Externalities and Public Goods
# Chapter 17

## Chapter Outline

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1</td>
<td>Externalities</td>
</tr>
<tr>
<td>17.2</td>
<td>Correcting Externalities</td>
</tr>
<tr>
<td>17.3</td>
<td>The Coase Theorem: Free Markets Addressing Externalities on Their Own</td>
</tr>
<tr>
<td>17.4</td>
<td>Public Goods</td>
</tr>
<tr>
<td>17.5</td>
<td>Conclusion</td>
</tr>
</tbody>
</table>
Pollution is a major fact of life around the world.

- The United States has areas (notably urban) struggling with air quality; the health costs are estimated at more than $100 billion per year.
- Much pollution is due to coal-fired power plants operating both domestically and abroad.

Other forms of pollution are also common.

- The noise of your neighbor’s party
- The person smoking next to you
- The mess in someone’s lawn
These outcomes are evidence of a market failure.

- Markets are efficient when all transactions that positively benefit society take place.
- An efficient market takes all costs and benefits, both private and social, into account.
- Similarly, the smoker in the park is concerned only with his enjoyment, not the costs imposed on other people in the park.
- An efficient market takes these additional costs into account.

Asymmetric information is a source of market failure that we considered in the last chapter. Here, we discuss two further sources.

1. Externalities
2. Public goods
Externalities: A cost or benefit that affects a party not directly involved in a transaction.

- **Negative externality**: A cost imposed on a party not directly involved in a transaction
  - Example: Air pollution from coal-fired power plants

- **Positive externality**: A benefit conferred on a party not directly involved in a transaction
  - Example: A beekeeper’s bees not only produce honey but can help neighboring farmers by pollinating crops.
Economic Inefficiencies from Externalities

In the presence of externalities, society’s benefit or cost is different from the private benefit or cost to those who are party to the transaction.

For example, consider a smoker.

The private costs of smoking (in part):
- The cost of purchase
- Smelly clothing, yellow teeth, occasional cigarette burns
- Private health costs

Societal costs (in part):
- Second-hand smoke’s health effects
- Any of the smoker’s health costs that are borne by society
- The smell imposed on nonsmokers
Externalities

Economic Inefficiencies from Externalities

**External marginal cost:** The cost imposed on a third party when an additional unit of a good is produced or consumed.

**External marginal benefit:** The benefit conferred on a third party when an additional unit of a good is produced or consumed.
Economic Inefficiencies from Externalities

When there are no externalities, society’s costs and benefits align with the costs and benefits of the private parties to a transaction.

When there are externalities, the social costs and social benefits will differ from the private costs and private benefits.

- **Social cost**: The cost of a transaction to society, equal to the private cost plus the external marginal cost.
- **Social benefit**: The benefit of a transaction to society, equal to the private benefit plus the external marginal benefit.
Externalities

Negative Externalities: Too Much of a Bad Thing

Negative externalities occur when a market transaction imposes an external cost on society.

Consider the example of a coal-fired power plant.

- The power plant produces electricity, which is good, but in the process, it releases pollutants into the air: particulate matter, nitrogen oxides (NOx), and sulfur dioxide (SO₂).
- These pollutants both directly and indirectly damage human and environmental health, leading to welfare losses.

The costs of operating the plant are borne by the plant, but the health effects are external costs, borne by society.

Consider a competitive market for electricity.
Figure 17.1 Negative Externalities in a Competitive Electricity Market

Social marginal cost, 
\[ SMC = MC_I + EMC \]

A competitive electricity market produces \( Q_{MKT} \) at market price \( P_{MKT} \) where \( S = MC_I = D \).

At this quantity, the industry imposes external marginal cost \( EMC \).

\( SMC \) equals the sum of \( MC_I \) and \( EMC \).

Total surplus is maximized at \( Q^* < Q_{MKT} \) where price \( P^* \) equals \( SMC \).
Negative Externalities: Too Much of a Bad Thing

The deadweight loss on the previous slide represents the social cost associated with the competitive outcome in the presence of an externality. The magnitude of the deadweight loss depends on two factors:

• The size of the externality
• Electricity that wouldn’t be bought if the price reflected the true social cost.
Positive Externalities: Not Enough of a Good Thing

Positive externalities exist when an economic activity has a spillover benefit enjoyed by third parties.

