CORE AGRICULTURAL ECONOMIC PRINCIPLES



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Core Agriculture Economics Principles: A Supplementary Text

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This text was compiled on 04/15/2026

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Agricultural Economics: Opportunity Costs

1.0 Introduction

Economics is a social science and is primarily concerned with the study of human decision-making. Decision-making involves making choices between competing alternatives. For example, (i) should I go to class today or sleep in; (ii) should I walk to campus or drive my car; and (iii) should I major in agricultural economics or animal science? In all of these and other decisions that we make, we have to make trade-offs. That is, to make one choice we have to give up something else. In economics, we formalize this trade-off or what has to be given up. We call this trade-off between making competing choices an **opportunity cost**. This chapter will introduce you to the concept of an opportunity cost; present different aspects of opportunity costs; and take you through a couple of detailed case studies about how opportunity costs are calculated and assessed. The case studies are provided to help illustrate the identification and calculation of opportunity costs. These case studies will help you to examine opportunity costs in different decision-making contexts and include questions that will help you go through the associated economic decision-making process.

1.1 Learning Objectives

At the end of this chapter you should be able to:

(1) *Define what an **opportunity cost** i*s; and

(2) *Be able to understand how to assess and calculate an **opportunity cost** in different problem situations.*

2.0 What is an Opportunity Cost?

By definition, an **opportunity cost** of making a choice or decision is the *value of the next best alternative that you gave up to make that choice or decision*. More specifically, an opportunity cost is the *value of a resource in its next best alternative use*. The use is what a firm or decision-maker could have done instead of making the choice or decision they did. While a person has the option of making many different choices, it is important to recognize that the opportunity cost only considers the value of the next best alternative, not of all the other possible choices or uses of a resource. This is an important distinction to keep in mind [1,2].

A couple of examples may help to solidify this idea.



Picture: Sleepy Student [3]

Example 1: As an undergraduate student, you usually have the option of going to class. Each day you have to decide if you will attend class or do something else. The other options could include sleeping in, going to the park, having lunch, studying for another

class, watching a movie, etc. The *opportunity cost* of choosing to attend class is the value of the next best alternative. Assume in this case that you could narrow down the choice to either going to class or sleeping in. The opportunity cost would then be the lost value you would have received from sleeping in a couple of extra hours (i.e. the value of that rest). This value could be measured in different ways, including time, alertness, or even satisfaction.



Picture: Restaurant Investment? [4]

Example 2: Consider a restaurant owner deciding on whether to open a new restaurant on the other side of town from his current location. The owner has saved $300,000 to invest in the new restaurant. The owner was approached by a good friend to invest that money in the stock market instead, where he could have earned a 15% annual return on the investment. Assume this is the next best alternative. The opportunity cost of investing in the new restaurant is the value of using the money (or resource) in its next best alternative. That is, investing the money in the stock market. In this case, we can calculate the monetary value of the opportunity cost, which represents the lost value or return from the investment. This value would be equal to $300,000 × 0.15 = $45,000. The value of the opportunity cost here is what the owner could have earned from the investment, not the $300,000, because the owner already has the $300,000 in their possession.

Example 3: Watch the following video. This video provides a brief explanation of *comparative advantage*, an important concept in economics. A *comparative advantage* exists when an individual has a superior or better ability to undertake an activity using their resources relative to other individuals [2]. For example, a trained accountant has a *comparative advantage* in preparing taxes compared to a carpenter given their specialized training and skills in accounting, which reduces the use of resources (e.g. time and labor) for them in this task. When examining comparative advantages we have to take into account opportunity costs. That is, we determine if a comparative advantage exists based on the opportunity costs. Go back to the example with the accountant and carpenter and preparing taxes. Consider the amount of time used in preparing the taxes. For the accountant, preparing a tax return may take 2 hours, while for the carpenter it may take 8 hours. Based on the amount of time it takes, the accountant has a comparative advantage with respect to time in preparing tax returns. The carpenter would be better off spending that time building, as he would lose 6 hours of his time if he prepared the tax return, which could be done by the accountant in 2 hours. That is, the opportunity cost of having the carpenter prepare a tax return is equal to 6 hours instead of the accountant. That time likely could be put to better use.



Comparative Advantage [5]

The three examples illustrate that opportunity costs can have actual monetary values, but can also be measured in other terms, such as lost time, satisfaction, rest, etc. There are other aspects of opportunity costs to take into account, as well. These are outlined below.

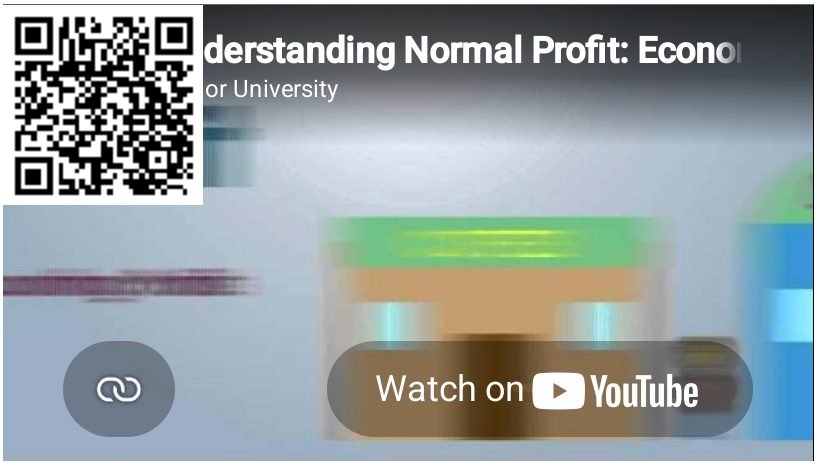
2.1 Aspects of Opportunity Costs

Here we talk about different aspects of opportunity costs that you will need to be aware of.

(1) *Opportunity costs only consider the value of the next best alternative.* - While firms and individuals face many choices or alternatives for every decision they make, opportunity costs are the value of **only** the next best alternative. By focusing on the next best alternative, it makes sure that people examine all the potential choices or alternatives available to determine that next best alternative. Furthermore, including opportunity costs in calculating the cost of making a decision using the next best alternative helps to make sure that we are making the best or optimal choice with the information we have available. In economics, when we calculate the cost of making a decision we take into account the actual monetary cost out of pocket, which we call the *accounting cost*, and the value of the resources being used in their next best alternative. We refer to these costs as *economic costs.* That is:

economic costs = accounting costs + opportunity costs.

