Public Management Economics

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Chapter 1

Introduction

Economics analyzes how individuals, households, firms, governments, and society in general employ scarce resources to produce goods and services. Economists are concerned about the efficient allocation of resources such that no other allocation would make society better off. Economists use mathematical, theory-based models to represent the aforementioned actors and how they interact in a market or some other economic activity. As with every model, only relevant features are included and not every detail. Empirical work is done to test economic theories with mathematics being a necessary tool for economists. Although this book limits the use of mathematics, the reader should keep in mind that there is a mathematical relationship behind every graph presented.

Economic concepts are used (explicitly or implicitly) by individuals, firms, and governments. An economist would say that most of your everyday life decisions are based on economic principles starting with the decision to get out of bed in the morning. The American Economic Association (AEA) has compiled a list of academic papers that help explain economic concepts using real world examples.

Microeconomics and macroeconomics are the two large branches in economics with the former being the main subject of this book. Microeconomics analyzes the behavior of individuals and firms whereas macroeconomics assesses the behavior of the economy as a whole. Important topics in macroeconomics are unemployment, interest rates, trade, national income, inflation, and many more. As mentioned before, this book covers microeconomics which includes the following topics:

- **Consumer theory**: Consumer theory uses the concept of utility maximization to derive the demand curve. Consumer theory is important in terms of welfare economics, e.g., what are the welfare effects for the consumer after a policy, price, or income change.

- **Producer theory**: Whereas the goal of consumer theory is to derive the demand function, producer theory derives the supply function for a good. Production theory is less abstract than consumer theory because terms such as profit maximization and cost minimization are easier to understand.
- **Demand and supply**: The combination of demand and supply determines the quantity and price which clear the market and lead to a market equilibrium, i.e., a situation with neither excess demand nor excess supply. It is important to differentiate between a change in quantity demanded (supplied) versus a change in demand (supply). There are many applications of demand and supply such as analyzing the effects of the 2012 drought in the Midwest on crop prices or how an increase in carbon fiber demand for wind farms has spill-over effects on the market for high-end bikes. The concept of elasticity is introduced in the context of demand and supply as well.
- **Perfect competition**: Once the supply and demand model is developed, we will focus on different market structures. The first such structure is perfect competition that is characterized by price-taking behavior of the market actors, i.e., consumers and producers.
- **Imperfect competition**: As opposed to a perfectly competitive market where producers are price takers, imperfect competition is characterized by price-setting behavior. If there is one producers for a particular good, we talk about a monopoly. A small number of producers is called oligopoly. Examples of oligopoly are widely available such as Airbus and Boeing or car manufacturing.
- **Game theory**: The strategic interaction among economic agents is analyzed with game theory. Each game has three components: (1) players, (2) actions, and (3) payoffs. Examples of games are auctions, bargaining, football, or chess.
- **Public Policy**: Besides imperfect competition, there are many other examples where the market fails to provide the efficient outcome. For example, most economic analysis requires the existence of a market. There are many goods for which no market exists. Many of them are found in environmental economics such as clean water and clean air. We are going to look at the implications of the absence of markets and the limitations to what people call the free market, e.g., Gulf of Mexico Hypoxic Zone. Another example of market failure is the presence of asymmetric information. The used car market is a good example because two parties enter a contract where one party (buyer) is not fully informed. For example, we will also learn why dressing nicely for a job interview is important or why you should post as many photos as possible when you sell your car.
- **Risk and uncertainty**: Almost all activities that are conducted by consumers or firms involve some sort of uncertainty. Decisions that are made today, affect the outcome tomorrow which is usually uncertain. How do individuals and firms make decision given those uncertainties.

There are many economic concepts that are useful in everyday life. Those concepts are analyzed in detail in the subsequent chapters. Some of the most important concepts are the following:

- **Marginal Analysis**: Economists focus on the margin, i.e., what is the benefit of the next good that is bought or sold, which leads to the concept of marginal analysis. Once you have purchased something, what matters is what you will do next. Can you make yourself better off? Our goal is to maximize total net benefit: the value of the good minus the cost. Hence, the additional (marginal) benefit must be bigger or equal the additional (marginal) cost. Examples are choosing the production quantity or renting a car. For the maximization of total benefit, we focus on marginal benefit and marginal cost. If the marginal benefit is larger than the marginal cost, total benefit will increase. If the marginal cost is larger than the marginal benefit, total benefit will decrease. The only time that total benefit will not rise or fall is when marginal benefit is equal to marginal cost. This is where total net benefit is maximized.
- **Sunk Cost**: A concept closely related to marginal analysis are sunk costs. Sunk costs are expenditures that have been made and cannot be recovered. Following from marginal analysis, sunk costs should be ignored. Since sunk costs cannot be changed, they should not influence decision-making. This concept is controversial because it does not always hold in reality.
- **Opportunity Cost**: Another example of costs that are considered by economists are opportunity costs which are the value of the next best alternative use of a resource, i.e., cost of forgone opportunities. For MPA students, the cost of going to the O'Neill School is tuition plus the opportunity cost, i.e., salary you forgo by not working. Opportunity costs are important to consider, but often ignored. Opportunity costs relate to the key concept of scarcity. Once a resource has been used, it cannot be used for something else.

Economics should be thought off in very broad terms and not just money and/or profit. Consider the example of saving human lives in the context of transport planning. In many regions in the U.S. and the world, people have a choice when it comes to transport modes (e.g., car, bike, train). Depending on the price of those modes, consumers substitute one for the other. There are also different fatality rates associated with each transport mode with cars probably having one of the highest. So if you increase train ticket prices to finance safety investments, people shift from the train to the road potentially causing more fatalities despite the investment in safety. Just focusing on road safety, an increase in the price of gasoline reduces road fatalities (Burke and Nishitateno, 2014).

1.1 Real versus Nominal Prices

Before starting with consumer theory, let us first look at index numbers, indices, and the difference between nominal and real prices. An index number assigns

a single value to several individual numbers in order to quantify trends. An index is series of index numbers used to track a variable's rise and fall over time. Important indices in economics are are the Consumer Price Index (CPI), the Dow Jones Industrial Average, or the S&P 500. The CPI is important because it allows us to differentiate between real and nominal prices. In general, only real prices are important. Let us illustrate this point with an example.

Suppose that your income in time period 1 is \$100. The price of apples and milk is \$5 and \$10, respectively. You purchase 4 apples and 8 gallons of milk. In time period 2, your income is \$120 and the price of apples and milk increased to \$6 and \$12, respectively. Although it seems that your income has increased from \$100 to \$120, you can only purchase the same quantities of apples and milk in both periods. The increase from \$100 to \$120 represents an increase in your nominal income. But since you cannot purchase more goods, your real income has remained the same. If your income increased to \$110 in the second period, then your nominal income has increased whereas your real income has decreased. Many people compare 1970 gasoline prices to today and complain about the price increase without realizing that they are comparing nominal prices. This would be similar to complaining about the cost increase of a Rolls-Royce. In 1921, a Rolls-Royce Silver Ghost cost \$12,000 which at the time was equivalent to the price of three Cadillac.

Besides the CPI, there are two other indices that can be used to differentiate real from nominal prices: GDP deflator and Producer Price Index (PPI). The GDP deflator includes goods and services purchased by businesses, governments, and foreigners whereas the CPI includes the price changes for consumer goods and services. The PPI includes goods and services purchased by producers and firms. For example, the price a large industrial firm pays for electricity is different, and behaves differently, than the price consumers pay. Very often, the prices of food and energy items are taken out of the CPI calculations because those prices are subject to large fluctuations and can result in an inaccurate reflection of the price level.

The figure below illustrates the evolution of the CPI since 1978. The CPI is a "measure of the average change over time in the prices paid by urban consumers for a market basket of consumer goods and services" (Bureau of Labor Statistics). The CPI is a basket of about 80.000 items. The approximate weights in the basket are food and beverages (15%), housing (43%), apparel (4%), transportation (17%), medical care (6%), recreation (6%), education and communication (6%), and other goods and services (3%). Urban consumers represent about 87% of the U.S. Population.

In this class, we measure all prices in real terms. We can use the following equation to calculate the CPI:

$$CPI_t = \frac{MB_t}{MB_b} \cdot 100$$

where MB_t and MB_b represents the cost of the market basket in time period t

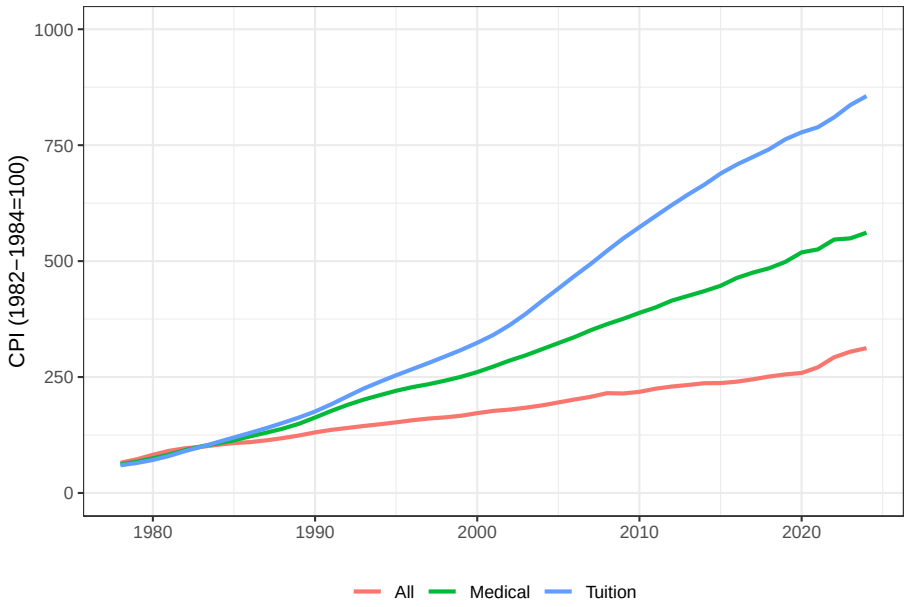


Figure 1.1: CPI for All Items in U.S. City Average, Medical Care in U.S. City Average, and Tuition, Other School Fees, and Childcare in U.S. City Average

and the base year b, respectively. The CPI base year is 1982 to 1984 but because it is an index, the base year can be adjusted for specific purposes. The CPI is also used as an economic indicator to set policy targets or to adjust dollar values such as pensions. It is also used as a deflator for price series to translate nominal into real prices. For example, the figure below shows the nominal and the real price of gasoline. We can see that in 2000, the nominal price of gasoline was around \$1.50 but the real price was over \$2.00. For real and nominal energy prices going back to 1970, see the Real Prices Viewer from the U.S. Energy Information Administration.

For constant dollar calculations, you first have to chose a base year. As mentioned above, the base year for the CPI is the period 1982 to 1984. But we can also chose a different base year, e.g., 2020. If we apply the below constant dollar calculations with the base year of 2020, then we convert a nominal dollar amount into 2020 Dollars. The constant dollar calculation can be written as:

$$CD_b = \frac{ND_t \cdot CPI_b}{CPI_t}$$

where CD_b represents the constant dollar or real value in the base year, ND_t is the nominal value in period t, and CPI_b and CPI_t are the Consumer Price Index in the base period and period t, respectively. For example, assume the following parameters: $ND_{1979} = 0.84$ (May 1979), $CPI_{1979} = 71.4$ ($CPI = 100$

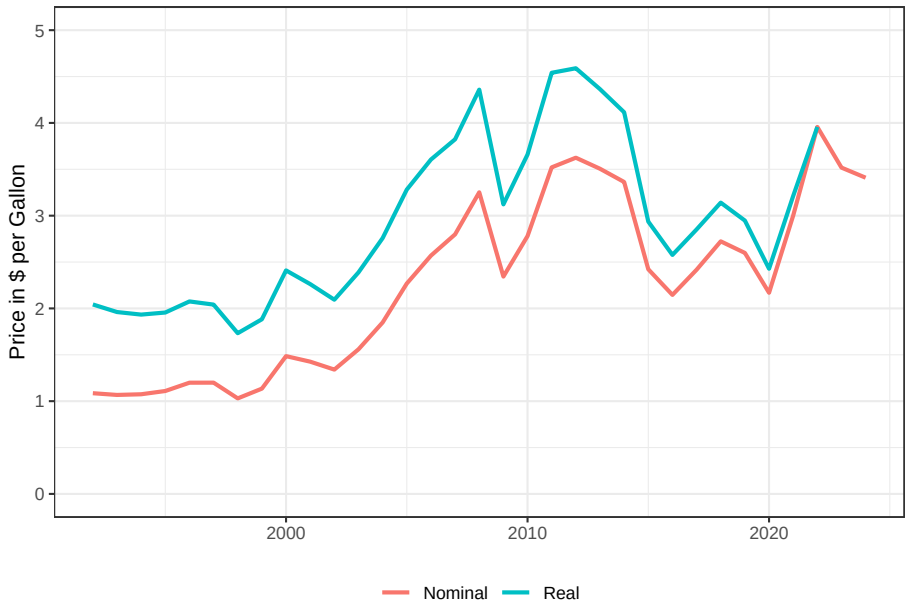


Figure 1.2: Real and nominal US Regular All Formulations Gas Price. The GDP Implicit Price Deflator in United States is used to deflate the prices. Source: Federal Reserve Economic Data.

in 1982-1984), $CPI_{2012} = 228.8$, $b = 2012$ and $t = 1979$. Plugging those values into the equation for the constant dollar calculation and we get:

$$CD_{2012} = \frac{ND_{1979} \cdot CPI_{2012}}{CPI_{1979}} = \frac{0.84 \cdot 228.8}{71.4} = 2.69$$

Let us consider a second example using the $12,000 Rolls-Royce Silver Ghost. Let us use January 1921 and June 2020 as the two time points of interest.

$$CD_{2020} = \frac{ND_{1921} \cdot CPI_{2020}}{CPI_{1921}} = \frac{12,000 \cdot 257.797}{19.0} = \$162,819.20$$

The figure below also shows that an increasing price series in nominal terms can actually be decreasing or flat in real terms. The fuel tax revenue in other states and at the federal level evolve similar to the one in Indiana.

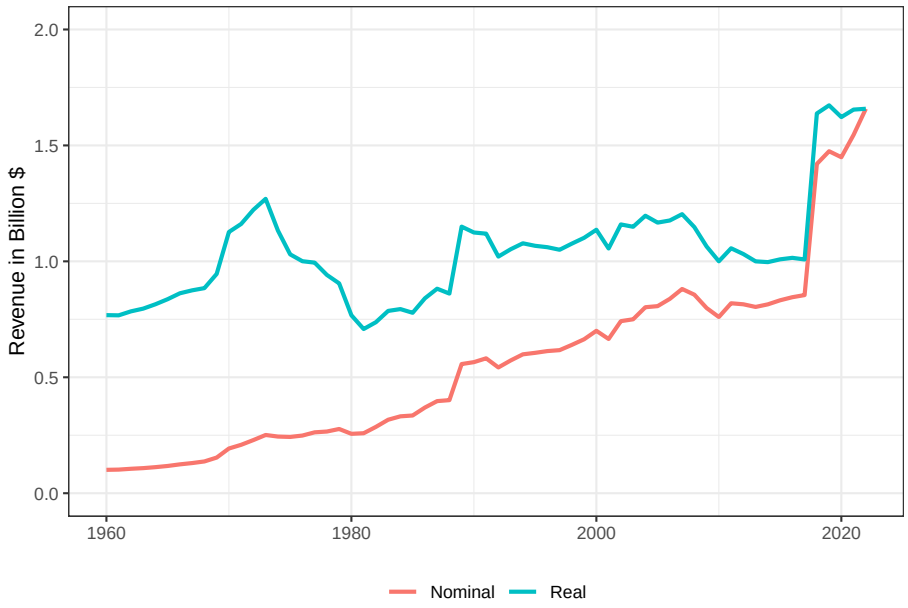


Figure 1.3: Real and nominal fuel tax revenue for Indiana. The GDP Implicit Price Deflator in United States is used to deflate the prices. Source: State Government Tax Collections, Motor Fuels - Selective Sales Taxes in Indiana from the Federal Reserve Economic Data.

There are some problems with the CPI. First, there is a substitution bias which refers to the situation where consumers shift their purchases away from goods whose relative prices increase towards cheaper goods. The second problem is associated with new, higher priced goods. The CPI fails to take quality improvements into account that are responsible for the increase in prices.

The last important concept presented in this section is the inflation rate which is the percentage change in the price level from one period to the next. The inflation rate can be calculated as follows:

$$\pi_t = \frac{CPI_t - CPI_{t-1}}{CPI_{t-1}} \cdot 100$$

The figure below shows the inflation annual inflation rate in the U.S. from 1960 to 2020.

Figure 1.4: Inflation as the growth rate from the previous period of the Consumer Price Index: Total All Items for the United States. Source: Federal Reserve Economic Data.

1.2 Exercises

The Federal Reserve Bank of St. Louis maintains the Federal Reserve Economic Data (FRED) database which contains thousands of economic time series. You will use FRED data for both exercises below.

1. ***Real Gasoline Price*** (**): For this exercise, you will calculate the real price of gasoline that prevailed several years ago. The base period is the most recent month for which the CPI is available. Proceed as follows:
    a. Take the first letter of your last name and determine its place in the alphabet. For example, if your last name starts with G then the

corresponding number is 7. Add that number to 1992 which results in the year you will be using for the nominal gasoline price. For example, if your last name starts with G, then the year of interest is 1999.

b. Go to the CPI for All Urban Consumers: All Items in U.S. City Average and determine the value of the CPI for two dates: (1) the most recent month available and (2) January of the year determined in part (a).

c. Go to US Regular All Formulations Gas Price and determine the price of gasoline in January of the year determined in part (a).

d. Calculate the real gasoline price that prevailed in January of the year of interest using the most recent month of the CPI available as the base period. In your answer, report the following: (1) year applicable to you, (2) the most recent CPI value, (3) the CPI value and gasoline price prevailing in January of the year applicable to you, (4) the constant/real gasoline price.

2. ***Annual State Government Tax Collections*** (***): For this exercise, go to Annual State Government Tax Collections and pick a state of your choice (except Indiana). Next, pick one of the following revenue categories: (1) General Sales and Gross Receipts Taxes, (2) Motor Fuels Sales Tax, (3) Motor Vehicle License, (4) Individual Income Taxes, or (5) Corporation Net Income Taxes. Download the data (i.e., state and revenue source over multiple years) to an Excel file. The data is in nominal terms and your tasks for this exercise are the following:

   a. Download the annual data for the GDP Deflator. Make sure to use the orange button "EDIT GRAPH" to get the annual data.

   b. Calculate the real tax revenue for the time series and state chosen. The base year is the most current year. In your answer, include a graph which shows the evolution of the tax revenue in real and nominal terms.

   c. Did the tax revenue increase or decrease in nominal terms? Did the tax revenue increase or decrease in real terms? Are the any implications given the size of the revenue source as a share of overall tax revenue in your state of choice?

Chapter 2

Consumer Theory

Consumer theory models individual decision making and consumer behavior. The goal of consumer theory is to derive the demand function. There are three components to consumer theory:

1. The **budget constraint** is the income constraint faced by the consumer given prices and income.
2. **Consumer preferences** are expressed using utility functions and indifference curves. Note that an indifference curves represent the contour line associated with a particular utility level of the utility function. Your preferences are independent of your income and prices!
3. **Optimal consumer choice** results from the combination of the budget constraint and consumer preferences. We look at how those optimal choices are affected given changes in prices, income, and/or policies?

It is important to understand that consumer preferences are independent of the prices and income. You can prefer a Bentley over a Toyota despite the fact that you cannot afford a Bentley. It is the consumer choice that determines what you buy based on your preferences and your budget.

2.1 Budget Constraint

A budget constraint represents all combinations of products that can be purchased for a fixed amount. All our examples in this section will be based on two goods, e.g., x and y. Of course, there are many more goods out there but two goods are all that are necessary to explain the main concepts. In this case, the budget constraint is written as:

$$B = P_x \cdot Q_x + P_y \cdot Q_y \quad \Rightarrow \quad Q_y = \frac{B}{P_y} - \frac{P_x}{P_y} \cdot Q_x$$

A change in income results in a shift of the budget line but the slope remains the same. If prices change, the budget line rotates and the slope changes. To illustrate those concepts, consider the following situations:

- Situation 1: $B = 100$, $P_x = 10$, and $P_y = 5$

$$100 = 10 \cdot Q_x + 5 \cdot Q_y \quad \Rightarrow \quad Q_y = \frac{100 - 10 \cdot Q_x}{5} = 20 - 2 \cdot Q_x$$

- Situation 2: $B = 150$, $P_x = 10$, and $P_y = 5$

$$150 = 10 \cdot Q_x + 5 \cdot Q_y \quad \Rightarrow \quad Q_y = \frac{150 - 10 \cdot Q_x}{5} = 30 - 2 \cdot Q_x$$

- Situation 3: $B = 100$, $P_x = 10$, and $P_y = 10$

$$100 = 10 \cdot Q_x + 10 \cdot Q_y \quad \Rightarrow \quad Q_y = \frac{100 - 10 \cdot Q_x}{10} = 10 - Q_x$$

Those changes are represented in the figure below.

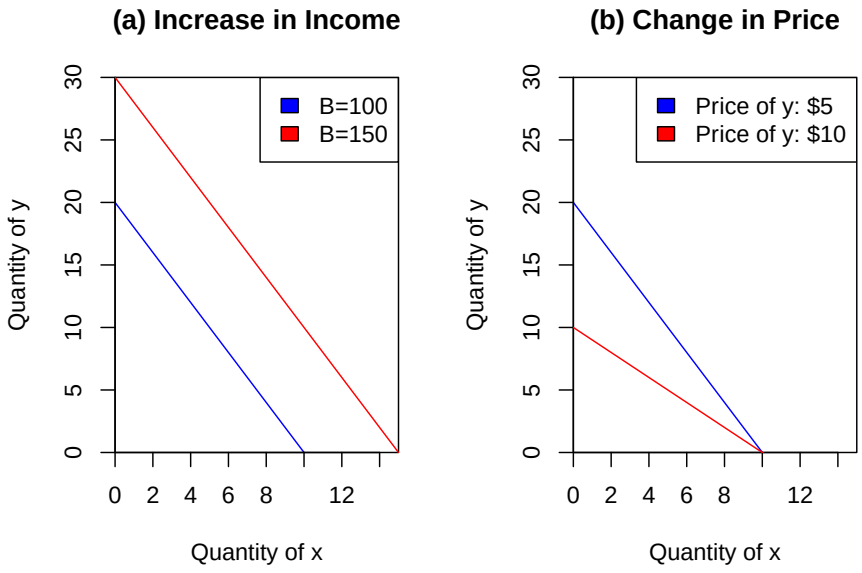


Figure 2.1: Changes in the budget constraint due to changes in income and price. If the income changes, the budget constraint shifts parallel as depicted in Panel (a). A change in price results in a different slope as depicted in Panel (b).

A budget constraint is linear only if there is no price change over the range. If there are restrictions on what can be bought, e.g., food stamps or quantity

discounts, the budget constraint is not linear anymore. To illustrate this point, draw the budget constraints for the following situations:

1. $M = 100$, $P_y = 2$, and $P_x = 4$
2. $M = 100$, $P_y = 2$, and $P_x = 4$ if less than 10 units are bought and $P_x = 3$ for units after 10.
3. $M = 100$, $P_y = 2$, and $P_x = 4$ if less than 10 units are bought and $P_x = 3$ on all units if more than 10 are bought.

2.2 Consumer Preferences

Before moving to consumer preference, consider below a 3-D representation of Mount Saint Helens in Panel (a) of the figure below. In consumer theory, the height of the mountain will represent the utility and the contour lines will represent the indifference curves.

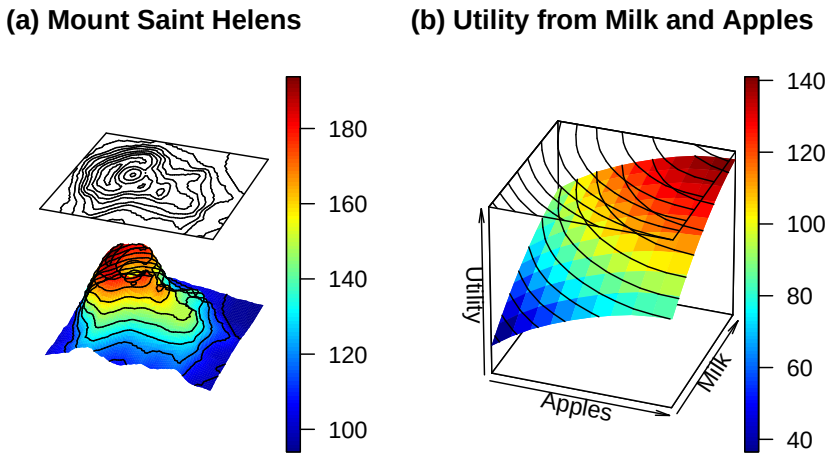


Figure 2.2: (a) Three-dimensional representation of Mount Saint Helens and contour lines. (b) Graphical representation of utility derived from various bundles of goods and services

Consumer theory makes the following assumptions about preferences:

- **Completeness**: Given two consumption bundles A and B, the consumer can make one of the following comparisons: (1) A is preferred to B, (2) B is preferred to A, or (3) A is indifferent to B.

- **Transitivity**: Given three consumption bundles A, B, and C and if a consumer prefers A to B and B to C, then the consumer also prefers A to C. For example, if a consumers prefers a BMW to a Toyota and a Toyota to a Chevrolet, then the consumer also prefers to BMW to Chevrolet.
- **Non-satiation**: More is better than less, i.e., utility does not decrease if more goods are consumed by the consumer.
- **Diminishing marginal utility**: The more of a good is already consumed, the smaller the additional utility gained.

2.2.1 Utility Functions

These assumptions in the previous section lead us to the concept of utility. Utility is the satisfaction a consumer gets from consuming a good or undertaking an activity. Utility can be either ordinal or cardinal. Ordinal utility is only concerned about the rank ordering of preferences, e.g., A is better than B. Cardinal utility measures the intensity of preferences, e.g., A is twice as good as B. In this class, we only care about ordinal utility. Note that we cannot make interpersonal comparisons of utility. At the end of this chapter, we present a method to make comparisons between consumers. Also, utility is independent of income and does not depend on the price of the product!

The change in utility from one more unit consumed is called the marginal utility. Marginal utility diminishes as you consume more of a good (the fifth ice cream cone is not as desirable as the first one). This is called the law of diminishing marginal utility. As long as the marginal utility is positive, total utility will increase.

Note that the assumption of non-satiation which was presented previously comes into play here. Since economics is about allocating scarce resources, i.e., asking what choices people make when faced with limited resources, looking at utility for a single good is not enough. We want to compare utility for different combinations of two or more goods. Consider the following table which represents the levels of utility associated with the consumption of milk and apples.

