Chapter 9

Market Failure and Public Policy

The requirements for markets to allocate resources efficiently are (1) that markets exist for all goods and services in the economy, (2) perfect competition, (3) perfect information, (4) property rights are assigned to all resources and commodities, and (5) there are no externalities. In the following sections, we analyze cases where those conditions are not satisfied and how public policy can intervene to improve or restore efficiency.

9.1 Externalities

Negative and positive externalities are costs and benefits, respectively, to non-market participants. There are no incentives for market participants to take those (social) costs and benefits into account; thus, they base their decisions only on private benefits and costs. Put differently, externalities differentiate between private marginal cost (PMC)—what markets consider for decision making—and social marginal cost (SMC) paid by society. The external marginal cost (EMC) is the difference between PMC and SMC, i.e., $PMC+EMC = SMC$. Consider the following examples of negative and positive externalities:

- A cigarettes manufacturer's PMC is the marginal cost of producing cigarettes. For example, the PMC associated with a cigarette may be \$0.03. The negative health outcomes paid by society are external marginal cost. Assume that the EMC in the case of cigarettes is \$0.02. Although the SMC is \$0.05 per cigarette, the cigarette manufacturer bases its production decision on \$0.03. A SMC above the PMC is a case of a negative externality in which the firm's supply curve does not capture all social costs associated with its product.

- Consider the production of sugary and fatty food and drink items. Producers and consumers do not take into account the cost on non-market participants associated with an increase in obesity. The following was published in *The Seattle Times* on December 21, 2011 under the title As passengers add girth, ferries drop capacity:

  > *The Washington state ferry service isn't going to start turning away hefty passengers, but it has had to reduce the capacity of the nation's largest ferry system because people have been packing on the pounds. Coast Guard vessel-stability rules that took effect nationwide Dec. 1 raised the estimated weight of the average adult passenger to 185 pounds from the previous 160 pounds, based on population information from the Centers for Disease Control and Prevention (CDC). During the past 20 years, there has been a dramatic increase in obesity in the United States and about one-third of American adults are now considered obese, the CDC says on its website. The state ferry system has complied with the new stability rules by simply reducing the listed capacity of its vessels, Coast Guard Lt. Eric Young said Wednesday. "That has effectively reduced the amount of passengers by about 250 passengers or so depending on the particular ferry," said Young, who is based in Seattle. "They generally carry about 2,000, so it's down to 1,750 now." With that many passengers, the ferry wouldn't tip over even if everyone ran to the side at the same time to look at a pod of killer whales, he said.*

- Examples of positive externalities are homeowners that upkeep their yards or engage in rodent control. When individuals maintain clean and attractive properties, the surrounding neighborhood also benefits through higher property values, improved aesthetics, and potentially a stronger sense of community. For example, neighbors may be able to sell their homes more easily at a higher price. Similarly, when homeowners engage in pest control, they reduce the likelihood of infestations spreading to neighboring houses, creating a safer and healthier environment for everyone. These actions generate benefits that extend beyond the individual decision-maker, illustrating how private choices can lead to social gains without direct compensation from others. Both, yard upkeep and rodent control, can easily turn into negative externalities if a homeowner does neither.

- Another market failure results in the Gulf of Mexico Hypoxic Zone. The Gulf of Mexico hypoxic zone, commonly called the "dead zone," illustrates a large-scale example of negative externalities in environmental economics. Excess nutrients such as nitrogen and phosphorus—largely originating from upstream agricultural runoff in the Mississippi River Basin—stimulate algal blooms that deplete oxygen when they decompose, creating low-oxygen conditions that harm marine ecosystems and fisheries. Farmers benefit privately from fertilizer use that boosts crop yields, but the

> downstream ecological and economic costs—such as reduced shrimp harvests, damaged marine habitats, and losses to coastal tourism—are borne by others who did not participate in the production decision. This mismatch between private and social costs exemplifies a market failure, as the fertilizer's price does not reflect its full environmental impact. Economically, the dead zone highlights the need for policy interventions such as nutrient management regulations, pollution taxes, or incentive-based programs that internalize external costs and align private behavior with the broader social interest.