(2) *The value of an opportunity cost does not necessarily have to be in monetary terms.* - As illustrated in Example 1, an opportunity cost does not have to take a monetary value. The value of the opportunity cost could be measured in the satisfaction lost or the minutes of sleep (time) lost. This is illustrated in the following video about an entrepreneur's decision to keep their coffee shop.



Coffee Shop Economic Decision Making [6]

(3) *All resources used have opportunity costs attached to them.* - All the resources used in completing a task or job have an associated opportunity cost [2]. Consider the case of deciding to plant corn on your farm next year. The primary resources used to plant the corn include the land the corn is planted on, the labor needed to manage the corn crop, the capital (or machinery) needed for the corn enterprise, and the operating capital (or money) needed to buy the inputs (e.g. seed, fertilizer, pesticides, etc.) to grow the crop. The opportunity cost of the land could be the value the farmer could earn by renting the land to a neighboring farmer. The opportunity cost of the labor (or farmer's time) could be the lost income from working off the farm at another job. The opportunity cost of the capital (or machinery) could be the value of that machinery being used in another enterprise. Finally, the opportunity cost of operating capital could be the return we would earn by investing that money in the stock market over the growing season. The overall or total opportunity cost of deciding to plant corn would be the sum of the values of all these opportunity costs.

(4) *Every decision may have one or more associated opportunity costs* - As illustrated in point (3) above, a decision can have multiple opportunity costs that need to be considered, one for each resource that would be used and its next best use. This aspect especially becomes useful when examining problems from an economic perspective, as economics is concerned with the allocation of scarce resources.

(5) *Taking into account opportunity costs helps individuals make the best "economic" choice.* - By taking into account opportunity costs, a decision-maker has to explicitly consider potential alternative choices and/or uses for their resources for the decision being made. Furthermore, the decision-maker has to rank these choices by valuing them in some manner to identify the best and next best alternatives. Thus, the decision-maker ensures that they make the choice that makes the best use of their resources, making the best "economic" choice.

To explore these aspects of opportunity costs we consider two detailed case studies below. The case studies will take you through a detailed decision-making situation and have you contemplate the potential opportunity costs and their associated values.

3.0 Case Study 1: To go or not to go to college?

The purpose of this case study is to examine the opportunity cost of going to college. While many of you have already chosen to attend college, did you consider the opportunity cost of that decision? The video below provides an overview of the decision-making process one may go through in deciding to go to college. Use this information to examine the college decision and answer the questions asked here in the case study. The video below will help to provide a basis to consider the aspects of this decision process.



Should I go to College? [7]

3.1: The Opportunity Cost of Earning a Bachelor's Degree

A significant decision lying ahead of most high school graduates is whether or not to attend college and obtain a college degree. The concept of opportunity cost can help us understand whether going to college is the right decision, or if you would be better off working after high school. To be able to consider this decision, we need to know the difference in earning potential from earning a college degree. To do this, we examine the net earnings (after expenses are accounted for) for each possible choice over a 15-year time horizon (or period of time) starting when a student is a freshman.

Consider a student who wants to attend Kansas State University. The total cost of attending Kansas State University includes 4 primary costs. The largest cost of attendance is tuition, which averages $9,500 per year. Tuition is closely followed by housing, which averages $8,400 per year. On top of housing, food expenses need to be included, which amounts to approximately $100 a week for groceries, providing a total food cost of $5,200 per year. Miscellaneous expenses then add up to $4000 per year. These expenses include books, supplies, going out to eat, concerts, athletics, gas, and other vehicle expenses, as well as clothing, travel, parking permits, etc [8]. Thus, assuming a degree is completed in four years, the total expense of attendance at Kansas State University adds up to $108,400. That is:

Total expenses of college: (9,500 + 8,400 + 5,200 + 4,000) x 4 = $108,400.00

Assume the student has the good fortune of having access to scholarships, grants, and a part-time job on campus while earning their degree at Kansas State University. We will assume the student (i) receives a scholarship for $2,000 per year and (ii) has a part-time job on campus that pays $12.00/hour. The student works 20 hours a week during the school year (36 weeks). During the summer, the student can work full-time (40 hours per week) at a job that pays $13.00/hour. The summer is 12 weeks in length. The total earnings by the student from the scholarship and job during their college career is $67,520. That is:

Total earnings during college: (2,000 + ($12 x 20 x 36) + ($13 x 40 x 12)) x 4= $67,520.00

After graduation, assume the student can find a job that pays an annual salary of $55,000. While the student now earns significantly more than they did in college, their living expenses are expected to double (after tuition is dropped). Individuals that have graduated and have higher incomes, will likely spend more money on higher quality items and more items in general. Living expenses for a college graduate are assumed to be $35,200 per year. Thus, a college graduate in industry will earn a net of $19,800 per year. That is:

Net earnings per year for a college graduate in industry: $55,000 - $35,200 = $19,800.00

The next best alternative for the student, if they did not attend college, is to find a full-time job after graduating high school. Assume a graduate from high school will earn on average, $15/hour working 40-hour weeks for 50 weeks of the year (2 weeks off for vacation). At this wage rate, the high school graduate will earn $30,000 per year. Assume a high school graduate will accrue living expenses totaling $22,000 per year (a slight increase in expenses over a college student). Thus, a high school graduate will earn $8,000 net per year. That is:

Net earnings per year for a high school graduate: $30,000 - $22,000 = $8,000

We now have the needed information to calculate the total net earning from both options available to the high school graduate: go to college or take a full-time job.

The total net earnings from each of these options will allow us to assess what is the best "economic" decision and the opportunity cost of going to college.

While this provides one example, the question of whether college is worth it for a particular individual is going to be dependent on the individual, where you go to school, how you pay for school, and what career path you choose, among others.

Now consider the opportunity cost or decision of going to graduate school.

3.2: The Opportunity Cost of Earning a Masters Degree

Following graduation from Kansas State University, and with a superb Agricultural Economics degree, a student has a few paths they might take. Many students wonder whether or not to go to graduate school. Fortunately, opportunity cost applies to this decision, as well. In this continuation of the above case study, you will do more of the calculations yourself. Again, answers will be provided with the questions to help you review and learn. Finally, as with the decision to go to college or not, we need to consider the earnings after earning a graduate degree, so for this example, we will consider a 10-year time horizon after graduation from K-State.



Graduation [9]

Now consider a student who has just recently graduated from Kansas State University. This student has to decide to find a job in industry or pursue a Master of Science degree (MS) in Agricultural Economics. The MS will take the student 2 years to complete, upon which they will obtain a job in industry.

