazing land. The village presently owns the land and allows all residents to graze cows freely. Some members of the village council have suggested that the land is being overgrazed. Is this likely to be true? These same members have also suggested that the village should either require grazers to purchase an annual permit, or sell off the land to the grazers. Would either of these be a good idea?

It is true that the common land is likely to be overgrazed since each individual will consider only their own private cost and not the true social cost of grazing. The social cost of grazing is likely to be higher than any one individual's private cost because no one individual has an incentive to take into account how his grazing affects the opportunities of others. For example, one individual could decide to graze only in certain areas during certain times of the year, while preserving other areas for other times of the year. However, the individual will not do this if the resource is common property as any other grazer can come along and freely disrupt the preservation system that the individual has set up. Selling annual permits or selling the land outright would be viable options to the overgrazing problem. By requiring the grazers to buy a permit, their marginal costs will go up and grazing should go down. If an individual purchases the land they will then have an incentive to consider all of the costs associated with using the land, and as a result will use it in such a way that the resource is preserved since they alone capture all of the benefits of preserving the resource.
12. Public television is funded in part by private donations, even though anyone with a television set can watch for free. Can you explain this phenomenon in light of the free rider problem?

The free-rider problem refers to the difficulty of excluding persons from consuming a nonexclusive commodity. Non-paying consumers can “free-ride” on commodities provided by paying customers. Public television is funded in part by contributions. Some viewers contribute, but most watch without paying, hoping that someone else will pay so they will not. To combat this problem these stations (1) ask consumers to assess their true willingness to pay, then (2) ask consumers to contribute up to this amount, and (3) attempt to make everyone else feel guilty for free-riding.

13. Explain why the median voter outcome need not be efficient when majority rule voting determines the level of public spending.

The median voter is the citizen with the middle preference: half the voting population is more strongly in favor of the issue and half is more strongly opposed to the issue. Under majority-rule voting, where each citizen’s vote is weighted equally, the preferred spending level on public-goods provision of the median voter will win an election against any other alternative. However, majority rule is not necessarily efficient, because it gives each citizen’s preferences equal weight. For an efficient outcome, we would need a system that measures and aggregates the willingness to pay of those citizens consuming the public good. Majority rule is not this system. However, as we have seen in previous chapters, majority rule is equitable in the sense that all citizens are treated equally. Thus, we again find a trade-off between equity and efficiency.

EXERCISES

1. A number of firms have located in the western portion of a town after single-family residences took up the eastern portion. Each firm produces the same product and, in the process, emits noxious fumes that adversely affect the residents of the community.

   a. Why is there an externality created by the firms?

      Noxious fumes created by firms enter the utility function of residents, and the residents have no control over the quantity of the fumes. We can assume that the fumes decrease the utility of the residents (i.e., they are a negative externality) and lower property values.

   b. Do you think that private bargaining can resolve the problem? Explain.

      If the residents anticipated the location of the firms, housing prices should reflect the disutility of the fumes; the externality would have been internalized by the housing market in housing prices. If the noxious fumes were not anticipated, private bargaining could resolve the problem of the externality only if there are a relatively small number of parties (both firms and families) and property rights are well specified. Private bargaining would rely on each family’s willingness to pay for air quality, but truthful revelation might not be possible. All this will be complicated by the adaptability of the production technology known to the firms and the employment relations between the firms and families. It is unlikely that private bargaining will resolve the problem.

   c. How might the community determine the efficient level of air quality?

      The community could determine the economically efficient level of air quality by aggregating the families’ willingness to pay and equating it with the marginal cost of pollution reduction. Both steps involve the acquisition of truthful information.
2. A computer programmer lobbies against copyrighting software, arguing that everyone should benefit from innovative programs written for personal computers and that exposure to a wide variety of computer programs will inspire young programmers to create even more innovative programs. Considering the marginal social benefits possibly gained by this proposal, do you agree with this position?