	Apples									
Milk	1	2	3	4	5	6	7	8	9	10
1	25	36	46	55	63	70	76	81	85	88
2	37	48	58	67	75	82	88	93	97	100
3	47	58	68	77	85	92	98	103	107	110
4	55	66	76	85	93	100	106	111	115	118
5	62	73	83	92	100	107	113	118	122	125
6	68	79	89	98	106	113	119	124	128	131
7	73	84	94	103	111	118	124	129	133	136
8	77	88	98	107	115	122	128	133	137	140
9	79	90	100	109	117	124	130	135	139	142
10	80	91	101	110	118	125	131	136	140	143

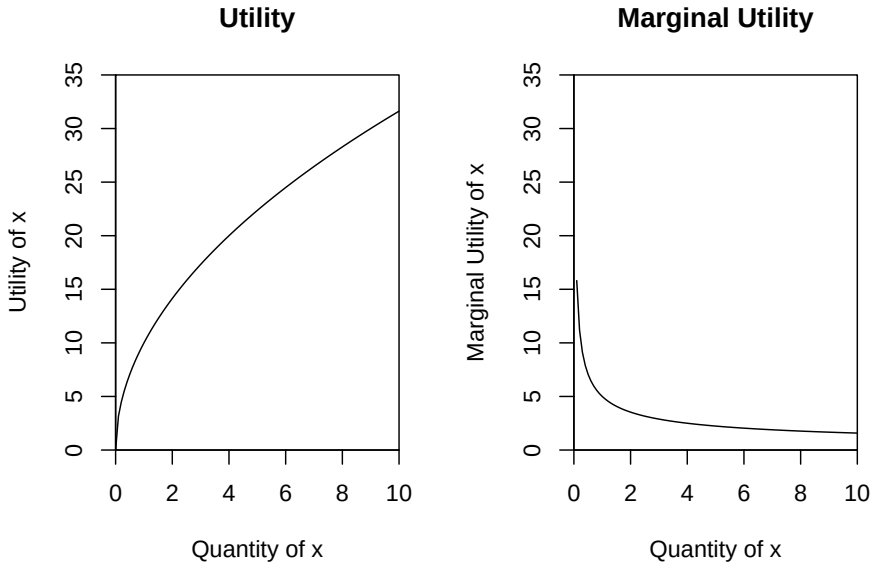


Figure 2.3: Univariate utility function and corresponding marginal utility

2.2.2 Indifference Curves

Indifference curves are all combinations of two goods that make the consumer equally well off and are the contour lines associated with the utility function. Those indifference curves can be represented using an indifference map. A point on a higher indifference curve is preferred to any point on a lower curve. Suppose a utility function of the form

$$U = x^{0.75} \cdot y^{0.25}$$

where U represents the utility and x and y represent the two goods. Solve the utility function for y. You should get

$$y = \frac{U^4}{x^3}$$

This is a function of the form $y = f(x, U)$. To get a particular indifference curve for a given level of utility, we fix U. If you fix $\bar{U}$ to say 2, you get the indifference curve because you have a function in x and y only. There are several important properties associated with indifference curves:

- Indifference curves do not intersect.
- Indifference curves slope downward.
- Indifference curves bend inward (are convex to the origin).

Let us consider an example in the 2-good space. We will be able to identify 3 regions: (1) Not preferred, (2) Preferred, and (3) Potentially indifferent.

2.3 Consumer Choice

Consumer maximize their utility subject to the budget constraint they face. Note that the slope of the budget constraint is

$$\frac{\Delta q_y}{\Delta q_x} = -\frac{p_x}{p_y}$$

The marginal rate of substitution (MRS) is the slope of the indifference curve:

$$MRS_{x,y} = -\frac{\Delta q_y}{\Delta q_x}\bigg|_{\Delta U=0}$$

So the optimality condition, i.e., optimal choice is

$$MRS_{x,y} = \frac{p_x}{p_y}$$

2.4 Derivation of the Demand Curve

Remember that the goal of utility theory is to derive the demand function of a product. The figure below illustrates the derivation of the demand function for good x for two examples of utility functions that are used frequently in economics: The Constant Elasticity of Substitution (CES) and the Cobb-Douglas utility functions. If we start out with the optimal choice given initial prices for both goods and the optimal choice (the point where the indifference curve is tangent to the budget constraint), we have the consumption of x for a particular price p_x. If we start to increase the price, the original consumption bundle will to be achievable anymore and the consumer has to choose a new consumption point given the new price for p_x. This gives us a second point of the demand curve. If we continue this process, we can trace out the entire demand function for x for all prices.

To obtain the market demand for a good, the individual demand functions have to be added horizontally. For example, consider three consumers with the following demand functions: $Q_1 = 10 - 2 \cdot P$, $Q_2 = 24 - 3 \cdot P$, and $Q_3 = 15 - P$. The inverse demand functions can be written as:

$$P = 5 - \frac{Q_1}{2} P = 8 - \frac{Q_2}{3} P = 15 - Q_3$$

The inverse demand functions are valid $Q_1 \in [0, 10]$, $Q_2 \in [0, 24]$, and $Q_3 \in [0, 15]$.

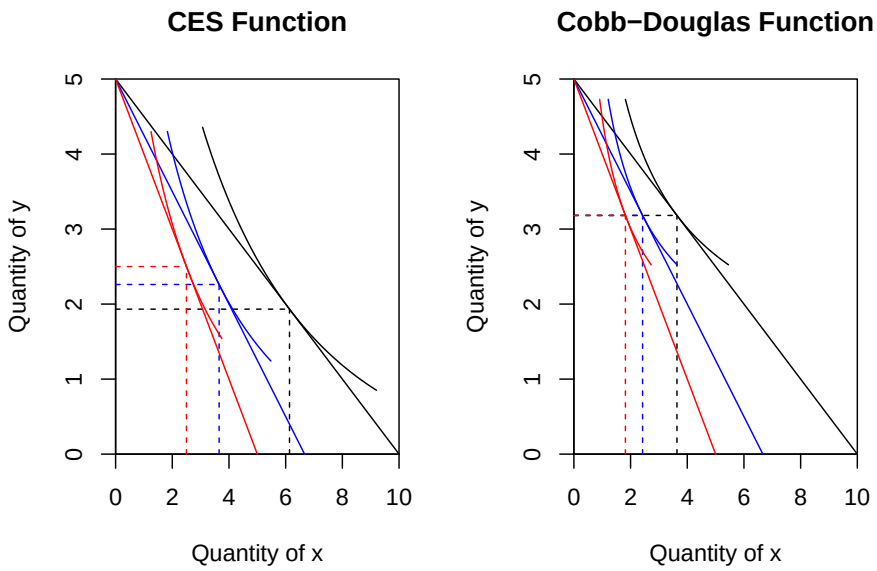


Figure 2.4: Derivation of the demand curve

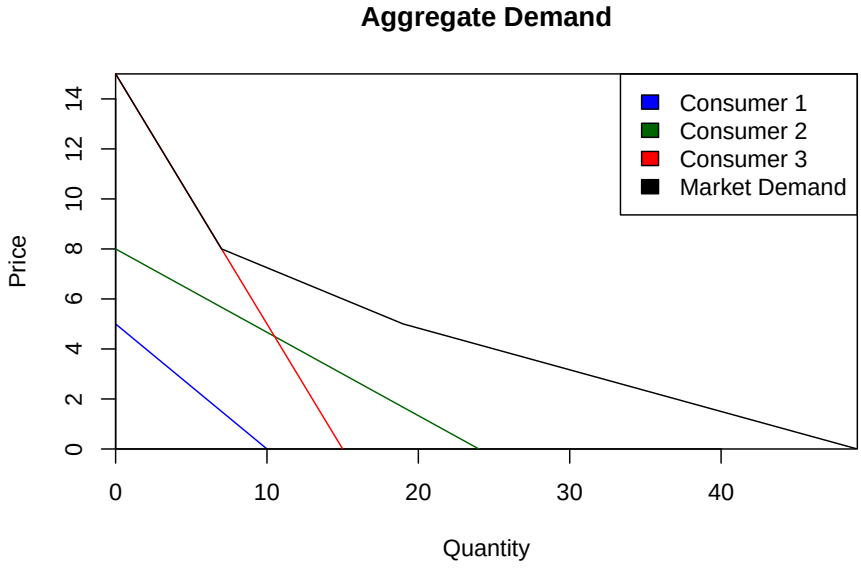


Figure 2.5: Derivation of the market demand curve given three individual demand functions.

2.5 Examples

This section covers some theoretical examples that can be translated to policy decisions as well as some applied examples from the economics literature.

2.5.1 Theoretical Examples

Switching food delivery services: Pamela uses a food delivery service which sends you the ingredients for meals and she just needs to combine and cook them at home for a nice meal. Currently, she purchases this services 20 times a month. Her income is $1,000 per month and the meals cost $20 per meal. All other goods cost $10 per unit. A new online service offers similar meals but charges a flat fee of $200 per month plus $10 per meal. This package lets her consume the same amount of food. However, because the slope of the budget constraint is different, the initial choice is not optimal anymore. By reallocating her consumption, she can get on a higher indifference curve. Panel "Food Delivery'' in Figure **??**.

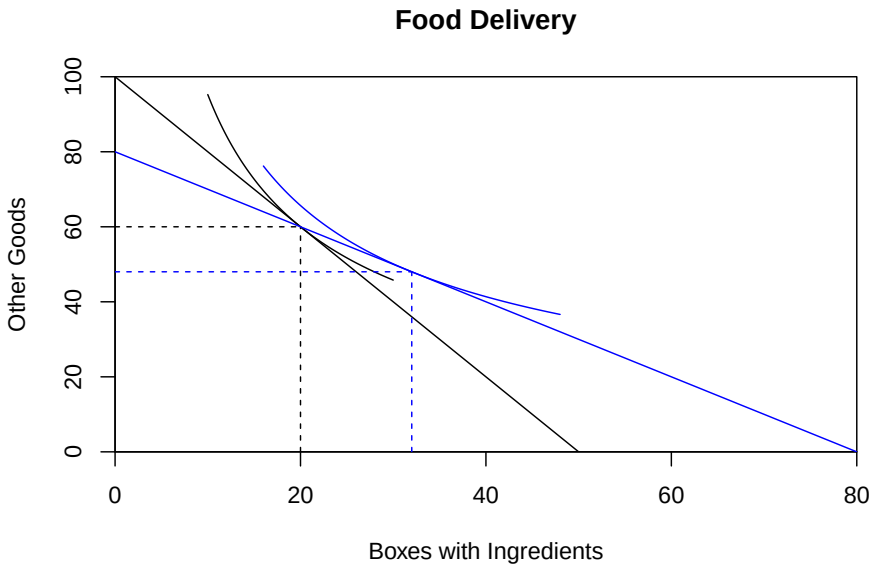
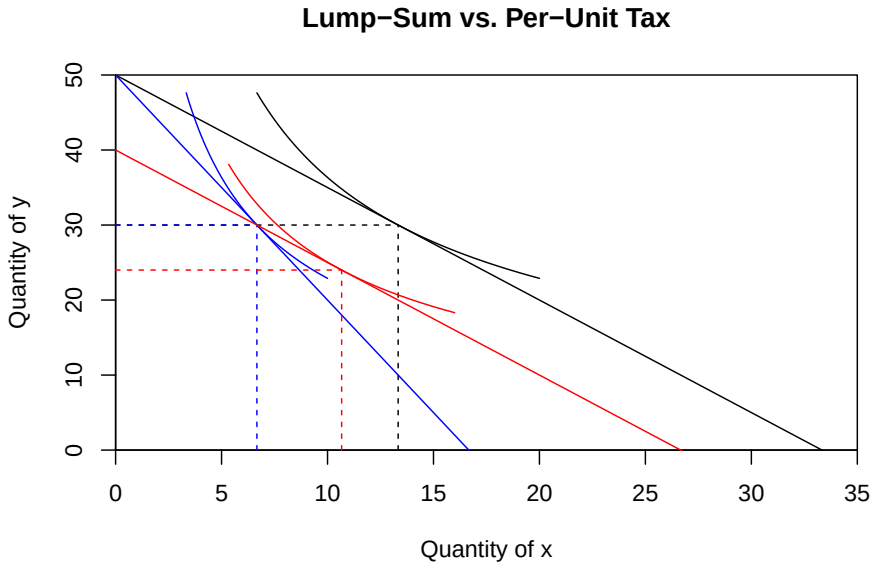


Figure 2.6: Theoretical examples about individual choice. Panel (a) demonstrates the switch from a per-unit purchasing system to a scheme which has a fixed cost and a lower per-unit price for subsequent purchases. Panel (b) contrasts the difference between a lump-sum tax and a per-unit tax.

Policy Example of a Lump-Sum Tax versus a Per-Unit Tax: A per-unit tax is the institution of an excise tax on some (but not all) goods a consumer purchases. A lump-sum tax is the collection of a single sum, independent of the

consumer's choices. Assume the following notation: p_x and p_y as the price of goods x and y, M as the income, t as the per-unit tax, T as the lump-sum tax. Table **??** and panel "Lump-Sum vs. Per-Unit Tax' in Figure **??** represent this problem. The graph in figure **??** is based on the following parameters: $M = 100$ (income), $P_x = 3$, $P_y = 2$, $t = 3$ (per unit tax), and the utility function is written as $U(x, y) = Q_x^a \cdot Q_y^{1-a}$ with $a = 0.4$.\



	Budget line	Choice
Original	$P_x \cdot Q_x + P_y \cdot Q_y = M$	$(x_1^\star, y_1^\star)$
Per-unit	$(P_x + t) \cdot Q_x + P_y \cdot Q_y = M$	$(x_2^\star, y_2^\star)$
Lump-sum	$P_x \cdot Q_x + P_y \cdot Q_y = M - T$	$(x_3^\star, y_3^\star)$

Subsidy for Low-Income Housing: Suppose you have to decide how to subsidize low-income housing. Assume that the family has an income of $1000 and that the price of other goods is $1. There are two subsidy plans: (1) a dollar-for-dollar subsidy or (2) a lump-sum payment. The initial consumption on housing is $500 ($250 from personal income and $250 subsidy from government). How does this differ from food stamps?

2.5.2 Policy Examples

In economics, we assume that all consumers are rational agents who have all the information they need to make informed decisions. This may not always be true even in every-day situations as illustrated in the first three examples. On

the other hand, the law of diminishing marginal utility may have some practical implications as demonstrated in the last example below.

Consumer Rationality: Burson et al. (2009) demonstrate how people reverse their preferences if faced with numbers that are scaled differently. In their experiment, they have respondents choose a cell phone plan. Under condition 1, 31% favor A and 53% favor B. Under condition 2, 69% favor A and 23% favor B. Note that both plans are identical (e.g., $\$32 \cdot 12 = \$384$) and people are simply attracted to a smaller number. If you listen to or watch advertisement, you always here "it's only $1 a day" and never "it's only $365 per year."

	Condition 1		Condition 2	
Option	Dropped Calls per 100	$ per Year	Dropped Calls per 1000	$ per Month
A	4.2	$384	42	$32
B	6.5	$324	65	$27

MPG Illusion: The second example illustrates the concept of MPG Illusion. Suppose that three people drive 10,000 miles per year. The fuel economy of the current cars are 10 MPG for person A, 16.5 MPG for person B, and 33 MPG for person C. They all trade-in their current cars for new cars that get 11, 20, and 50 MPG for A, B, and C, respectively. Who saves the most gas after the trade-in assuming that their driving habits do not change? See the figure below for a graphical representation of the relationship between MPG and gasoline consumption.

The table below compares using MPG to using gallons per mile.

MPG	10	11	12.5	14	16.5	20	25	33	50
gal. /10000 miles	1000	900	800	700	600	500	400	300	200

Marginal Utility and Malnourishment A paper by Jensen and Miller (2010) which was also cover in an article by The Economist titled People's spending choices are a good way to assess levels of hunger questions the usefulness of a fixed calorie threshold to quantify undernourishment. Their argument is based on the observation that in some countries, caloric intake decreases while real income increases. Instead of measuring the number of calories consumed, researchers and policy makers should turn to measure the amount of staples such as rice and millet consumed. Both goods are low cost sources of calories and thus, people consuming a large share of their total calories from those foods are likely to be malnourished. Consuming those foods results in a significant increase in utility very quickly and very cheaply. The authors in the article use the term staple calorie share as a measure of undernourishment.

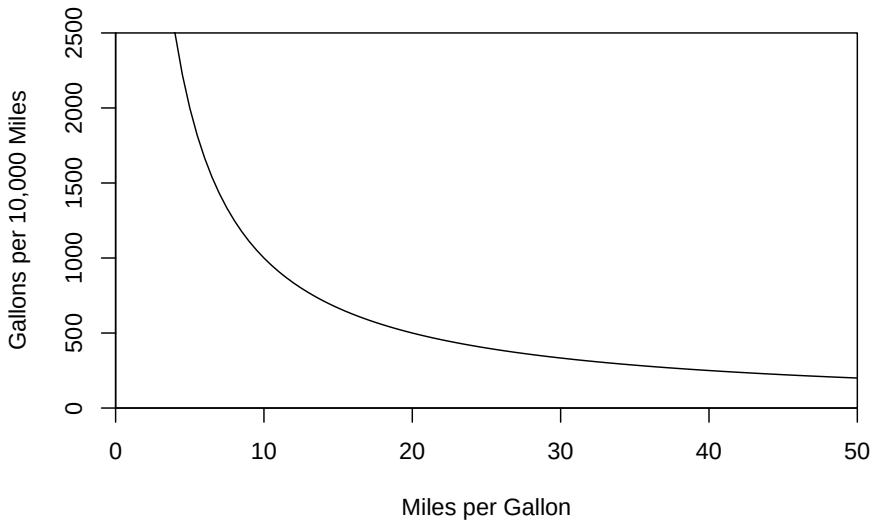


Figure 2.7: MPG Illusion: Gallons of gasoline consumed based on driving 10,000 miles per year.

Automatic Bill Payment and Electricity Consumption Sexton (2015) shows that enrollment in automatic bill payment (ABP) increases residential and commercial electricity consumption by up to 4.0% and 8.1% respectively. The result is attributed to the saying out of sight, out of mind.

2.6 Exercises

For all questions, assume that quantities are perfectly divisible, i.e., purchasing 2.5 textbooks is possible.

1. ***Veal for a Vegetarian*** (*): Draw the indifference curves of a vegetarian for veal and spinach.
2. ***Muesli*** (**): Sunny is a spoiled kid and forces her daddy to add a tablespoon of nuts for each tablespoon of fruits to her Muesli. The price of nuts and fruit per tablespoon is \$0.10 and \$0.20, respectively. He allocates a total of \$3 for her entire breakfast. Draw her indifference curves for nuts and fruits. How many tablespoons are used for her breakfast each morning?
3. ***Revealed Preferences*** (***): To better understand preferences, researchers often present respondents with different price and income

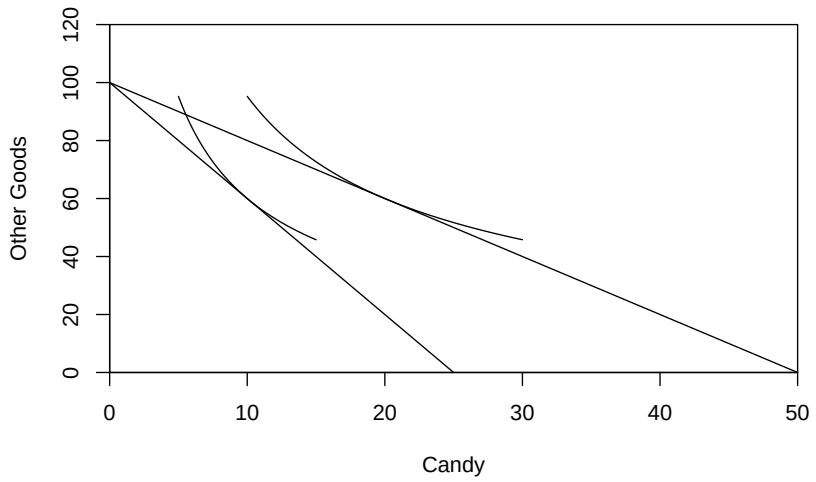
situations and ask them to choose between various consumption bundles (see Grebitus and Dumortier (2016) for an example). Consider the following two situations:

- Situation 1: Income is \$100 and prices are $p_x = \$10$ and $p_y = \$20$. In this situation, the respondent has the choice between two bundles: Either bundle A with $Q_x^A = 2$ and $Q_y^A = 4$ or bundle B with $Q_x^B = 4$ and $Q_y^B = 3$. The consumer picks bundle A.
- Situation 2: Income is \$80 and prices are $p_x = \$20$ and $p_y = \$10$. In this situation, the respondent has the choice between two bundles: Either bundle C with $Q_x^C = 1$ and $Q_y^C = 6$ or bundle A with $Q_x^A = 2$ and $Q_y^A = 4$. The consumer picks bundle C.

Rank the consumer's preferences for bundles A, B, and C from highest to lowest preference. Next, assume there is a fourth bundle D with $Q_x^D = 5$ and $Q_y^D = 5$. How does bundle D compare in terms of preference ordering compared to the other three bundles. Do you have all the information you need to determine bundle's D place in the ranking?

4. ***Textbook Gift Voucher*** (***): Tom is in college and receives \$500 from his parents each semester to spend on textbooks and other goods. The price of books is \$20 and the price of other goods is \$10. Assume that the number of textbooks is a choice. In the initial situation, Tom purchases six text books and the rest is spend on other goods. Draw Tom's budget constraint and the indifference curve indicating the optimal choice. To ensure that Tom spends sufficient amounts of money on textbooks, his parents replace the cash payment of \$500 with a bookstore gift certificate of \$300 and \$300 in cash. Draw the budget constraint under the new regime. Is Tom better off? On a new graph, draw a situation under which he is better off with a cash payment from his parents of \$600 than the \$300 cash/\$300 gift certificate split.

5. ***Obesity in Pawnee*** (***): Because of rampant obesity in Pawnee, the city government decides to tax candy. In the figure below, you have the original budget constraint with the optimal choice in the absence of any tax. The income of the consumer is \$100, the price of candy is \$2 per unit, and the price of other goods is \$1 per unit. Without the tax, consumers buy 20 units of candy and 60 units of other goods. With the tax of \$2 per unit, the consumer buys 10 units of candy and 60 units of other goods. How much does the city government collect in taxes? Assume that political pressure forces the city government to return the amount of the tax collected to the consumer in form of a lump-sum payment at the end of the year. Draw the new budget constraint given the lump-sum payment using the figure provided. Is the consumer as happy as in the case with neither tax nor subsidy. Interpret. See Figure for a template.



6. ***Per-Diem Meal and Hotel Rates*** (***): Suppose you work for a company which subsidizes your traveling with $1,000 per month. However, you cannot exceed $600 for hotel and $400 for meals. Assume that everywhere you travel, the price for one night in a hotel is $100 and the price of one meal is $20. Assume that you always exhaust your budget for traveling. Draw the budget constraint for this problem with hotel on the horizontal axis and meals on the vertical axis. Explain to your boss why you would (most likely) be better off with $1,000 but no restrictions on spending. Draw the relevant indifference curves.

7. ***Church Roof*** (***): Philip is a rich atheist but has a soft spot for the leaking roof of his hometown church. The church currently spends $2,000 on the roof and $8,000 on other activities.

    a. Draw the budget constraint for his hometown church with roof repairs on the horizontal axis and other activities on the vertical axis. Assuming utility maximization of the church, draw the indifference curve corresponding to the current situation.
    b. Philip offers the church a $1,000 grant with the constraint that the money can only go towards roof repairs. Put differently, it cannot be used for other activities. Will the amount of money spent on roof repairs increase by exactly $1,000 or will it change by a different amount. Justify your answers.

8. ***Gasoline in Iran*** (***): The Iranian government has provided substantial subsides on gasoline to its citizens in past decades. After international sanctions were imposed on the country due to its suspect nuclear program, those subsidies where not sustainable in the long-run from a financial per-

spective. Thus Iran eliminated the subsidies but replaced them with a cash transfer to ease the financial burden for its citizens. Assume that gasoline is on the horizontal axis and all other goods are on the vertical axis. The price of other goods does not change throughout the question.

a. Draw the initial budget constraint and the optimal consumption bundle. Assume that both goods are initially consumed.
b. How does the budget constraint change if the government eliminates subsidies on gasoline and the price of gasoline increase subsequently? Show this effect in the graph.
c. Given the new prices, the government provides a subsidy that raises income such that the consumers are as happy as before. Illustrate in your graph.
d. Why is this increase in income cheaper than the subsidy on gasoline? Illustrate in your graph.

Chapter 3

Producer Theory

The goal of producer theory is to derive the supply curve. We will first look at production functions and profit maximization. In the subsequent chapter, we will talk about cost minimization which ultimately leads to the supply function.

3.1 Production Functions

Production is the process of combining inputs to make goods and services. A production function indicates the maximum amount of output a firm can produce over some period of time from each combination of inputs. Inputs can be hours of labor, $ of capital, cubic feet of natural gas, or tons of raw material. There are similarities between consumer theory and producer theory:

- Preferences $\Leftrightarrow$ Production technology
- Budget constraint $\Leftrightarrow$ Cost constraints
- Consumption choices $\Leftrightarrow$ Production choices
- Indifference curves and budget lines become isoquants and isocost lines

Production functions can be thought of in a very broad context, e.g., studying for an exam or running a 100 meter world record (9.58 seconds). Consider Panel (a) "Fertilizer Application" in the figure below. In the graph, we have yield as a function of nitrogen application: $y = f(N)$. This application could be of interest if you consider the cost associated with water quality and water treatment plants, e.g., Eagle Creek.

3.2 Production in the Short- and Long-Run

In producer theory, we differentiate between the short-run and the long-run. In the short-run, some inputs cannot be adjusted and they are so-called fixed inputs. Examples of fixed inputs are machinery and factories. We classify fixed input

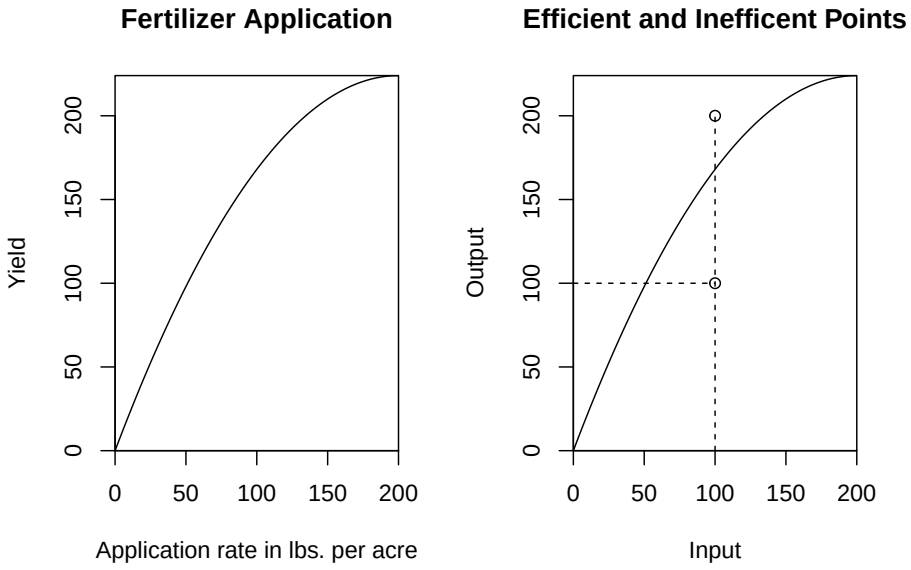


Figure 3.1: Production functions: Panel (a) on the left shows crop yield as a function of fertilizer application. Panel (b) on the right illustrates the concept of inefficient and unattainable production points.

as capital (K). The short-run production function is written as $q = f(\bar{K}, L)$. The long-run is a time horizon long enough for a firm to vary all of its inputs. Variable inputs can be adjusted up or down as the quantity of output changes. Consider production in the short run with labor (L) as the only input. The total product is the maximum quantity of output that can be produced from a given combination of inputs. The marginal product of labor is the additional output produced if one more worker is hired, i.e.,

$$MPL = \frac{\Delta Q}{\Delta L}$$

And the average product is defined as the average quantity per worker

$$AP = \frac{Q}{L}$$

The law of diminishing marginal product says that as more and more of any input is added to a fixed amount of other inputs, its marginal product will eventually decline. Note that for low inputs, we can have an increasing marginal product to labor, i.e., MPL increases as more labor is hired. But in most cases, we are faced with diminishing marginal product of labor. Examples that you find in everyday life are studying for an exam or training for a marathon.

Returns to scale can be either constant, increasing, or decreasing.

- Constant returns to scale: $t \cdot f(x) = f(t \cdot x)$
- Increasing returns to scale: $t \cdot f(x) < f(t \cdot x)$
- Decreasing returns to scale: $t \cdot f(x) > f(t \cdot x)$

The figure below illustrates the relationship between production function, average product, and marginal product. The production function depicted also exhibits increasing marginal product due to specialization at the beginning and then decreasing marginal returns.