Given externalities, there is a mismatch between social marginal benefits/costs and private marginal benefits/costs which leads to an inefficient allocation of resources. Similar to a monopoly, there is a deadweight loss from externalities. The subsequent sections show that a product generating a negative externality is over-produced and over-consumed whereas a good generating a positive externality is under provided. Externalities arise if property rights have not been established, e.g., clean air, toys for children, fishing in a lake, congestion. Economists argue whether externalities are a market failure or failure of a markets to exist. For example, a polluting firm is essentially using clean air as an input for which it is not paying for. If a market existed for this input—as it does for labor and capital—the input would be priced in the market. That is, the owner of clean air would have to agree to sell just as the owner of labor agrees to sell. Similarly, a positive externality is a product that is produced but no market exists and is consumed for free. Whether we are talking about positive or negative externalities, a deadweight loss exists and a good is either over-produced (negative externality) or under-produced (positive externality).

9.1.1 Coase Theorem

On the notion of property rights, the Coase Theorem, developed by economist Ronald Coase, needs to be introduced first. The theorem states that if transaction costs are low or zero, the establishment of clear property rights leads to an efficient allocation of resources (Coase 1960). Participating parties will negotiate until a mutually advantageous and efficient solution is reached. This implies that no government intervention is necessary as long as property rights are established. Although the allocation of wealth and income will vary depending on how property rights are established, it does not affect efficiency. Coase illustrated his argument with several examples that involve conflicts over resource use and externalities. Some of the examples used are the following:

- Farmer and rancher: This example describes a situation where a rancher's cattle stray onto a neighboring farmer's land, damaging crops. Coase uses this to show that the efficient outcome (the socially optimal number of cattle or level of damage prevention) can be achieved through bargaining, regardless of whether the rancher or the farmer is legally liable for the damage—provided transaction costs are zero and property rights are clearly defined.

- Railway and farmer: Coase discusses sparks emitted by trains that ignite farmers' crops along the tracks. He argues that either the railway company could compensate the farmers for damages or the farmers could pay the railway to install spark-prevention equipment, depending on who has the right to operate without liability. The efficient solution, again, does not depend on the initial assignment of rights but on minimizing total social costs.
- Noise and land-use conflicts: Coase also uses examples such as the noise from a confectioner's machinery disturbing a neighboring doctor's practice (a case he adapted from English common law). These illustrate how both parties contribute to the externality—the issue is not simply who causes harm, but how rights and costs are distributed between the parties.

Through these examples, Coase demonstrates that externalities are reciprocal problems—one party's gain is another's loss, and that efficiency requires considering both sides of the interaction, not merely assigning blame or imposing liability. The examples about the farmer and rancher can also be applied to a tree falling a neighbors property as handled by law in Indiana. If a tree on one property falls and damages a neighbor's property, liability depends on negligence and the foreseeability of the harm. If the tree was healthy and fell due to an unforeseeable event—such as a storm—then the owner is typically not liable, because the damage was not preventable at reasonable cost. However, if the tree was dead or visibly decaying, the owner may be liable for damages, since the risk was foreseeable and could have been mitigated through maintenance. From a Coasean perspective, this rule structure reflects the same underlying principle: Legal rights (to grow trees or to be free from damage) must be clearly defined, but efficiency ultimately depends on how easily parties can bargain or take preventive action. If transaction costs are low, neighbors might negotiate—perhaps one agrees to remove a risky tree or the other to tolerate it. Where bargaining is impractical or costly, the law steps in to assign responsibility in a way that encourages the least-cost avoider to act. In both the Indiana case and Coase's rancher–farmer scenario, the economic logic of property rights aims to align private incentives with socially efficient outcomes.