Computer software as information is a classic example of a public good. Since it can be costlessly copied, the marginal cost of providing software to an additional user is near zero. Therefore, software is nonrival. (The fixed costs of creating software are high, but the variable costs are low.) Furthermore, it is expensive to exclude consumers from copying and using software because copy protection schemes are available only at high cost or high inconvenience to users. Therefore, software is also nonexclusive. As both nonrival and nonexclusive, computer software suffers the problems of public goods provision: the presence of free-riders makes it difficult or impossible for markets to provide the efficient level of software. Rather than regulating this market directly, the legal system guarantees property rights to the creators of software. If copyright protection were not enforced, it is likely that the software market would collapse, or that there would be a significant decrease in the quantity of software developed and supplied, which would reduce the marginal social benefits. Therefore, we do not agree with the computer programmer.

3. Assume that scientific studies provide you with the following information concerning the benefits and costs of sulfur dioxide emissions:

Benefits of abating (reducing) emissions: \( MB = 500 - 20A \)

Costs of abating emissions: \( MC = 200 + 5A \)

where \( A \) is the quantity abated in millions of tons and the benefits and costs are given in dollars per ton.

a. What is the socially efficient level of emissions abatement?

To find the socially efficient level of emissions abatement, set marginal benefit equal to marginal cost and solve for \( A \):

\[
500 - 20A = 200 + 5A
\]

\[
A = 12.
\]

b. What are the marginal benefit and marginal cost of abatement at the socially efficient level of abatement?

Plug \( A = 12 \) into the marginal benefit and marginal cost functions to find the benefit and cost:

\[
MB = 500 - 20(12) = 260
\]

\[
MC = 200 + 5(12) = 260.
\]

c. What happens to net social benefits (benefits minus costs) if you abate 1 million more tons than the efficient level? 1 million fewer?

Net social benefits are the area under the marginal benefit curve minus the area under the marginal cost curve. At the socially efficient level of abatement this is equal to area \( a + b + c + d \) in Figure 18.3.c or

\[
0.5(500-200)(12) = 1800 \text{ million dollars.}
\]

If you abate 1 million more tons then the net social benefit is area \( a + b + c + d - e \) or

\[
1800 - 0.5(265-240)(1) = 1800 - 12.5 = 1787.5 \text{ million dollars.}
\]

If you abate 1 million less tons then the net social benefit is area \( a + b \) or

\[
0.5(500-280)(11) + (280-255)(11) + 0.5(255-200)(11) = 1787.5 \text{ million dollars.}
\]
d. Why is it socially efficient to set marginal benefits equal to marginal costs rather than abating until total benefits equal total costs?

It is socially efficient to set marginal benefit equal to marginal cost rather than total benefit equal to total cost because we want to maximize net benefits, which are total benefit minus total cost. Maximizing total benefit minus total cost means that at the margin, the last unit abated will have an equal cost and benefit. Choosing the point where total benefit is equal to total cost will result in too much abatement, and would be analogous to choosing to produce where total revenue was equal to total cost. If total revenue was always equal to total cost by choice, then there would never be any profit. In the case of abatement, the more we abate, the costlier it is. Given that funds will tend to be scarce, dollars should be allocated to abatement only so long as the benefit of the last unit of abatement is greater than or equal to the cost of the last unit of abatement.

![Diagram](image)

Figure 18.3.c

4. Four firms located at different points on a river dump various quantities of effluent into it. The effluent adversely affects the quality of swimming for homeowners who live downstream. These people can build swimming pools to avoid swimming in the river, and firms can purchase filters that eliminate harmful chemicals in the material dumped in the river. As a policy advisor for a regional planning organization, how would you compare and contrast the following options for dealing with the harmful effect of the effluent:

a. An equal-rate effluent fee on firms located on the river.

First, one needs to know the value to homeowners of swimming in the river. This information can be difficult to obtain, because homeowners will have an incentive to overstate this value. As an upper boundary, if there are no considerations other than swimming, one could use the cost of building swimming pools, either a pool for each homeowner or a public pool for all homeowners. Next, one needs to know the marginal cost of abatement. If the abatement technology is well understood, this information should be readily obtainable. If the abatement technology is not understood, an estimate based on the firms' knowledge must be used.
Chapter 18: Externalities and Public Goods

The choice of a policy tool will depend on the marginal benefits and costs of abatement. If firms are charged an equal-rate effluent fee, the firms will reduce effluents to the point where the marginal cost of abatement is equal to the fee. If this reduction is not high enough to permit swimming, the fee could be increased. Alternatively, revenue from the fees could be used to provide swimming facilities, reducing the need for effluent reduction.

b. An equal standard per firm on the level of effluent that each can dump.