- Marginal social benefit of an economic activity higher than the private marginal benefit (i.e., the demand curve)

The classic example of a positive externality is education.

- Education is associated with private benefits, including higher lifetime earnings and many others.
- Education is also associated with broader social benefits, such as an increase in overall entrepreneurial activity, higher incomes, and a faster pace of technology growth.

We can examine positive externalities with a figure.
Externalities

Figure 17.2 Positive Externalities in the Market for College Degrees

- **Price ($/degree)**
- **Demand (D)**
- **Social Demand (SD)**
- **External Marginal Benefit (EMB)**
- **Marginal Cost (MC)**
- **Socially Optimal Quantity (Q*)**

- The social demand for college degrees (SD) equals the private marginal benefit curve D plus the external marginal benefit EMB.

- The socially optimal number of college degrees, Q*, is found at point A, the intersection of the marginal cost curve S = MC and SD.

- In an unregulated market for college degrees, production occurs at point B (Q_MKT, P_MKT), where D = S = MC.

- Deadweight loss from externality $\Delta = \frac{1}{2} (P_MKT - P^*) Q^*$

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.1</td>
<td>Externalities</td>
</tr>
</tbody>
</table>

---

**Equations:**

- Social demand: $SD = D + EMB$
- Socially optimal quantity: $Q^*$
- Deadweight loss: $\Delta = \frac{1}{2} (P_MKT - P^*) Q^*$
Competitive markets with externalities produce more or less than is socially efficient. A number of market interventions can help correct externalities.

- Some work through their effect on prices (e.g., taxes).
- Some target the quantity produced and consumed.

First, determine the size of the externality and thus the amount by which production must be changed to reach the socially efficient outcome.
Example: The Efficient Level of Pollution

The goal is to determine the socially efficient level of pollution, or the level of emissions necessary to produce the efficient quantity of the good tied to the externality.

- The resulting level of production occurs where the marginal benefit of production of a good (willingness to pay) is equal to the marginal cost (private + external).
- This also implies that the marginal costs of pollution (e.g., health costs) are equivalent to its marginal benefits (increased production of goods and/or services).
The efficient level of pollution \((POLL^*, P_{POLL}^*)\) occurs where the marginal cost of pollution, \(MCP\), equals the marginal benefit or marginal abatement cost of pollution \((MBP = MAC)\).
Correcting Externalities

The Efficient Level of Pollution

✓ Why does the marginal cost of pollution (MCP) curve slope upward?
  • At low levels of pollution, the damage associated with an additional unit of pollution is relatively low.
  • At higher levels of pollution, health effects become more severe, and additional units of pollution are more costly to society.

✓ Why does the marginal benefit of pollution (MBP) curve slope downward?
  • High levels of pollution are associated with high levels of production, hence lower market prices. As pollution falls, so does production, and the forgone consumer and producer surplus is an opportunity cost.
  • As pollution falls, the cost of further reducing pollution increases because easy methods are exhausted.
The Efficient Level of Pollution

**Marginal abatement cost:** The cost of reducing emissions by one unit; includes technological costs and forgone production

Figure 17.3 is very similar to the supply and demand figures we have been using throughout this class.

- *MBP* is demand for pollution; *MCP* is the marginal societal cost, or supply.
- This represents a hypothetical market for pollution, with a resulting optimal price and quantity placed on pollution.
- Since this market doesn’t exist in the real world, what can be done to induce private parties to produce and consume at the socially efficient level?
Using Prices to Correct Externalities

Consider changing the price of goods produced in the presence of externalities so that the social and private benefits and costs align.

• For a negative externality, levy a tax on production or consumption.
• For a positive externality, subsidize production or consumption.

In the presence of negative externalities, economists often advocate for the use of a **Pigouvian tax**.