Similar to the example of noise and land-use conflict, consider a baker and a doctor occupying the same building. The baker needs to run noisy machinery in order to bake bread and make a living. The doctor needs silence in order to practice in her office. The problem in this case is that the property rights with regard to the "noise level" in the building are not clearly established. Now suppose that the doctor could soundproof the walls at a cost of \$100 and the baker could purchase quiet machinery at a cost of \$50. If the property "noise level" is given to the doctor, then the baker will purchase quiet machinery for \$50. If the noise level is attributed to the baker, the doctor will pay the baker \$50 to purchase new and more quiet machinery. The efficient solution, i.e., purchasing machinery for \$50, is reached independently of who is assigned the property rights.

9.1.2 Externalities and Deadweight Loss

The presence of negative or positive externalities leads to a deadweight loss (DWL). The quantity exchanged in a market with a negative externality is too high whereas for a positive externality, the quantity exchanged is too low. In a first step, the example of a production negative externality is considered in which the externality is caused by the producer. The welfare loss is identical for a negative consumption externality.

9.1.2.1 Negative Externality

Consider a market with the following private, external, and social marginal costs labelled PMC, EMC, and SMC, respectively:

$$\begin{aligned}
\text{PMC}(Q) &= 10 + 2 \cdot Q \\
\text{EMC}(Q) &= 10 + Q \\
\text{SMC}(Q) &= \text{PMC}(Q) + \text{EMC}(Q) = 20 + 3 \cdot Q
\end{aligned}$$

The inverse demand function for the good is written as $P(Q) = 100 - 4 \cdot Q$. In a competitive market in which externalities are not internalized, i.e., taken into account by the market actors, firms set price equal to PMC. The resulting quantity is labeled Q_M:

$$P(Q_M) = \text{PMC}(Q_M)$$

Substituting the functional forms from above leads to the following equation:

$$100 - 4 \cdot Q_M = 10 + 2 \cdot Q_M$$

Solving results in a market outcome of $Q_M = 15$ and a market price of $P_M = 40$. This situation is depicted in Figure 9.1 which shows the various components associated with the negative externality. At the output of 15 and the market price of 40, the consumer and producer surplus for the market participants is shown in Panel (a). Since the product generates an externality, the cost to society is shown in Panel (b) and corresponds to the area underneath the social marginal cost and above the private marginal cost. Subtracting the societal cost from the consumer and producer welfare of the market participants leads to the deadweight loss shown in Panel (c).

The efficient allocation is where the price equals the social marginal cost:

$$P(Q_E) = \text{SMC}(Q_E)$$

Substituting the functional forms:

$$100 - 4 \cdot Q_E = 20 + 3 \cdot Q_E$$

Solving for the efficient equilibrium leads to $Q_E = 11.43$ and a market price $P_E = 54.29$.