Standards will be efficient only if the policy maker has complete information regarding the marginal costs and benefits of abatement, so that the efficient level of the standard can be determined. Moreover, the standard will not encourage firms to reduce effluents further when new filtering technologies become available.

c. A transferable effluent permit system in which the aggregate level of effluent is fixed and all firms receive identical permits.

A transferable effluent permit system requires the policy maker to determine the efficient effluent standard. Once the permits are distributed and a market develops, firms with a higher cost of abatement will purchase permits from firms with lower abatement costs. However, unless permits are sold initially, rather than merely distributed, no revenue will be generated for the regional organization.

5. Medical research has shown the negative health effects of “secondhand” smoke. Recent social trends point to growing intolerance of smoking in public areas. If you are a smoker and you wish to continue smoking despite tougher anti-smoking laws, describe the effect of the following legislative proposals on your behavior. As a result of these programs, do you, the individual smoker, benefit? Does society benefit as a whole?

Since smoking in public areas is similar to polluting the air, the programs proposed here are similar to those examined for air pollution. A bill to lower tar and nicotine levels is similar to an emissions standard, and a tax on cigarettes is similar to an emissions fee. Requiring a smoking permit is similar to a system of emissions permits, assuming that the permits would not be transferable. The individual smoker in all of these programs is being forced to internalize the externality of “second-hand” smoke and will be worse off. Society will be better off if the benefits of a particular proposal outweigh the cost of implementing that proposal. Unfortunately, the benefits of reducing second-hand smoke are uncertain, and assessing those benefits is costly.

a. A bill is proposed that would lower tar and nicotine levels in all cigarettes.

The smoker will most likely try to maintain a constant level of consumption of nicotine, and will increase his or her consumption of cigarettes. Society may not benefit from this plan if the total amount of tar and nicotine released into the air is the same.

b. A tax is levied on each pack of cigarettes sold.

Smokers might turn to cigars, pipes, or might start rolling their own cigarettes. The extent of the effect of a tax on cigarette consumption depends on the elasticity of demand for cigarettes. Again, it is questionable whether society will benefit.

c. Smokers would be required to carry government issued smoking permits at all times.

Smoking permits would effectively transfer property rights to clean air from smokers to non-smokers. The main obstacle to society benefiting from such a proposal would be the high cost of enforcing a smoking permits system. In addition, the cost of the permit raises the effective price of the cigarettes and the resulting affect on quantity smoked will depend on the elasticity of demand.
6. The market for paper in a particular region in the United States is characterized by the following demand and supply curves

\[ Q_D = 160,000 - 2000P \] and \[ Q_S = 40,000 + 2000P, \]

where \( Q_D \) is the quantity demanded of paper in 100 lb. lots, \( Q_S \) is the quantity demanded of paper in 100 lb. lots, and \( P \) is the price per 100 lb. lot of paper. Currently there is no attempt to regulate the dumping of effluent into streams and rivers by the paper mills. As a result, dumping is widespread. The marginal external cost (\( MEC \)) associated with the production of paper is given by the curve \( MEC = 0.0006Q_S \).

a. Calculate the output and price of paper if it is produced under competitive conditions and no attempt is made to monitor or regulate the dumping of effluent.

The equilibrium price and output would be where quantity demand is equal to quantity supplied:

\[ 160,000 - 2000P = 40,000 + 2000P \]
\[ 4000P = 120,000 \]
\[ P = $30 \text{ per 100 lb. lot} \]
\[ Q = 100,000 \text{ lots of 100 lb. each}. \]

b. Determine the socially efficient price and output of paper.