The more interesting case is production in the long-run where all inputs are variable. So in this section, we consider the inputs labor (L) and capital (K). The figure below shows a so-called Cobb-Douglas production function for the case of two inputs.

The Marginal Rate of Technical Substitution (MRTS) is the rate at which a firm can substitute one input for another while keeping output constant. The MRTS decreases as we move rightward along an isoquant. It is also the slope of the isoquant.

$$MRTS = -\frac{\Delta K}{\Delta L} = \frac{MP_L}{MP_K}$$

Recall that

$$MP_K = \frac{\Delta Q}{\Delta K} \quad \text{and} \quad MP_L = \frac{\Delta Q}{\Delta L}$$

Every firm wants to minimize its costs:

$$C = p_L \cdot L + p_K \cdot KTC = w \cdot L + w \cdot KK = \frac{TC}{r} - \frac{w}{r} \cdot L$$

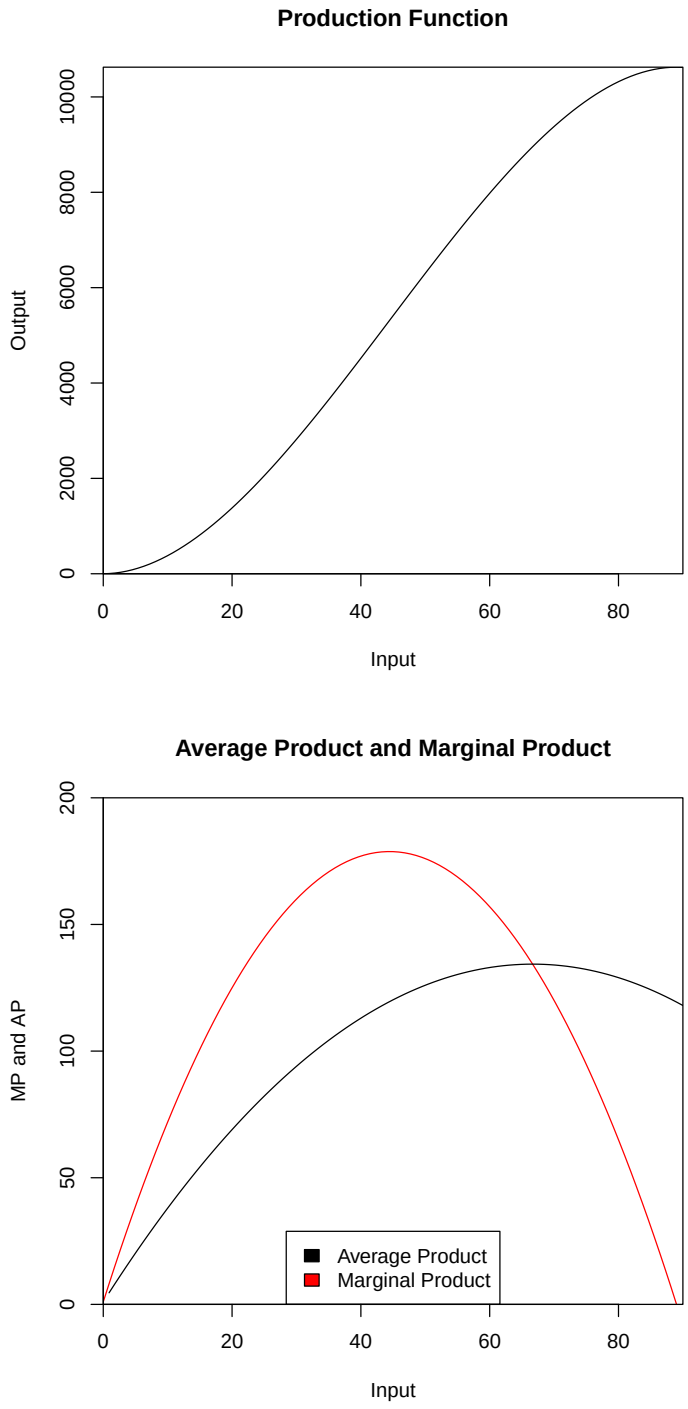


Figure 3.2: Relationship between production function, average product, and marginal product

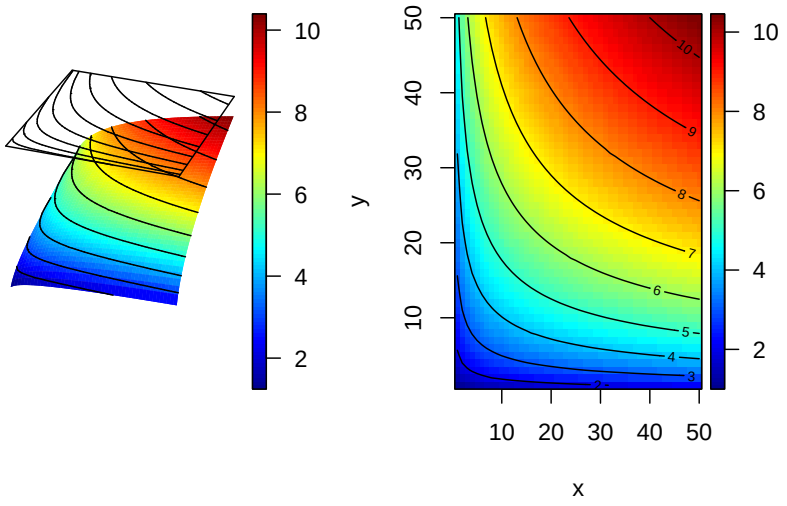


Figure 3.3: Production function with two inputs.

The optimal choice is the point where an isocost line is tangent to the isoquant for that output level

$$MRTS = -\frac{\Delta K}{\Delta L} = \frac{p_L}{p_K}\frac{MP_L}{p_L} = \frac{MP_K}{P_K}$$

For any number of inputs: The marginal product per dollar of any input will be equal to the marginal product per dollar of any other input.

3.3 Profit Maximization

Assume we have a single output that uses workers. The output price is p and the wage per worker is w. Then the profit maximization problem can be written as:

$$\max \quad p \cdot f(L) - w \cdot L$$

And the solution to this problem can be written as:

$$p \cdot f'(L) = w \quad \Leftrightarrow \quad f'(L) = \frac{w}{p}$$

Put differently $\pi = p \cdot y - w \cdot x$. Solving for y:

$$y = \frac{\pi - w \cdot x}{p} = \frac{\pi}{p} + \frac{w}{p} \cdot x$$

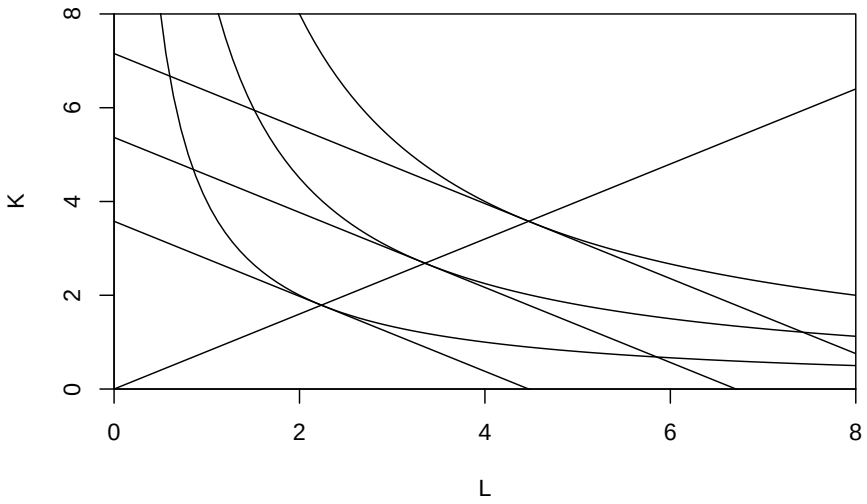


Figure 3.4: Short-run and long-run expansion path

The profit maximization problem as a function of output is $\pi(q) = R(q) - C(q)$ where $R = p \cdot q$. To find the profit maximizing output, we need the marginal revenue

$$\frac{\Delta R}{\Delta q} = p$$

and the marginal cost

$$\frac{\Delta C}{\Delta Q} = MC$$

Hence, the profit maximization condition is: $MC(q) = MR(q)$. This is true for any market structure. What differs across market structures is marginal revenue.

3.4 Exercises

1. ***Nitrogen Use*** (*): A farmer uses nitrogen (N) as an input to produce corn yield as the output. The production function which relates nitrogen inputs to corn yield is written as $y = f(N)$. With the current management practices, the farmer obtains $y^\star$ bushels of corn with $N^\star = 120$ pounds of nitrogen fertilizer. Given that setup, we have $y^\star < f(120)$. Are the inputs used efficiently? Use a graph to justify your answer.

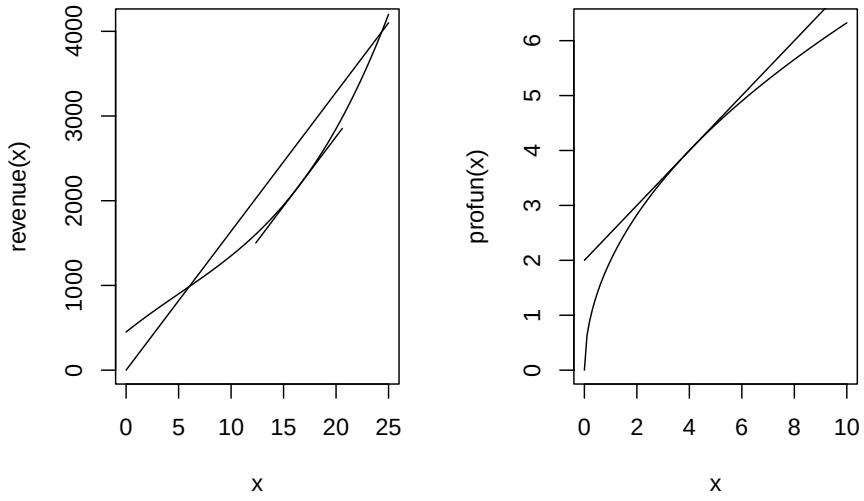


Figure 3.5: Two different ways of illustrating profit maximization

2. ***Malthus*** (*): The Malthusian Catastrophe was the prediction by the English cleric and scholar Thomas Malthus (1766-1834) that population will grow faster than agricultural production. Use the concept of diminishing returns to labor in the short-run to explain his reasoning. Explain why it did not happen. Use a graph to justify your answer.

3. ***Profit Function*** (**): The production function of a firm is written as $f(x) = 8\sqrt{x}$ where x are the units of input. The per-unit output price is \$100 and the per-unit input cost is \$75. Write down the profit only as a function of x.

4. ***Electricity Producer*** (***): Assume an electricity producer that currently uses a mix of natural gas and coal as inputs to produce electricity as depicted in the figure below. In the short-run, the electricity producer can adjust neither coal nor natural gas as the input for electricity production, i.e., both inputs are fixed. The initial input mix of coal and natural gas is depicted in the figure belwoas well as the current isoquant. The output does not change throughout the exercise.

    - Reproduce the figure and sketch an isocost for the quantity of electricity produced.
    - Assume that in the short-run, the price of coal decreases relative to natural gas. What happens to the isocost line? Is the choice of inputs

optimal after the price change? Justify your answer.

- In the long-run, what will happen to the combination of coal and natural gas used in the production of electricity if the price of coal remains low. Illustrate in your graph.

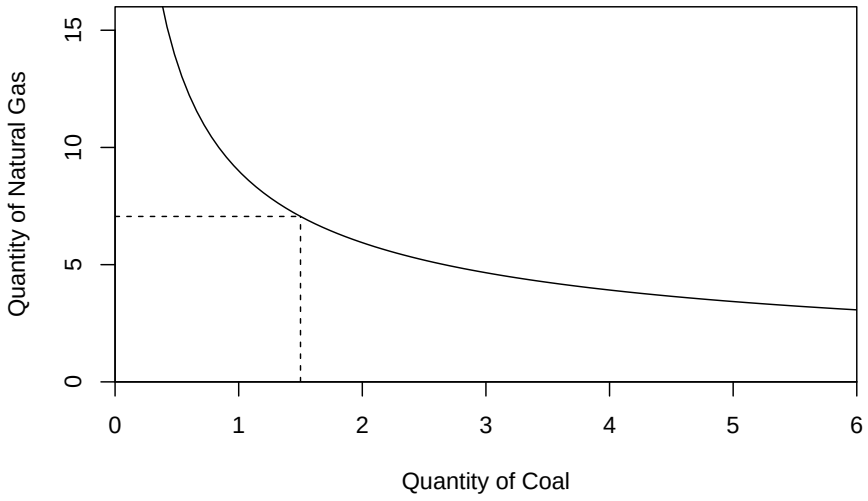
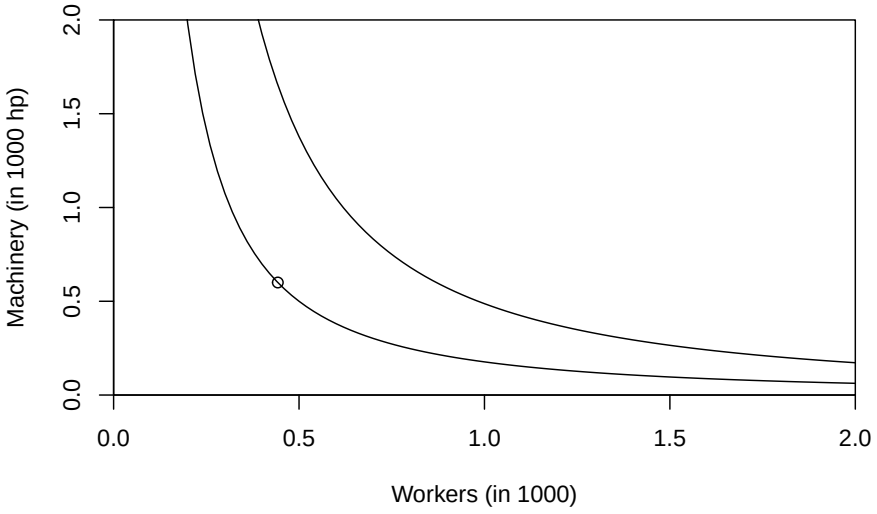


Figure 3.6: Electricity production with natural gas and coal.

6. ***Copper Mine*** (***): Suppose you are running a copper mine. You can either use machinery or workers to extract the copper. Currently, you are using a 600 horse power train to get the copper out of the mine. You have signed a leasing agreement for that train which you cannot change in the short-run. In the figure below, you will see two isoquant curves and a point indicating the initial (optimal) combination of workers and the train. The input prices remain unchanged throughout the question. Sketch the corresponding isocost line through the initial, optimal point. Assume that the machinery is fixed at 600 horse power and cannot be changed in the short-run. Due to changed demand, you need to expand production to the higher isoquant line. Show the new isocost line? Is it optimal? If yes, why? If no, why not? You are now able to adjust workers and machinery in the long-run while staying on the higher isoquant curve. What is the effect on cost? What is the effect on the optimal input combination. Support your answer in the graph.


Machinery (in 1000 hp)
0.0
0.5
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0
Workers (in 1000)

Chapter 4

Cost Theory

Recall from the previous section the differentiation between the short-run and the long-run in production. The short-run is a time period during which at least one of the firm's inputs is fixed. Fixed inputs cannot be adjusted as output changes in the short-run. The short-run production function is written as $Q = f(\bar{K}, L)$. The long-run is a time horizon long enough for a firm to vary all of its inputs depending on changes in output quantities and/or input prices.

Consider the example of Southwest Airlines compared to other major carriers. Southwest only operates one type of airplane, i.e., Boeing 737. Other carriers use a wide variety of airplane models. The advantage of using only one airplane model is reduced cost in training and operation. The disadvantage is no flexibility when it comes to serving routes with smaller or larger airplanes depending on demand. In our context, the number and types of airplanes as an input in the production process of transportation is fixed. You can only adjust the number of flights (e.g., lowering or increasing the number of flight personnel) in the short-run.

4.1 Accounting versus Economic Profit

Before relating production cost to production functions, let us first consider the difference between economic profit and accounting profit. Consider Al who owns a shoe store. In a given year, he sells shoes valued at $250,000 and the cost to purchase those shoes at the wholesale level is $200,000. From an accounting perspective, the store makes an accounting profit of $50,000. Now suppose that Al could instead be working in a shoe store at the mall making $60,000. This salary is considered the opportunity cost of owing his own store. Thus, the economic profit is the accounting profit minus the opportunity cost, i.e., $50,000-$60,000=-$10,000. If the salary for the position at the mall was only $40,000 then he would make a positive economic profit of $10,000.

4.2 Relationship between Production and Cost

Assume the following production function using workers L and capital K as inputs:

$$Q = 10 \cdot \sqrt{K \cdot L}$$

The price of capital is $r = 1$ and the wage is $w = 2$. Assume $K = 9$ in the short-run and thus, the production function becomes:

$$Q = 30 \cdot \sqrt{L}$$

Solving for L and plugging the result into the cost equation, i.e., $C = w \cdot L + r \cdot K$, results in the following total cost function:

$$C(Q) = \frac{Q^2}{450} + 9$$

In reality, it is much easier to observe the cost of a firm and how it relates to output than to observe the production function. Keeping in mind that there is a direct relationship (so-called duality in microeconomic theory) between the production technology and the total cost function.

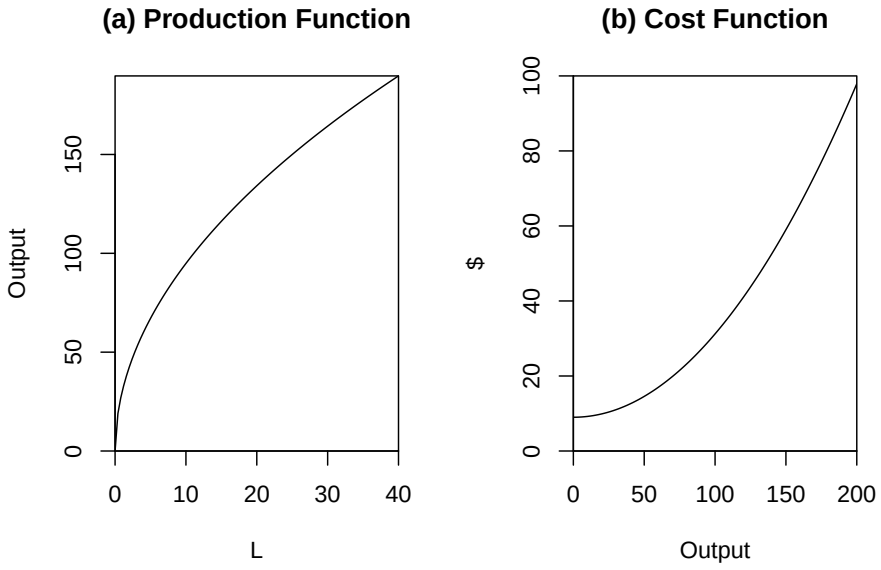


Figure 4.1: Moving from the Production Function to Total Cost Function. Panel (a) depicts the production function. Panel (b) shows the corresponding cost function with a fixed cost of 9 due the K being fix in the short-run.

The relationship is also shown in the table assuming $Q = 10 \cdot \sqrt{K \cdot L}$ and $r = 1$, $w = 2$, and $\bar{K} = 9$ below.

worker	output	TC
0	0	9
1	30	11
4	60	17
9	90	27
16	120	41
25	150	59

4.3 Total, Average, and Marginal Cost Functions

The total cost function of a firm can be decomposed into to parts: fixed cost and variable cost. Fixed costs are independent of output and need to be paid even if the firm does not produce anything, i.e., $Q = 0$. For example, if you have rented space for your coffee shop, then rent is due even if you are not selling any coffee. The same is true if you are an airline and all your planes are grounded due to a pandemic, then you still have to pay the interest for the financing of your planes. As opposed to fixed cost, variable cost vary with output. The variable cost of a coffee shop would be coffee beans and milk. If your output is zero then your variable costs are zero as well. Hence we can define total cost (TC) as total fixed cost (TFC) plus total variable cost (TVC). Given the definition of total, fixed, and variable costs, we have the following cost relations:

- Average Fixed Cost (AFC):

$$AFC = \frac{TFC}{Q}$$

- Average Variable Cost (AVC):

$$AVC = \frac{TVC}{Q}$$

- Average Cost (AC):

$$AC = \frac{TC}{Q} = AFC + AVC$$

- Marginal Cost (MC):

$$MC = \frac{\Delta TC}{\Delta Q}$$

Consider a total cost function of the following form:

$$C(Q) = 450 + 100 \cdot Q - 3 \cdot Q^2 + 0.2 \cdot Q^3$$

The fixed cost for this cost function is \$450. The resulting cost functions are presented in the table below:

Output	TC	MC	TFC	TVC	AC	AFC	AVC
0	450.0	NA	450	0.0	NA	NA	NA
1	547.2	94.6	450	97.2	547.2	450.0	97.2
2	639.6	189.2	450	189.6	319.8	225.0	94.8
3	728.4	283.8	450	278.4	242.8	150.0	92.8
4	814.8	378.4	450	364.8	203.7	112.5	91.2
5	900.0	473.0	450	450.0	180.0	90.0	90.0

One of the most important concepts in economics is marginal cost. The marginal cost is the additional cost from an additional unit of output. This is illustrated by $\Delta TC/\Delta Q$ where Δ represents "change in." Marginal costs plays an important role in deriving the supply function of the firm (see figure below).

4.4 Profit Maximization and Cost Functions

The cost function can be used to derive the profit maximizing quantity. The total revenue (TR) of a firm is written as $TR = P \cdot Q$ and thus, the profit can be written as follows:

$$\pi = P \cdot Q - 450 - 100 \cdot Q + 3 \cdot Q^2 - 0.2 \cdot Q^3$$

What is the profit maximizing quantity if $P = 160$? $P = 160$? $P = 110$? $P = 86$?

4.5 Policy Examples

In this chapter, we have seen that marginal cost plays an important role in determining the supply function. In this section, we are looking at two examples in which marginal cost play an important role.

Philanthropic Giving: Gneezy et al. (2010) conducted a field experiment in a large amusement park in which roller coaster riders were able to purchase photo after their ride. They used a 2×2 design matrix, i.e., (1) purchasing the photo at \$12.95 or pay-what-you-want (PWYW) and (2) no charitable giving or 50% goes to charity. In the control group (i.e., the status quo sales policy by the amusement park), riders paid \$12.95 for the photo and total revenue was \$1,823. With 50% going to charity, photo revenue was \$2,331. With PWYW and charity, photo revenue was \$6224.22. the lost revenue was achieved with PWYW at \$2175.80. The marginal cost of printing the photo is probably very close to zero for the amusement park company. Thus, the profit margin per photo can be relatively high.

Marginal Cost and Oil Extraction: The marginal cost of oil extraction depends on the type of oil (e.g., onshore versus offshore) and geographical loca-

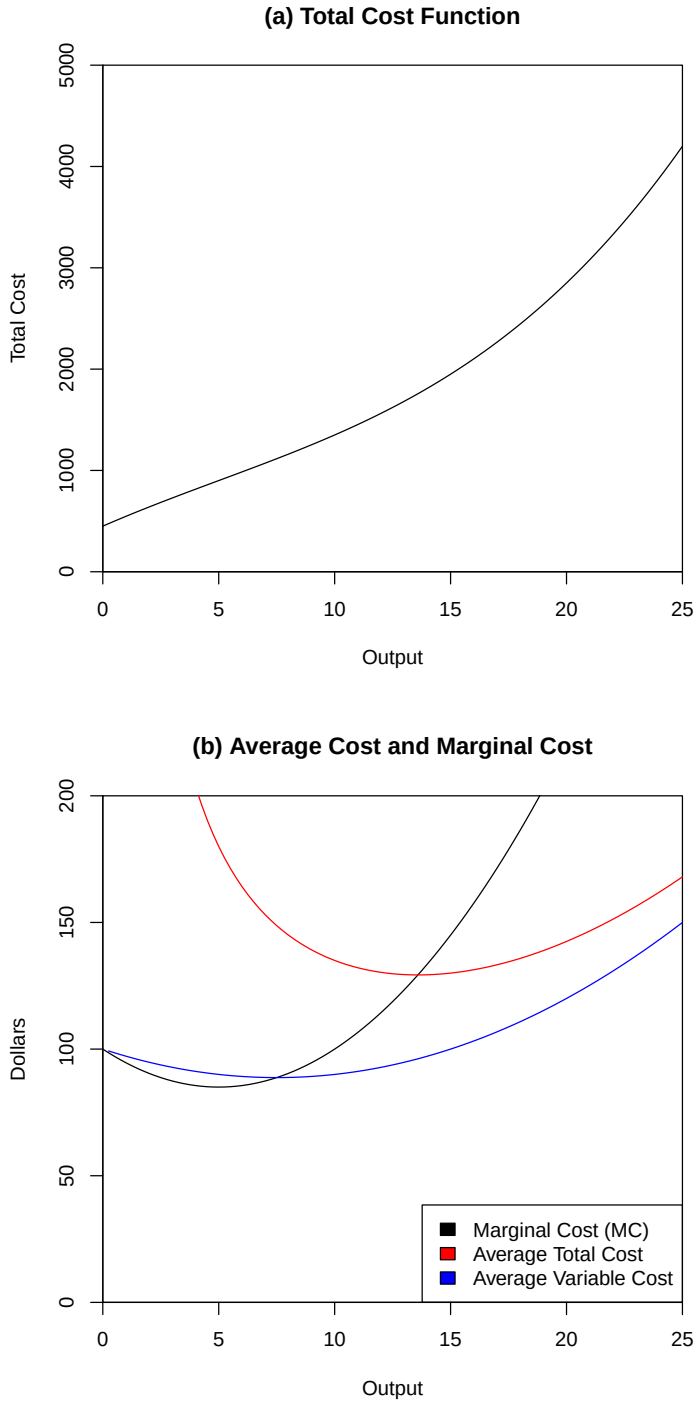


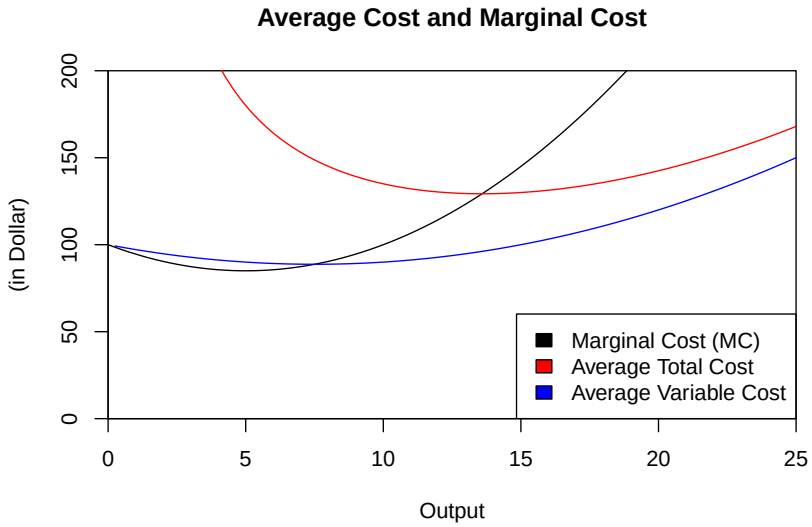
Figure 4.2: Derivation of the supply function. Panel (a) represents the total cost function. Panel (b) shows the average and marginal costs associated with the total cost function.

tion. Illustrations of the marginal cost of oil extraction can be found in Bank of Canada and Arezki et al. (2017).

4.6 Exercises

1. ***Cost Function Components*** (**): A firm's total cost function is given by the equation $TC = 4000 + 5 \cdot Q + 10 \cdot Q^2$. Write an expression for each of the following cost concepts: (1) Total Fixed Cost, (2) Average Fixed Cost, (3) Total Variable Cost, (4) Average Variable Cost, and (5) Average Total Cost.