In graduate school, graduate students have the opportunity to receive a tuition waiver and/or a graduate research assistantship to help with the cost of graduate school. The tuition waiver covers all in-state tuition. The graduate research assistantship hires the student as a part-time university employee and provides them with a stipend for living expenses. Based on competitive rates, assume the annual stipend for the student is $17,000 per year. The assistantships are year-round, and most students do not work during their master's program outside of school. Expenses for a grad student are similar to those for an undergraduate student, except that we will assume they receive a tuition waiver. Housing runs an average of $8,400 per year. Food expenses need to be included, which are approximately $100 a week, totaling $5,200 per year. Miscellaneous expenses add up to $4000 per year. Finally, we assume the student is responsible for books and fees, which come to $1000 per year. Totaling all the expenses for the student while earning their MS degree over 2 years, barring any extenuating circumstances is equal to $37,200.

Now assume that after earning their MS degree, the student finds an industry job that pays an annual salary of $75,000. Assume living expenses after graduation are $35,200 per year. Use this information to answer the following questions.

Alternatively, if a student were to choose not to go to graduate school, they would earn approximately $55,000 per year from their first industry job and their living expenses would be $35,200 (as before). We will assume they stay in the same job for all 10 years. Use this information to answer the following questions.

4.0 Case Study 2: Investing in Agricultural Livestock

Many farms in Kansas and around the nation raise livestock. One of the most significant livestock industries is cattle. Kansas ranks 3rd in the nation for the size of its cattle livestock industry. As of the beginning of 2018, Kansas had 6.3 million cattle, almost twice the state's human population. This industry generated revenues of over $7.8 billion in 2016 and was responsible for over $12.9 billion in direct and associated economic activities in 2012 [10].



Kansas State University Cattle [11]

To be able to do economic assessments of livestock enterprises on farms, a common tool is the use of enterprise budgets, which provide a detailed outlay of the costs that are faced by a livestock producer. For this case study, enterprise budgets were developed for a rangeland-based ranching operation that included production activities for stocker cattle and is based on an actual livestock operation in Kansas [12]. Stocker cattle are weaned calves grazing pastureland that are allowed to grow to a mature size that will be later moved to a feedlot.

With this information, consider the case of a rancher who owns and operates a 500-head stocker cattle ranch on 5000 acres in central Kansas. The rancher has recently received a significant inheritance from past relatives of $200,000 in cash and 2000 acres of rangeland. The rancher is interested in estimating the opportunity cost of purchasing an additional 200 head of stocker cattle this upcoming year, which would require both land and capital. Assume that each additional acre of rangeland and every dollar of the inheritance would be used in raising the additional 200 head of stocker cattle.

Provided the mortality rate remains low (i.e. below 2%), there is an opportunity for profit. The tables below provide a breakdown of the returns and additional costs per head of cattle for the coming year, providing us with a basis for opportunity cost analysis for the land and capital resources [12].

Return Per Head	
Price at Market ($/cwt)	$165.00
Initial Weight at Purchased (lbs)	550
ADG (Average Daily Gains) (lbs)	1.8
Weight at Sale (lbs)	820
Sale Value ($/cwt)	$138.00
Revenue Per Head ($)	$1,131.60
Less Cost of Animal Purchase Price	$907.50
Less Death Loss (2%)	$18.15
Return Per Head	$205.95

Additional Costs Per Head	
Supplemental Mineral and Salt	$6.00
Veterinary Drugs and Supplies	$15.00
Commissions and Marketing	$10.00
Professional Fees	$2.00
Miscellaneous	$8.00
Additional Costs per Head	$41.00

If the rancher decides not to purchase an additional 200 head of stocker cattle, the next best alternative would be to rent out the rangeland at $16 per acre and invest the $200,000 in the stock market at an annual interest rate of 6% for the grazing season (which is approximately 5 months or 41% of the year).

The rancher is interested in whether the net benefits of purchasing an additional 200 head of stocker cattle outweigh the net benefits of the next best alternative. Use this information to answer the following questions.

Remember, that an opportunity cost can represent the value of a resource in its next best use. The farmer had two resources that would be needed to manage the 200 additional stocker cattle: land and operating capital. The land is the additional 2000 acres they inherited and the operating capital is the $200,000 they inherited (or the money needed to purchase the cattle and inputs). Using this information, determine the opportunity costs of land and operating capital for the farmer.

5.0 Concluding Remarks

This chapter introduced you to the concept and aspect of opportunity costs used in economics. The notion of an opportunity cost allows decision-makers to take explicit account of the alternatives available to them to make sure that they are making the best "economic" decisions. This was illustrated in detail in both case studies examining the decision to earn a college degree and purchase additional stocker cattle on a ranch. Whether we recognize it or not, when making decisions and taking account of alternative choices or options, we are taking into account the opportunity costs of those decisions.

6.0 References

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[1] Anderson, D.A. *Economics by Example*. New York, NY: Worth Publishers, 2007.

[2] Barkely, A. and P.W. Barkley. *Principles of Agricultural Economics*, 2nd ed. New York, NY: Routledge, 2016.

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[6] Video courtesy of Saylor Academy through Youtube, under license CC BY Attribution 3.0 Unported

[7] Video courtesy of BU Newsservice through Youtube, under licencse CC BY Attribution 3.0 Unported.

[8] Kansas State University, Office of Student Financial Assistance, Undergraduate Students 2017-2018, Costs. Available at: http://www.k-state.edu/sfa/cost/undergraduate.html.

[9] Image courtesy of Quan Nguyen through Wikimedia Commons, under license CC Attribution-ShareAlike 3.0 Unported. No changes were made to the image.

[10] Kansas Livestock Association. "Economic Impact of the Kansas Livestock Industry." 2018. Available at: https://www.kla.org/industryeconomics.aspx.

[11] Image courtesy of K-State Research and Extension through Flickr, under license CC BY 2.0.

[12] D. McCollum, personal communication, 2018.

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Agricultural Economics: Elasticity



Food Market [1]

1.0 Introduction

Perhaps one of the most useful concepts in economics is the notion of elasticity. Taken from engineering, economists adopted this term into their toolset to be able to provide an intuitive mechanism for examining the marginal changes in economic processes, such as changes in the prices of goods on the quantity demanded (consumed) or supplied (produced) of that good. Elasticity can help us answer questions like (i) how much should a firm produce?; (ii) how will a change in demand impact a firm's sales?; (iii) how much can a firm charge for a product given a competitor's position in the market?; and (iv) should the government tax a particular good to raise more revenue for public programs? All of these decisions revolve around a marginal change in one variable in response to a marginal change in another variable. A *marginal change* is defined as the addition of one or more units of a given economic variable (e.g. goods produced) to the current level of that economic variable We call this relative or marginal response an **elasticity**.