To find the socially efficient solution, we need to consider the external costs, as given by \( MEC = 0.0006Q_S \), as well as the private costs, as given by \( Q_S = 40,000 + 2000P \).

Rewriting the supply curve, the private costs are \( P = 0.0005Q_S - 20 = MC \). Therefore,

\[ MSC = MC + MEC = 0.0005Q_S - 20 + 0.0006Q_S \]
\[ MSC = 0.0011Q_S - 20. \]

Setting the marginal social cost equal to the demand curve, or the marginal benefit,

\[ 0.0011Q_S - 20 = 80 - 0.0005Q \]
\[ Q = 62,500 \text{ lots of 100 lb. each}. \]
\[ P = $48.75 \text{ per 100 lb. lot}. \]

c. Explain clearly why the answers you calculated in parts a and b differ.

The equilibrium quantity declined and the equilibrium price rose in part b because the external costs were considered. Ignoring some of the costs will result in too much output being produced and sold at too low of a price.

7. In a market for dry cleaning, the inverse market demand function is given by \( P = 100 - Q \) and the (private) marginal cost of production for the aggregation of all dry cleaning firms is given by \( MC = 10 + Q \). Finally, the pollution generated by the dry cleaning process creates external damages given by the marginal external cost curve \( MEC = Q \).

a. Calculate the output and price of dry cleaning if it is produced under competitive conditions absent regulation.

To find the answer, set price equal to marginal cost:

\[ 100 - Q = 10 + Q, \]
\[ Q = 45, \text{ and } P = 55. \]

b. Determine the socially efficient price and output of dry cleaning.

To find the answer here, we must first calculate the marginal social cost (MSC), which is equal to the marginal external cost plus the private marginal cost. Next,
set MSC equal to the market demand function to solve for price and quantity. When all costs are included, the quantity produced will fall and the price will rise:

\[ MSC = MC + MEC = 10 + 2Q = 100 - Q, \]

\[ Q = 30, \text{ and } P = 70. \]

c. **Determine the tax that would result in a competitive market producing the socially efficient output.**

If there is a unit tax, then the new marginal private cost function is \( MC' = 10 + Q + tQ \). If we now set this new marginal cost function equal to the price of 70 and substitute in 30 for the quantity, we can solve for \( t \):

\[
\begin{align*}
10 + Q + tQ &= 70 \\
Q(1 + t) &= 60 \\
1 + t &= 2 \\
t &= 1.
\end{align*}
\]

The tax should be $1 per unit output. Note that with the tax equal to 1, the new private cost function is the same as the marginal social cost function.

d. **Calculate the output and price of dry cleaning if it is produced under monopolistic conditions without regulation.**

The monopolist will set marginal cost equal to marginal revenue. Recall that the marginal revenue curve has a slope that is twice the slope of the demand curve so \( MR = 100 - 2Q = MC = 10 + Q \). Therefore, \( Q = 30 \) and \( P = 70. \)

e. **Determine the tax that would result in a monopolistic market producing the socially efficient output.**

The tax is equal to zero since the monopolist will produce at the socially efficient output in this case.

f. **Assuming that no attempt is made to monitor or regulate the pollution, which market structure yields higher social welfare? Discuss.**

In this case it is actually the monopolist that yields the higher level of social welfare over the competitive market since the monopolist’s profit maximizing price and quantity are the same as the socially efficient solution. Since a monopolist tends to produce less output than the competitive equilibrium, it may end up producing closer to the social equilibrium when a negative externality is present.

8. A beekeeper lives adjacent to an apple orchard. The orchard owner benefits from the bees because each hive pollinates about one acre of apple trees. The orchard owner pays nothing for this service, however, because the bees come to the orchard without his having to do anything. Because there are not enough bees to pollinate the entire orchard, the orchard owner must complete the pollination by artificial means, at a cost of $10 per acre of trees.