• A tax on an activity that causes a negative externality
• Serves to equate the external marginal cost imposed by an externality
• Designed to correct market failures and therefore improve societal welfare (rather than distorting markets like other taxes)

Consider the power plant.
**Figure 17.4 A Pigouvian Tax Corrects for a Negative Externality**

In an unregulated market, a power company overproduces quantity $Q_{MKT}$ at price $P_{MKT}$ (point $B$).

A Pigouvian tax $T$ equal to the external marginal cost $EMC$ shifts up the supply curve $S$, from marginal cost, $S = MC_I$, to the social marginal cost curve, $SMC$. 

\[
\begin{align*}
SMC &= MC_I + T \\
S &= MC_I \\
EMC &= T \\
EMC &= Tax, T \\
\end{align*}
\]
Using Prices to Correct Externalities

Similarly, in the presence of positive externalities, economists often advocate for the use of a Pigouian subsidy.

- A subsidy for an activity that produces a positive externality
- Serves to equate the external marginal benefit imposed by an externality

Consider education.
Correcting Externalities

Figure 17.5 A Pigouvian Subsidy Corrects for a Positive Externality

In an unregulated market, colleges underproduce quantity $Q_{MKT}$ college degrees, at price $P_{MKT}$ (point $B$).

A Pigouvian subsidy $Sub$ equal to external marginal benefit $EMB$ shifts demand $D$ out to social demand $SD$.

In the graph:
- $EMB = Sub$
- $S = MC_1$
- $SD = D + EMB = D + Sub$
- $EMB = Subsidy, Sub$
- $Q_{MKT}$ and $Q^*$ represent the quantity of college degrees.

Price ($/degree$) vs. Quantity of college degrees.
Quantity Mechanisms to Correct Externalities

Quantity-based interventions have the same goal as taxes or subsidies: to move a market with externalities toward the efficient outcome.

**Quota:** A regulation mandating that the production or consumption of a certain quantity of a good or externality be limited (negative externality) or required (positive externality).
In an unregulated market, a power company overproduces quantity $Q_{MKT}$ at price $P_{MKT}$ (point $B$).

When the government enacts a quota limiting production to $Q^*$, the private marginal cost curve $MC$ becomes vertical at $Q^*$, intersecting the social marginal cost $SMC$ at the socially optimal quantity $Q^*$ and price $P^*$ (point $A$).
Correcting Externalities

17.2

Price-Based versus Quantity-Based Interventions with Uncertainty

With perfect information, price and quantity instruments are equally effective in controlling externalities.

Without perfect information, significant problems face regulators.

• The costs of controlling externalities (marginal abatement costs) are often difficult to ascertain *ex ante*.
• The benefits of controlling externalities (marginal pollution costs) are similarly difficult to estimate; in the case of pollution, valuing changes to human health, ecosystems, and such.

When there is uncertainty in marginal abatement costs, price and quantity mechanisms are *not* equivalent.
Price-Based versus Quantity-Based Interventions with Uncertainty

The equivalence between price and quantity instruments breaks down under uncertainty because of a simple difference between the two.

- Price instruments correct the *price* of pollution; for example, a pollution tax imposes a fixed cost on polluters for each unit emitted.
- Quantity instruments fix the *quantity* of pollution.

Consider what happens when marginal abatement costs turn out to be larger than expected.

- Under a pollution permit system, firms are forced to abate a fixed amount of pollution.
- Under a pollution tax system, firms will abate *less* pollution.
  - They will limit pollution until the additional cost of reducing one more unit of pollution is equal to the tax, and then they will simply pay the tax.
Correcting Externalities

17.2

Price-Based versus Quantity-Based Interventions with Uncertainty

✓ What happens to the outcomes under taxes and permits when the marginal benefits of reducing pollution ($MCP$) are greater than expected?

- Nothing. Firms operating under a pollution tax system will not change their control efforts except in response to a change in the private costs of control (marginal abatement costs).
- The benefits of reducing pollution are in the form of reduced external costs. As these costs are not borne by polluting firms, the choice of how much pollution to emit is not affected.
- Uncertainty about benefits does not alter the equivalence between price and quantity interventions.
Price-Based versus Quantity-Based Interventions with Uncertainty

When are price-based interventions preferable to quantity-based interventions and vice versa?