This chapter will introduce you to the concepts of elasticity, present different forms of elasticities found in economics, and take you through a set of detailed case studies about how elasticity can be calculated, interpreted, and used. The case studies will show you how elasticity is one of the most important concepts in economics.

1.1 Learning Objectives

By the end of this chapter, you should be able to:

(1) *Define the concept of an elasticity*;

(2) *Calculate and interpret different types of elasticities, including own price elasticities, price elasticities, and income elasticities;* and

(3) *Be able to use the concept of elasticity in different economic problem situations.*

A few case studies are provided that help illustrate the calculation and usefulness of elasticities. These case studies will help you to examine elasticities in different decision-making contexts and include questions to help you review and go through these examples on your own. In addition, the case studies will present you with some additional concepts related to elasticities and extend how they are useful in different economic situations and decision-making.

2.0 What is Elasticity?

The concept of elasticity originally arose in the fields of engineering and physics. Elasticity refers to the capability of a body that has been strained to recover its size and shape after deformation. Another perspective is how easily an object can be stretched [2]. It is this latter definition that gives rise to the notion of elasticity in economics. From an economic perspective, it is how much an economic variable can be "stretched" or how responsive that variable is to a given change in another economic variable.

By definition, **elasticity** is the *responsiveness of one economic variable to a marginal change in another related economic variable*. Mathematically, elasticity can be defined as the *percentage change in one variable in response to the percentage change in another variable*. When used as a single term, elasticity usually refers to "own-price elasticity", which is a measure of the percentage change in the quantity demanded or supplied of a good in response to a percentage change in the "*own*" price of that same good. By "own" price, we mean the price of the good or service we are examining. The ability of an elasticity to capture this responsiveness or marginal change in economics makes the concept of elasticity especially important in conducting *marginal analysis*, one of the main tools used in economics. For example, elasticity is very useful in measuring the responsiveness of consumers' demand to different output prices, income, and other economic variables, which can help provide a basis for firms or businesses to make more profitable production and marketing decisions. These decisions include how much to spend on advertising, offering discounts, increasing/decreasing production, which markets to sell in, and many more [3,4].

Elasticity can be represented mathematically. It is the mathematical formula and calculation that illustrates the usefulness of this concept in economics.

To begin, elasticity is the relationship between two economic variables. Let Y represent the economic variable of interest, say the quantity demanded of a good. We are interested in how responsive Y is to a change in another related economic variable X, say the price of that same good. To be able to calculate an elasticity using data, we need, at a minimum, two points of data. Let these two points be (Y_1, X_1) and (Y_2, X_2). We are interested in the marginal change ($\triangle$) in each variable. That is:

Marginal Change in Y: $\triangle Y = Y_2 - Y_1$; and

Marginal Change in X: $\triangle X = X_2 - X_1$

We want to make the changes *unitless*. That is, to compare the marginal change in one variable to a marginal change in another variable in more general terms, we can use the percentage changes of each variable. As the two variables are measured in percentage changes, the units cancel out [3]. In addition, using percentage changes helps to avoid problems of scale or differences in the units of the variables being examined. To do this, we convert the above marginal changes into percentage changes (%$\triangle$) by:

Percentage change in Y: $\% \triangle Y = \frac{\triangle Y}{Y_1}$

Percentage change in X: $\% \triangle X = \frac{\triangle X}{X_1}$

We can put these together to calculate an elasticity. Using the two variables defined here, the elasticity is the percentage change in Y given a percentage change in X. The elasticity (E) can be calculated as:

$$E = \frac{\% \triangle Y}{\% \triangle X} = \frac{\triangle Y}{Y_1} \times \frac{X_1}{\triangle X} = \frac{\triangle Y}{\triangle X} \times \frac{X_1}{Y_1} \quad (1)$$

The formula given by equation (1) is known as a *point elasticity*, as it is calculated relative to the point (Y_1, X_1). It should be noted here that the point (Y_2, X_2) could have been used instead.

We will show another related formula known as the *arc elasticity* in section 2.1.1, as it provides a more accurate estimate of the marginal changes being captured by the elasticity in some cases.

The elasticity formula is a general formula, which can be used to look at the responsiveness of a large number of economic variables to marginal changes in other economic variables. Substituting different economic variables into equation (1) gives rise to

a multitude of different elasticity measures, as will be seen in this and the next section.

The *interpretation* follows from this mathematical formula. The formula in equation (1) tells us by how much Y will change as a percentage, given a 1% change in X. Consider the case where Y is the quantity supplied of shoes, and X is the price of shoes, then E here represents the own price elasticity of supply for shoes (to be discussed in more detail later). If say $E = 1.5$, then a 1% increase in the price of shoes (X), will increase the quantity supplied of shoes (Y) by 1.5 %. Now consider the following question.

In general, elasticities are classified into three separate categories based on the responsiveness of the economic variable of interest Y to a change in another economic variable \(X\. The three categories, which are based on the absolute value of the elasticity, are:

1. Elastic: $|E| > 1.0$

2. Unitary Elastic: $|E| = 1.0$

3. Inelastic: $|E| < 1.0$

We now turn to looking at different types of elasticities commonly used in economics, how to compute them, and how to interpret them. The following video provides a review of this material and focuses on the own price elasticity of demand, which you will encounter in the next section.



Own Price Elasticity of Demand [5]

2.1 Types of elasticities

As mentioned earlier, numerous types of elasticities are useful in economics. We want to examine a number of these in this section. All of these elasticities are calculated using the same formula, the only difference being the economic variables involved. For now, we will focus on 3 fundamental elasticities: own price elasticity of demand and supply, cross price elasticities, and income elasticities.

2.1.1 Arc vs. Point Elasticities

We presented equation (1) initially as the formula for calculating elasticity. While point elasticity can be useful, this measure is highly dependent on the point being chosen and does not take into consideration the information from other points (or data) used to calculate the elasticity.

An alternative formula advocated in economics is the *midpoint arc elasticity formula* or, more commonly known, the ***arc elasticity formula***. This measure uses the average of the points in the formula, rather than one point, as in the point elasticity formula. That is, an arc elasticity is calculated using the following formula:

$$E = \frac{\triangle Y}{\triangle X} \times \frac{\overline{X}}{\overline{Y}} \tag{2}$$

(2)

where $\overline{Y} = \frac{Y_1+Y_2}{2}$ and $\overline{X} = \frac{X_1+X_2}{2}$. That is, instead of using the point (Y_1, X_1), we use the averages of the two points, $(\overline{Y}, \overline{X})$, to calculate the elasticity.