Beekeeping has a marginal cost of \( MC = 10 + 5Q \), where \( Q \) is the number of beehives. Each hive yields $40 worth of honey.

a. **How many beehives will the beekeeper maintain?**

The beekeeper maintains the number of hives that maximizes profits, when marginal revenue is equal to marginal cost. With a constant marginal revenue of $40 (there is no information that would lead us to believe that the beekeeper has any market power) and a marginal cost of \( 10 + 5Q \):

\[ 40 = 10 + 5Q, \text{ or } Q = 6. \]
b. **Is this the economically efficient number of hives?**

If there are too few bees to pollinate the orchard, the farmer must pay $10 per acre for artificial pollination. Thus, the farmer would be willing to pay up to $10 to the beekeeper to maintain each additional hive. So, the marginal social benefit, $MSB$, of each additional hive is $50, which is greater than the marginal private benefit of $40. Assuming that the private marginal cost is equal to the social marginal cost, we set $MSB = MC$ to determine the efficient number of hives:

$$50 = 10 + 5Q,$$

or $Q = 8$.

Therefore, the beekeeper's private choice of $Q = 6$ is not the socially efficient number of hives.

c. **What changes would lead to the more efficient operation?**

The most radical change that would lead to more efficient operations would be the merger of the farmer's business with the beekeeper's business. This merger would internalize the positive externality of bee pollination. Short of a merger, the farmer and beekeeper should enter into a contract for pollination services.

9. **There are three groups in a community.** Their demand curves for public television in hours of programming, $T$, are given respectively by

- $W_1 = 200 - T$,
- $W_2 = 240 - T$,
- $W_3 = 320 - 2T$.

Suppose public television is a pure public good that can be produced at a constant marginal cost of $200 per hour.

a. **What is the efficient number of hours of public television?**

The efficient number of hours is the amount such that the sum of the marginal benefits is equal to marginal cost. Given the demand curves representing the marginal benefits to each individual, we sum these demand curves vertically to determine the sum of all marginal benefits. From the table below one can see that $MSB = MC$ at $T = 140$ hours of programming.

<table>
<thead>
<tr>
<th>Time</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Vertical Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>200</td>
<td>240</td>
<td>320</td>
<td>760</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>140</td>
<td>120</td>
<td>360</td>
</tr>
<tr>
<td>120</td>
<td>80</td>
<td>120</td>
<td>80</td>
<td>280</td>
</tr>
<tr>
<td>140</td>
<td>60</td>
<td>100</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>160</td>
<td>40</td>
<td>80</td>
<td>0</td>
<td>120</td>
</tr>
<tr>
<td>180</td>
<td>20</td>
<td>60</td>
<td>0</td>
<td>80</td>
</tr>
</tbody>
</table>

b. **How much public television would a competitive private market provide?**

To find the number of hours that the private market would provide, we add the individual demand curves horizontally. The efficient number of hours is such that the private marginal cost is equal to the private marginal benefit. The demand curve for group 1 lies below $MC = 200$ for all $T > 0$. With marginal cost equal to $200$, only
groups 2 and 3 would be willing to pay $200. At that price, 100 hours of programming would be provided.

<table>
<thead>
<tr>
<th>Price</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Horizontal Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>220</td>
<td>0</td>
<td>20</td>
<td>50</td>
<td>70</td>
</tr>
<tr>
<td>200</td>
<td>0</td>
<td>40</td>
<td>60</td>
<td>100</td>
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<tr>
<td>180</td>
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<td>60</td>
<td>70</td>
<td>150</td>
</tr>
<tr>
<td>160</td>
<td>40</td>
<td>80</td>
<td>80</td>
<td>200</td>
</tr>
<tr>
<td>140</td>
<td>60</td>
<td>100</td>
<td>90</td>
<td>250</td>
</tr>
</tbody>
</table>

10. Reconsider the common resource problem as given by Example 18.5. Suppose that crawfish popularity continues to increase, and that the demand curve shifts from \( C = 0.401 - 0.0064F \) to \( C = 0.50 - 0.0064F \). How does this shift in demand affect the actual crawfish catch, the efficient catch, and the social cost of common access? (Hint: Use the marginal social cost and private cost curves given in the example.)