2. ***Cost Function and Profit*** (*): Consider the figure below and assume that the current price is at 150. In the graph, show the profit maximizing quantity produced and present the profit in the graph.



3. ***Production and Cost Function Relationship*** (***): This question will make you show the connection between the production function and the cost function. It will also visualize the marginal and average product of labor. The homework must be done in Excel. Be sure to use the functions available in Excel to make your life easy. Especially the use of "$" to keep referencing a particular cell. Except for the input of labor and/or capital columns, every other column should be based on a function starting with "=". For your Excel file, make sure that the sheets, tables, and graphs look neat and presentable. The polynomial production function first rises at an increasing rate and then increases at a decreasing rate. That is, the marginal product of labor is first increasing due to specialization and then

decreasing. The function you will be looking at is written as:

$$Q = a \cdot L + b \cdot L^2 + c \cdot L^3$$

where Q represents the output quantity and L represents the labor input. The parameters of the function are a, b, and c. In our case, we will define $a = 10$, $b = 20$, and $c = -0.6$. Openan empty Excel spreadsheet and name the sheet *Poly Function*.

a. Write "a=" in cell A1, "b=" in cell A2, and "c=" in cell A3.
b. Put the values of 10, 20, and -0.6 in cells B1, B2, and B3, respectively.
c. Assume that the wage w is 10 per unit of L and that the fixed costs are 100. Put "w=" and "FC=" in cells C1 and C2, respectively. Put 10 and 100 in cells D1 and D2, respectively. Put the following labels in cells A4 through G4: *L*, *Q*, *MPL*, *APL*, *FC*, *VC*, and *TC*. Those columns represent the units of labor, the output quantity, the marginal product of labor, the average product of labor, the fixed costs, the variable cost, and the total cost.
d. Put 0 in cells A5, 0.25 in cell A6,... until you reach 20 in cell A85 (Once you have the first two values, simply mark both and drag them down until cell A85.). Now, you have all the information you need to fill out the columns for *Q*, *MPL*, *APL*, *FC*, *VC*, and *TC*.
e. In three new sheets, I want you to graph your results. Graph the production function in the first sheet. Graph the average product and marginal product of labor in the second sheet. And lastly, draw the cost function in the last sheet. Be careful with the cost function, it should not be a linear line! Use the scatter plot function of Excel.

4. ***Cobb-Douglas Production Function*** (***): A Cobb-Douglas production function is used very often in economics because its functional form is very flexible. In general it is written as follows:

$$Q = A \cdot K^{\alpha} \cdot L^{\beta}$$

Create a new sheet called *Cobb Douglas* and type in the following information regarding parameters:

- A1 to A4: *K Fixed*, *alpha*, *beta*, *A*.
- B1 to B4: 9, 0.5 0.3, 10
- C1 to C2: *w*, *r*
- D1 to D2: 0.5, 0.2 In cells A5 through H5, put the following labels: *Kfixed*, *L*, *Q*, *MPL*, *APL*, *FC*, *VC*, and *TC*.

a. Ranging from 0 to 10 in increments of 0.1, put the units of labor in cells C6 through C106. Then fill in the remaining columns.
b. In three new sheets, I want you to graph your results. Graph the production function in the first sheet. Graph the average product and marginal product of labor in the second sheet. And lastly, draw the cost function in the last sheet. Be careful with the cost function,

it should not be a linear line! Make sure you use the scatter plot function of Excel.

5. ***Multi-Plant Production*** (***): In class, we have considered producing with one production facility only. Our analysis and results (e.g., price equals marginal cost) is easily extendable to multiple production facilities. Assume that you are a producer who has two production plants. You incur no fixed cost for running both plants and only face variable costs. The total cost for the plant 1 (TC_1) and 2 (TC_2) are $TC_1(Q_1) = 2 \cdot Q_1^3$ and $TC_2(Q_2) = Q_2^2$. The marginal cost is written as $MC_1 = 6 \cdot Q_1^2$ and $MC_2 = 2 \cdot Q_2$. In Excel, write Q in cell A1 and write $0, 0.1, \ldots, 5$ in cells A2 to A52 (do not enter those numbers manually but make sure to just drag the little square down). Name cells B1 through E1 as *TC1*, *TC2*, *MC1*, *C2*. Use the provided functions to fill out cells B2 through E52. Next, graph the two total cost functions in the same chart and name the sheet *TC*. Do the same for the marginal cost functions. Based on the functions and charts provided, what is your total production if the price is \$6? Do you produce in one plant or both plants? Provide an intuitive explanation for your answer? What is your revenue? What is your total cost?

6. ***Supply Function Derivation*** (***): This problem recreates the derivation of the supply function using Excel. It is a good opportunity to strengthen the understanding of the concepts associated with total cost, average total cost, average variable cost, and marginal cost. The total cost is given by the following equation:

$$TC = 450 + 100 \cdot Q - 3 \cdot Q^2 + 0.2 \cdot Q^3$$

   a. Pick an empty Excel sheet and type *Price* in cell A1. For now, put the number 160 in cell B1. Name the cells A2 to H2 as follows: *Q*, *Cost*, *Marginal Cost (MC)*, *Average Total Cost (ATC)*, *Average Variable Cost (AVC)*, *Revenue*, *Profit*, *Price*. Fill in the production quantities in cells A3 to A28 ranging from 0 to 25 in increments of 1.

   b. Fill in the marginal cost, average total cost, average variable cost, revenue, profit, andprice columns. Make the make the revenue, profit, and price columns a function of cell B1.

   c. Once you have filled out the table, I want you to create three new sheets: (1) Sheet *Profit*: A graph that displays the profit as a function of the quantity produced, (2) Sheet *Cost and Revenue*: A graph that displays cost and revenue as a function of quantity, and (3) Sheet *MC and AC*: A graph that displays MC, ATC, AVC, and price. Once you have done this, you can play around with the price by changing cell B1, i.e., the price, and seehow profit and output decisions change.

Chapter 5

Demand and Supply

We derived the demand and supply function for a good in the previous two sections on consumer and producer theory. In this chapter, we determine the market equilibrium and analyze how the market equilibrium evolves under shifting supply and demand. If the market is not in equilibrium, we call this a market imbalance. In the case of excess supply, the price is above the equilibrium. In the case of excess demand, the price is below the equilibrium.

5.1 Demand Curve

The quantity demanded of a good or service is the number of units that all buyers in a market would choose to buy over a given time period, given the constraints that they face. There is a negative relationship between price and quantity demanded as shown in consumer theory. The demand curve is a function of price (p), price of substitutes (p_S), price of complements (p_C), income (I), and possibly other factors such as advertising, tastes, taxes, weather, etc. Hence, the demand curve is usually expressed as a function $Q^d = f(p, p_S, p_C, I, ...)$

Substitutes are goods that are similar to each other and can serve as an alternative for a good. Examples for substitutes are maple syrup, honey, sugar, jam. Complements are goods that are bought together. Examples of complements are pancake mix and maple syrup or cars and tires.

The demand function is usually represented as a function form. For example the demand for natural gas as a function of price (P) and temperature (T):

$$Q^d = 200 - 4 \cdot P - \frac{T}{2}$$

Given the functional form, the demand can then be either represented in a table format or as a graph. For example, given the above demand for natural gas, you can draw the demand if the temperature is say $T = 80$ or $T = 20$.

The law of demand states that when the price of a good rises and everything else remaining the same, the quantity demanded of the good will fall. In economics, "...everything else remains the same..." is called *ceteris paribus*. A change in any variable that affects demand, except for the good's price, causes the demand curve to shift. There is a difference between *change in quantity demanded* and *change in demand*. It is important to differentiate between a shift in demand and a price change. In the case of a price change, we have

- Price decrease ⇒ Movement to the right along the curve
- Price increase ⇒ Movement to the left along the curve

Some important factors that make the demand curve shift are:

- **Income or wealth**: An increase (decrease) in income or wealth shifts the demand function to the right (left).
- **Price of substitutes**: An increase (decrease) in the price of substitutes shifts the demand function to the right (left).
- **Price of complements**: An increase (decrease) in the price of complements the demand function to the left (right).
- **Population**: An increase (decrease) in population shifts the demand function to the right (left).
- **Expected price**: An increase (decrease) in the expected price shifts the demand function to the right (left).

5.2 Supply Curve

The quantity supplied is the number of units of a good that all sellers in the market choose to sell over some time period, given the constraints that they face. The quantity supplied maximizes producer profits. The supply function can be expressed as $Q^s = f(p, p_r, w, T, \dots)$.

Quantity supplied (Q^s) is a function of output price (p), price of inputs (r), wages (w), technology (T), and possibly other factors such as taxes, subsidies, etc. The law of supply states that when the price of a good rises and everything else remains the same, the quantity of the good supplied will rise. In case of a price change, we have

- Price decrease ⇒ Movement to the left along the curve
- Price increase ⇒ Movement to the right along the curve

Table **??** summarizes the effect on supply for some important factors.

Factor	Right shift	Left Shift
Price of input	↓	↑
Price of alternatives	↓	↑
Number of firms	↑	↓
Expected price	↓	↑

5.3 Market Equilibrium

A market is a group of buyers and sellers with the potential to trade with each other. The equilibrium price is determined by the intersection of the demand and supply curves. It is the price at which the quantity demanded equals the quantity supplied. Figure **??** provides example of changes in market equilibrium such as (1) shift in demand, e.g., demand due to biofuels, (2) shift in supply, e.g., fertilizer price, and (3) shift in demand and supply, e.g., biofuels and fertilizer price.

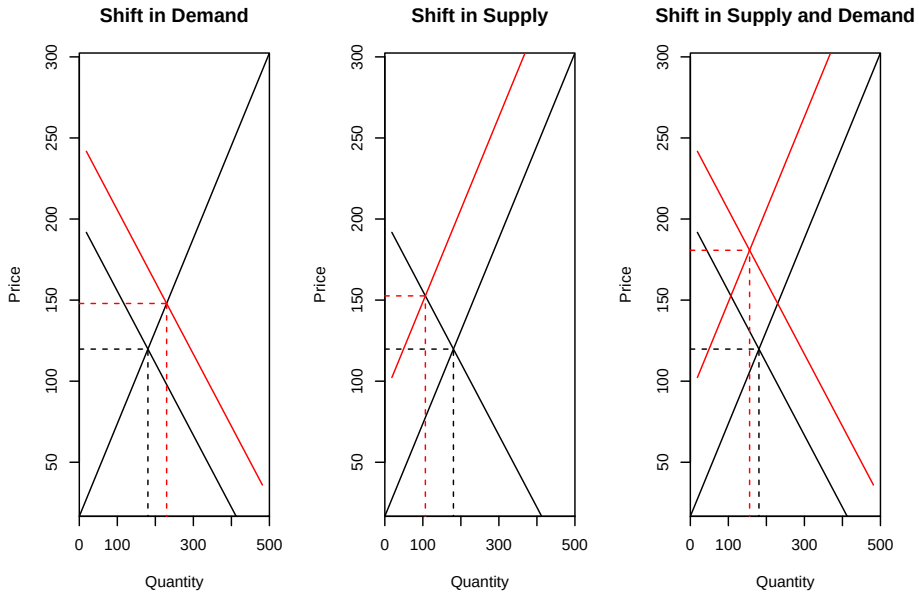


Figure 5.1: Shifts in demand and supply

Simultaneous shift of demand and supply leads to ambiguous effect on price and quantity. If both curves shift, the effect of quantity and price is ambiguous. To determine the exact effect, we need mathematics.

	Demand ↑	Demand ∘	Demand ↓
Supply ↑	P?,Q ↑	P↓,Q ↑	P↓,Q ?
Supply ∘	P↑,Q ↑	P ∘,Q ∘	P↓,Q ↓
Supply ↓	P↑,Q ?	P↑,Q ↓	P?,Q ↓

In 2012, a severe drought hit farmers and cropland in the United States. The British News Magazine The Economist had at least two articles on this subject titled The 2012 drought will dent farm profits and push up food prices and

Supply shocks: Feeling a drought which summarizes the effects on agricultural markets. The figure below illustrates the areas affected by the drought and the intensity. The world price of corn increases by 30% because the U.S. is responsible for 52.5% of world corn exports.

5.3.1 Examples

Consider demand as a function of price (P) and income (I):

$$Q^D = 300 - 2 \cdot P + 4 \cdot I$$

Supply is a function of price:

$$Q^S = 3 \cdot P - 50$$

What is the market equilibrium if the income level is $I = 25$? What if $I = 50$?

Consider the market for U.S. wheat in 1998:

$$Q^D = 3244 - 283 \cdot PQ^s = 1944 + 207 \cdot P$$

This situation leads to an equilibrium price of $P = 2.65$. At the end of 1998, Indonesia and Brazil opened their market for U.S. wheat, i.e., 200 million bushels of additional demand. Thus, the demand function becomes:

$$Q^D = 3444 - 283 \cdot P$$

This results in an equilibrium price of $P = 3.06$.

5.4 Elasticity

Elasticity measures the percentage change in one variable (y) divided by the percentage change in some other variable (x).

$$\epsilon = \frac{\%\Delta\text{Dependent variable}}{\%\Delta\text{Independent variable}}$$

Own-price elasticity is the change in quantity demanded of good i with respect to the price of good i:

$$\epsilon_P = \frac{\%\Delta Q_i}{\%\Delta P_i} = \frac{P_i}{Q_i}\frac{\Delta Q_i}{\Delta P_i}$$

For example, if the own-price elasticity of a good is -0.6, then if the price of that good increases by 1%, the quantity demanded for the good will decrease by $-0.6 \cdot 1\% = -0.6\%$. The elasticity works for small percentage changes in the price. Given the elasticity of -0.6, if the price of that good increases by 3%, the quantity demanded for the good will decrease by $-0.6 \cdot 3\% = -1.8\%$. Note

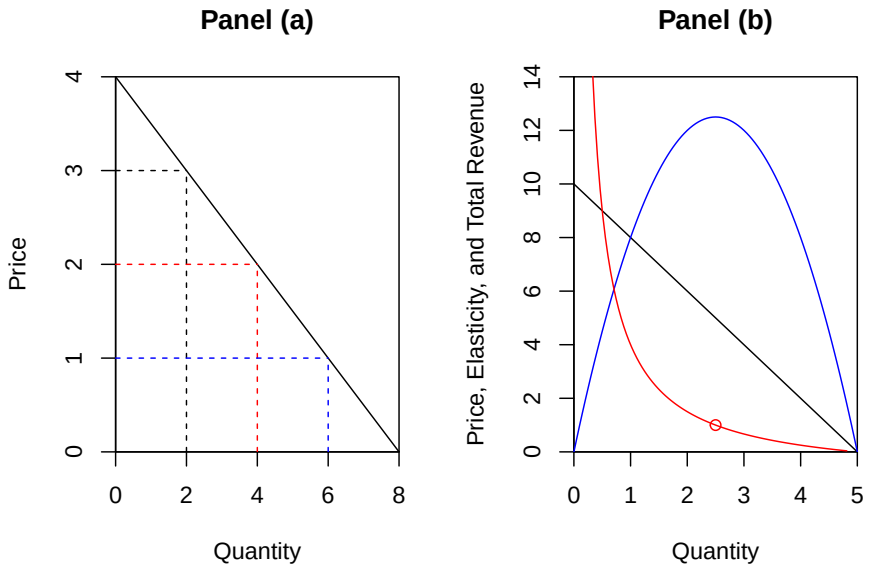


Figure 5.2: Panel (a): Determination of elasticity for a linear demand function. Panel (b): Relationship between elasticity and total revenue

that the elasticity for a linear demand function is not constant. For example, assume that $Q = 8 - 2 \cdot P$. In the case of a linear demand function, we have

$$\text{constant} = \frac{\Delta Q_i}{\Delta P_i}$$

What is the elasticity at $p = 4$, $p = 3$, $p = 2$, $p = 1$, and $p = 0$ in Panel (a) of the figure above? Demand can be either elastic, inelastic, or unit elastic.

- Demand is elastic if the percentage change in quantity is greater than the percentage change in price.
- Demand is inelastic if the percentage change in quantity is less than the percentage change in price.
- Demand is unit elastic if the percentage change in quantity is equal to the percentage change in price.

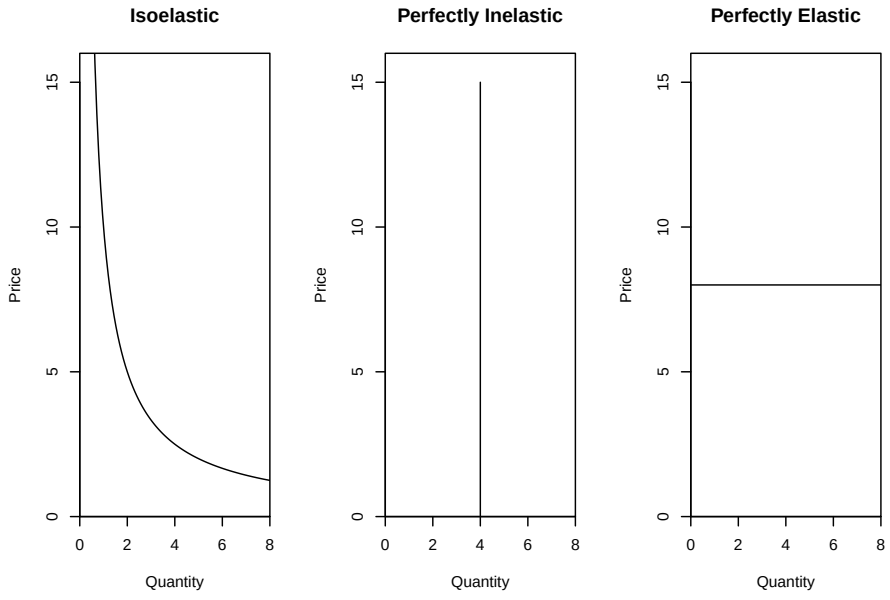
Besides the own-price elasticity, we also have the income elasticity and cross-price elasticity. *Income elasticity* is the change in quantity demanded of good i with respect to income:

$$\epsilon_I = \frac{\%\Delta Q_i}{\%\Delta I} = \frac{I}{Q}\frac{\Delta Q}{\Delta I}$$

And the *cross-price elasticity* is the change in quantity demanded of good i with respect to price of good j:

$$\epsilon_C = \frac{\%\Delta Q_i}{\%\Delta P_j} = \frac{P_j}{Q_i}\frac{\Delta Q_i}{\Delta P_j}$$

There are also come special cases of elasticity depicted in Figure.



The relationship between elasticity and revenue can also be explained with a demand function graph and the area in terms of revenue change.

5.5 Consumer and Producer Surplus

Consider a demand function of the form $Q = 10 - P$ and a supply function of the form $Q = P - 2$.

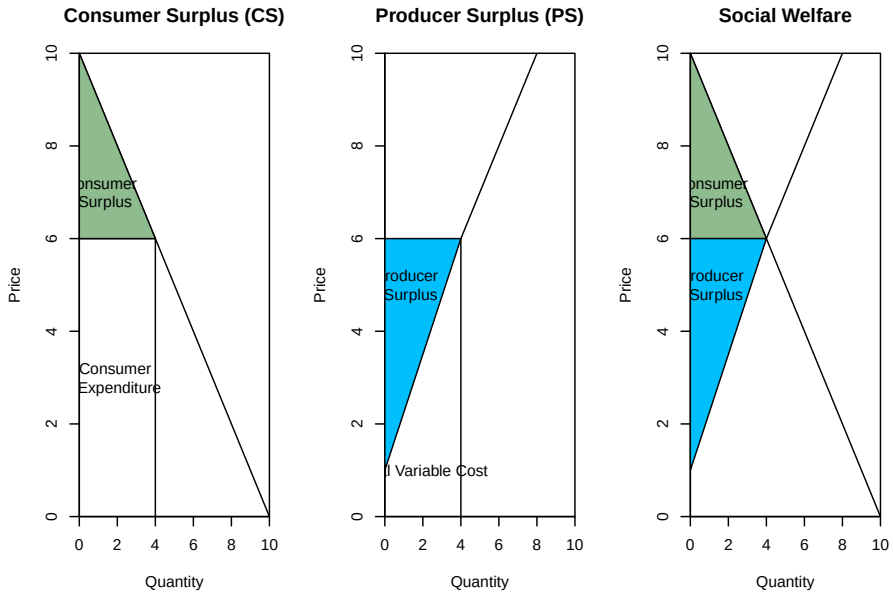


Figure 5.3: The sum of consumer surplus and producer surplus is called social welfare.

5.5.1 Policy Examples

There are some interesting applications of elasticities to public and economic policy. Consider for example services such as public transportation or the U.S. Postal Service. Very often the discussion centers around whether a price increase results in an increase or decrease in revenue. An argument can be made for both cases. Thus, it is important to know if prices are in the elastic or inelastic section of the demand. Income elasticity places a role in determining the future evolution of demand given income projections.

The sign of the cross-price elasticity determines whether two goods are substitutes or complements.

- $\epsilon_C < 0 \Rightarrow$ complements

- $\epsilon_C > 0 \Rightarrow$ substitutes

This can have important implications in anti-trust cases where the market power of a firm needs to be determined. Companies who have had troubles in the past are Office Depot and Staples (test in 40 cities), Alcoa (aluminum market), DuPont (cellophane), or Continental Can (acquiring a glass manufacturer) to name a few.

In a 2005 article To Reduce the Cost of Teenage Temptation, Why Not Just Raise the Price of Sin? in the New York Times lists examples how an increase in the price of cigarette and alcohol taxes reduces the consumption of those goods by teenagers. Those consumers have a much higher elasticity with respect to consumption than adults. The article states that

> In just about every state that increased beer taxes in recent years, teenage drinking soon dropped. The same happened in the early 1990's when Arizona, Maryland, New Jersey and a handful of other states passed zero-tolerance laws, which suspend the licenses of under-21 drivers who have any trace of alcohol in their blood. In states that waited until the late 90's to adopt zero tolerance, like Colorado, Indiana and South Carolina, the decline generally did not happen until after the law was in place. Teenagers, it turns out, are highly rational creatures in some ways. Budweisers and Marlboros are discretionary items, and their customers treat them as such.

5.6 Exercises

1. ***Books*** (*): The demand for books is $Q^D = 81 - P$ and the supply of books is $Q^S = 8 \cdot P$. What is the equilibrium quantity and price?

2. ***Gasoline Demand*** (*): The demand for gasoline in the U.S. is very inelastic. Why do you think that is the case? Assume that it is -0.2. If gasoline prices decrease by 3%, by how many percent does the quantity demanded change?

3. ***Ice Cream Demand*** (**): The demand function for ice cream is $Q = T - 5 \cdot P - 40$ where Q, P, and T represent the quantity, price, and temperature, respectively.

   a. Draw the demand curve for $T = 80$.
   b. In your graph, show what happens if the temperature drops to 70. Does the demand curve shift or are we moving along the demand function?
   c. The price of ice cream decreases from \$4 to \$3 without a change in temperature ($T = 80$). In your graph, show how this affects the quantity demanded. Does the demand curve shift or are we moving along the demand function?

4. ***Societal Collapse*** (**): During the COVID-19 pandemic, a (non-economist) friend of mine was getting gasoline and noticed many nozzles had bags over them since the gas station was low on supply despite low prices. Fearing the beginning of societal collapse, he sent me a text message because he did not understand how prices and supply could be low simultaneously. Draw a demand and supply graph starting with the pre-COVID equilibrium price and quantity. Then, show what happens if people change their driving behavior towards fewer trips. How would you have explained the situation to my friend? (It later turned out that the gas station simply forgot to put the restock order in with corporate.)

5. ***Feeling a Drought*** (***): The following is an extract of an article title Supply shocks: Feeling a drought from the British news magazine The Economist. Read the paragraph and answer the question below.

   > Much of America's agricultural heartland is in the grips of extreme to exceptional drought. It is becoming increasingly clear that this drought will take a significant toll on some of the nation's principal food crops, especially corn, wheat, and soybeans. As a result, food prices are soaring - the price of corn rose 23% in July - and those food price increases are beginning to make their way into official inflation figures. This morning, the Bureau of Labour Statistics released its July producer price index. Headline prices for finished goods rose 0.3% for the month, above expectations. The internals of the report show a sharp division between food price trends and the movement of prices for most other goods. Finished core prices rose a strong 0.4% to 0.5% for finished foods. But core prices for intermediate and crude goods actually fell in July, while intermediate and crude food indexes soared. Prices for crude food stuffs rose by 5.2% in July alone. The impact of the drought on production is quite clearly a supply shock; productive capacity has actually been diminished and prices have risen as a result. Other things equal, the economy will grow a bit less than expected before the scope of the drought became clear and inflation will be a bit higher.

   Corn is a significant input to the production of meat because a high proportion of livestock feed uses corn. I want you to draw two supply and demand graphs (i.e., two markets): One for corn and one for meat. Illustrate the effects of the drought on the market for corn and how this translates into the market for meat.

6. ***War on Drugs*** (***): Concerned about the high consumption of illegal, highly addictive drugs in the state, the governor solicits ideas to address the problem. State Representative Carson, a hardliner on drugs, suggests that the police should focus on reducing the number of drug dealers in the state. Representative Carter suggests an education campaign to inform potential consumers (e.g., high school students) about the adverse effects

of using addictive drugs. To answer the question, assume that both proposals work in reality and have the desired effects. Using two supply and demand graphs for the drug market (i.e., one for each representative), illustrate the effects of the two proposals. Assume that the market for drugs is initially in equilibrium. Then proceed to show the effects of the policy proposals. Based on your analysis, which policy would you recommend? Why?

Chapter 6

Perfect Competition

Perfect competition is characterized by many buyers and many sellers in the market. All market participants are price taking agent, i.e., everyone takes the price prevailing in the market as given. Examples for perfectly competitive markets are agriculture, restaurant business, standardized products (e.g., office supplies), or unskilled labor market. The opposite case is a monopoly where we have a market with many buyers but only one seller. The monopoly is characterized by price-setting behavior. Examples are De Beers, IUPUI parking system, or the Bombardier 415 Superscooper. The third market structure that we are going to analyze in this course is the most common one: an oligopoly. In an oligopoly, we have many buyers but only a "handful'' of sellers. Examples are Airbus and Boeing, or car manufacturers. Some oligopolies are not as well known as other such as the industry composed of BHP Billiton ($66b), Rio Tinto ($51b), Vale ($44b), Glencore ($232b), (compare to GM ($155b) and Lilly ($23b)). Other market structures include monopsonies (one buyer many sellers) and oligopsonies (few buyers and many sellers). Examples are defense contracts (Lockheed Martin, Boeing, Airbus) or Walmart in the case of monopsonies.

As aforementioned, perfectly competitive markets are characterized by price-taking behavior. Individual economic agent cannot influence the price and hence, there is a nonstrategic environment. In order for price taking behavior to occur, a large number of buyers and sellers is necessary. Individual firm faces a horizontal demand curve, i.e., perfectly elastic, at the market price. One assumption that is usually made is that products are homogenous, i.e., all the products are the same such as T-shirts, wheat, etc. We will see later that free entry and exit in and out of the market are important. No entry and exit barriers exist. Under perfect competition: $MR = p$, i.e., an individual firm's demand curve is a straight line (perfectly elastic).

The firm takes the market price as given and sets $p = MC$ to obtain the profit-maximizing output level, i.e., slides along its MC curve (above average variable

cost) with changing output price. Recall how profit and loss can be derived from the marginal and average cost functions based on the price (Figure **??**). In the short-run, competitive firms can earn economic profit, or suffer an economic loss. The market sums buying and selling preferences of individual consumers and producers, and determines the market price. Each buyer and seller takes market price as given and is able to buy or sell the desired quantity. In the long-run, entry and exit of firms because of profits or losses. This shifts the market supply curve and changes the market price. Positive economic profit attracts new entrants until economic (not accounting!) profit is zero. This is called the zero economic profit condition in the long-run.

Before turning to the Zero Economic Profit Condition, let us first consider the First Welfare Theorem.

> Under certain conditions, decentralized markets maximize total surplus for society, leaving no possible way for anyone to change the situation and make someone better off without making anyone else worse off.