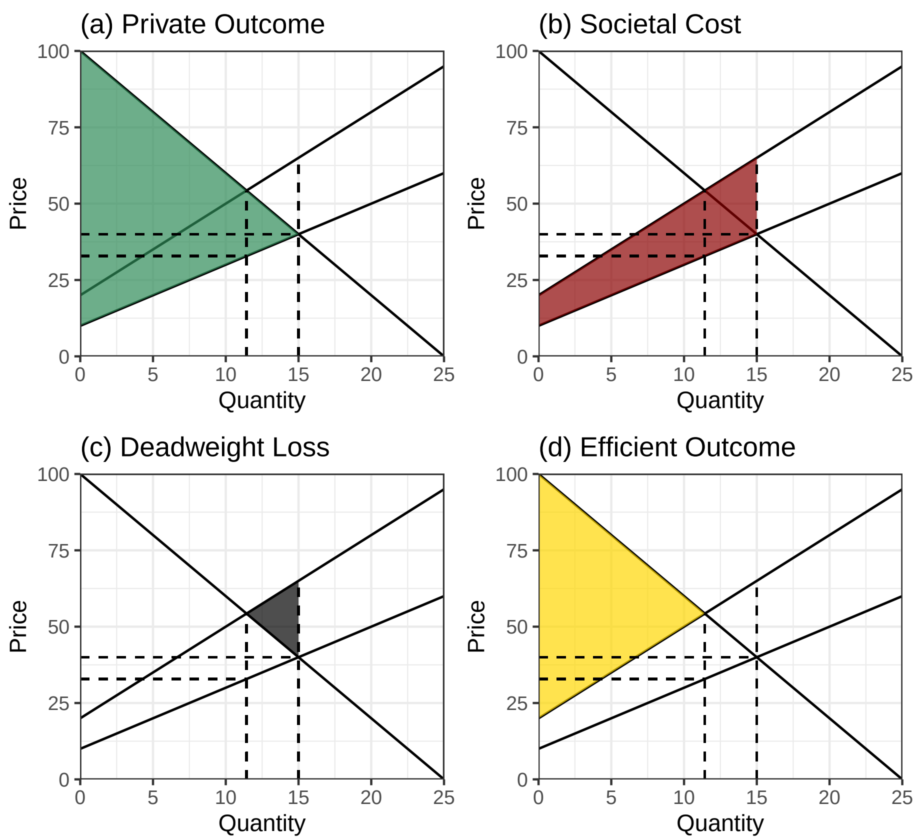

Figure 9.1: Panel (a): Producer and consumer surplus ignoring the cost associated with the negative externality. Panel (b): Societal cost not taken into account by either the producer or the consumer. Panel (c): DWL resulting from subtracting the societal cost in panel (b) from the producer and consumer surplus in Panel (a). Panel (d): Producer and consumer surplus from producing at the efficient level.

9.1.2.2 Positive Externality

A positive externality occurs when an individual's or firm's private actions generate additional benefits for others that are not reflected in the market price. Common examples include education, vaccination, or home landscaping that improves neighborhood aesthetics. In these cases, the social marginal benefit (SMB) exceeds the private marginal benefit (PMB) observed in the market.

Consider the following market with private and social marginal benefits—labelled PMB and SMB, respectively—and marginal cost.

$$\begin{aligned} \text{PMB}(Q) &= 100 - 4 \cdot Q \\ \text{SMB}(Q) &= \text{PMB}(Q) + 10 + Q \\ \text{MC}(Q) &= 10 + 2 \cdot Q \end{aligned}$$

Note that the PMB represents the demand function. In a competitive market, individuals equate private marginal benefit with marginal cost:

$$\text{PMB}(Q_M) = \text{MC}(Q_M)$$

or equivalently:

$$100 - 4 \cdot Q_M = 10 + 2 \cdot Q_M$$

The market equilibrium quantity is $Q_M = 15$ and $P_M = 40$. But since there is a marginal external benefit, the socially optimal level is calculated as follows when social marginal benefit equals marginal cost:

$$\text{SMB}(Q_E) = \text{MC}(Q_E)$$

$$100 - 4 \cdot Q_E + 10 + Q_E = 10 + 2 \cdot Q_E$$

The market equilibrium quantity is $Q_E = 20$ and $P_E = 50$ (Figure 9.2).

9.1.3 Correcting Externalities

To correct a negative externality and achieve the efficient outcome, a so-called Pigouvian tax must be introduced. The Pigouvian tax is a per-unit production tax equal to the difference between PMC and SMC at the efficient output quantity. By reducing the market quantity to the efficient quantity, a Pigouvian tax eliminates the DWL from the negative externality. The difference between Pigouvian tax and pollution tax is that the former is a per-unit tax on output and the latter is a per-unit tax on pollution. To correct a positive externality and achieve the efficient outcome, a subsidy must be implemented that increases the outcome to the efficient level. Those corrective measures are sometimes challenging to implement due to difficult-to-estimate private and social costs and benefits.