The relevant information is now the following:

**Demand:** \( C = 0.50 \cdot 0.0064F \)

**MSC:** \( C = -5.645 + 0.6509F. \)

With an increase in demand, the demand curve for crawfish shifts upward, intersecting the price axis at $0.50. The private cost curve has a positive slope, so additional effort must be made to increase the catch. Since the social cost curve has a positive slope, the socially efficient catch also increases. We may determine the socially efficient catch by solving the following two equations simultaneously:

\[
0.50 \cdot 0.0064F = -5.645 + 0.6509F, \text{ or } F^* = 9.35.
\]

To determine the price that consumers are willing to pay for this quantity, substitute \( F^* \) into the equation for marginal social cost and solve for \( C \):

\[
C = -5.645 + (0.6509)(9.35), \text{ or } C = $0.44.
\]

Next, find the actual level of production by solving these equations simultaneously:

**Demand:** \( C = 0.50 \cdot 0.0064F \)

**MPC:** \( C = -0.357 + 0.0573F \)

\[
0.50 \cdot 0.0064F = -0.357 + 0.0573F, \text{ or } F^{**} = 13.45.
\]

To determine the price that consumers are willing to pay for this quantity, substitute \( F^{**} \) into the equation for marginal private cost and solve for \( C \):

\[
C = -0.357 + (0.0573)(13.45), \text{ or } C = $0.41.
\]

Notice that the marginal social cost of producing 13.45 units is

\[
MSC = -5.645 + (0.6509)(13.45) = $3.11.
\]

With the increase in demand, the social cost is the area of a triangle with a base of 4.1 million pounds (13.45 - 9.35) and a height of $2.70 ($3.11 - 0.41), or $5,535,000 more than the social cost of the original demand.
11. The Georges Bank, a highly productive fishing area off New England, can be divided into two zones in terms of fish population. Zone 1 has the higher population per square mile but is subject to severe diminishing returns to fishing effort. The daily fish catch (in tons) in Zone 1 is

\[ F_1 = 200(X_1) - 2(X_1)^2 \]

where \( X_1 \) is the number of boats fishing there. Zone 2 has fewer fish per mile but is larger, and diminishing returns are less of a problem. Its daily fish catch is

\[ F_2 = 100(X_2) - (X_2)^2 \]

where \( X_2 \) is the number of boats fishing in Zone 2. The marginal fish catch MFC in each zone can be represented as

\[ MFC_1 = 200 - 4(X_1) \quad \text{MFC}_2 = 100 - 2(X_2). \]

There are 100 boats now licensed by the U.S. government to fish in these two zones. The fish are sold at $100 per ton. Total cost (capital and operating) per boat is constant at $1,000 per day. Answer the following questions about this situation:

a. If the boats are allowed to fish where they want, with no government restriction, how many will fish in each zone? What will be the gross value of the catch?

Without restrictions, the boats will divide themselves so that the average catch (\( AF_1 \) and \( AF_2 \)) for each boat is equal in each zone. (If the average catch in one zone is greater than in the other, boats will leave the zone with the lower catch for the zone with the higher catch.) We solve the following set of equations:

\[ AF_1 = AF_2 \quad \text{and} \quad X_1 + X_2 = 100 \]

\[ AF_1 = \frac{200X_1 - 2(X_1)^2}{X_1} = 200 - 2X_1 \quad \text{and} \]

\[ AF_2 = \frac{100X_2 - (X_2)^2}{X_2} = 100 - X_2. \]

Therefore, \( AF_1 = AF_2 \) implies

\[ 200 \cdot 2X_1 = 100 \cdot X_2, \]

\[ 200 \cdot 2(100 \cdot X_2) = 100 \cdot X_2, \text{ or } X_2 = \frac{100}{3} \quad \text{and} \]

\[ X_1 = 100 - \left( \frac{100}{3} \right) = \frac{200}{3}. \]

Find the gross catch by substituting the value of \( X_1 \) and \( X_2 \) into the catch equations:

\[ F_1 = (200) \left( \frac{200}{3} \right) - (2) \left( \frac{200}{3} \right)^2 = 13,333 - 8,889 = 4,444, \quad \text{and} \]

\[ F_2 = (100) \left( \frac{100}{3} \right) - \left( \frac{100}{3} \right)^2 = 3,333 - 1,111 = 2,222. \]

The total catch is \( F_1 + F_2 = 6,666 \). At the price of $100 per ton, the value of the catch is $666,600. The average catch for each of the 100 boats in the fishing fleet is 66.66 tons.