The invisible hand by Adam Smith refers to the information contained in prices and the self-interest by the market participants. The following is a quote from An Inquiry into the Nature and Causes of the Wealth of Nations by Adam Smith (1723-1790):

> It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest. We address ourselves, not to their humanity but to their self-love, and never talk to them of our own necessities but of their advantages.

Note that the first welfare theorem contains the expression "under certain conditions.'' The necessary conditions are:

- No policies that distort prices, e.g., taxes, subsidies, price floors/ceilings, in a perfectly competitive market.
- No market power such as in monopolies and oligopolies exist.
- No externalities. Externalities can be either negative, e.g., pollution, or positive, e.g., recreational amenities.
- No asymmetric information

6.1 Zero Economic Profit Condition

Shifting of the average cost and marginal cost curves occur if the variables costs are affected. If the fixed costs change, only the average cost curve shifts.

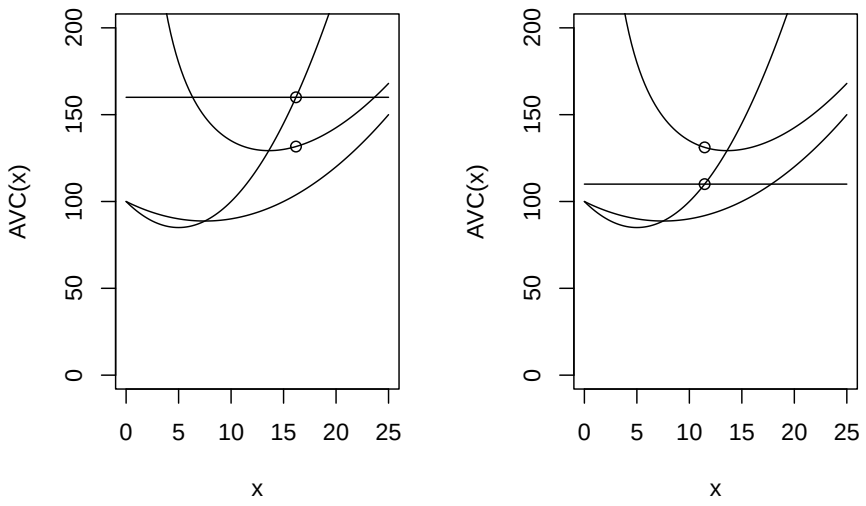


Figure 6.1: Derivation of profit and loss from the marginal and average cost functions based on the price

6.2 Market Interventions

6.2.1 Taxes and Subsidies

The economic incidence of a tax falls disproportionately on those who are less responsive to price changes; i.e., those whose behavioral response to price is more inelastic. In the case of a subsidy, there is an increase in the equilibrium quantity, a decrease in the price by consumers, and an increase in the price received by producers. The incidence of the subsidy is identical to the tax case.

Imposing a per-unit tax on either the consumer or the producer results in the same outcome. Assume that the demand is written as

$$Q^D = 10 - 2 \cdot P$$

and the supply is written as

$$q^s = 2 \cdot p - 2$$

Without any taxes, this results in a market equilibrium:

$$10 - 2 \cdot p = 2 \cdot p - 2 \Rightarrow p^* = 3 \Rightarrow q^* = 4$$

Now assume that we impose a tax on the producer. The price received by the producer is now $p - t$, i.e., supply is written as $q^s = 2 \cdot (p - t) - 2$. And the

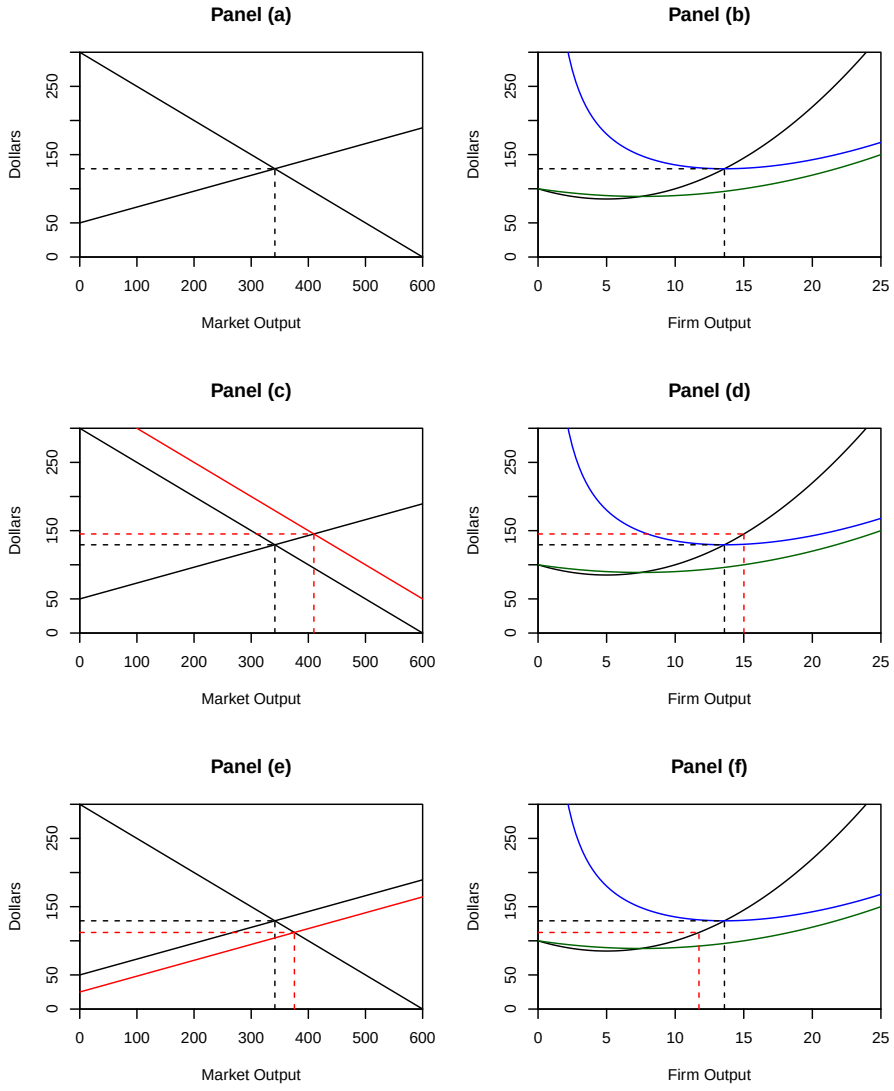


Figure 6.2: Long-Run Equilibrium

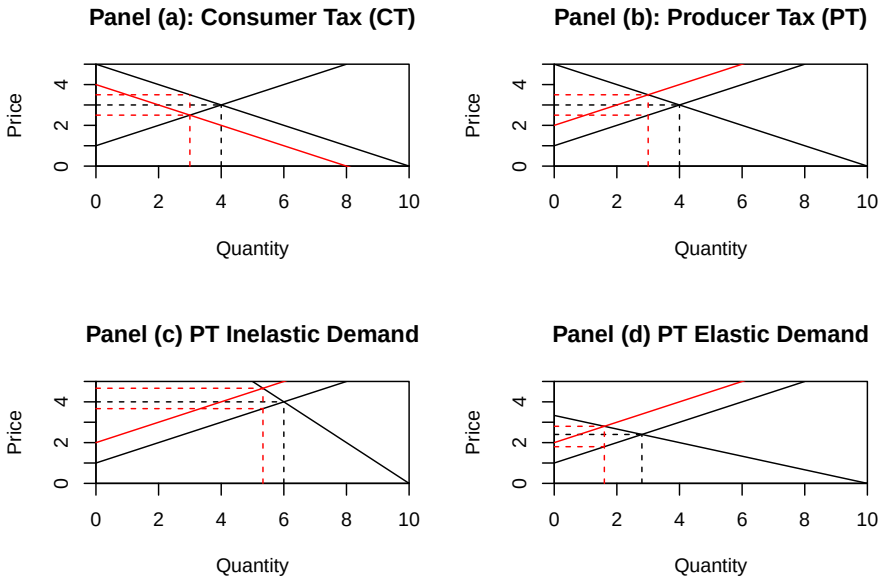


Figure 6.3: Consumer and producer taxes example (Panels (a) and (b). Effect on tax burden under inelastic demand (Panel (c)) and elastic demand (Panel (d)).

resulting market equilibrium

$$10 - 2 \cdot p = 2 \cdot (p - t) - 2 \Rightarrow p^* = 3 + \frac{1}{2} \cdot t \Rightarrow q^* = 4 - t$$

If $t = 1$, the consumer pays $p^d = \$3.50$ and the producer receives $p^s = \$2.50$. The equilibrium quantity is $q^* = 3$. If the tax is imposed on the consumer, the consumer pays $p + t$ and demand is written as $q^d = 10 - 2 \cdot (p + t)$. The resulting market equilibrium

$$10 - 2 \cdot (p + t) = 2 \cdot p - 2 \Rightarrow p^* = 3 - \frac{t}{2} \Rightarrow q^* = 4 - t$$

If $t = 1$, the consumer pays $p^d = \$3.50$ and the producer receives $p^s = \$2.50$. This is equivalent to the producer tax scenario. The equilibrium quantity is $q^* = 3$. Consider the equilibrium quantity as a function of the tax rate, i.e., $q^* = 4 - t$. This function also determine the tax revenue (l) for the government as a function of t, i.e., $l = t(4 - t)$.

6.2.2 Price Floors and Price Ceilings

A price floor is a minimum legal price mandated in a particular market, making all trades at prices below the price floor illegal. Non-price rationing in the market under price floors to reduce excess supply. Non-price mechanism to ensure supply equals demand; e.g., exit of producers. Non-price rationing by the government under price floors results in the government purchasing any surplus not sold at the price floor. Examples are the minimum wage or price floors for agricultural commodities. Price ceilings are maximum legal price mandated in a particular market, making all trades at prices above the price ceiling illegal.

Until 1978, there were price floors for airline tickets in the U.S. which artificially inflated ticket prices. Deregulation made those airline tickets decrease since 1980. Price floors for airlines.

6.3 Exercises

1. ***Fair Trade Coffee*** (***): The following questions ask you to consider the market for Regular Coffee and Fair Trade Coffee. Fair Trade USA defines fair trade as follows:

   > Fair Trade goods are just that. Fair. From far-away farms to your shopping cart, products that bear our logo come from farmers and workers who are justly compensated. We help farmers in developing countries build sustainable businesses that positively influence their communities.

   Suppose that there is an advertising campaign that promotes the purchase of fair trade coffee. Assume that the marketing campaign works and that

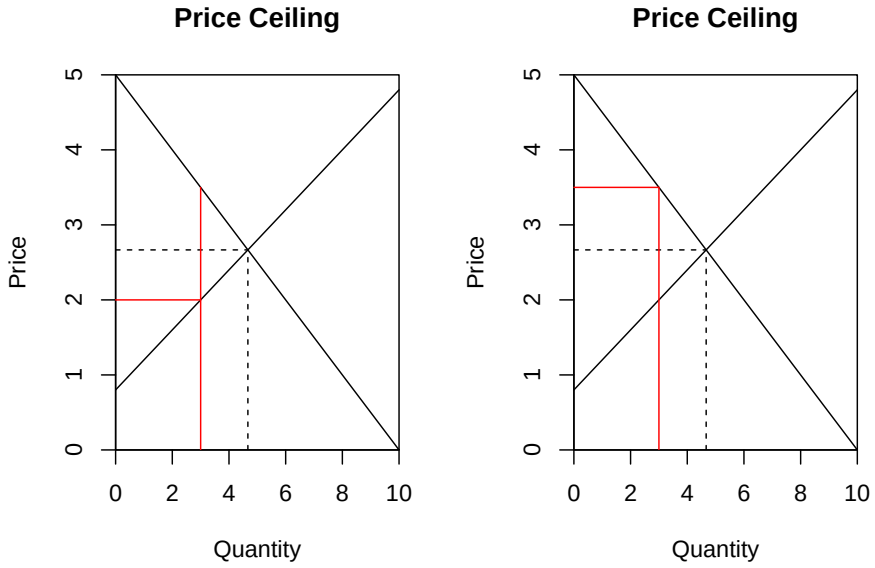


Figure 6.4: Consumer and producer taxes example (Panels (a) and (b). Effect on tax burden under inelastic demand (Panel (c)) and elastic demand (Panel (d)).

it influences the demand for fair trade coffee, i.e., consumers change their tastes and some consumers switch to fair trade coffee.

   a. Draw two supply and demand graphs; one for Fair Trade Coffee and one for Regular Coffee. Assume that both markets are in equilibrium before the marketing campaign. Mark the equilibrium price and quantity.
   b. Show the new equilibrium quantity and price in the graph for the Fair Trade Coffee.
   c. Illustrate the effects in the market for Regular Coffee. Show the new equilibrium quantity and price in the graph for the Regular Coffee. What conclusions do you draw? How does the zero-economic profit condition affect the market for Regular Coffee?

2. ***Pontoon Boats*** (***): The demand function for pontoon boat rentals on Lake Michigan is written as $Q^D = 50 - 0.2 \cdot P$. The supply curve is $Q^S = 0.3 \cdot P$. When answering, be sure to differentiate between the price paid by the consumer and the price received by the producer. For each part, also calculate producer and consumer surplus.

   a. What are the equilibrium price and equilibrium quantity?
   b. Because of air and noise pollution, a per-unit tax of $10 per rental is imposed on consumers. What are the new equilibrium price and equilibrium quantity?
   c. A state representative from one of the bordering states argues that pontoon boat rental operators only have revenue in the summer and thus, suffer from the tax. Hence, they propose a per-unit subsidy of $6 to the rental operators. What are the new equilibrium price and equilibrium quantity under this scheme? Note that we have a tax on consumers and a subsidy for producers at the same time.
   d. What if the per-unit tax on consumers is reduced to $4 and the per-unit subsidy for rental operators is eliminated? How is this different from the answer in the previous part?

3. ***License Fee Reduction*** (***): Draw a marginal and average total cost curves for a perfectly competitive industry that is in the long-run equilibrium. What is the profit of the firm in the initial situation? The legislator wants to support business and reduced the annual (fixed) business license fee for all firms. What happens to this industry in the short- and long-run? Illustrate in your graph.

4. ***Hallstatt*** (***): Take any tourist spot around the world and you will find the same situation: A lot of producers (technically, they are vendors but let us stay with the term producer) selling some cheesy souvenir item. Let us consider this market which is characterized by a lot of producers and a lot of consumers (tourists). Suppose that the place for which you are answering this question is a small town. To put the question in context, consider the folowing excerpt from a Washington Post article titled

"Nothing to see here: Popular European destinations want fewer tourists:''

> Hallstatt may not have the same name-recognition as Venice or Amsterdam. But if you Google Austria, you'll see the village dominates the images that pop up. It looks a lot like Arendelle in Disney's Frozen, with the bell tower of the Lutheran Church standing in for the central tower of Queen Elsa's castle. A salt-mining town dating from the late Bronze Age, and a UNESCO World Heritage site since 1997, Hallstatt has become especially popular among travelers from Asia. The hype began with a 2006 South Korean TV series, "Spring Waltz,'' that was partially shot in Hallstatt. Six years later, the China Minmetals mining company opened a life-size replica of Hallstatt in the southern Chinese province of Guangdong. The company even mimicked Hallstatt's central church, although the Chinese version contains a banquet hall. Residents of the real Hallstatt, who hadn't been consulted on the project, were stunned when they learned of it. Now, filmmakers, journalists and tourists alike come to Hallstatt in droves. The town, with a population of about 800, drew 1 million visitors last year.

a. Assume that this market is initially in its long-run equilibrium. Draw this initial situation in two, interconnected graphs. One the left side, you have the market and on the right side, you have one individual, representative producer.
b. A TV show brought fame to our small city and suddenly, many more tourists come to the town. What happens to the demand for the souvenir item in the town in the short-run? What happens in the long-run? Use your graph to illustrate the effects.

Chapter 7

Imperfect Competition

Market power implies that at least one firm can influence the market price with its output decision. Recall that price-taking behavior in perfect competition means that neither an individual consumer nor an individual producer can influence the market price. Under imperfect competition, there is price-setting behavior and individual producers influence the market price. This section covers imperfect competition from the producer's perspective but it can also occur on the consumer side in which case it is called monopsony (single consumer) or oligopsony (few consumers).

7.1 Monopoly

A monopoly is an industry with only one producer and there are no close substitutes. In general, a monopolist reduces output to raise price. However, to increase the quantity sold, a monopolist must lower the price on each unit sold. Hence, the monopolist makes money on the additional quantity sold but loses money on the quantity that was already selling because there is now a lower price.

There are multiple reasons for a monopoly to exit but those are usually related to barriers to enter the market:

- **Economies of scale**: One firm can operate at lower average cost than multiple firms and there are decreasing average cost over the entire market range. A natural monopoly can produce for the entire market and/or there may be large sunk cost and/or fixed cost.
- **Legal barriers**: Protection of intellectual property (e.g., copyrights, patents), control over a scarce resource, or barriers put in place by firms to discourage entry.
- **Network externalities**: Added benefits for all users of a good or service that arise because other people are using it too. Joining a large network

is more beneficial than joining a small network. Think about Facebook and LinkedIn.

As opposed to perfect competition, there is the possibility of profits in the long-run. It is difficult to find a straightforward example of a monopolist because there are sometimes other aspects (e.g., time and space) to consider as will the following examples illustrate:

- **Microsoft**: The software company was often considered a monopolist in the market for operating systems which lead to antitrust law cases in the U.S. (*United States of America v. Microsoft Corporation*) and the EU (*Microsoft Corporation v. Commission of the European Communities*)
- **EssilorLuxottica**: The company is the result of a merger of the French company Essilor and the Italian company Luxottica and controls a large share of the global lens and eyewear market. Known brands are Oakley, Ray-Ban, and many more. Check out their webpage and see which brands you recognize.
- **De Beers**: The company controls large parts of the global diamond mining industry.
- **IUPUI parking system**: On a smaller scale, IUPUI (and many other universities) has a monopoly on the parking spaces on campus. Note though that there are substitutes such as downtown parking.

- **Internet Providers**: Although there are three large internet providers in Indianapolis, there is a spatial separation of the territory they serve. Some residents of Indianapolis have only access to one of the providers which makes it a monopoly in that area despite the fact that it is not a single provider in Indianapolis.
- **Electricity Transmission**: The electricity transmission network in the U.S. is owned by many companies. But the system works very much like a road and there can be congestion or closed down roads due to accidents or construction. Thus, it can happen that a particular power transmission company can have a monopoly for a very short period of time if it operates the only open line.

The next sections outline that a monopoly is (in general) inefficient, i.e., reduces societal welfare, which is the reason why countries around the world have antitrust laws. Those laws also apply to groups of producers who act as if they were a monopoly. That is the case of a cartel, e.g., Organization of the Petroleum Exporting Countries (OPEC). There is also the case of a durable good monopoly which is a monopoly creating competition to itself. A durable good does not depreciate once it is on the market. Imagine being the owner of the only gold mine on Earth. At the beginning, this is a monopoly. But given that gold is never really lost, there will soon be a second hand gold market which competes with the initial monopoly. It can be argued that college textbooks create the problem of a durable good monopoly since some of the books do not really depreciate in terms of information presented in them. Thus, textbook

publishers are selling new editions to overcome the problem of a durable goods monopoly.

7.1.1 Overview

The monopolist sets marginal revenue equal to marginal cost, i.e., $MR{=}MC$, in order to find the profit maximizing output quantity. Recall that under perfect competition, we have marginal cost pricing, i.e., $p{=}MC$. It is important to understand that a firm in a perfectly competitive market also sets $MR{=}MC$ but because the price is determined by the market, the marginal revenue from selling an additional unit is p. The difference between a perfectly competitive firm and a monopolist is illustrated in the figure below.

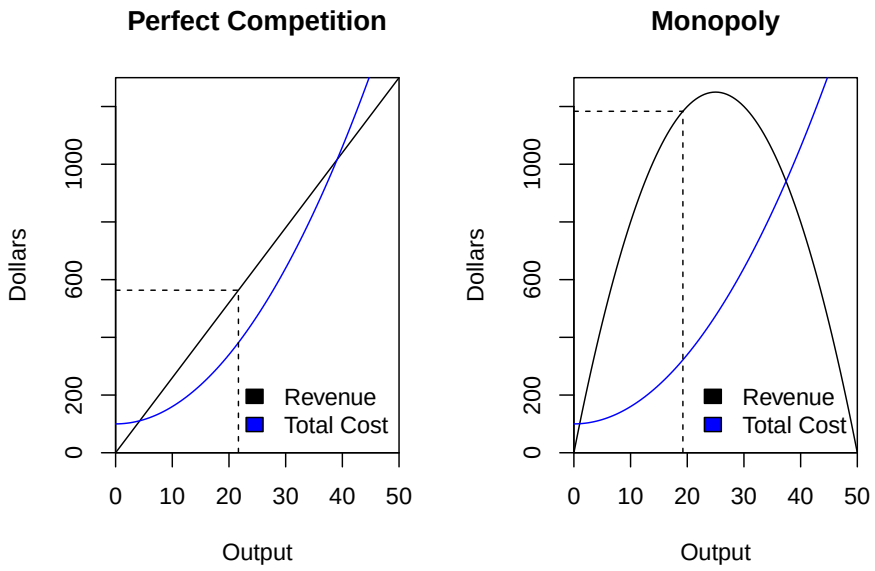


Figure 7.1: Under perfect competition as well as under a monopoly situation, the profit maximizing output quantity is determined where marginal revenue is equal to marginal cost.

The next sections illustrate the monopolist's output decision under (1) constant and (2) increasing marginal cost. Note that a monopolistic market results in a deadweight loss. This is not caused by higher prices for consumers or higher profits for the monopolist but by the underproduction of goods.

7.1.2 Constant Marginal Cost

Assume a monopolist is faced with a demand that can be written as $Q = 50 - P/2$. The inverse demand function can thus be written as $P = 100 - 2 \cdot Q$. The revenue can be written as

$$R = P \cdot Q = (100 - 2 \cdot Q) \cdot Q = 100 \cdot Q - 2 \cdot Q^2$$

Marginal revenue is written as $MR = 100 - 4 \cdot Q$. Assume *MC=20*, then under perfect competition, we have *P=MC*, i.e., $20 = 100 - 2 \cdot Q$. And hence, the socially optimum output quantity is $Q_c = 20$. Under monopoly pricing, we have *MC=MR*, i.e., $20 = 100 - 4 \cdot Q$. And hence, the monopoly output quantity is $Q_m = 20$. This situation is illustrated in Panel (a) of the figure below.

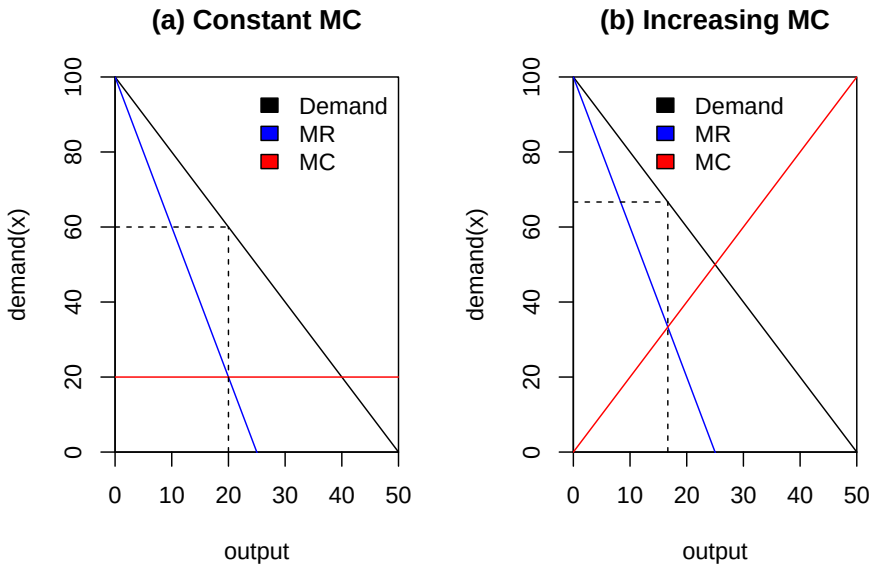


Figure 7.2: Examples of output decisions by a monopolist under constant and increasing marginal cost.

7.1.3 Increasing Marginal Cost

Suppose that the cost function is written as $C = 100 + Q^2$ with increasing marginal cost function $MC = 2 \cdot Q$. If the inverse demand function is written as $P = 100 - 2 \cdot Q$, then the marginal revenue function is $MR = 100 - 4 \cdot Q$. Similar to the example with constant marginal cost, we set *MR=MC*, i.e., $100 - 4 \cdot Q = 2 \cdot Q$. Solving leads to $Q_m = 100/6$ which is illustrated in Panel (b) of the figure above. Again the quantity chosen by the monopolist is not socially optimal.

Let's consider two policies to restore efficiency:

- Per-unit tax
- Price ceiling

7.1.4 Monopoly and Elasticity

A monopolist produces on the elastic portion of the demand curve. It can be shown that

$$\underbrace{\frac{p - MC}{p}}_{\text{Lerner Index}} = -\frac{1}{\epsilon_D} \quad \Leftrightarrow \quad p \cdot \left(1 + \frac{1}{\epsilon_D}\right) = MC$$

The interpretation of the above equation is that the more elastic demand, the higher the availability of substitutes. Markup over marginal cost is reduced if the elasticity becomes larger (see figure below).

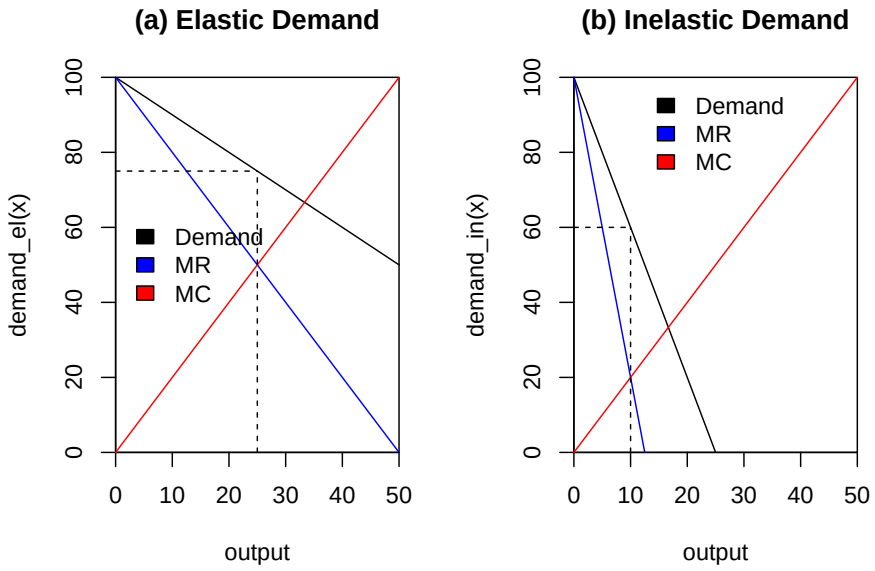


Figure 7.3: The magnitude of above marginal cost pricing depends on the elasticity of the demand function.

7.2 Price Discrimination

A single-price monopoly is limited to charging the same price for each unit of output sold. If price discrimination is possible, the monopolist charges different prices to different customers, i.e., the monopolist can divide customers into different categories based on their willingness-to-pay (WTP). The firm must (1)

have market power, (2) identify consumers' WTP, and (3) prevent low-price customers from reselling to high-price customers in order for price discrimination to be feasible. Price discrimination is always beneficial to producers otherwise they would not charge different prices to different consumers. It can harm consumers because there will be a higher price for some consumers but it also has lower prices for others. The additional producer's profit represents a monetary loss to consumers. Examples are movie theaters, buses, trains, airplanes, amusement parks, or restaurants where a difference in prices is based on groups, e.g., students, seniors, children. Price discrimination can also be observed for events such as sport games where season tickets and quantity discounts are offered. There are three types of price discrimination:

- **First Degree**: This is also known as perfect price discrimination and is achieved if the marginal revenue curve is equivalent to the demand curve.
- **Second Degree**: This is also known as nonlinear pricing and occurs with different types of consumers without observation of type. This results in offering different quantities of the good at different prices. Consumers self-select into a type. Common examples are different classes of service, hobbling a product (restrictions on the use of a device), quantity discounts, and so on.
- **Second Degree**: Also known as imperfect price discrimination occurs with different types of consumers with observation of type. Common examples for this type of price discrimination are museum or movie theatre entries with senior or student pricing.