The use of the arc elasticity formula was advocated by R.G. D. Allen, especially for the case when using elasticities to look at comparative statics for market demand and supply. The arc elasticity has the following useful properties: (1) it is symmetric with respect to the two economic variables being examined, (2) it is not dependent on units of measure, and (3) it is equal to one for the own price elasticity of demand and supply if total revenues or expenditures (price times quantity) at the two points being examined are equal. [6].

2.1.2 Own Price Elasticity

The own-price elasticity (more often referred to as just "elasticity") measures the change in quantity (Q) demanded or supplied as a result of a change in the price (P) of the good. The own price elasticity can be represented as a mathematical function, based on equation (2), as:

$$E = \frac{\% \triangle Q}{\% \triangle P} = \frac{\triangle Q}{\triangle P} \times \frac{\overline{P}}{\overline{Q}} \tag{3}$$

More specifically, there are two own price elasticities of interest. These are:

Own price elasticity of demand: This elasticity is represented by the Greek letter η and it measures the responsiveness of consumers' consumption or quantity demanded of a good or service to a change in the market (or own) price of that good or service. These elasticities are usually negative, following the Law of Demand. The own price elasticity of demand (η) is calculated as:

$$\eta = \frac{\% \triangle Q^D}{\% \triangle P} = \frac{\triangle Q^D}{\triangle P} \times \frac{\overline{P}}{\overline{Q^D}} \tag{4}$$

(3)

where Q^D is the quantity demanded of the good or service being examined.

Own Price elasticity of supply: This elasticity is represented by the Greek letter ϵ and it measures the responsiveness of a firm's production or quantity supplied of a good or service to a change in the market price of the good or service being produced. These elasticities are usually positive, following the Law of Supply. The own price elasticity of supply (ϵ) is calculated as:

$$\epsilon = \frac{\% \triangle Q^S}{\% \triangle P} = \frac{\triangle Q^S}{\triangle P} \times \frac{\overline{P}}{\overline{Q^S}} \tag{5}$$

(4)

where Q^S is the quantity supplied of the good or service being examined.

Own price elasticities are classified into three separate categories, as seen earlier, based on the responsiveness of the quantity demanded or supplied to a change in the market price of the good or service being examined. The three categories are:

1. Price Elastic: $|\eta| > 1.0$ or $\epsilon > 1.0$

2. Unitary Elastic: $|\eta| = 1.0$ or $\epsilon = 1.0$

3. Inelastic: $|\eta| < 1.0$ or $\epsilon < 1.0$

From a demand perspective, goods that are price elastic have changes in quantity demanded that are greater than 1% when the (own) price changes by 1%. These goods may have many substitutes in consumption, and as price increases, consumers will substitute these goods for cheaper goods. Goods that are price inelastic have changes in quantity demanded that are less than 1% when price changes by 1%. As such, these goods tend to have fewer substitutes and include products like food staples, cigarettes,

and alcohol. The use of substitutes/complements in consumption/production will be more closely examined using cross price elasticities.

Based on this information, consider the following question to test your understanding.

Now let's look at how to calculate and interpret own price elasticities of demand and supply by examining the market for bananas.



Bananas at Market [12]

For this example, assume the demand schedule for bananas for a small group of people is given in the table below.

Price of Bananas (P)	Quantity Demanded of Bananas (Q)
$1	8
$2	6
$3	4
$4	2

Along a linear demand curve, the own price elasticity of demand will change as you move down the curve (as the price decreases). Let's consider what the own price elasticity of demand will be going from $1 to $2 (a price increase). To calculate the elasticity, we will use the arc elasticity formula given by equation (3).

For this calculation, we are given the following two points, (P_1, Q_1^D) = $(1, 8)$ and (P_2, Q_2^D) = $(2, 6)$, from the demand schedule. To calculate the arc elasticity, we first need to find the change in the market price and quantity demanded. These are given by:

$$\triangle Q^D = 6 - 8 = -2$$ and \(△P =2-1=1\).

Second, we will need the average quantity demanded and price, which are given by:

$$\overline{Q^D} = \frac{6+8}{2} = 7 \text{ and } \overline{P} = \frac{2+1}{2} = 1.5$$

Plugging these values into the formula for the own price elasticity for demand given above gives:

$$\eta = \frac{\triangle Q^D}{\triangle P} \times \frac{\overline{P}}{\overline{Q^D}} = \frac{-2}{1} \times \frac{1.5}{7} = \frac{-3}{7} = -0.4 \quad (6)$$

rounded to the first decimal place. The value of the elasticity is negative due to the Law of Demand and it indicates that demand for bananas is price inelastic between $1 and $2.

How do we interpret this elasticity? The calculated own price elasticity of demand for bananas tells us that for every 1% increase in the price of bananas (P), consumers in the small group will decrease their consumption or quantity demanded (Q^D) by 0.4%, and vice versa. Now let's consider what would happen if the price of bananas increased by 5% when the current price is between $1 and $2. Remember that for each 1% increase in price, the quantity demanded of bananas decreases by 0.4 %. If the price increases by 5%, then the quantity demanded will decrease by 5 x 0.4% = 2%.

Now let's have you calculate and interpret the own-price elasticity of demand using the above example.

First, let's calculate the elasticity of demand for bananas between $2 and $3

On your own, you can now calculate the average quantity and average price that will be needed to calculate the arc elasticity of demand for bananas between $2 and $3 using equation (3). Once you have these values answer the next question.

Now try the calculation fully on your own and interpret some of the results obtained.

For the next two questions, refer back to your answer to Question #7.

Calculating and interpreting the own price elasticity of supply will follow the same procedures as in the above example and text.

2.1.3 Income Elasticity of Demand

We now begin to look at factors that impact demand (and supply) other than the own price. Remember these are referred to as determinants of demand (and supply). The following video provides a review of the income elasticity of demand. Watching this will help understand how elasticity can be used to look at the impact of changes in determinants of demand on the demand for a good or service.



Income Elasticity of Demand [8]

As a review for the coming discussion, answer the following question:

We focus on income as a determinant of demand in this subsection to introduce the income elasticity of demand or income elasticity for short. This elasticity measures the percentage change in quantity demanded in response to a percentage change in consumers' income. We will designate the income elasticity of demand as E^I. Income elasticity can be calculated using the following mathematical formula:

$$E^I = \frac{\%\triangle Q^D}{\%\triangle I} = \frac{\triangle Q^D}{\triangle I} \times \frac{\overline{I}}{\overline{Q^D}} \tag{7}$$

(5)

where I is income, $\triangle I = I_2 - I_1$, $\overline{I} = \frac{I_1+I_2}{2}$ and $\overline{Q^D} = \frac{Q_1^D+Q_2^D}{2}$. The formula is calculated using two points (I_1, Q_1^D) and (I_2, Q_2^D).