- When the marginal abatement cost (MAC) and marginal cost of pollution (MCP) curves are linear, two factors determine the relative superiority of one intervention or the other.
  1. The slope of the MAC curve
  2. The slope of the MCP curve
Government officials initially believe abatement costs to be $\text{MAC}_e$. If government regulators incorrectly estimate farmers’ marginal abatement costs ($\text{MAC}_e < \text{MAC}$), the quantity-based intervention would reduce pollution to $\text{POLL}_B < \text{POLL}^*$, while the Pigouvian tax would increase pollution to $\text{POLL}_C > \text{POLL}^*$.
Figure 17.8 When Price Mechanisms Are Preferable to Quantity Mechanisms

Government officials initially believe abatement costs to be $\text{MAC}_e$. If government regulators incorrectly estimate farmers' marginal abatement costs ($\text{MAC}_e < \text{MAC}$), the quantity-based intervention would reduce pollution to $\text{POLL}_B < \text{POLL}^*$, while the Pigouvian tax would increase pollution to $\text{POLL}_C > \text{POLL}^*$. 

In the diagram:
- $\text{MBP} = \text{MAC}$
- $\text{MBP}_e = \text{MAC}_e$
- Deadweight loss from quantity mandate
- Deadweight loss from Pigouvian tax
- Government officials initially believe abatement costs to be $\text{MAC}_e$. If government regulators incorrectly estimate farmers' marginal abatement costs ($\text{MAC}_e < \text{MAC}$), the quantity-based intervention would reduce pollution to $\text{POLL}_B < \text{POLL}^*$, while the Pigouvian tax would increase pollution to $\text{POLL}_C > \text{POLL}^*$.
A Market-Oriented Approach to Reducing Externalities: Tradable Permits Markets

Using price or quantity interventions takes a lot of effort.

- Firms may differ dramatically in their abatement costs.
- Often, pollution control regulations require a fixed aggregate emissions reduction; it is difficult to enforce this with taxes.

In response to these challenges, many regulatory agencies issue **tradable permits** to control pollution.

- A government-issued permit that allows a firm to emit a certain amount of pollution and that can be traded to other firms.
- In theory, effective in achieving **allocative efficiency**, or marginal abatement costs equalized across firms.
Why do we need tradable permits? Can’t the regulator assign emissions reductions to firms efficiently?

- It is difficult for regulators to ascertain firms’ costs of reducing pollution.
- Many firms do not perfectly understand the costs of reducing pollution.
- There is the problem of moral hazard: firms have an incentive to overstate costs to regulators, hoping to reduce their financial liability.

 Tradable permits solve these problems.

- High-cost firms purchase permits from low-cost firms until no mutually beneficial trades remain.
- The market-clearing price of permits will be equal to $MAC$ for each firm.
- This is exactly how any market works.
Under certain circumstances, it may be possible to reach the efficient market outcome through private negotiation.

**The Coase theorem:** costless negotiation among market participants will lead to the efficient market outcome regardless of who holds legal property rights.

- It does not matter who has property rights.
- If outcomes can be monitored and individuals can costlessly coordinate and negotiate, parties should be able to reach the efficient outcome.
- Coordination is often very difficult, particularly with many participants and/or information problems.
The Coase Theorem and Tradable Permits Markets

The Coase theorem has been used to help inform the design of government regulations for controlling externalities.

- Consider discussion of the concept of tradable permits for pollution control.
- **How should a regulatory agency distribute rights to pollute? Should the rights be given away? Allocated by sector? Auctioned to the highest bidder?**
  - The Coase theorem suggests it does not matter who is endowed with the rights or how they are distributed.
  - So long as there is monitoring and the ability to coordinate participants in a way that facilitates negotiation, the outcomes should be the same no matter the initial allocation.
  - This is one reason markets for tradable permits receive attention in the literature; markets make coordination easier.
There is another type of good for which markets can fail to deliver the socially optimal level of output: public goods, which are accessible to anyone who wants to consume them.