7.3 Oligopoly

An oligopoly market is characterized by few sellers, blocked entry and exit, imperfect dissemination of information, and the opportunity for positive economic profits in the long-run. There is a strategic interdependence among the firms that is commonly represented by the Bertrand model, Cournot model or the Stackelberg model. A very powerful approach to model the strategic interaction among firms is game theory which will be covered in the next chapter.

The barriers to entry can result from (1) economies of scale or natural oligopoly, (2) reputation, (3) strategic barriers, or (4) legal barriers. In the case of economies of scale, one firm can supply a large part of the market (not all of it) which leads to lower per-unit cost than many small firms. Established oligopolists are likely to have favorable reputation as well. Strategic barriers can result from excess production capacity, market saturation, special contracts with distributors or from long-term arrangements with customers. As with the monopoly, legal barriers such as patents, copyrights, or zoning regulations can occur as well.

Oligopoly is a very common market structure. There can be a dominant single firm surrounded by a number of smaller firms (Anheuser-Busch 47% and

MillerCoors 30%), three dominant firms (Universal Music Group 39%, Sonic Music Entertainment 30%, and Warner Music Group 19%), duopoly which is an oligopoly with only two sellers (Airbus and Boeing). Examples of less concentrated markets are cereals with Kellogg, General Mills, Post, and Quaker Oats. But there are far more examples such as oil/gasoline, cars, cable/internet, smartphones, textbooks, rental cars, airlines, aluminum etc. at the national level or gasoline, food, and various professional services at the local level.

7.3.1 Measurement of Market Concentration

The economic census provides a comprehensive statistical profile of the economy. Industry statistics are classified using the North American Industry Classification System (NAICS). The main categories are Agriculture, Forestry, Fishing and Hunting (Code 11), Mining, Quarrying, and Oil and Gas Extraction (Code 21), Utilities (Code 22), Construction (Code 23), Manufacturing (Code 31-33), Wholesale Trade (Code 42), Retail Trade (Code 44-45), Transportation and Warehousing (Code 48-49), Information (Code 51), Finance and Insurance (Code 52), Real Estate and Rental and Leasing (Code 53), Professional, Scientific, and Technical Services (Code 54), Management of Companies and Enterprises (Code 55), Administrative and Support and Waste Management and Remediation Services (Code 56), Educational Services (Code 61), Health Care and Social Assistance (Code 62), Arts, Entertainment, and Recreation (Code 71), Accommodation and Food Services (Code 72), Other Services (except Public Administration) (Code 81), Public Administration (Code 92). In the table below, we have data from the 2007 Economic Census for military armored vehicle, tank, and tank component manufacturing (336992), dog and cat food manufacturing (311111), quick printing (323114), ready-mix concrete manufacturing (327320).

NAICS	Firms	Sales in billion	CR_4	CR_8	CR_{20}	CR_{50}	HHI
336992	61	10,988	81.8	93.7	98.0	99.9	2,477.1
311111	199	14,505	71.0	83.5	92.6	98.2	2,325.1
323114	6,041	3,263	3.8	5.8	10.3	17.4	8.4
327320	2,460	34,837	22.6	28.2	39.9	52.9	312.9

There are two common measures for the concentration of market power within a particular industry: (1) Concentration ratio and (2) Herfindahl-Hirschman Index.

The concentration ratio measures the combined market share percentage of the n leading firms:

$$CR_n = \sum_{i=1}^{n} \frac{\text{Firm Sales}_i}{\text{Industry Sales}} \times 100$$

For a monopoly, we have $CR_n = 100$ and for a perfectly competitive industry we have $CR_n \approx 0$, that is, the concentration ratio decreases for many firms. The Herfindahl-Hirschman Index (HHI) is the sum of squared market share percentage for all competitors:

$$HHI = \sum_i \left(\frac{\text{Firm Sales}_i}{\text{Industry Sales}} \times 100 \right)^2$$

For a monopoly, HHI=10,000 and for a perfectly competitive industry $HHI \approx 0$. Suppose we have four firms (labeled F_i) in the market and three industries (A, B, and C). The revenues of those firms are presented in the table below:

Industry	F_1	F_2	F_3	F_4	Industry Sales	CR_2	HHI
A	30	30	30	30	120	50	2500
B	84	28	17	11	140	80	4209
C	114	110	36	20	280	80	3417

7.3.2 Cournot, Bertrand, and Stackelberg Models

The following models attempt to explain competitive behavior among two or more firms. All three models are relatively old. The Cournot model was published in 1838, the Bertrand model was formulated in 1883, and the Stackelberg model was described in 1934.

The Cournot Model assumes that there are two firms in the market producing an identical good. Suppose that the demand is written as follows:

$$P = 40 - Q = 40 - Q_1 - Q_2$$

where Q_1 and Q_2 are the output quantities of the two firms. The marginal cost is equal to 2. Each firm i maximizes its profits:

$$\pi_i = (40 - Q_i - Q_j) \cdot Q_i - 2 \cdot Q_i = 38 \cdot Q_i - Q_i^2 - Q_i \cdot Q_j$$

Taking the first order condition and setting it to zero yields:

$$38 - 2 \cdot Q_i - Q_j = 0$$

And thus, the reaction function is written as:

$$Q_i = 19 - \frac{Q_j}{2}$$

Since the reaction function is the same for both firms, the resulting quantities are $Q_1 = Q_2 = 12.67$ and the price is $P = 14.67$.

The Bertrand Model assumes that competition between the two firms leads to the perfectly competitive outcomes, i.e., price equals marginal cost. In this case, $P = 2$ and $Q_1 = Q_2 = 19$

In the Stackelberg model, the leading firm moves first (i.e., sets the production quantity) and the follower observes the action of the leading firm and decides on output quantity. Assume that the leader is firm 1 and the follower is firm 2. In this case, firm 1 maximizes its profit given the reaction function of firm 2:

$$\pi_1 = \left(40 - Q_1 - 19 + \frac{Q_1}{2}\right) \cdot Q_1 - 2 \cdot Q_1 = 19 \cdot Q_1 - \frac{Q_1^2}{2}$$

Taking the first order conditions results in $19 - Q_1 = 0$ and thus, we have $Q_1 = 19$, $Q_2 = 9.5$, and $P = 11.5$. Note that the leading firm is producing more in the Stackelberg Model than the follower.

7.3.3 Cartel and Collusion

The previous section on the models developed by Cournot, Bertrand, and Stackelberg illustrates that competition reduces the profits and there is a strategic interaction. There is a way around competition which is highly illegal in all countries: cartels. Here cartels for legal products are considered and not drug cartel which adds a whole different category of legal problems.

In a cartel, multiple firms act as if they are a monopolist. In the previous section, the following demand function was considered: $P = 40 - Q$. The marginal revenue associated with this (inverse) demand function is $MR = 40 - 2 \cdot Q$. Thus, setting marginal revenue equal to marginal cost ($MC = 2$) leads to a monopolistic production quantity of $Q = 19$. Both firms could agree to produce 9.5 units each which would lead to a price of 21.

Note that firms do not need to engage in explicit collusion (i.e., direct communication) but can engagne in implicit collusion simply by using a tit-for-tat strategy. Assuming multiple periods, an individual firm could raise prices in one period and see if the other firm follows the signal by raising prices as well. From an economic perspective, cartels are unstable because prices are high and firms can undercut each other. This instability is used by antitrust agencies to destabilize them even more. For example, legislation usually has no penalty for the first firm blowing the whistle on a cartel.

The United Potato Growers of America *aspires to be to potatoes what OPEC is to oil by carefully managing supply to keep demand high and constant, resulting in a more stable return for farmers.* This is how the Wall Street Journal describes the situation in the U.S. potatoes market in This Spud's Not for You: Growing Co-Op of Farmers Seeks to Become OPEC of Potatoes by Controlling Supply. The Capper-Volstead Act exempted farmers from federal antitrust laws which allowed the United Potato Growers of America to destroy 680 million pounds of potatoes in 2005 in order to keep prices high. This increased the price of potatoes by 48.5% which was mostly absorbed by retailers and thus, consumers did not see a large price increase. There has been an issue of overproduction of potatoes which resulted in a decrease of price. Controlling the supply helped stabilize (or increase) the price of potatoes.

There have also been allegations that major container shipping lines engage in price-fixing (cartel) behavior. Those charges were dropped though.

7.4 Exercises

1. ***Drug Monopoly*** (***): Mark is a producer who has the monopoly on a drug curing a particular disease. The following equations characterize his economic environment:

   - Demand:$Q = 150 - 3 \cdot P \Leftrightarrow P = 50 - \frac{Q}{3}$
   - Total revenue: $TR = 50 \cdot Q - \frac{Q^2}{3}$
   - Marginal revenue: $MR = 50 - \frac{2}{3} \cdot Q$
   - Total cost: $TC = 4 \cdot Q$
   - Marginal cost: $MC = 4$

   What is the profit maximizing price and output quantity? What is his profit? What is the efficient price and output quantity? Calculate the deadweight loss associated with the monopoly situation? To regulate the monopoly, a tax of $1 is imposed. Given the tax, calculate the new price, quantity, and deadweight loss.

2. ***Electricity Market Monopoly*** (***): An electric utility company has a monopoly in a large metropolitan area. The inverse demand and marginal revenue functions are $P = 50 - Q$ and $MR = 50 - 2 \cdot Q$. The marginal cost function is $MC = 10 + 2 \cdot Q$. What is the profit maximizing price and output quantity? What is the efficient price and output quantity? Calculate the deadweight loss associated with the monopoly situation? The government sets a price ceiling at $p = MC$. What is the price and output of the regulated monopoly?

3. ***Monopoly Profit Tax*** (**): Assume a regulator wants to impose a 25% tax on the profit of a monopolist to reduce the inefficiency associated with the monopolist. What is the effect of this policy on the deadweight loss. Use a graph to illustrate.

4. ***Government Monopoly*** (**): A city is considering privatizing their parking spaces because members on the city council are under the impression that handing it over to a private business "increases efficiency." The city currently set the price equal to (constant) marginal cost. Use graphs to answer the following issues. Assume that the marginal cost and demand do not change in any of the cases.

   a. Explain to the city council members why selling the parking spaces to a single, profit maximizing (unregulated) firm will decrease efficiency.
   b. What price policy can be implemented to avoid the abovementioned loss in efficiceny?
   c. If the council members still want to sell the parking spaces but do not want to get involved in price regulation, what third option do

they have.

5. ***Concentration Ratio*** (*): Calculate CR_3 for the example about the four firms in three industries.

Chapter 8

Game Theory

Game theory considers situations where so-called players (e.g., people, firms, political parties) make decisions as strategic reactions to other players' actions. Examples are reality TV shows with people competing against each other, political parties choosing their position on an issue or during an election, or pricing strategies of firms in an oligopolistic environment. In addition, almost every sport as well as war is based on game theory. The final scene of the 1983 movie WarGames is an excellent example of game theory.

In economics and business, one of the most general problems is outguessing a rival. Strategic interaction means that a player's payoff depends on other players' actions. A player's optimal action depends on the expectations of what other players will do. Strategic interactions among players is considered in a non-cooperative setting, i.e., binding agreements among players do not exist. For example, there is no cooperation in the game of two sport teams. Cooperation may or may not occur among players as a result of rational decisions, e.g., trigger strategies. Full information, i.e., players are aware of the payoff structure of games, is assumed for this chapter.

Economic models based on game theory allow drawing conclusions that can be used to understand real world strategic interactions. Every game has three components:

1. Players: Finite number of players (at least 2)
2. Actions: Set of actions for each player
3. Payoffs: Those can be ranked at least ordinally

Payoffs may be in form of a change in (marginal) utility, revenue, profit, or some non-monetary change in satisfaction. A player's strategy is the complete contingent plan. If it could be written down, any other agent could follow the plan and duplicate player's actions. Thus, a strategy is a player's course of action involving a set of actions (moves) dependent on actions of other players.

A unique equilibrium or a set of equilibria may occur within a set of strategies is called a Nash equilibrium (after mathematician John Nash). Not all games have a Nash equilibrium and some games may have a number of Nash equilibria. In the movie A Beautiful Movie, John Nash's discovery is portrayed to have happened in a bar:

> If we all go for the blonde and block each other, not a single one of us is going to get her. So then we go for her friends, but they will all give us the cold shoulder because no one likes to be second choice. But what if none of us goes for the blonde? We won't get in each other's way and we won't insult the other girls. It's the only way to win.

Note that the movie is wrong about the Nash Equilibrium. The situation described is not a Nash Equilibrium.

8.1 Single Shot Games

We now present several classical simultaneous move games that you can find in almost every economics textbook and illustrate different concepts associated with game theory.

8.1.1 Prisoner's Dilemma

The best-known game is the Prisoner's Dilemma. The payoff table for the two players is represented as:

		Player B	
		Confess	Deny
Player A	Deny	1,1	20,0
	Confess	0,20	5,5

In the prisoner's dilemma game, there is one Nash Equilibrium. Note that it is not the optimal outcome. Every Nash Equilibrium is characterized as a state where no player has the incentive to deviate. A more thorough video explaining the prisoner's dilemma can be found here.

For a more real world application of a simultaneous move game consider a penalty shot-out in soccer. There are two players (one of them is the goal keeper) and assume (for simplicity) that they have two actions: left or right. That is, the player kicking the ball has to decide whether to kick the ball in the left or right corner and the goalkeeper has to decide whether to jump left or right. Note that the soccer ball travels to fast and the goal keeper cannot observe the direction of the ball. How this looks is demonstrated in this sequence of a penalty shootout between Argentina and the Netherlands.

8.1.2 Stag Hunt

Consider the following game:

		Player B	
		Stag	Hare
Player A	Stag	2,2	0,1
	Hare	1,0	1,1

8.1.3 Up or Down

A dominant strategy is a strategy that is preferred to another no matter what other players do. When all players have a dominant strategy, an equilibrium of dominant strategies exists that is determined without a player having to consider behavior of other players. Consider the following game:

		Player B	
		up	down
Player A	up	10,10	7,7
	down	7,7	5,5

8.1.4 Rock, Paper, Scissors

It is also possible to have a game with no Nash Equilibrium. Rock, Paper, Scissors is an example for such a game:

		Player B		
		R	P	S
Player A	R	d,d	l,w	w,l
	P	w,l	d,d	l,w
	S	l,w	w,l	d,d

If there is no Nash Equilibrium with a pure strategy, we can resort to a mixed strategy. If you think about how you play rock, paper, scissors, you can imagine what a mixed strategy does: randomize your actions.

8.1.5 Cartel Game

Let us now turn to games that are more specific to economics. Consider a cartel with two firms. Both firms have to decide whether to cheat or comply with the cartel agreement:

		Player B	
		Don't cheat	Cheat
Player A	Don't cheat	50,50	45,54
	Cheat	54,45	48,48

8.1.6 Beach location game

Games do not necessarily need to be displayed in a payoff matrix. Consider a game where beach-goers are uniformly distributed on a stretch of beach that goes from A to B . You have two ice cream vendors located at A and B initially. Customers go to the nearest vendor. In this initial situation, each vendor gets 50% of the market. Is this initial situation a Nash Equilibrium?

8.2 Repeated Games

We have seen that in the single shot prisoner's dilemma there is no Nash Equilibrium. It is possible to identify an optimal strategy for an infinitely repeated game. This is called a trigger strategy. In the first round, player A cooperates and does not confess. In every round after, if player B cooperated on previous round, A cooperates. If B defected on previous round, A then defects. Strategy does very well because it offers an immediate punishment for defection and has a forgiving strategy. An application is the carrot-and-stick strategy that underlies most attempts at raising children. Consider the following game between Pepsi and Coca-Cola. Note that one-time win from a low price is 5 and the loss in repeated games is 4 (discount rate becomes important).

		Player B	
		Don't cheat	Cheat
Player A	Don't cheat	12,12	6,17
	Cheat	17,6	8,8

8.3 Sequential Games and Entry Deterrence

There is a YouTube video associated with this section explaining the concepts presented:

- Sequential Games and Entry Deterrence

In a sequential game, one player knows the other player's choice before taking an action (perfect information). For example, a firm determines consumer demand before making a pricing decision or a politician knows the opponent's stance on an issue before making their own. So-called backward induction determines a sub-game perfect Nash equilibrium by working backward toward the root in

a game tree. Once the game is understood through backward induction, players play it forward. To apply backward induction, first determine the optimal actions at last decision nodes. Then determine optimal actions at next-to-last decision nodes, assuming that optimal actions will follow at next decision nodes. Backward induction implicitly assumes that a player's strategy will consist of optimal actions at every node in game tree.

Sequential games can be used for entry deterrence. Firms or governments who act first have an advantage which leads to a preemption games. Strategic precommitments can affect future payoffs. For example, a firm adopting a large production capacity in a new market can saturate the market and make it difficult for other firms to enter.

8.4 Exercises

Note that in all the questions, the term Nash Equilibrium is used but it also refers to the plural, i.e., Nash Equilibria.

1. ***Apple Juice Companies*** (**): Two competing companies in the apple juice industry simultaneously decide on their weekly pricing strategy. The actions available to each firm are price low or price high. The payoffs associated with this situation is depicted in the payoff matrix below. In a single shot game, what is the Nash Equilibrium. In a repeated game, describe a trigger strategy and the resulting Nash Equilibrium.

		Player B	
		Price low	Price high
Player A	Price low	30, 30	60, 20
	Price high	20, 60	50, 50

2. ***Emergency Call*** (**): Perhaps you have been in this situation before. You (and many others) witness an accident or a crime and you have to decided whether to call 911 yourself or rely on other witnesses to do so. The problem is that you usually do not know whether an emergency call was made or not. Suppose an event is witnessed by two people and the cost of making an emergency call is $c > 0$. Both people get a benefit of x from the event being reported to first responders and $x > c$. A payoff of zero is received if the event goes unreported. Draw the payoff matrix and determine the Nash Equilibrium. This is a simultaneous move game. What is the Nash equilibrium if there are more than two people?

3. ***Being on Time*** (**): A friend of mine (actually, more than just one) regularly arrives late. It annoys them when they have to come on time. If I know that they come late on a regular basis, should I adjust my timing as well? Consider the following payoff matrix and find the Nash Equilibrium:

		My friend	
		On time	Late
Me	On time	100, 80	10, 90
	Late	80, 80	90, 90

4. ***Public Goods Game*** (**): There is a public goods game in experimental economics. Each player initially has $20 and then secretly selects whether to contribute the amount to a public pool or not. If the player does not contribute, they simply get the $20. If the money is contributed, the amount in the public pool is multiplied by 1.5 and divided equally by the number of players and returned. The game represents a situation where the contribution to a public good (e.g., education or infrastructure) increases the payoff for everyone in society. For example, if both players contribute, they get back $(\$40 \cdot 1.5)/2 = \$30$. Draw the payoff matrix and identify the Nash Equilibrium strategies

5. ***Holiday Gifts*** (**): My parents do not want to exchange gifts during the holiday season because it increases stress during an already busy period. Of course, my parents and I have the possibility to purchase gifts anyway and deviate from the arrangements of not purchasing gifts. So each party has two possible actions: (1) buy gifts and (2) no gifts. The utility of the parties is depicted in the matrix below. Of course, the most catastrophic outcome is when your parents purchased a gift and I sit there empty-handed. The payoff for that situation below reflects that shame (me) and disappointment (parents). What is the Nash Equilibrium? What is the problem with that Nash Equilibrium?

		Parents	
		Buy gifts	No gifts
Me	Buy gifts	100,100	50,10
	No gifts	0,0	95,95

6. ***Collaborative Work*** (***): You and another student are engaged in a group project for a class. Each of you can exert three levels of effort: Low, medium, and high. Let us assign the numeric values of 1, 2, and 3 to low, medium, and high effort, respectively. The score you receive (together) on the project depends on the sum of effort you each put in. Let the total work be w then the score s you receive is given by $s = 18 + 46 \cdot \ln(w)$ where ln represents the natural log. Round to the nearest integer for the subsequent calculations. We can do a simple example to illustrate how the equation works. Suppose that both of you put in the lowest effort. In that case, $w = 2$ and $s = 18 + 46 \cdot \ln(2) = 49.88$. Rounded to the nearest integer, you receive a score of 50 for the homework. Your payoff (π) is

determined by the grade minus the effort you put in: $\pi = grade - 10 \cdot w$. So your payoff given the example would be 30.

a. Suppose you independently have to decide how much effort to put in the project. You do not observe the effort of the other person prior to receiving the grade. What is the Nash Equilibrium?
b. Suppose that one of you works on the project first and then submits the part to the other person. That person can see the effort that was exerted and decides how much effort to put in. What is Nash Equilbrium in this sequential game?

Chapter 9

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 look at cases where those conditions are violated and where public policy can intervene to improve or restore efficiency.

9.1 Externalities

Externalities are costs (negative externalities) or benefits (positive externalities) on non-market participants. There are no incentives for market participants to take those (social) costs and benefits into account and thus, they base their decisions only on private benefits and costs. Consider the following examples of externalities:

- The manufacturer of cigarettes observes private marginal cost, i.e., the marginal cost of producing cigarettes, but ignores the cost of negative health outcomes that is paid by society. For example, the marginal cost of producing a cigarette may be 3 cents and the marginal external cost of smoking the cigarette may be 2 cents. Thus, the private marginal cost is 3 cents but the social marginal cost is 5 cents. The cigarette manufacturer bases its production decision on 3 cents. A social marginal cost above the private marginal cost is an example of a negative externality. The firm's supply curve does not capture all social marginal costs associated with its product.
- Consider the production of sugary and fatty food and drink items. Producers and consumers of those items do not take the cost into account that the resulting increase in obesity has on non-market participants. 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.

- An example of a positive externality is the upkeep of your yard. If you keep your yard clean and even do some landscaping, you are not only increasing the value of your own home but also the value of the homes around you. For example, your neighbor may be able to more easily sell her or his house at a higher price.

There is a mismatch between social marginal benefits/costs and private marginal benefits/costs which leads to an inefficient allocation of resources. As with the monopoly, there is a deadweight loss from externalities. Externalities arise if property rights have not been established, e.g., clean air, toys for children, fishing in a lake, congestion. People 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, i.e. 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). The four figures below demonstrate the inefficiency of a negative externality.

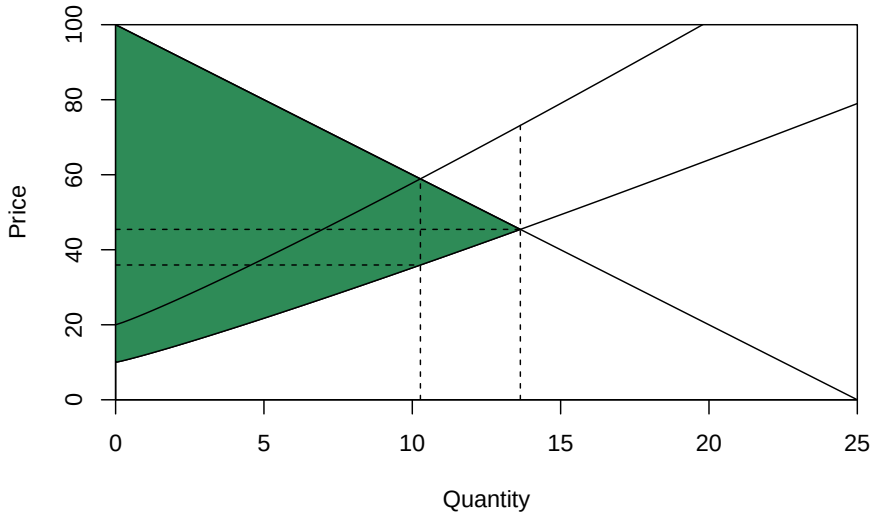


Figure 9.1: Consumer and Producer Surplus

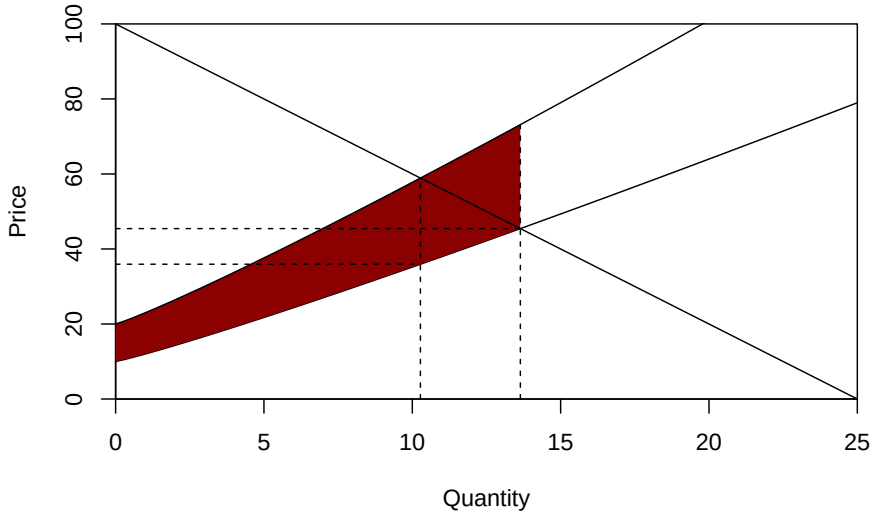


Figure 9.2: Societal Cost

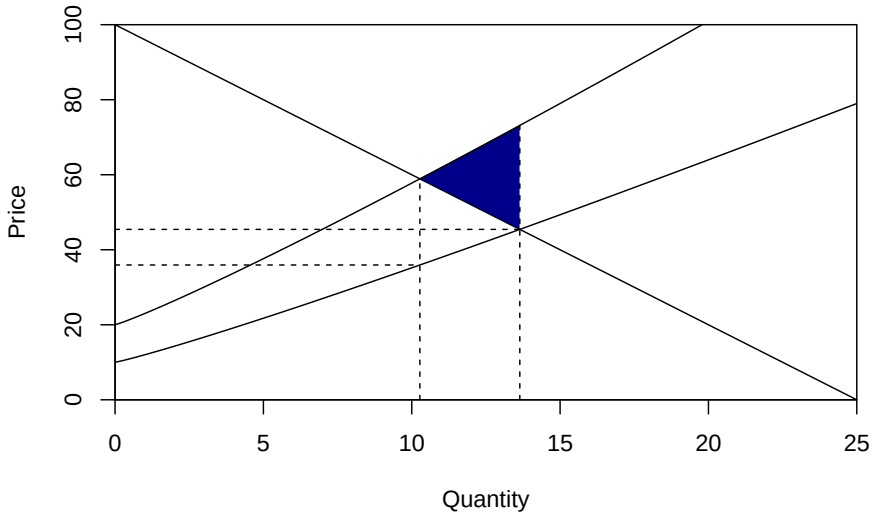


Figure 9.3: Deadweight Loss

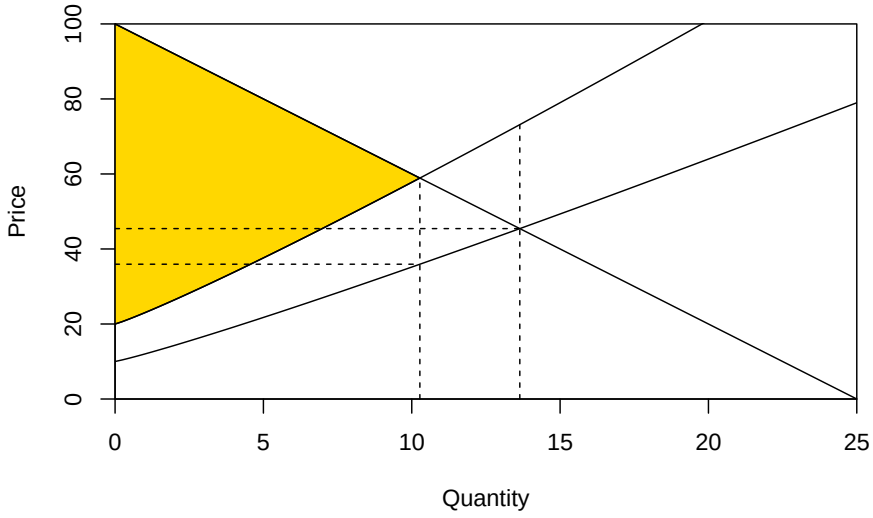


Figure 9.4: Efficient Outcome

9.1.1 Pigouvian Tax

A Pigouvian tax is a per-unit production tax equal to the difference between social marginal cost and private marginal cost. It is difficult to implement because of unknown social costs of externality. By reducing the market quantity to the efficient quantity, a Pigouvian tax eliminates the DWL from the pollution externality. 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.