Four different types of goods are relatively important concerning income elasticity of demand: normal, necessity, luxury, and inferior goods. The definition and presentation of these types of goods should be reviewed. The income elasticity can indicate the type of good being examined as follows:

· Normal Goods: $E^I > 0$

o Necessity Goods: $0 < E^I < 1$

o Luxury Goods: $E^I > 1$

· Inferior Goods: $E^I < 0$

Normal goods are those goods with a positive income elasticity. That is, an increase in income will increase the consumption of a normal good. Normal goods can be broken down into two sub-categories: necessity and luxury goods.

Necessity goods are goods considered to have a positive income elasticity but are less than one in value. A 1% increase in income results in a less than 1% increase in the consumption of the good. Examples of necessity goods may include rice, beans, and corn.

Luxury goods are goods that consumers consume more of as income increases at an increasing rate. That is a one percent increase in income results in a larger than one percent increase in consumption of the good. Examples of luxury goods for consumers could include yachts, expensive wines, art, and jewelry.

Inferior goods are goods with a negative income elasticity. That is, an increase in income will result in a decrease in consumption of an inferior good. Possible inferior goods for consumers include public transportation, generic foods, and off-brand electronics.

Let's now consider an example of how to calculate and interpret income elasticity. Consider a farmer whose farm income increases from $75,000 to $90,000 per year. Earning $75,000 a year, the farmer would go and play 10 rounds of golf. Earning $90,000 a year, the farmer would now go and play 15 rounds of golf.

What is the income elasticity of demand for golf for the farmer between these two levels of income? To answer this question, we will use equation (5). Our two data points are $(I_1, Q_1^D) = (75,000, 10)$ and $(I_2, Q_2^D) = (90,000, 15)$. Using these two points we can compute:

$\triangle I = 90,000 - 75,000 = 15,000$

$\triangle Q^D = 15–10 = 5$

$\overline{I} = \frac{75,000+90,000}{2} = 82,500$ and

$\overline{Q^D} = \frac{15+10}{2} = 12.5$

Plugging all of this into equation (5) gives:

$$E^I = \frac{\triangle Q^D}{\triangle I} \times \frac{\overline{I}}{\overline{Q^D}} \times \frac{5}{15,000} \times \frac{82,500}{12.5} = 2.2 \tag{8}$$

The income elasticity calculated tells us that a one percent increase in income for the farmer increases their playing or consumption of golf by 2.2 percent. This makes golf a luxury good for the farmer.

Now consider what happens when the farmer's income decreases from $75,000 to $50,000. In this case, the farmer will reduce their playing of golf from 10 games to 7 games. Use this information to answer the following questions.

Income elasticities are important to consider because as income grows for consumers in the economy, the demand for goods and services will grow, as well. For elastic goods, as income increases, consumption of these goods will increase at an increasing rate. For inelastic goods, as income increases, consumption of these goods will increase at a decreasing rate. This type of information can be useful for firms planning marketing and production decisions, as well as governments looking to plan fiscal policy. For

example, if a government wants to determine recession-proof goods or consumer staple stocks that will be produced in enough quantities for consumers in times of economic hardships, the government may want to look for highly income inelastic goods [14].

2.1.4 Cross Price Elasticity

Another important elasticity that captures the effects of changes in determinants of supply and demand is cross price elasticity. Cross price elasticity measures the quantity change of one good in response to a change in the price of another good. For example, butter and margarine, which are not produced together, impact the price and quantity demanded/ supplied by one another inversely. That is, they are substitutes. This relationship can be captured by the cross price elasticity. What we will find is that the cross price elasticity can be applied to both demand and supply.

Cross price elasticity of demand: This measure captures the responsiveness of consumers' consumption (quantity demanded) of a good or service in response to a change in the price of a related good or service. As with other elasticities, this can be captured using percentage changes. The cross price elasticity of demand here is represented by the symbol σ_X^D. The formula for the cross price elasticity of demand for a good concerning the price of good X is given by the following function:

$$= \sigma_X^D = \frac{\% \triangle Q^D}{\% \triangle P_X} = \frac{\triangle Q^D}{\triangle P_X} \times \frac{\overline{P_X}}{Q^D} \tag{9}$$

(5)

where P_X is the price of the related good $\overline{P}_X = \frac{P_{X,1}=P_{X,2}}{2}$.

Cross price elasticity of supply: This measure captures the responsiveness of firms' production (quantity supplied) of a good or service in response to a change in the price of a related good or service. As with other elasticities, this can be captured using percentage changes. The cross price elasticity of supply here is represented by the symbol σ_X^S. The formula for the cross price elasticity of supply for a good concerning the price of good X is given by the following function:

$$= \sigma_X^S = \frac{\% \triangle Q^S}{\% \triangle P_X} = \frac{\triangle Q^S}{\triangle P_X} \times \frac{\overline{P_X}}{Q^S} \tag{10}$$

where P_X is the price of the related good $\overline{P}_X = \frac{P_{X,1}=P_{X,2}}{2}$

Depending if one is looking at demand or supply, the cross price elasticities can be categorized into two different categories: substitutes or compliments, based on their sign, as follows:

(i) Substitutes:

· Substitutes in Consumption: $\sigma_X^D > 0$

· Substitutes in Production: $\sigma_X^S < 0$

(ii) Complements:

· Complements in Consumption: $\sigma_X^D < 0$

· Complements in Production: $\sigma_X^S > 0$

Recall, that substitutes are goods that are produced or consumed as an alternative to the original good.

Substitutes in consumption are goods that impact the price and quantity demanded of one another in the same direction. That is, as the price of a substitute good increases, the consumption of the good being examined increases, and vice versa. An example of substitutes in consumption are tortilla chips and potato chips. A consumer will tend to buy more of the cheaper product to minimize their expenses on food.

Substitutes in production are goods that impact the price and quantity supplied of one another inversely. That is, as the price of a substitute in production increases, the production of the good being examined decreases, and vice versa. An increase in the price of the substitute will increase revenue from that good for the producer. Assuming costs are unchanged, it is now more profitable for the producer to produce more of the substitute good, as they now earn more revenue relative to the other good. For example, farmers must usually decide how many different crops to plant each year to maximize their profit. These crops, e.g. corn, sorghum, soybean, wheat, and cotton are often substitutes in production.