- Good that benefits the individual consumer even as others consume it
- These goods (e.g., national defense, a fireworks display, clean air) remain just as valuable to the consumer, even as other people consume them.

Similar to positive externalities

- Provide positive external benefits to everyone, regardless of who purchases them; however, public goods differ in a fundamental way.
- Public goods are nonrival, a defining property of a public good that describes how one individual’s consumption of the good does not diminish another consumer’s enjoyment of the same good.

Using the definitions of excludability and rivalry, we can construct a table characterizing four types of goods.
### Table 17.1: Examples of Goods by Characteristics

<table>
<thead>
<tr>
<th>Excludable</th>
<th>Nonexcludable</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rival</strong></td>
<td><strong>Nonrival</strong></td>
</tr>
<tr>
<td><em>One individual’s consumption affects another’s consumption.</em></td>
<td><em>One individual’s consumption has no effect on another’s consumption.</em></td>
</tr>
<tr>
<td><strong>Excludable Individuals can be kept from consuming.</strong></td>
<td><strong>Nonexcludable Individuals cannot be kept from consuming.</strong></td>
</tr>
<tr>
<td><strong>Private good:</strong> tacos, gasoline, paper</td>
<td><strong>Common resource:</strong> shared property, fisheries, interstate highways</td>
</tr>
<tr>
<td><strong>Club good:</strong> satellite TV services, private parks, movies</td>
<td><strong>Public good:</strong> fireworks display, mosquito abatement, national defense</td>
</tr>
</tbody>
</table>
The Optimal Level of Public Goods

Market efficiency requires that a good be produced until the marginal benefits of production are equal to the marginal costs.

- Since public goods are nonrival, the marginal benefit of a given level of provision is the vertical sum of all individuals’ marginal benefit curves.
- Total marginal benefit is defined as

\[ MB_T = \sum MB_i \]

where \( i \) indicates each individual.
- The cost side is the same as with any other good.
The two consumers of a public good have marginal benefit curves, $MB_1$ and $MB_2$, respectively. At the efficient point, both consumers consume $Q_{Pub}^*$ of the public good, where their total marginal benefit curve $MB_T$ intersects the marginal cost curve $MC$. 

**Figure 17.9 Efficiency in the Market for a Public Good**

Marginal benefit, marginal cost

- **Total marginal benefit:** $MB_T = MB_1 + MB_2$
- $MC$ curve
- $Q_1$, $Q_2$, $Q_{Pub}^*$ points
- The quantity of public good

Public Goods
The Optimal Level of Public Goods

There are two reasons markets will underprovide public goods.

The first is illustrated by the figure on the previous slide.
- If individuals purchase the goods themselves, they will do so only until private marginal benefit equals marginal cost.
- The efficient level occurs when the total marginal benefits equal marginal cost.

A second problem results from the nonexcludability of public goods.
- This is called the free-rider problem: A source of inefficiency resulting from individuals consuming a public good or service without paying for it
- Why take on any private costs when you can simply benefit from it without paying anything (e.g., NPR)?
Solving the Free-Rider Problem

The most common way that the free-rider problem is dealt with is by government.

• The power to tax is often used to provide public goods such as national defense, air traffic control, and weather forecasting.

There are other possible solutions.

• Groups of private citizens can form to provide public goods (e.g., homeowner associations).

• People do not always succumb to the free-rider problem. Often private motivations are more complicated than assumed by the theory of rational agents.
Public Goods

The Tragedy of the Commons
Because everyone has free access to a common resource, the resource is used more intensively than if it were privately owned, which leads to a decline of the value of the resource for everyone.

• Another pervasive form of a negative externality
• A common resource is a good that all individuals can use freely and whose value to the individual consumer decreases as others use it.
  – Many lake, river, coastal, and ocean fisheries; public forests; reservoirs, aquifers, and other sources of water; the atmosphere
  – Public airways, bathrooms
  – Key characteristic is nonexcludability: consumers cannot be prevented from consuming the good once it is available.
The Tragedy of the Commons

Nonexcludability means that users have little private incentive to protect the resource for others, as they do not realize the full cost of overuse.