9.1.2 Coase Theorem

The Coase Theorem states that if transaction costs are low or zero, the establishment of clear property rights will lead to an efficient allocation of resources. 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. Note, that the allocation of wealth and income will vary depending on how the property rights are established but that this does not affect efficiency. For example, assume a baker and a doctor are in 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 his 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 quite machinery at a cost of $50. If the property "noise level" is given to the doctor, then the baker will purchase quite machinery for $50. If the noise level is attributed to the baker, the doctor will pay the baker $50 to purchase new and more quite machinery. The efficient solution, i.e., purchasing machinery for $50, is reached independently of who is assigned the property rights.

9.1.3 Pollution Control

What is the optimal level of pollution? Waste is produced in 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, aesthetic effects, as well as the cost of reducing pollution. The cost of reducing pollution is represented by the marginal abatement cost function. We will be looking at three different pollution control policies:

1. Command-and-control: 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.

2. Emission tax: In an emission/pollution tax scenario, firms set the marginal cost of abatement equal to the tax rate and the aggregate cost for a given level of pollution is minimized. An emission tax is efficient.

3. Cap-and-trade: Under a cap-and-trade policy, firms set the marginal cost of abatement equal to the permit price. Problems with cap-and-trade: leakage, e.g., fertilizer, coal, etc. A cap-and-trade policy is efficicent.

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.

Assume two firms, 1 and 2, with the following total abatement cost function and marginal abatement cost function:

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

Suppose that both firms emit 50 tons of pollution per year and the government wants to reduce pollution by 10 tons. Consider the following three scenarios: (1) Proportional reduction, (2) emission tax of $24 per ton, and (3) cap-and-trade system with a cap set to 40 tons.

9.1.4 Policy Examples: SO_2 Allowance Trading Program

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).

9.2 Public Goods

Public goods can be consumed by more than one individual at the same time, e.g., national defense, police officers in a city (up to a certain extent). A good is rival if it cannot be consumed by more than one individual at a time. It is excludable if non-paying consumers can be excluded from consumption. Our

primary focus so far has been on pure private goods - goods that are both rival and excludable. The Tragedy of the Commons arises when rival goods are made non-excludable through common ownership. Public goods are both non-rival and non-excludable; e.g. national defense, lighthouse. Club goods are non-rival but excludable; e.g. public swimming pools.

	Rival	Non-Rival
Excludable	Private Good	Club Good
Non-Excludable	Common Good	Public Good

Common goods lead to the "Tragedy of the Commons' ', e.g., swimming pool as a club good, free rider problem. Suppose that two future roommates need to decided whether to bring a TV to the dormitory. The value of a TV for each player is $100 and the cost of a TV is $150.

		Player B	
		Buy	Dont' buy
Player A	Buy	1,1	20,0
	Don't buy	0,20	5,5

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:

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

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

$$MB_a = MC \quad \Rightarrow \quad q = 1 MB_b = MC \quad \Rightarrow \quad q = 2$$

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.
- **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 marginal external 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.

6. ***Pareto vs. Kaldor-Hicks Efficiency*** (**): Consider the following table. Does this project meet the criteria of Pareto efficiency? Kaldor-Hicks efficiency? Would it pass a majority vote?

Individual Resident	Individual Benefit	Cost Share
A	\$4,500	\$3,000
B	\$1,000	\$3,000
C	\$2,500	\$3,000
D	\$4,500	\$3,000
E	\$1,500	\$3,000
Total Benefit	\$14,000	\$15,000

7. ***Streetlight Installation*** (**): Three neighbors vote on installing a streetlight. If they vote in favor of the streetlight, each neighbor has to pay \$100. They each value the streetlight at \$200, \$150, and \$50, respectively. Does this project meet the criteria of Pareto efficiency? Kaldo-Hicks efficiency? Would it pass a majority vote?

Chapter 10

Risk and Uncertainty

So far, we considered decisions based on the assumption that there is no uncertainty. In reality, we are surrounded by uncertainty such as changes in prices, income, and so on. Good (or bad) stuff happens. Some examples of risks that affect you are retirement funds (e.g., mutual fund, stock market, etc.), gasoline (energy) prices, accidents (e.g., home, car, health, etc.), or sub-prime mortgages. Most decisions are based on expectations about the future. Many economic questions and issues are associated with risk: How do people make decisions under uncertainty? Is there a market (and hence, a price) for risk? Can we reduce risk?

10.1 Uncertainty

Suppose that you can engage in one of the following three games (or gambles):

- Receiving \$100.
- Flipping a coin and receiving \$200 if the result is heads and \$0 if the result is tails.
- Die roll and receiving \$400 for 1, \$70 for 2, \$55 for 3, \$40 for 4, \$25 for 5, and \$10 for 6.

The expected outcome is \$100 in each case but you certainly have a preference for which option you pick. However, the variances are 0, 10,000, and 18,375. We will soon see that uncertain outcomes are worth less in terms of utility than certain outcomes (like receiving \$100) even when the expected payoffs are identical. A prime example to illustrate this concept is called the St. Petersburg Paradox. The game is simple: Flip a coin and I will pay you $\$2^n$ where n is the number of flips until heads. So the expected payoff is

$$\text{Expected Payoff} = \frac{1}{2} \cdot 2 + \frac{1}{4} \cdot 4 + \frac{1}{8} \cdot 8 + \cdots = \infty$$

An actuarially fair game is where the cost of entry equals the expected payoff. That is $E(X) = \Pr_{win} \cdot \pi_{win} + \Pr_{lose} \cdot \pi_{lose} = 0$.

A probability distribution refers to a list of outcomes and probabilities associated with those outcomes. The sum of the probabilities across all outcomes is always 1. Consider a project investment as outlined in the table below. The profits from projects A and B depend on the state of the economy.

Economic State	Probability	Profit A	Profit B
Recession	40%	4000	0
Mormal	35%	5000	5000
Boom	25%	1000	8000

To achieve some quantification of risk associated with those projects, we need to calculate the expected value and the variance. The expected value is calculated as follows:

$$E(\pi) = \sum_i \pi_i \cdot p_i$$

and thus, the expected values of projects A and B are

$$E(\pi_A) = 0.4 \cdot 4000 + 0.35 \cdot 5000 + 0.25 \cdot 1000 = 3600$$

$$E(\pi_A) = 0.4 \cdot 0 + 0.35 \cdot 5000 + 0.25 \cdot 8000 = 3750$$

The variance is calculated as:

$$Var(\pi) = \sum \left[\pi_i - E(\pi)\right]^2 \cdot p_i$$

For projects A and B, we have

$$Var(\pi_A) = 2,440,000 \Leftrightarrow \sigma_A = 1560$$

$$Var(\pi_A) = 10,687,500 \Leftrightarrow \sigma_B = 3269$$

10.2 Expected Utility

The expected utility is the sum of the utilities associated with all possible outcomes, weighted by the probability that each outcome will occur. From Jensen's inequality, we have

- $E[U(w)] = U[E(w)] \Rightarrow$ Risk-neutral
- $E[U(w)] < U[E(w)] \Rightarrow$ Risk-averse
- $E[U(w)] > U[E(w)] \Rightarrow$ Risk-seeking

The risk premium is the maximum amount of money a risk averse person will pay to avoid taking a risk. Note that this is an extremely important concept. For example, the risk premium leads to higher interest rates for consumers or

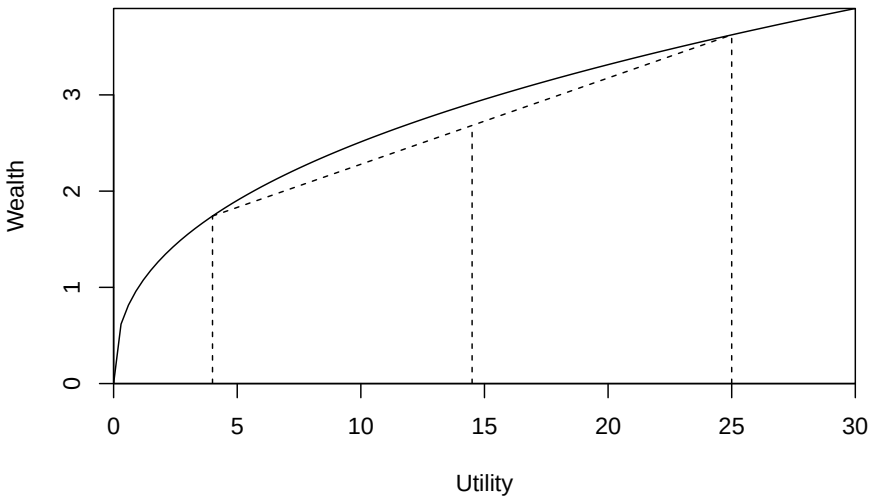
companies with a low credit rating. To illustrate the concept of expected utility, assume that we have a risk averse individual and two possible outcomes: (1) Getting \$1 with a probability of 60%, and (2) Getting \$8 with a probability of 40%. The expected value of wealth is

$$E(w) = 0.6 \cdot 1 + 0.4 \cdot 8 = 3.80$$

And the expected utility is:

$$E(U) = 0.6 \cdot U(\$1) + 0.4 \cdot U(\$8)$$

We also have $u(\$3.8)$. Note that $u(\$3.8) > 0.6 \cdot u(\$1) + 0.4 \cdot u(\$8)$



10.3 Risk Diversification

The colloquial expression for risk diversification is not to put all eggs in one basket. There are gains from diversification as long as assets are not perfectly correlated. You can think about the stock market or if you have a football team with only one good quarterback not only poor backup quarterbacks. Consider an investment possibility in two firms: raincoats and sunglasses.

- Raincoat company: $p_0^R = 10$ and $p_1^R = 5$ if sunny or $p_1^R = 20$ if rainy
- Sunglasses company: $p_0^S = 10$ and $p_1^S = 20$ if sunny or $p_1^S = 10$ if rainy

In this case, a diversification strategy that allocates \$5 to the raincoat company and \$5 to the sunglasses company allows a return of 25% if sunny and 50% if rainy.

10.4 Insurance Market

If people are risk averse then why do insurance companies exist? The key here is that insurance companies can engage in what is called risk pooling. To illustrate the concept, suppose that you are flipping a coin and must predict the share of tails. The expected value of the share of heads (or tails) is $E(H) = E(T) = 0.5$. The variance of n coin tosses is written as

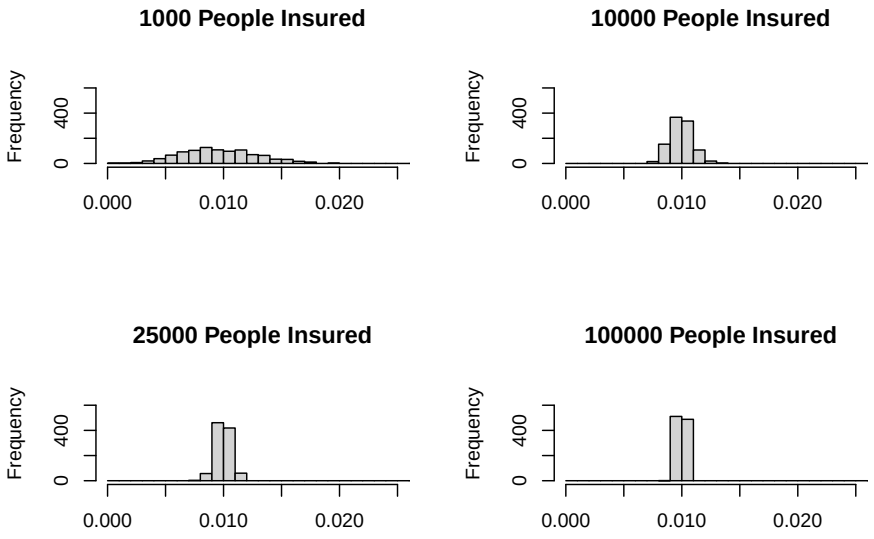
$$Var(n) = \frac{p \cdot (1-p)}{n} = \frac{0.5 \cdot 0.5}{n}$$

Thus, for 1, 10, and 1000 coin flips, the variances are $Var(1) = 0.5$, $Var(10) = 0.025$, $Var(1000) = 0.00025$, respectively. That is, the variance associated with the share of coin flips decreases with an increasing number of flips. Think about how difficult it is to predict the correct share of heads from a single coin flip but how easy it is to predict the share of heads from several thousand coin flips. The same concept applies for an insurance company. Given a large number of policy holders, there is almost perfect predictability of the number (or share) of claims in a year. Note that the key assumption here is independence of events/claims.

To illustrate this concept, assume that the probability of a house fire is 1%. To simulate the number of claims an insurance policy faces each year, a simulation is conducted involving the following steps:

1. Simulate the damage of n homeowners
2. Calculate the share
3. Repeat 1,000 times
4. Generate histogram

An actuarially fair insurance premium is equal to the probability of a claim times to payout.



10.5 Exercises

1. ***Expected Utility*** (**): The utility function of an individual is written as $U = \sqrt{M}$. The person faces a gamble in which income is \$36 with probability 1/2 and \$100 with probability 1/2.
   a. What payoff with certainty is indifferent to this gamble?
   b. What is the risk premium associated with this gamble?
   c. How much would the individual be willing to pay to avoid taking the risk?

Chapter 11

Dynamic Aspects

This chapter introduces the concept of time into economic analysis. The first section covers the concept of Net Present Value (NPV), which is often used by private, public, and nonprofit managers to make investment decisions. The second section introduces the concept of assets, which is best understood given some examples on natural resource management in the third section. The chapter concludes with intertemporal decision making that relates consuming, saving, and borrowing across time periods.

11.1 Net Present Value

Net present value (NPV) analysis is based on the idea that a dollar today is different from a dollar tomorrow. Suppose a person has the choice of receiving \$1,000 either today or in a year from now. The person would certainly take the money today and not wait a year because they can take the money know, put it in a bank account, and receive the \$1,000 plus interest in a year from now. For example, assume that the interest rate is 2% per year. If you make a bank deposit of \$1,000 today ($t = 0$), then the value of the bank account in one year will be $V_1 = \$1,000 \cdot 1.02 = \$1,020$. The bank account value in two years ($t = 2$) will be $V_2 = \$1,000 \cdot 1.02 \cdot 1.02 = \$1,040.40$. The general equation (compound interest) for the bank account value is n years given an interest rate of r is:

$$V_n = \$1,000 \cdot (1 + r)^n$$

The opposite of compound interest is discounting. Assume a stream of income of \$100 at the end of each year over the next three years.

$$NPV = \frac{100}{1 + r} + \frac{100}{(1 + r)^2} + \frac{100}{(1 + r)^3}$$

Assuming that you receive \$100 at the end of the following three years with an interest rate of 2%, then the NPV of that stream is \$288.39. Put differently, if you deposit \$283.39 today, you can withdraw exactly \$100 at the end of years 1, 2, and 3. The net present value formula of a stream of X_t per year t:

$$NPV = \sum_{t=1}^{T} \frac{X_t}{(1+r)^t}$$

Net present value calculations are often used in investment decisions by firms but also in court cases relating to wrongful death. In particular, if a person dies while still working, families can seek compensations in the amount of the net present value of earnings. For example, assume that a person who was supposed to retire at age 65 dies in a car accident at age 60. That person was earning \$50,000 at the time of death and the expected growth rate (g) of the earnings were 2% per year. Note that the person could have also died of other causes between the age of 60 and 65 and thus, we need to account for that probability (d). To do so, we can consult so called life tables compiled by the Centers for Disease Control and Prevention (CDC). The 2014 table reveal the probabilities of dying displayed in the table below.

Age	60-61	61-62	62-63	63-64	64-65
d_t	0.008959	0.009606	0.010288	0.010995	0.011735

Hence, if we assume the person would have received \$50,000 this year and over the next five years, we can use the following equation to calculate the net present value of earnings given a discount rate of 5%.

$$NPV = 50,000 + \sum_{t=1}^{5} \frac{50,000 \cdot (1+g)^t \cdot (1-d_t)}{(1+0.05)^t}$$

Hence, the net present value of earnings is \$277,013.36. Note that the perpetual stream of X dollars

$$NPV = \frac{X}{r}$$

This means that the present value of an infinite stream of money is finite.

11.2 Assets

Assets provide either a service flow (e.g., consumption from a house or a car) or a monetary flow (e.g., financial assets such as stocks or mutual funds) over time. Assets differ in terms of liquidity, i.e., how fast assets can be converted to cash. For example a house is very difficult to convert to cash compared to mutual fund holdings. Assets also differ in terms of returns, risk, and tax characteristics. In

the absence of uncertainty, all assets should have identical returns. Otherwise, only the asset with the highest return would be purchased.

Consider asset A with a current price of p_0 and future price p_1.

$$p_0^A \rightarrow p_1^A$$

Asset B has a current price p_0 and interest rate r. This can be expressed as

$$p_0^B \rightarrow (1+r) \cdot p_0^B$$

Furthermore, assume that the total investment is \$1. Then the necessary investment is

$$p_0^A \cdot x = 1 \Leftrightarrow x = \frac{1}{p_0^A}$$

For example $p_0^A = \$2$ and $p_1^A = \$2.50$. The future value of \$1 is

$$FV = p_1 \cdot x = \frac{p_1^A}{p_0^A}$$

The equilibrium condition:

$$1 + r = \frac{p_1}{p_0} \quad \Leftrightarrow \quad p_0 = \frac{p_1}{1+r}$$

Sometimes this called the no-arbitrage condition. Those concepts may seem overly theoretical and thus, let us examine a real world example that illustrates this concept:

11.3 Natural Resource Management

This section considers two common examples of resource management:

- Forest Rotation
- Fisheries
- Depletable Resource Extraction

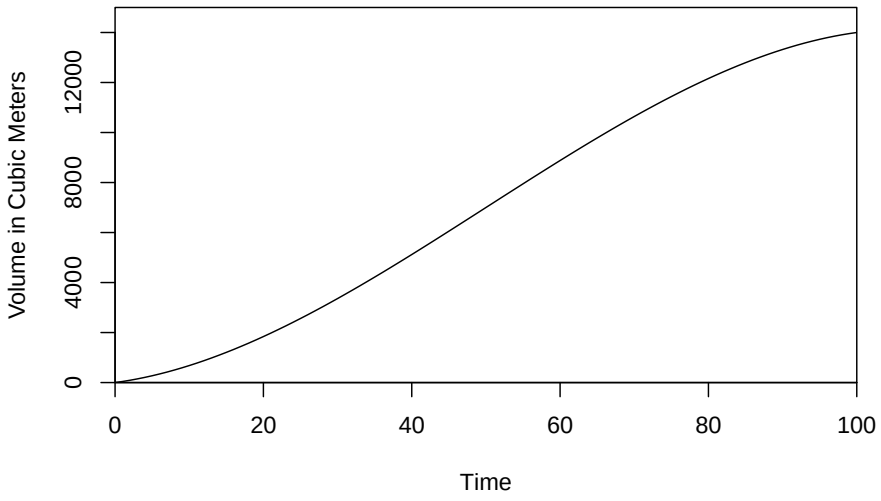
Before introducing the forestry example, the topic of Net Present Value (NPV) must be presented. Although dynamic aspects of economics are covered later in the book, NPV must be introduced to understand the forestry example.

11.3.1 Forest Management

This section covers the optimal harvest of trees, which is also known as rotation period. The growth function of trees is usually assumed to be S-shaped, i.e., slow growth in early and late years but high growth in the intermediate years. Assume a tree growth function of the following function form:

$$g = a_1 \cdot t + a_2 \cdot t^2 + a_3 \cdot t^3$$

where g represents the total timber volume in cubic meters and t represents time. Assume that the growth parameters a_1, a_2, and a_3 take the values 40, 3, and -0.02, respectively. Then over a 100-year period, the total volume of the tree looks as depicted in the figure below.



Assume that the price of timber per cubic meter is \$2 and that the harvest cost of the tree consists of a fixed and variable part. The fixed cost is \$1,000 and the variable cost is \$0.3 per cubic meter. The net present value is calculated for three different interest rates, i.e., 1%, 3%, and 5%.

11.3.2 Fisheries

Let $g = f(S)$ denote the net growth rate, i.e., births minus deaths excluding harvest, of a fish species. The fish population stock is denoted with S and the maximum fish population is denoted with K, which is often referred to as the carrying capacity with unsustainable quantity after this amount. Assume that the function takes the following functional form:

$$g = S \cdot \left(1 - \frac{S}{K}\right)$$

This growth function is depicted in the figure below assuming a carrying capacity of $k = 100$:

Before the peak, fish population rapidly grows and there is plenty of food and space for the species. After the peak, depletion of the fish population occurs because of food scarcity and less space for the species. It can be shown that the

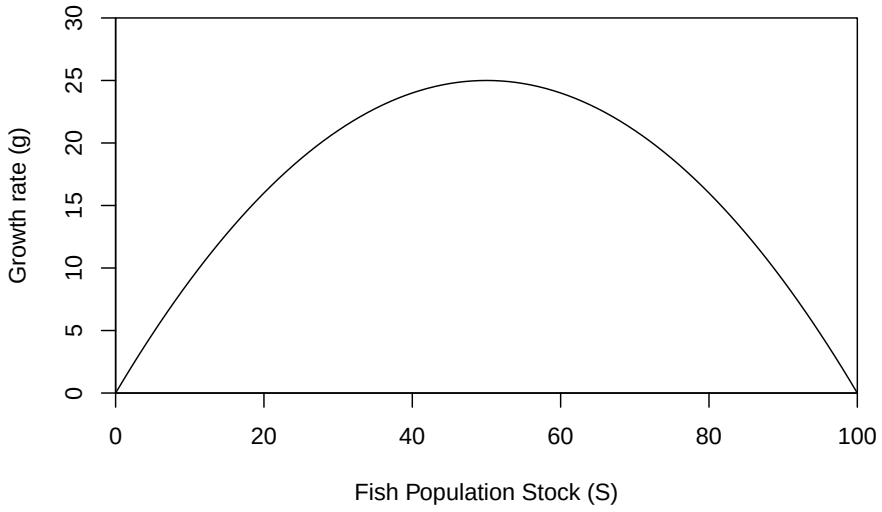


Figure 11.1: Growth rate of fish as a function of stock

maximum sustainable yield, i.e., peak growth, is at $K/2$. Assuming $K = 100$, the maximum amount of fish that can be harvested in a sustainable way from the fishery is 25. If no harvesting occurs, the equilibrium stock is 100.

Next, assume that harvest is a result of the fish population and effort (e.g., number of fishing boats), i.e., $h = f(S, E)$, with S representing fish population and E representing effort. Assume that the harvest function can be written as:

$$h = \theta \cdot S \cdot E$$

where θ represents a coefficient that measures the ease of harvesting fish. More effort and higher fish population leads to a higher harvest. This implies that the same harvest rate can be achieved but with different levels of fish population and effort. In the steady state required for long-term sustainable harvesting, the harvest rate equals net growth of fish, i.e., $g = h$:

$$S \cdot \left(1 - \frac{S}{K}\right) = \theta \cdot S \cdot E$$

Isolating S leads to the following:

$$S = (1 - \theta \cdot E) \cdot K$$

Substituting the fish stock as a function of effort back into the harvest function and simplifying leads to:

$$h = \theta \cdot E \cdot K \cdot (1 - \theta \cdot E)$$

Next, the price of fish and the cost of effort must be taken into account. Assume that the price of fish is p and that the cost of effort is c. Then, profit (π) equation can be written as

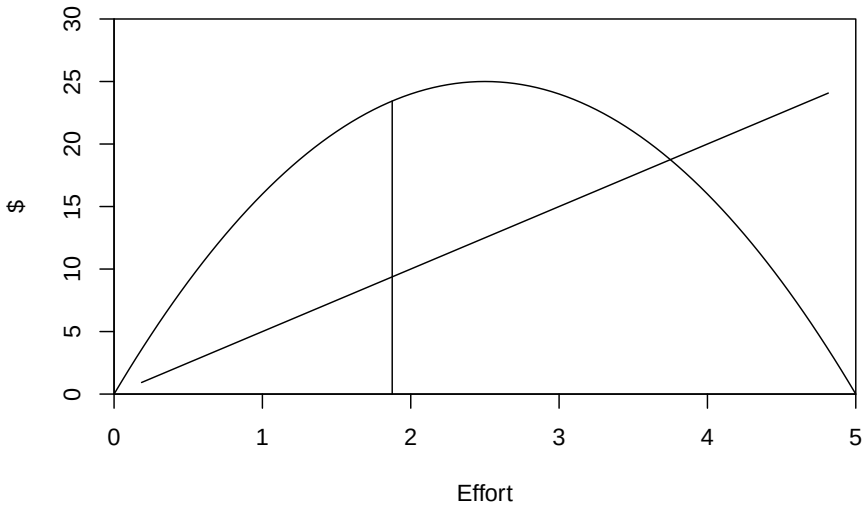
$$\pi = p \cdot h - c \cdot E$$

This results in the following profit function:

$$\pi = p \cdot [\theta \cdot E \cdot K \cdot (1 - \theta \cdot E)] - c \cdot E$$

It can be shown that the effort level E, which maximizes profit is written as:

$$E = \frac{p \cdot \theta \cdot K - c}{2 \cdot p \cdot \theta^2 \cdot K}$$



11.3.3 Depletable Resource Extraction

Consider a depletable natural resource such as oil and natural gas. For simplicity, no new stocks are discovered. We can show that in equilibrium, we have the following relationship:

$$\frac{P_{t+1} - c}{P_t - c} = 1 + r$$

where P_t is the price in time period t, c is the per-unit cost of extraction, and r is the interest rate. The resource is left in the ground if $P_{t+1} - c > (1+r) \cdot (P_t - c)$ and is taken out if $P_{t+1} - c < (1 + r) \cdot (P_t - c)$.

Consider a depletable resource with stock $S = 50$ remaining in $t = 0$. The interest rate is 5%. The demand for the resource can be written as $P = 8 - 0.4 \cdot Q$.