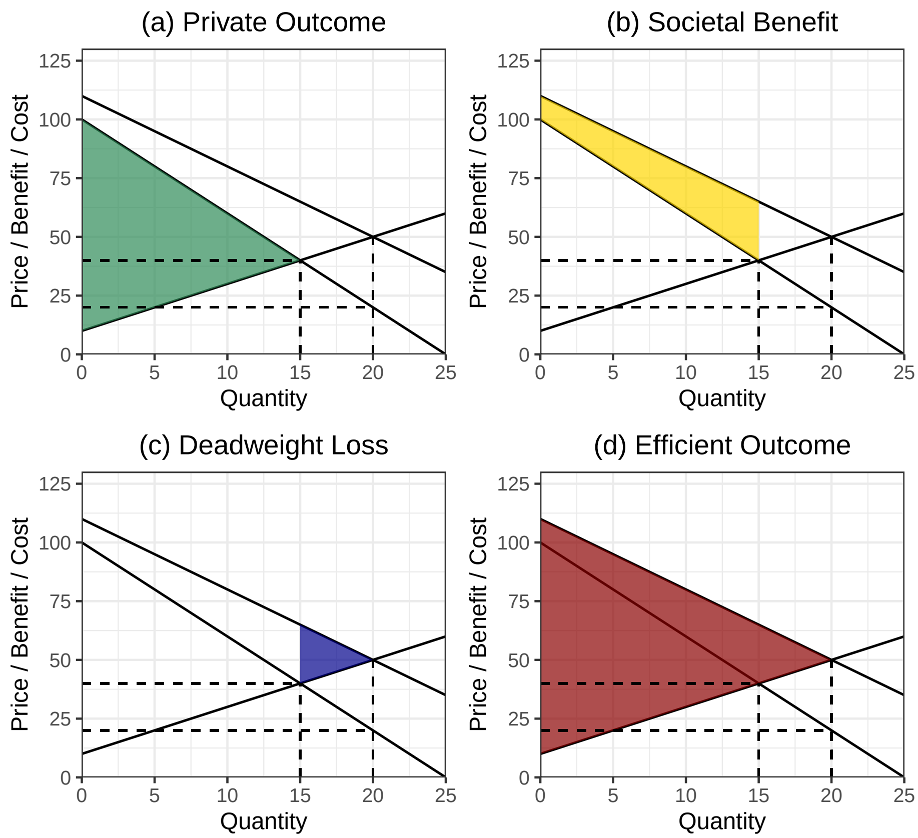

Figure 9.2: Panel (a): Producer and consumer surplus ignoring the benefit associated with the positive externality. Panel (b): Societal benefit not taken into account by either the producer not the consumer. Panel (c): DWL resulting from adding the societal benefit in panel (b) to the producer and consumer surplus in Panel (a). Panel (d): Producer and consumer surplus from producing at the efficient level.

9.1.4 Pollution Control

Waste is produced by almost any activity and thus, the optimal level of pollution is not equal to zero. Optimal level of pollution is a function of the social cost associated with pollution (e.g., effect on human health) as well as the cost of reducing pollution which is represented by the marginal abatement cost function.

Assume two firms that emit each 25 tons of pollution per year and the government wants to reduce pollution by 10 tons. The total abatement cost and marginal abatement cost functions are written as follows:

$$TC_1(a_1) = 3 \cdot a_1^2 \Rightarrow MC_1(a_1) = 6 \cdot a_1$$
$$TC_2(a_2) = 2 \cdot a_2^2 \Rightarrow MC_2(a_2) = 4 \cdot a_2$$

There are three policy instruments that can be implemented: (1) Command-and-control, (2) emission tax, and (3) cap-and-trade. Only the emission tax and the cap-and-trade achieve the least cost (efficient) outcome. The emission tax is considered a price instrument (i.e., setting the price of pollution) and cap-and-trade is considered a quantity instrument (i.e., setting the quantity of pollution).