To determine the profit per boat, subtract total cost from total revenue:

\[ \pi = (100)(66.66) - 1,000, \text{ or } \pi = 5,666. \]

Total profit for the fleet is $566,600.
b. If the U.S. government can restrict the boats, how many should be allocated to each zone? What will be the gross value of the catch? Assume the total number of boats remains at 100.

Assume that the government wishes to maximize the net social value of the fish catch, i.e., the difference between the total social benefit and the total social cost. The government equates the marginal fish catch in both zones, subject to the restriction that the number of boats equals 100:

\[ MFC_1 = MFC_2 \text{ and } X_1 + X_2 = 100, \]
\[ MFC_1 = 200 \cdot 4X_1 \text{ and } MFC_2 = 100 \cdot 2X_2. \]

Setting \( MFC_1 = MFC_2 \) implies:

\[ 200 - 4X_1 = 100 - 2X_2, \]
\[ 200 - 4(100 - X_2) = 100 - 2X_2, \]
\[ X_2 = 50 \text{ and } X_1 = 100 - 50 = 50. \]

Find the gross catch by substituting \( X_1 \) and \( X_2 \) into the catch equations:

\[ F_1 = (200)(50) - 2(50^2) = 10,000 - 5,000 = 5,000 \text{ and } \]
\[ F_2 = (100)(50) - 50^2 = 5,000 - 2,500 = 2,500. \]

The total catch is equal to \( F_1 + F_2 = 7,500 \). At the market price of $100 per ton, the value of the catch is $750,000. Total profit is $650,000. Notice that the profits are not evenly divided between boats in the two zones. The average catch in Zone A is 100 tons per boat, while the average catch in Zone B is 50 tons per boat. Therefore, fishing in Zone A yields a higher profit for the individual owner of the boat.

c. If additional fishermen want to buy boats and join the fishing fleet, should a government wishing to maximize the net value of the catch grant them licenses? Why or why not?

To answer this question, first determine the profit-maximizing number of boats in each zone. Profits in Zone A are

\[ \pi_A = (100)(200X_1 - 2X_1^2) - 1,000X_1 \text{ or } \pi_A = 19,000X_1 - 200X_1^2. \]

To determine the change in profit with a change in \( X_1 \) take the first derivative of the profit function with respect to \( X_1 \):

\[ \frac{d\pi_A}{dX_1} = 19,000 - 400X_1. \]

To determine the profit-maximizing level of output, set \( \frac{d\pi_A}{dX_1} \) equal to zero and solve for \( X_1 \):

\[ 19,000 - 400X_1 = 0, \text{ or } X_1 = 47.5. \]

Substituting \( X_1 \) into the profit equation for Zone A gives:

\[ \pi_A = (100)(200(47.5) - 2(47.5^2)) - 1,000(47.5) = $451,250. \]

For Zone B follow a similar procedure. Profits in Zone B are

\[ \pi_B = (100)(100X_2 - X_2^2) - 1,000X_2, \text{ or } \pi_B = 9,000X_2 - 100X_2^2. \]

Taking the derivative of the profit function with respect to \( X_2 \) gives

\[ \frac{d\pi_B}{dX_2} = 9,000 - 200X_2. \]
Chapter 18: Externalities and Public Goods

Setting \( \frac{d\pi_B}{dX_2} \) equal to zero to find the profit-maximizing level of output gives

\[ 9,000 - 200X_2 = 0, \text{ or } X_2 = 45. \]

Substituting \( X_2 \) into the profit equation for Zone B gives:

\[ \pi_B = (100)((100)(45) - 45^2) \cdot (1,000)(45) = $202,500. \]

Total profit from both zones is $653,750, with 47.5 boats in Zone A and 45 boats in Zone B. Because each additional boat above 92.5 decreases total profit, the government should not grant any more licenses.