11.4 Intertemporal Decision Making

Intertemporal decision making involves the question of how much to consume in time period t, i.e., c_t. For now, assume two time periods $t \in \{1, 2\}$. Given incomes m_1 and m_2 and given consumption prices p_1 and p_2, what is the most preferred intertemporal consumption bundle (c_1,c_2)? To answer this question, we need to know:

- Intertemporal budget constraint Intertemporal consumption preferences

11.4.1 No Price Effects

Assume for now that $p_1 = p_2 = \$1$ and that there is neither borrowing nor saving:

- Consumption bundle: $c_1 = m_1$ and $c_2 = m_2$

Intertemporal budget constraint:

- No consumption in period 1 ($c_1 = 0$): Assume that the interest rate is r and that the consumer does not consume in period $t = 1$. The savings of the consumer will be $s = m_1$. The available income for consumption in the second period is now $c_2 = m_2 + (1 + r) \cdot m_1$
- No consumption in period 2 ($c_2 = 0$): The consumer has to pay back the borrowing from period 1 in period 2:

$$b_1(1 + r) = m_2 \quad \Leftrightarrow \quad b_1 = \frac{m_2}{1 + r}$$

So the largest possible consumption level c_1 is

$$c_1 = m_1 + \frac{m_2}{1 + r}$$

Suppose that c_1 units are consumed in period 1. This costs c_1 and leaves $s = m_1 - c_1$ saved. Period 2 consumption will then be $c_2 = m_2 + (1 + r) \cdot (m_1 - c_1)$ which can be re-written as

$$c_2 = \underbrace{m_2 + (1 + r) \cdot m_1}_{\text{Intercept}} \underbrace{- (1 + r)}_{\text{Slope}} \cdot c_1$$

So the intertemporal budget constraint can be written as *future-valued*

$$(1 + r)c_1 + c_2 = (1 + r)m_1 + m_2$$

or as *present-valued*

$$c_1 + \frac{c_2}{1 + r} = m_1 + \frac{m_2}{1 + r}$$

11.4.2 Price Effects

Let us relax the assumption of $p_1 = p_2 = 1$. The maximum possible consumption in period 2 is $c_2 = \frac{m_2+(1+r)m_1}{p_2}$. Similar, the maximum possible consumption in period 1 is

$$c_1 = \frac{m_1 + m_2/(1+r)}{p_1}$$

If c_1 units are consumed in period 1 then the consumer spends $p_1 \cdot c_1$ in period 1, leaving $m_1 - p_1 c_1$ saved in period 1. The available income in period 2 will then be $m_2 + (1+r)(m_1 - p_1 c_1)$ and thus

$$p_2 c_2 = m_2 + (1+r)(m_1 - p_1 c_1)$$

So the intertemporal budget constraint including the prices can be written as *future-valued*

$$(1+r)p_1 c_1 + p_2 c_2 = (1+r)m_1 + m_2$$

or as *present-valued*

$$p_1 c_1 + \frac{p_2}{1+r} c_2 = m_1 + \frac{m_2}{1+r}$$

So the slope of the intertemporal budget constraint is

$$Slope = -(1+r) \cdot \frac{p_1}{p_2}$$

11.4.3 Inflation

Define the inflation rate as π such that $p_1(1+\pi) = p_2$. So we can write

$$p_1 c_1 + \frac{p_1(1+\pi)c_2}{1+r} = m_1 + \frac{m_2}{1+r}$$

With inflation, the slope of the budget constraint can be written as

$$1 + \rho = \frac{1+r}{1+\pi}$$

where ρ represents the real interest rate.

11.4.4 Choice Problem

The consumer has preferences represented as follows:

$$U(c_1, c_2) = u(c_1) + \beta u(c_2)$$

To determine the effects of a change in the interest rate on consumers, we have to differentiate between an increase/decrease of the interest rate and whether the consumer is initially a lender/saver or borrower. An increase in the interest rate is a change in the price of consumption in period 1 relative to period

2. An increase in the interest rate is equivalent to an increase in the price of first period consumption. At a higher interest rate, you give up more second period consumption in order to have a unit of first period consumption. So the substitution effect says the consumer should consume less and save more in the first period if the interest rate increases.

- **Initial lender/saver and increase in interest rate**: Increasing the interest rate tilts the budget line to make it steeper. An initial lender remains a lender. There are two effects:
  - Income effect: If a lender/saver, then the higher interest rate increase income for a given amount of saving. The effect of the interest rate increase for an initial lender is to raise the value of the consumer's initial savings because the consumer earns a higher return on this savings. The reduces first period consumption.
  - Substitution effect: The interest rate ρ is the relative price of consumption in period 1 to consumption in period 2, i.e., c_1 becomes more expensive relative to c_2. This increases c_2 and reduces c_1. For a lender/saver, an increase in ρ increases c_2 and may increase or decrease c_1.
- **Initial lender/saver and decrease in interest rate**. A lender might or might not become a borrower.
- **Initial borrower and increase in interest rate.** A borrower might or might not become a lender. For a consumer who is an initial borrower, the income effect goes in the same direction as the substitution effect, i.e., a higher interest rate means less …first period consumption. The interest rate increase makes borrowing more expensive, so the consumer is poorer and chooses less …first period consumption. There are two effects: (1) Income and (2) substitution effect. Income effect: If borrower, then the income effect is negative for c_1 and c_2. Substitution effect: Gross interest rate $1 + r$ is relative price of consumption in period 1 to consumption in period 2: c_1 becomes more expensive relative to c_2: This increases c_2 and reduces c_1. For a borrower an increase in ρ reduces c_1 and may increase or decrease c_2:
- **Initial borrower and decrease in interest rate.** In this case analogous reasoning shows that if the consumer is initially a borrower, and the interest rate declines, the consumer must remain a borrower; becoming a lender would violate revealed preference. There are two effects:

There is an ambiguous effect of an interest rate increase on c_1, s_1 for an initial saver/lender.

Unambiguous Effect of an Interest Rate Increase for an Initial Borrower Thus the effect of an interest rate increase for an initial borrower is to reduce first period consumption and increase savings. The overall effect of the interest rate on savings is thus ambiguous, assuming the economy has some borrowers and

some lenders.

11.4.5 Life Cycle Hypothesis

Individuals want a smooth consumption profile over their life. Labor income varies substantially over a lifetime, starting out low, increasing until retirement, and ending with no labor income after retirement. The life-cycle hypothesis states that individuals turn a very non-smooth labor income profile into a very smooth consumption profile by saving (and borrowing). The main prediction is that current consumption depends on total (expected) lifetime income and given initial wealth. Saving should follow a very pronounced life-cycle pattern with borrowing in the early periods of an economic life, significant saving in the high earning years from 35-50, and reducing savings in retirement years. One empirical puzzle: older household do not reduce saving to the extent predicted by the theory. Several explanations

- Individuals are altruistic and want to leave bequests to their children.
- Uncertainty with respect to length of life and health status.

Permanent income hypothesis

11.5 Exercises

1. ***Net Present Value*** (*): Calculate the NPV of the following income stream over three four years: \$150, \$175, \$200, and \$300. Use an interest rate of 5%. By how much does the NPV change if the interest rate is changed to 1%?

Chapter 12

Case Studies

The following case studies offer insights into economic applications that you may face while working for government, industry, or a nonprofit. Those case studies are abstract representations of reality and many more aspects are usually involved. The reporting of the case studies should be in the form of a policy brief. The Food and Agriculture Organization of the United Nations (FAO) describes a policy brief as *a concise summary of a particular issue, the policy options to deal with it, and some recommendations on the best option* (see Writing Effective Reports for more information).

The policy brief should be easy to understand for the (non-economist) audience it is intended for. There are two types of policy briefs: (1) advocacy brief and (2) objective brief. Whereas the former argues for a particular action to take, the latter informs objectively about the various options including the pros and cons for each possible action. For the case studies, you are writing an objective brief. Decision makers usually have limited time available to read a document and it should be to the point. Decision makers are also more interested in the results and conclusion and not necessarily the technical aspect, e.g., details on economic modelling, which they assume is done correctly. I suggest you structure the policy brief as follows: (1) Title (no title page), (2) Executive Summary, (3) Introduction to the Issue, (4) Analysis, (5) Policy Implications, and (6) Conclusion. Limit the length of the policy briefs associated with the five case studies to 1000 words (excluding text in graphs and tables) and five pages maximum (including graphs and tables).

For some of the case studies, you will need to include a table in your policy brief and useful templates are included in the Excel file Public Management Economics. The sheets in the Excel file correspond to the following case studies:

- **NONPROFIT**: Profit Maximization for a Nonprofit
- **PARKS**: Parks and Recreation
- **TAXATION**: Fuel Taxation and Low-Income Families

- **ENVIRONMENT**: Environmental Policy

12.1 Profit Maximization for a Nonprofit

Farm-to-Table 4 All is a nonprofit 501(c)(3) organization providing healthy food choices in low income neighborhoods. Dena, Eric, and Cullen are its founders and current directors and believe that nutritious food choices are part of a healthy lifestyle. They have three restaurant locations: North, East, and South. At all three locations and each day, those restaurants serve meals including a small appetizer and a dessert. The non-profit has received an endowment of $1,000,000 from a local corporation under the constraint that meal prices cannot exceed $9 per meal. Since there are fixed costs and the marginal cost per meal is $7, Farm-to-Table 4 All has to rely on donations besides the food service provision and the endowment revenue.

Besides providing good food, their main long-run objectives is to not run a deficit. Although nonprofit organizations do not disburse profits, they are subject to the same economic constraints than private firms. A loss over multiple years will ultimately lead to the demise of the organization. Since none of the three founders are economists (or have any basic understanding of economics at all), they asked you to help them with some of their decisions. Out of the goodness of your heart, you have decided to offer your consulting services for free. Farm-to-Table 4 All derives its revenue from three sources (engaging in all three of them is mandatory): (1) Food service provision, (2) donations, and (3) endowment.

- *Food Service Provision*: Over the last months, Farm-to-Table 4 All determined that the inverse demand for its services can be written as follows for the three locations (where Q is the quantity of meals demanded per month and P is the price per meal):
  - North: $Q = 2000 - 120 \cdot P$
  - East: $Q = 1200 - 175 \cdot P$
  - South: $Q = 1750 - 100 \cdot P$ Of course, the quantity demanded cannot be negative. All employees are volunteers and Farm-to-Table 4 All only has to pay the rent which is $1,000, $1,500, and $1,250 per month for the North, East, and South location, respectively. Note that they are able to price discriminate based on location. What this means is that they can charge different prices at different location.
- *Donations from foundations, individuals, and/or industry*: Donation amount D rise with the number of workers L hired that specialize in fundraising. The amount of donations is given by the function $D = 90000 \cdot L^{0.6}$. Each worker is paid an annual wage of $40,000.
- *Endowment*: As aforementioned, they have received an endowment of $1,000,000. The endowment is invested in safe bonds and yields a return ranging from 1% to 5% depending on the macroeconomic environment. Because the returns are uncertain, the directors would like to do all your calculations for the possible range of returns in increments of 1%.

The directors of Farm-to-Table 4 All need advise on how much fundraising to engage in and what price to charge for their meals. They want to keep the meal pricing simple and just want to know the meal pricing strategies using integer dollar amounts. They also know that any strategy which results in any loss is unacceptable. Also, the principal of the endowment can never be touched. The directors want you to answer the following questions (based on one year):

1. How much to charge per meal at the three locations. Those pricing strategies should include the objective of maximizing the surplus/profit which can go into the endowment as well as maximizing the number of people served.
2. How many people to hire for the fundraising activity.

Be careful in differentiating between the monthly and yearly information above. This case study should be answered in yearly terms. The returns from the endowment are independent of the pricing strategy and the number of fundraisers hired. The number of fundraisers is independent of the pricing strategy and the endowment. The number of workers that will maximize the surplus from fundraising will be between one and eight. It is also suggested to construct a table as outlined in the sheet NONPROFIT in the file Public Management Economics.

12.2 Parks and Recreation

You are a management consultant who has been contracted by the Department of Natural Resources (DNR) in SPEAstate. The DNR usually does not get involved with local issues like those explained in the following brief, but the issues of whether or not to open public outdoor recreation facilities is becoming a highly contested issue in the state. You have committed to providing the DNR with a brief report that analyzes the economic issues related the public facilities in two cities: SPEAton and SPEAville. Both cities are medium-sized and have approximately 200,000 residents.

SPEAton has already opened an outdoor recreation area on 10 acres of land. The city acquired the land for $500,000. It cost an additional $500,000 to improve the land, which included clearing away trash, construction of parking facilities, and installation of baseball diamonds, basketball courts, and bike pathways. SPEAton borrowed the funds for land acquisition and improvement. The city borrowed the funds at 0% interest and needs to pay them back over 20 years, i.e. $50,000 total per year. The park covers 10 acres of land and is abutted by three interstate highways and bounded by an industrial zone. The current admission fee is $0.50.

SPEAville is considering a similar project. City officials believe they can buy the land for the proposed project for $500,000 and make the necessary improvements for $500,000. They also plan to borrow the funds for land acquisition and improvement for the same conditions, i.e., payback of $50,000 per year for 20

years. Like the existing SPEAton park, the SPEAville project site is on 10 acres and bounded by a few interstate highways and an industrial zone.

Based on related data of parks across the nation, an economist has completed a study that provides user demand at various prices for a medium-sized city of approximately 200,000 residents. The demand function is written as $Q = 140,000 - 100,000 \cdot P$. For example, if the admission price is \$0.50, the resulting yearly demand would be 90,000. In addition to construction and land acquisition, operating costs are estimated at \$0.30 per user at both facilities. The two facilities are five hours apart so they would not be competing attractions.

Like any public issue, investment of resources in a recreational facility has opponents and proponents. In SPEAton, the opponents argue that buying land from a private, out-of-state, owner has taken the \$10,500 that was collected through property taxes off property tax roles (public land is exempt from property tax, i.e., no tax is collected on that land). They argue that the land should be sold. In fact, they know that the previous owner has offered to purchase the property back for \$600,000, assuming that the land will be zoned for commercial use (the zoning designation prior to the city's acquisition). The city would receive \$30,000 yearly for 20 years ($\$30,000 \cdot 20 = \$600,000$). Reassessment of the property reflecting the higher market value would raise the annual tax revenues to \$12,600. Although the merits of selling the parcel are disputed, all available information suggests that the sales price estimate presented by the opponents of the park is reliable, as is the estimate of the impact of returning the parcel to the tax roles. Proponents of the project reject the opponents' argument. They reject selling the land and argue that the city would make the best use possible of the land by providing recreational facilities. They further argue that the city should focus on reducing the fee from \$0.50 per person to \$0.20 per person.

The debate in SPEAville is centered around building the park or not. The land is currently zoned as commercial land and the property tax revenue is \$10,500. A current reassessment confirmed this value. Other than that, the same demand, cost, and revenue calculations as in SPEAton apply. In addition, because the facilities are well served by existing roadways and public transit and because recreational trips tend to be off-peak the expanded use is not expected to add significantly to congestion or pollution in the area.

The two towns are only considering admission fees ranging from \$0 to \$1.40. The Department of Natural Resources has been clear on the issues they want you to address which are the following:

- What is the quantity demanded and the consumer surplus for three admission fees: (1) Current fee, (2) No fee, and (3) Optimal fee?
- Calculate the accounting profit resulting from admission revenue, operating cost, and loan repayment.
- What is the total economics benefit if consumer surplus is taken into account?
- Based on these estimates of benefits and costs, do you recommend that

the sell the facility in SPEAton? If so, why? If not, at what admission fee should the park be operated?

- Assuming that no significant impacts would result from the project other than the direct impacts of additional recreational use, what are the quantity demanded, the consumer surplus, and the accounting and total economic benefit associated with the project in SPEAville?
- Based on an assessment of total benefits and total costs to city residents, should SPEAville build a recreational facility? Explain why this answer is the same or different from the answer to whether SPEAton should operate a recreational facility?
- What types of costs and benefits were omitted in the analysis for both SPEAton and SPEAville? What this imply about the use of costs and benefits for decision making?

Because you feel a little overwhelmed, you quickly send an email to your SPEA-V 517 instructor. You ask him for a little assistance in putting this report together. Here are the responses:

- You are given demand function to do the calculations. Remember that the consumer surplus is the area above the price and below the demand function. The choke price is \$1.40. So the formula for the consumer surplus as a function of quantity and price is:

$$CS = (1.4 - P) \cdot \frac{Q}{2}$$

  For both cities, you should compare the cost and benefits with and without a park. You should set up an Excel spreadsheet similar to table found in the sheet NONPROFIT.

- Calculate the total economic benefits with the park and without the park for both cities.

- The land improvement cost for SPEAton are sunk cost and cannot be recovered. They have done the improvements and hence, they have to pay back the loan of \$50,000 and get the \$30,000 from the previous owner. You have to take the difference. In general, think about the flow of money with and without the park and keep in mind that we have consumer surplus.

For SPEAville, the issues are slightly different compared to SPEAton because they have not build the park and thus, the loan repayments will be absent.

You also had a colleague help you by doing a literature review of cost-benefit analysis of recreational facilities in a medium-sized city. They put together a few important points (see below). You do not need to address the literature review in your analysis. However, it might be helpful for answering the final question of interest to DNR.

- Green space in an urban area is considered an amenity. Several researchers have found that it increases nearby property values.

- Urban attractions, like recreational facilities, have been found to increase sales at local business establishments.
- Crime can increase surrounding new amenities in an urban area.
- Some argue that increased sales to nearby establishments is simply a shift from other establishments in the local area.
- Obesity is a problem the state of SPEAstate.
- Recreational facilities are often used as ways to clean up abandoned areas.
- Industrial sites can sometimes produce negative externalities to neighboring properties.
- Traffic congestion can result from urban attractions.
- Some researchers have found that nearness to recreation facilities increases physical activities of some residents.
- Crime is sometimes a problem on vacant parcels of an urban area.
- Youth in organized recreational programs are more likely to not create social disturbances than youth who do not participate in organized recreation programs.
- Industrial and commercial parcels produce more tax revenue and require less tax revenue than residential parcels.

12.3 Perfect versus Imperfect Competition for the Marijuana Industry

You are the state governor and elections are coming up. And although you believe that all drugs are bad and people should just say no to drugs, you are not letting your beliefs ruin your re-election chances since a majority of voters are in favor of legalizing marijuana. Your state is facing significant budgetary constraints due to declining tax revenues and increasing public expenditures. Thus, your goal is also to raise new tax revenue while at the same time reduce the burden on law enforcement and the criminal justice system by redirecting resources away from marijuana-related law enforcement and prosecution. In addition, the marijuana industry can have a multiplier effect on the economy, as businesses within the industry purchase goods and services from other sectors. This could stimulate economic activity and job creation beyond the marijuana sector. The proposed policy for legalizing marijuana includes the following elements:

- Legalization Framework: The policy establishes a legal framework for the cultivation, distribution, sale, and consumption of marijuana for recreational purposes. Specific regulations and licensing requirements will be put in place to ensure responsible and safe practices within the industry.
- Taxation: The state will multiple taxes on the industry. The corporate tax rate is 4% on all profits of firms. Your state currently has a sales tax of 6%, from which marijuana sales could potentially be exempt from in favor of a per-unit tax. In addition, there is a licensing fee for businesses operating within the marijuana industry. The tax revenue generated will be allocated

to specific areas such as education, public health, and substance abuse treatment programs. The licence fee is $50,000.

- Regulation: The state will establish a regulatory body responsible for overseeing the marijuana industry. This body will develop and enforce rules on product quality, marketing restrictions, and retailer compliance.

There is one economic dilemma that you are facing and which needs to be carefully analyzed in this case study. Since legalizing marijuana creates a new industry in your state, the first firms selling the product in the marketplace will benefit from higher prices but as more firms are entering the market, prices are going to decline rapidly. This has been observed, for example, in Michigan since the legalization where prices dropped from $18.06 to $3.21 per gram from January 2020 to December 2022 (see Michigan's Plummeting Cannabis Prices: A Closer Look. On one hand, new marijuana firms need to pay an annual licence fees which generates revenue but on the other hand, more firms are increasing supply and put downward pressure on prices. If you were to impose a sales tax, you are afraid that sales tax revenue is declining as well if you distribute too many licences.

You have collected information about the marijuana industry from other states as well as from the (so far thin) academic literature.

- Demand: Based on the consumption in other states, you estimate the following annual inverse demand function with P representing the price in dollars per gram and Q representing the market demand in grams:

$$P = 30 - \frac{20}{50000000} \cdot Q$$

- All firms potentially entering the market are identical and have the following cost function:

$$TC(Q) = 2000000 + 8 \cdot Q$$

The firms are engaging in a Cournot-like competition. You envision two possible policy designs:

1. Sales tax: The current sales tax rate of 6% ($m = 0.06$) is applied to the industry. If N is the number of firms operating in the industry, the output for each individual firm i is given by the following equation (with A and B representing the intercept and slope of the inverse demand function, respectively, and C representing the marginal cost):

$$Q_i = \frac{A - (1+m) \cdot C}{(N+1) \cdot B}$$

2. Per unit tax: In this case, the industry would be exempt from the sales tax and a per-unit tax of $1 per gram would be applied. In that case, the output of each individual firm is given by the following equation:

$$Q_i = \frac{A - t - C}{(N+1) \cdot B}$$

You are willing to have a maximum of 50 firms operating in the state. Remember that you can control the number of firms by restricting licensing. For each of the two scenarios, calculate the price prevailing for consumers, the quantity of marijuana sold in the market, the profit for each firm, and the government revenue. Remember that the government revenue comes from the licence fees, corporate taxes, and either a sales or a per unit tax. What is the optimal number of firms operating in the market from a tax revenue standpoint.

12.4 Fuel Taxation and Low-Income Families

You are the governor of a Midwestern state and concerned about the poor condition of roads. The state's fuel tax has not be adjusted for more than 20 years and thus, inflation has eroded away the purchasing power. You want to raise the gasoline tax by 20% but face critics who claim that an already regressive tax will make the situation for low-income people even worse. Thus, you consider raising the gas tax while implementing a tax credit to low-income people. However, the tax credit must be financed somehow because the increase in gas tax goes to roads and not the tax credit. So you are a little bit in a dilemma. Before you start design a tax proposal, let us look at the current residents, their preferences, and taxes in your state.

There are ten residents in your state. Think about those ten residents to be representative for each of the income deciles as presented in the Consumer Expenditure Survey Deciles of Income before Taxes. Their utility functions can be represented by a Cobb-Douglas function:

$$U(x_G, x_A) = x_G^{\alpha} \cdot x_A^{\beta}$$

where x_G and x_A are the physical quantities of gasoline and all other goods, respectively. The values of the preference parameters α and β are listed in Table **??**. The demand functions resulting from the Cobb-Douglas utility function are written as:

$$x_G = \frac{\alpha}{\alpha + \beta} \cdot \frac{m}{p_G}$$
$$x_A = \frac{\beta}{\alpha + \beta} \cdot \frac{m}{p_A}$$

where m represents the income of the consumer and prices for gasoline and other goods are denoted as p_G and p_A, respectively. The current gasoline wholesale price (i.e., price without tax) is \$2.30. The current tax rate on gasoline is \$0.20 per gallon. The wholesale price on other goods is \$1.00 and the sales tax is 6%. Note that there is no sales tax on gasoline. The current income tax rate is flat at 3% independent of income.

- Current Situation: Unchanged income and gasoline tax.

- 20% Gasoline Tax Increase: The gasoline tax increases by 20% and the other taxes are unchanged.
- 20% Gasoline Tax Increase, Tax Credit, and Flat Income Tax Increase: In this scenario, residents earning less than $40,000 before taxes receive a tax credit of $200. To finance the tax credit, the income tax which is currently at 3% is raised uniformly.
- 20% Gasoline Tax Increase, Tax Credit, and Tiered Income Tax Increase: In this scenario, residents earning less than $40,000 before taxes receive a tax credit of $200. To finance the tax credit, the income tax rate which is raised for residents earning more than $40,000.

The sales and income tax go into the General Fund. That means that both taxes serve as substitutes for each other. The gas tax goes into the Highway and Road Fund. Money between the General Fund and the Highway and Road Fund are not exchangeable, i.e., there is no cross-subsidization.

12.5 Ride Sharing in Your Hometown

You are the mayor of one of the largest cities in the Midwest. Your term is not going well due to rising crime, social injustice, and a crumbling infrastructure. You are now facing an additional problem related to transportation in your city. A start-up ride-sharing company called Unter started to operate in your city. Their business model is simple. You download an app to your phone and you can be either (1) a driver offering rides to customers or (2) a customer ordering rides to a particular destination. The app knows the location of the customer who orders a ride and sends the closest driver to pick them up. Needless to say, the local taxi drivers are in uproar. Unter also uses what is called "surge pricing" which means that they raise the price when demand is high. "Surge pricing" is not used by taxis and cab drivers argue that the surge pricing is unfair to consumers. You vaguely remember from your economics class the concepts of consumer surplus, producer surplus, and deadweight loss. You come to the conclusion, that you may want to look at this from an economic perspective. At the end of your analysis, you should be able to answer the following basic questions (among others):

- Should Unter be allowed to operate in your city from a societal welfare perspective?
- Should Unter be allowed to use "surge pricing" in the case of high demand?

You have to answer those questions and provide context and explanations to your administration. You have the following information. The regular demand for rides (either cabs or Unter) is written as:

$$Q = 3250 - 500 \cdot P$$

The "peak" (also known as "surge") demand function is written as:

$$Q = 4750 - 500 \cdot P$$

Unter and the cab companies operating in your city are using a similar vehicle fleet. So the marginal cost function can be written as:

$$MC = 0.5 + 0.001 \cdot Q$$

Currently, the number of cabs operating in your city is fixed at 1500. In reality, cities distribute so-called medallions to taxi drivers. There is a limited number of medallions and thus, the number of taxis is limited by the number of medallions distributed. Also, cabs are not allowed to change their price based on demand. The price they must use is the equilibrium price under normal demand.

Prepare a policy brief which examines the two broad questions mentioned above but with more in-depth analysis. Calculate the consumer surplus, producer surplus under all possible situations. That is, with or without Unter, with or without surge pricing for cabs and/or Unter, etc. Be as thorough as possible.

12.6 Environmental Policy

You are a policy analyst for the Department of Natural Resources (DNR) in SPEAstate. The two largest firms in SPEAstate are SPEAoil (oil refinery) and SPEApaper (paper mill). Both firms are located at a river and discharge the identical pollutant into the river. The DNR would like to increase the water quality because recreational activities downstream are sometimes restricted due to a high concentration of pollutants. The DNR considers three possible policies: (1) command and control, (2) pollution tax, and (3) cap-and-trade.

Currently, the total quantity of pollutants discharged into the river by both firms is 170 tons per year. SPEAoil and SPEApaper contribute 90 and 80 tons, respectively. Each firm has one pipe discharging the pollutant into the river and hence, the DNR can determine exactly how much pollution is coming from each firm. The goal of the DNR is to limit total pollution to 130 tons per year. For all policy scenarios, the DNR is interested in the quantity of pollution and abatement for each firm and in total. In addition, they want to know the cost to each firm, the revenue to the government (if any) and the societal cost of the policies. To reduce pollution, SPEAoil and SPEApaper can install abatement technology. If a_o and a_p are the quantities abated by SPEAoil and SPEApaper, respectively, then the total cost and marginal costs can be written as: $TC(a_o) = 4 \cdot a_o^2$, $TC(a_p) = 3 \cdot a_p^2$, $MC(a_o) = 8 \cdot a_o$, and $MC(a_p) = 6 \cdot a_p$.

- ***Command-and-Control Policy***: The DNR limits the total pollution discharged to 130 tons and imposes separate emission standard for each firm. The emission standard allows each firm to pollute proportional to its current pollution.

- ***Emission Tax I***: The second policy option taxes each ton of pollutant at $120. Hence, each firm can chose to invest in abatement or can pay the tax on emissions. Calculate each firm's abatement and total cost associated with this policy. How much money will the government collect? Does the DNR achieve the target pollution level? The amount spent by the firm is composed of the abatement amount and the tax payment.
- ***Cap-and-Trade***: Under the cap-and-trade option, the DNR allocates 65 emission permits to each firm. The emission permit gives the firm the right to pollute. For example, if a firm owns 65 permits, it has the right to discharge 65 tons of pollutant. If it discharges more, a very expensive fine is imposed. After the permit allocation, the DNR then allows the firms to sell and buy the permits to each other. How many permits will each firm buy and sell? Note that the total cost to firms includes the expense/revenue from buying/selling the permits. What is the permit price?
- ***Emission Tax II***: Revisit the emission tax scenario but with a modified tax rate, i.e., assume the DNR would set the tax rate to the permit price found under the Cap-and-Trade scenario. Compare the cost to the firms of the tax and the cap-and-trade system. What are your conclusions?