Under a command-and-control policy, there are either design standards that require the use of a particular technology or performance standards that set the maximum pollution level for individual sources. This policy achieves the desired outcome in terms of pollution but is inefficient. in the above example, assume that each firm must reduce its emissions to 20 tons. In that case, the costs to firms 1 and 2 are as follows:

$$TC_1(5) = 3 \cdot 5^2 = 75$$
$$TC_2(5) = 2 \cdot 5^2 = 50$$

In an emission/pollution tax scenario, firms set the marginal cost of abatement equal to the tax rate. Assume that in the present case, the emission tax is set to \$24 per ton. An emission tax is efficient since the aggregate cost for a given level of pollution is minimized.

$$MC_1(a_1) = 6 \cdot a_1 = 24 \Rightarrow a_1^* = 4 : TC_1(4) = 48$$
$$MC_2(a_2) = 4 \cdot a_2 = 24 \Rightarrow a_2^* = 6 : TC_2(6) = 72$$

Note that firms still need to pay the tax but this does not affect efficiency from an economic perspective since it is simply a transfer of wealth to the government. Note that for the same level of abatement, the total abatement cost is \$120 as opposed to \$125 in the command-and-control case.

Under a cap-and-trade policy, the government distributes emission permits to firms with the total amount being equal to the desired level of pollution. Each permit gives the firm the right to emit one ton of pollutant. In addition, the firms can trade permits similar to stocks at a price P_E. Each firm sets the marginal cost of abatement equal to the permit price. In equilibrium, the following conditions are met:

$$MC_1(a_1) = MC_2(a_2) = P_E$$
$$a_1 + a_2 = \text{Total Abatement}$$

Note that the second equation is crucial to solve for the equilibrium in the market. Otherwise, the solution to the first equation can not be determined since there are two unknowns. Solving the above examples leads to a permit price of \$24 and the same abatement levels than the emission tax. The emission tax was chosen such that the two examples are comparable. In reality, the permit price is unknown upon implementation of the policy give that the marginal abatement costs of firms can only be estimated and are not known with certainty. This is the reason why cap-and-trade is called a quantity instrument because the resulting level of pollution is known but not at which cost.

9.1.5 Policy Examples

Theoretically, a well designed pollution tax or cap-and-trade can minimize the total cost of achieving environmental protection Stavins (1998). The SO_2 Allowance Trading Program established under Title IV of the Clean Air Act amendment of 1990 aimed at reducing emissions by 10 million tons over 1980 levels. The purpose of the program was to control for acid rain to reduce acidification of forest and aquatic ecosystems. However, there have been significant benefits to human health as well . In this program, it was also possible to bank allowances for later use. The compliance with the program was enforced by a penalty of \$2,000 per ton of emissions exceeding the allowance together with the requirement to offset the emissions the following year. The program was mostly successful due to a liberalization in railroads Schmalensee and Stavins (2013). Also, the cost of the program was ten times cheaper than initially estimated Kerr (1998).

Examples of cap-and trade in the U.S. are the Acid Rain Program and the Clean Air Act. Sulfur dioxide (SO_2) and nitrogen oxides (NOx) react in the atmosphere (with water oxygen and oxidants) to form various acid compounds. Health concern: detrimental effects. Ozone affects respiratory illnesses and contributing to permanent lung damage. Market based instruments focus on the quantity and cost of pollution reduction and not who generates the pollution. The animated maps on the website of the National Atmospheric Deposition Program illustrate the outcomes of those policies using the National Trends Network (NTN) concentration and deposition maps for a variety of pollutants.

	Rival	Non-rival
Excludable	Private Good	Club Good
Non-excludable	Common good	Public good

Table 9.1: Categorization of goods along the dimensions of excludability and rivalry.

9.2 Public Goods

Most goods consider so far are private goods and this section introduces a so-called public goods. Although many public goods are provided by the public sector—and it will be shown why that is the case—the term as used in economics reflects the characteristics of the good and not its provider. Specifically, public goods can be consumed by more than one individual at the same time and use of the good cannot be prevented. The two prime examples illustrating public goods are national defense and light houses. National defense is provided by the public sector (i.e., national government) and it does not matter how many people live (and use) national defense, everyone consumes the same. It is also impossible to exclude a particular person living in a country to consume the good "national defense." The same argument can be made for light houses but with a subtle difference. Suppose that the lighthouse is owned and operated by a private person. Although the lighthouse is not in the hands of the public sector, it is still considered a public good since its use by ships cannot be prevented and it does not matter how many ships use it as a guidance for navigation.