Consider a lake fishery owned by a single person.

- Subject to a few assumptions about the price of fish, the cost of fishing, and the biological growth of fish, the owner will treat the fishery as an asset.
- She will recognize that removing a fish to sell today comes with three costs:
  i. The cost of catching the fish
  ii. The opportunity cost, not being able to catch the fish in the future
  iii. Any lost reproduction or natural growth that would have occurred
- Since the resource is treated like an asset, it will earn a resource rent, just as labor and capital each earn a rent (wage and interest).
The Tragedy of the Commons

Now, consider the case of a lake fishery with no limits on use.

- Individual fishermen will consider only their private cost of fishing when determining how much to fish.
- They cannot capture the benefits of leaving a fish in the lake.
  - The option to catch it or its offspring in the future
- Fisheries with open access will be subject to rent dissipation, whereby any positive economic profit is driven to zero by new entrants and/or greater fishing pressure.
- Open-access fisheries have also undergone severe overexploitation, with some historically important fisheries collapsing.
- So private property rights have been used in fisheries to help manage the problem of nonexcludability.
In this chapter, we delved into the issues that develop when markets are missing or otherwise incomplete.

- Externalities occur when costs and/or benefits are not completely captured by those making production and consumption decisions.
- Nonexcludable common pool goods are subject to overuse and/or underinvestment.
- Public goods are underprovided by private agents because of free riding and the misalignment of private and total marginal benefits.

In the final chapter, we examine situations in which consumers and producers may not appear to be the rational, utility- and profit-maximizing agents we have modeled throughout this text.
Assume that notebook paper is sold in a perfectly competitive industry. The industry’s short-run supply curve (or marginal cost curve) is $P = MC = 2Q$, where $Q$ is measured in millions of reams per year. The inverse demand for notebook paper is $P = 40 - 8Q$.

Answer the following questions:

a. What are the equilibrium market price and quantity sold?

b. Suppose that in their production process, paper manufacturers have been dumping waste in nearby streams. The external marginal cost is estimated to be $0.50 for each ream produced. Calculate the socially optimal level of output and price for the paper industry.
a. First, rearrange the inverse supply and demand equations to put them in terms of quantity supplied and quantity demanded:

Supply

\[ P = 2Q \]
\[ Q^s = 0.5P \]

Demand

\[ P = 40 - 8Q \]
\[ 8Q = 40 - P \]
\[ Q^D = 5 - 0.125P \]

Market equilibrium occurs where \( Q^D = Q^s \):

\[
0.5P = 5 - 0.125P \\
0.625P = 5 \\
P = $8
\]

When \( P = $8 \),

\[ Q^s = 0.5(8) \]
\[ Q^s = 4 \text{ million reams} \]

\[ Q^D = 5 - 0.125(8) \]
\[ Q^D = 4 \text{ million reams} \]
b. The social marginal cost is equal to the industry marginal cost plus the external marginal cost:

\[ SMC = MC + EMC = 2Q + 0.50 \]

To find the social optimum, equate SMC with the inverse demand:

\[ 2Q + 0.5 = 40 - 8Q \]
\[ 10Q = 39.50 \]
\[ Q^* = 3.95 \text{ million reams} \]

The socially optimal price can be found by substituting the optimal quantity into either the social marginal cost or inverse demand curves:

\[ P = 2Q + 0.5 = 2(3.95) + 0.5 \text{ or } \]
\[ P = 40 - 8Q = 40 - 8(3.95) \]
\[ P^* = $8.40 \]
Suppose leather is sold in a perfectly competitive industry. The industry short-run supply curve (marginal cost curve) is \( P = MC = 3Q \), where \( Q \) is measured in millions of hides per year. The inverse demand for leather hides is given by \( P = 60 - 7Q \).