Complements in consumption are goods that impact the price of a related good and quantity demanded of the good of interest inversely. That is, as the price of a complement in consumption increases, the consumption of the good of interest decreases, and vice versa. An example of goods that are complements in consumption include cake and frosting. As the price of cake increases, you will likely purchase less frosting, given you consume less cake.

Complements in production are goods that are produced together. Therefore, if the price of a complement in production increases, the production of the good of interest will increase, and vice versa. For example, peanut oil and peanut meal must be produced together, as peanut meal is a byproduct from the production of peanut oil. In fact, peanut meal has its own market and can be used for a number of different uses, including as a feed source for livestock. This makes peanut oil and peanut meal complements in production.

Let's examine the use of cross price elasticity by looking at the production of ethanol and a byproduct of the production process, distiller's dried grains (DDGs). DDGs are a good source of protein for livestock feed rations.



Ethanol Plant [10]

Assume that 5 billion gallons of ethanol are produced and the price of DDGs is $90 per dry ton. A change occurs in the market over time increasing the production of ethanol to 6 billion gallons and the price of DDGs changes to $100 per ton. Use this information and the above material on cross price elasticities to answer the following questions [11].

2.2 Important Aspects of Elasticity

Much of the importance, calculation, and interpretation of different types of elasticities was discussed in the prior subsections of this section of the chapter. In this short subsection, we want to highlight briefly two points to keep in mind about elasticities.

(1) While several different elasticities were presented above, there are many more used in the field of economics. As stated earlier the relationship of many economic variables can be summarized using an elasticity. That is, elasticities can be used in general to compare many different relationships between two economic variables. It is a widely applicable and used concept in the field of economics and other related disciplines. You will encounter some additional elasticity measures in the case studies below.

(2) Elasticities provide a generalizable and intuitive way to not only capture the sign (e.g. positive or negative) of the relationship between two economic variables, but elasticities provide a measure that captures the magnitude of this relationship (i.e. if it is elastic or inelastic). These properties allow the use of elasticities to do "back of the envelope" types of calculations for a quick assessment of changes in the market or of policy changes that are accessible and understandable by more lay groups (who may not fully understand economics). These quick assessments though should be placed in context, as the use of an elasticity usually

assumes that all other variables are held constant. That is, when using elasticities we are implicitly invoking the notorious *ceteris paribus* clause often encountered in economic analysis.

The remainder of the chapter provides some in-depth case studies to provide you with more practice in using, calculating, and interpreting different elasticity measures.

3.0 Case Studies

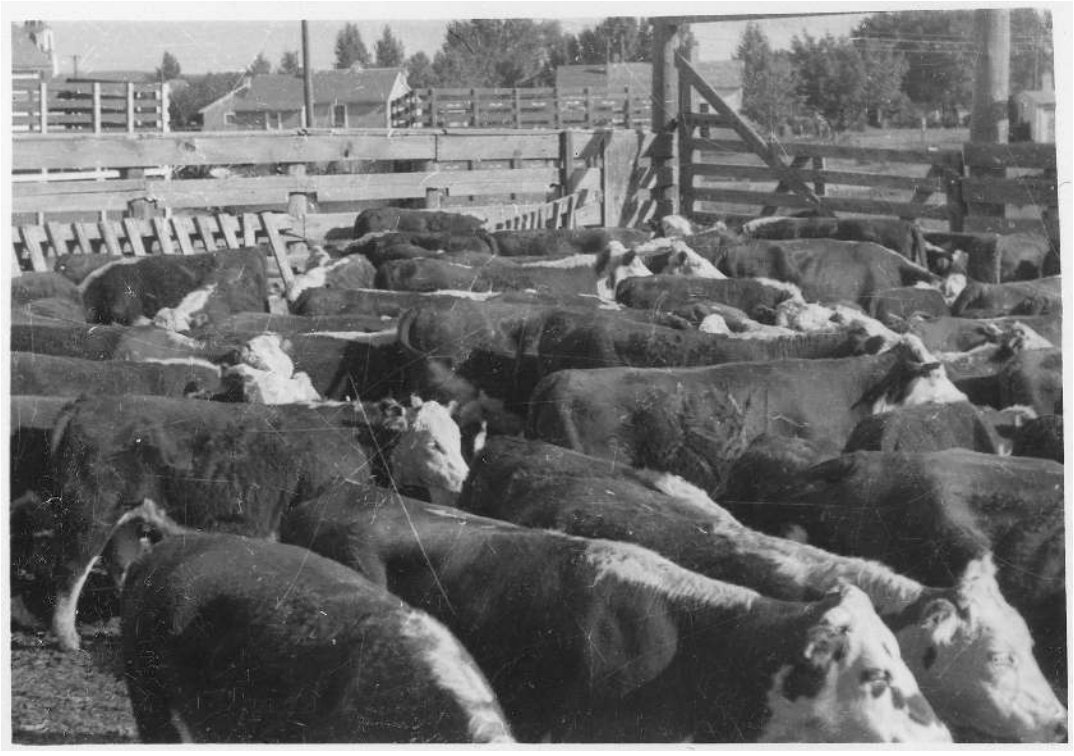
In this section of the chapter, we examine three in-depth case studies on beef demand, parking demand on campus, and agricultural land use.

3.1 Beef Demand and Cattle Producer Competitiveness

The own price elasticity of demand may be one of the most useful elasticity measures in economics. It is a crucial and highly important measure for agribusiness to take account of and try to determine. Knowing or having an accurate prediction of the own price elasticity of demand can help a firm figure out how much product to produce; the effect of sales, discounts, or other promotions on their product; allow them to be more competitive in the market; determine the impact of government taxing policies; among other benefits [3,4]. The purpose of this case study is to examine the impact of knowing the own price elasticity of demand for beef on agribusiness firm decision-making.