Goods can be categorized—within the context of public goods—along two dimensions: Excludability and rivalry. Excludability refers to the characteristic of whether the use of the good by one person can be prevented or not. Imagine a streetlight whose use by people cannot be prevented. Rivalry refers to the characteristic that the consumption of the good by one person dpes (or does not) affect the consumption of another person. Consider the good national defense in this context. Person A "consuming" the good national defense does not affect person's B consumption as long as both live in the same country.

Additional categories are displayed in Table 9.1. A private good is both rival and excludable. The sandwich owned and eaten by one person illustrates a public good. The tragedy of the commons arises when rival goods are made non-excludable through common ownership. Club goods are non-rival but excludable; e.g. public swimming pools. Public goods lead to the problem of free-riding. That is, people enjoying the consumption of the good without paying for it. Thus, public goods are usually underprovided (if left to private markets).

9.2.1 Pubblic Goods in a Partial Equilibrium Setting

Suppose that the utility of a public good associated with its total quantity Q_T can be represented as follows for consumer can bet written as:

$$U_A(Q_T) = 10 \cdot Q_T - Q_T^2 = 10 \cdot (Q_A + Q_B) - (Q_A + Q_B)^2$$

And the utility for consumer B is expressed as:

$$U_B(Q_T) = 10 \cdot Q_T - \frac{Q_T^2}{2} = 10 \cdot (Q_A + Q_B) - \frac{(Q_A + Q_B)^2}{2}$$

The cost of acquiring the good is $C(Q_T) = 8(Q_A + Q_B)$. So the total benefit to society can be written as

$$B_S(Q_A, Q_B) = 20 \cdot (Q_A + Q_B) - 1.5 \cdot (Q_A + Q_B)^2 - 8 \cdot (Q_A + Q_B)$$

Solving the first-order conditions leads to $20 - 3 \cdot (Q_A + Q_B) = 8$. Thus, societal benefit is maximized if $Q_T = 4$. The key characteristic of a public good that the unit purchased by one consumer can also be consumed by all other consumers. So if $MB_a = 10 - 2q$, $MB_b = 10 - q$, and $MC = 8$, then we have

$$\begin{aligned} MB_a = MC &\quad \Rightarrow \quad Q = 1 \\ MB_b = MC &\quad \Rightarrow \quad Q = 2 \end{aligned}$$

But since individual A has already purchased 1 unit, individual B will free ride and they will end up with 2 units.

9.3 Asymmetric Information

Asymmetric information occurs if two or more parties engage in an transaction and at least one party has more information than the other. This causes high cost customer or low quality suppliers to participate in the market without the other party or parties knowing the cost and/or quality issue. The prime example for asymmetric information is the used car market. The seller has more information about the reliability and quality of the car than the buyer. There are multiple strategies to prevent or reduce asymmetric information. Some examples are:

- Used Car Market: Companies like Carfax that track the repair and accident history of cars can help uncover possible issues with a used car. Another example of market failure is the presence of asymmetric information. The prime example here is the used car market because two parties enter a contract where one party (buyer) is not fully informed.
- Life Insurance: An insurance company can require a health exam prior to selling a life insurance policy.
- Labor Market: Job interview are designed to reduce the asymmetric information for the employer. The potential job candidate has better information on their ability than the employer.