**Answer the following questions:**

a. Find the equilibrium market price and quantity sold.

b. Suppose leather tanning releases chromium and other pollutants into local waterways. The external marginal cost is estimated to be $4 for each hide produced. Calculate the socially optimal level of output and price for leather hides.
figure it out

a. To find the competitive outcome, set the inverse demand and supply curves equal to one another:

\[ 3Q = 60 - 7Q \]
\[ 10Q = 60 \]

Using the supply curve to solve for the equilibrium price yields

\[ P = 3Q = \$18 \]

b. The social marginal cost is equal to the industry marginal cost plus the external marginal cost:

\[ SMC = MC + EMC = 3Q + 4.00 \]

To find the social optimum, equate SMC with the inverse demand (or supply)

\[ 3Q + 4.00 = 60 - 7Q \Rightarrow 10Q = 56 \Rightarrow Q^* = 5.6 \text{ million hides} \]

And the socially optimal price is

\[ P = 3Q + 4.00 = 16.8 + 4 \Rightarrow P^* = \$20.8 \]
Return to paper reams (Figure it Out 17.1). Suppose the government imposes a tax of 50 cents on every ream of paper sold. The industry short-run supply curve (or marginal cost curve) is $P = MC = 2Q$, where $Q$ is measured in millions of reams per year. The inverse demand for notebook paper is $P = 40 - 8Q$.

**Answer the following questions:**

**a.** What price would buyers pay? What price would sellers receive net of the tax?

**b.** How many reams of paper would be sold?
a. Use the method from Chapter 3, so that the price paid by buyers, $P^B$, is equal to the price received by sellers, $P^S$, plus the tax, $T$. Therefore, $P^B = P^S + 0.50$.

The demand and supply curves:

\[ Q^D = 5 - 0.125P^B \]
\[ Q^S = 0.5P^S \]

Substituting $P^B = P^S + 0.5$ into the demand curve,

\[ Q^D = 5 - 0.125(P^S + 0.5) \Rightarrow Q^D = 4.9375 - 0.125P^S \]

Solving for the equilibrium price for sellers by setting $Q^D$ equal to $Q^S$,

\[ 4.9375 - 0.125P^S = 0.5P^S \Rightarrow 4.9375 = 0.625P^S \Rightarrow P^S = 7.90 \]
\[ P^B = P^S + $0.50 \Rightarrow P^B = 7.90 + $0.50 \Rightarrow P^B = $8.40 \]

To solve for quantity sold, substitute $P^B$ into the demand curve or $P^S$ into the supply curve.
b. To solve for quantity sold, substitute $P^B$ into the demand curve or $P^S$ into the supply curve.

\[ P^B = 8.40 \Rightarrow Q^D = 5 - 0.125P^B \]
\[ Q^D = 5 - 0.125(8.40) \]
\[ Q^D = 3.95 \text{ million reams} \]

\[ P^S = 7.90 \Rightarrow Q^S = 0.5P^S \]
\[ Q^S = 0.5(7.90) \]
\[ Q^S = 3.95 \text{ million reams} \]

This is the socially optimal quantity.
Return to leather tanning. Suppose the government imposes a tax of $4 on every hide sold. The industry short-run supply curve (marginal cost curve) is \( P = MC = 3Q \), where \( Q \) is measured in millions of hides per year. The inverse demand for hides is given by \( P = 60 - 7Q \). (Remember, the externality was equal to $4 per hide.)

**Answer the following questions:**

a. What price would buyers pay? What price would sellers receive net of the tax?

b. How many hides would be sold?
a. Use the method from Chapter 3: the price to buyers, $P^B$, is equal to the price received by sellers, $P^S$, plus the tax, $T$. Therefore, $P^B = P^S + 4$.

The demand and supply curves:

\[ P^B = 60 - 7Q^D \Rightarrow Q^D = 8.57 - 0.143P^B \]
\[ 3Q^S = P^S \Rightarrow Q^S = 0.33P^S \]

Substituting $P^B = P^S + 4$ into the demand curve yields

\[ Q^D = 8.57 - 0.143(P^S + 4) \Rightarrow Q^D = 8.57 - 0.143P^S - 0.572 \Rightarrow \]
\[ Q^D = 7.998 - 0.143P^S \]

The equilibrium price for sellers, setting $Q^D$ equal to $Q^S$:

\[ 7.998 - 0.143P^S = 0.33P^S \Rightarrow 7.998 = 0.473P^S \quad P^S = $16.91 \]

\[ P^B = P^S + $4 \Rightarrow P^B = 16.91 + $4 \]
\[ P^B = $20.91 \]

To solve for quantity sold, substitute $P^B$ into the demand curve or $P^S$ into the supply curve.
To solve for quantity sold, substitute $P_B$ into the demand curve or $P_S$ into the supply curve.

\[ P_B = \$20.91 \Rightarrow Q^D = 8.57 - 0.143P_B \]
\[ Q^D = 8.57 - 0.143(\$20.91) \]
\[ Q^D = 5.58 \text{ million hides} \]

\[ P_S = \$16.91 \Rightarrow Q^S = 0.33P_S \]
\[ Q^S = 0.33(\$16.90) \]
\[ Q^S = 5.58 \text{ million hides} \]

This is the socially optimal quantity.
Green Acres Fertilizer Company is near Barney’s Dry Cleaning Service. Green Acres’ production process emits noxious odors that are absorbed by the clothing Barney cleans. The result is that Barney has lost many customers over time. Barney estimates that the odors cost his business $10,000 per year. Green Acres can eliminate its odors by altering its production process at a cost of $12,000 per year.

Answer the following questions:

a. If Green Acres has the right to emit the odors, what will the socially optimal outcome be? How will it be reached? Will any money change hands?

b. If Barney has the right to odor-free air, what will the socially optimal outcome be? How will it be reached? Will any money change hands?
a. The socially optimal outcome will occur when Green Acres emits the odor. The cost of eliminating the emissions ($12,000 per year) is greater than the external cost of the odor ($10,000 per year). If Green Acres has the right to emit odors, it will continue to do so. Barney does not value clean air enough to purchase that right from Green Acres, so no money will change hands.

b. The socially optimal outcome will still be for Green Acres to emit the odor. The optimal outcome is determined by the relative values that Green Acres and Barney place on the resource (air). Because Green Acres values the air more than Barney does, it should use the resource and emit the odor. However, because Barney has a right to odor-free air, Green Acres will have to purchase the right to emit odors from him. Assuming that this can be done costlessly, Green Acres will have pay Barney between $10,000 and $12,000 for that right.
Dale and Casey are neighbors in a rural area. They are considering joint installation of a large fountain near their shared property line so that each can enjoy its beauty and also improve the value of his property. Dale’s marginal benefit from the fountain is $MB_D = 70 - Q$, where $Q$ measures the diameter of the fountain (in feet). Casey’s marginal benefit from the fountain can be represented as $MB_C = 40 - 2Q$. Assume that the marginal cost of producing the fountain is constant and equal to $80$ per foot of diameter.

Answer the following questions:

a. What equation represents the total marginal benefit of the fountain?

b. What is the socially optimal size of the fountain?

a. The total marginal benefit is the vertical summation of Dale’s and Casey’s individual marginal benefit curves:

\[ MB_T = MB_D + MB_C = (70 - Q) + (40 - 2Q) = 110 - 3Q \]

b. The socially optimal size of the fountain occurs where \( MB_T \) equals the marginal cost of producing the fountain:

\[ MB_T = MC \Rightarrow 110 - 3Q = 80 \]
\[ 30 = 3Q \Rightarrow Q = 10 \]

The socially optimal diameter for the fountain is 10 feet.
c. Dale will not be willing to build a fountain that is 10 feet in diameter because his private marginal benefit is less than the marginal cost:

\[ MB_D = 70 \quad Q = 70 \quad 10 = 60 < MC \quad (80) \]

Casey also will be unwilling to build a 10-foot fountain because his private marginal benefit from a 10-foot fountain is lower than the marginal cost:

\[ MB_C = 40 \quad 2Q = 40 \quad 20 = 20 < MC \quad (80) \]

Therefore, the optimal-sized fountain will **not** be built.

Neither of them would even be willing to build the smallest possible fountain, with a diameter of 1 foot \((Q = 1)\).

Dale’s marginal benefit would be $70 and Casey’s would be $40; both of these are less than the marginal cost of $80.