Assume that the demand for car insurance is $Q = 20 - 2 \cdot P$. The inverse demand is $P = 10 - Q/2$. Further, the marginal costs associated with a safe and unsafe drivers are $MC_S = 2$ and $MC_u = 6$, respectively. A perfectly competitive market without asymmetric information results in welfare maximizing marginal cost pricing. For the safe driver, this leads to:

$$2 = 10 - \frac{Q}{2}$$

Thus, quantity and price for safe drivers are $Q = 16$ and $P = 2$. Similarly, for the unsafe driver:

$$6 = 10 - \frac{Q}{2}$$

Thus, quantity and price for safe drivers are $Q = 8$ and $P = 6$. Calculating the consumer surplus from this pricing policy leads to $CS_S = \$128$ and $CS_U = \$32$. The total surplus of \$160. If the insurance company cannot determine in which category a driver falls, it has to charge a uniform price. Assuming an equal amount of safe and unsafe drivers, the company sets the price at \$4. It can be shown that this leads to a surplus of \$144, which is lower than the \$160 under no asymmetric information. This insurance problem is also illustrated in the video Asymmetric Information and Insurance Markets.

9.4 Exercises

1. ***Negative Production Externality I*** (***): Suppose that the inverse demand function for a particular good can be written as $P = 400 - 5 \cdot Q$ and that private marginal cost $PMC = 5 \cdot Q$. The additional external damage per unit produced is $D = 2 \cdot Q$. Support the answers to the questions below by using a graph.
   a. Calculate the market price, quantity, and deadweight loss.
   b. What are the efficient quantity and price?
   c. Calculate the per-unit tax that would achieve the efficient outcome.
2. ***Negative Production Externality II*** (***): Demand and supply for a good are written as $Q^D = 1000 - 5 \cdot P$ and $Q^S = 2 \cdot P - 100$, respectively. The external marginal cost is \$7. Support the answers to the questions below by using a graph.
   a. Calculate the market price, quantity, and deadweight loss.
   b. What are the efficient quantity and price?
   c. Calculate the per-unit tax that would achieve the efficient outcome.
3. ***Polluting Monopolist*** (***): John has a monopoly in the oil refinement market. The oil demand function is $P = 80 - Q$ and the marginal revenue is $MR(Q) = 80 - 2 \cdot Q$. The private marginal cost is $MC = 10$. During the refinement process, air, water, and soil pollution occurs at a constant cost of \$5 per unit of oil. Support the answers to the questions below by using a graph.
   a. What are the profit maximizing price and quantity?

b. What are the efficient price and quantity?
c. Calculate the deadweight loss associated with the monopoly situation? Should the government tax emissions? If yes, at what rate? If no, why?

4. ***Pollination*** (***): Pollination by bees is very important for plant reproduction and substantial fees are paid to beekeepers (Rucker et al., 2012). Imagine a beekeeper and an apple orchard farmer being neighbors. Note this is a situation of a positive externality. The beekeeper receives the revenue from selling honey but in the absence of any payments, does not receive any money for the bees pollinating nearby orchards or fields. Suppose that one beehive (H) can pollinate one hectare. The pollination of an hectare without the bees costs \$20. The beekeeper can sell the honey from a beehive at \$50. The total cost of the beekeeper is $TC = H^2 + 20$ and marginal costs $MC = 2 \cdot H$. Support the answers to the questions below by using a graph.
   a. How many hives would the beekeeper maintain if operating independently of the farmer?
   b. What is the socially efficient number of hives?
   c. In the absence of transaction costs, what outcomes do you expect to arise from bargaining between the beekeeper and the farmer?
   d. How high would total transaction costs have to be to erase all gains from bargaining?
5. ***Efficient Polluting Monopolist*** (**): Externalities and monopoly power lead to a deadweight loss when looked at separately. Using a graph, illustrate the case where a polluting monopolist can be efficient in the absence of any intervention. Draw a linear demand function and the corresponding marginal revenue function. Next, draw an upward sloping marginal cost function starting at the origin (note that the result does not change if you draw the marginal cost function with an intercept). Determine the profit maximizing output and price. Next draw an external marginal cost function such that the initially determine quantity and output are efficient, i.e., with no deadweight loss.