Consider the following:

From the late 1940's to the late 1960's, leaders of the cattle industry urged producers to be conservative about their cattle herd sizes to improve cattlemans' market positions. At the same time, recommendations from academic livestock and range researchers focused on improving range management practices as a means of increasing range carrying capacity and in turn beef output. The motivation for this research was in part due to the rising demand for beef during the period following World War 2. Cattle producers were being pushed by industry leaders to decrease their output to increase the price received per pound (lb.) of beef, while simultaneously range researchers were looking to increase beef production, provided that beef prices would not decrease significantly as the quantity of beef increased [12]



Cattle Yard Circa 1950s [13]

From a beef producer's standpoint, the own price elasticity of demand is arguably a very important economic measure to estimate and understand. Unfortunately, it can also be one of the hardest measures to accurately determine. Many researchers and

agribusinesses use historical data from the past to figure out or estimate the own price elasticity of demand for beef in the market. A cattle producer will be interested in deciding the best course of action for the future, but this decision can be enhanced by knowing the own price elasticity of demand in the market and past market trends. The table below provides historical data for the beef market, including the beginning period beef price, ending period beef price, the beginning quantity of beef consumed in the market for a period, the ending quantity of beef consumed in the market for a period, the average price over the period, and the average quantity of beef consumed over the period [12].

All the quantities in the table are in lbs per capita.

	Beginning Price	End Price	Beginning Quantity	Ending Quantity	Average Price	Average Quantity
1947-1951	$42.42	$56.30	69.6	56.1	$47.59	63.22
1952-1956	$53.21	$37.89	62.2	85.4	$42.08	77.46

Type caption for table (optional)

We are interested in estimating the own price elasticity of demand for beef and determining how changes in the price of beef will impact the beef market and producers' decisions. The following questions ask you to use the arc elasticity formula given by equation (3) to answer the following questions. For these calculations use the average price and quantity provided in the above table instead of calculating $\overline{P}$ and $\overline{Q^D}$.

The own price elasticity of demand for beef is concerned with how the quantity demanded of beef changes as a percentage, because of a one percent change in price. Producers may likely be interested in the inverse relationship, as well. Given that price and quantity in the market are simultaneously determined, producers may want to know the effect a one percent change in the quantity demanded has on the price of beef.

Inversely related to the own price elasticity of demand, *price flexibility* shows the percentage change in price as a result of a one percent change in quantity demanded (or consumed). Price flexibility has the inverse interpretation of price elasticity. Each can be used separately to derive the percentage change in price or the percentage change in quantity demanded of a good. We introduce price flexibility as an alternative elasticity measure that may also be useful for market analysis. Price flexibility is denoted here by the symbol λ and is mathematically represented as:

$$\lambda = \frac{\% \triangle P}{\% \triangle Q^D} = \frac{1}{\eta} \tag{11}$$

where η is the own price elasticity of demand. Thus, if you know the own price elasticity of demand, you can easily calculate the price flexibility and vice versa.

For example, assume the price elasticity of demand (η) for a good is -0.90. The elasticity can be interpreted as follows: a 1% increase in the price of the good would decrease the quantity demanded by 0.90%. The price flexibility for the good can then be calculated as $(\frac{1}{\eta})$ or $\frac{1}{-0.90} = -1.12$. The price flexibility can be interpreted as a 1% increase in the quantity demanded of the good will decrease the price of the good by 1.12%. Just as the own price elasticity of demand is negative, so will the corresponding price flexibility.

Consider a 5% increase in total beef consumption following 1951. That is consumption is now equal to $1.05\% \times 56.1 = 58.91$ lbs per capita after the increase. The price flexibility can help us determine if we need to increase or decrease herd size by determining the corresponding percent change in price. In our case, the percent change in quantity is +5%.

To determine a % change in price given a percent change in the quantity demanded, it is useful to know the price flexibility (λ). The resulting percentage change in price from a given percentage change in the quantity demanded can be derived from the price flexibility equation. If one knows the price flexibility and the given percent change in Q^D then the percentage change in price can be found using the following formula:

$$\% \triangle P = \lambda \times \% \triangle Q^D \tag{12}$$

As seen in the discussion above, knowing the own price elasticity of demand and price flexibility can have a significant impact on a producer's bottom line, primarily through their total revenue (TR). TR is impacted because it is a function of both the market price and quantity sold. From the above example, if the quantity demanded of beef increases by 5% in the future, then we know the price will decrease due to the Law of Demand. The price flexibility in Question #19 gives us the expected percentage change in price.

Assume that it is the year 1957. We use the historical information from the period 1947 to 1951 to estimate the own price elasticity of demand, assuming the livestock industry improves in the near future similar to the average conditions in that period. The ending beef price in 1956 and the current price for us is $37.89. The current level of consumption (ending quantity demanded in 1956) is 85.4 lbs per capita. A 5% increase in consumption results in an increase in consumption from 85.4 to 85.4 x 1.05 = 89.67 lbs per capita.

Before the change in demand, total revenue for beef producers was TR = $37.89 x 85.4 = $3235.81. After the increase in the quantity demanded and the resulting change in price, TR = $3164.45. Thus, producers would know to expect their TR to fall and to lower their prices and increase their herd size marginally to be able to remain competitive in the market, assuming producers are in a perfectly competitive market. If a producer did not lower their price, they would likely make even less sales and even lower TR, reducing their profitability more than they may have expected. Thus, knowing the market and the associated demand elasticities can help a firm to remain competitive and profitable.

3.2 Parking Demand on University Campuses

Applications of elasticity may impact you even closer to home. Consider the issue of parking on college campuses. The own price elasticity of demand plays a role even here.



University Parking [14]

Consider the following:

Parking availability for dorms at many universities is relatively more substantial than for students who live off campus and pricing for parking permits may be relatively high. A reason for this is that students who live on campus have fewer options for parking their cars than students off campus. Thus, the demand for parking on campus by students living on campus is greater than for those living off campus. University parking services can take advantage of this when determining how much to price parking permits and

how many parking spots to offer. These decisions will be impacted by the own price elasticity of demand for parking spaces by students living on campus.

Parking services at universities are in place to manage parking, but they can also generate revenue for the university. Thus, it may be reasonable to assume that their objective is revenue maximization. From this point of view, parking services would want to charge the highest possible price for a permit that maximizes the number of students parking in their lots. Considering there are limited viable parking substitutes (e.g. parking on side streets around campus) available to students living on campus and the close proximity of parking lots to the dorms (compared to other options); the own price elasticity of demand for on-campus parking can be thought of as "relatively inelastic". Let's assume the own price elasticity of demand is -0.25.

Assume parking services are attempting to maximize potential revenue for the coming school year and assume costs remain unchanged (due to no change in the size of the parking lot). Then the primary factor of importance for maximizing parking revenues is the total revenue to parking services.

Assume that there are 1000 parking spaces available and that parking services can charge whatever they see fit for each parking space. We know that parking services charged $200 per spot last year, and 850 of the spots were used. Use this information to answer the following question.

When considering total revenue (TR), we are interested in how changes to the price of parking permits impact the quantity demanded of the permits (as this will impact how many are sold) and in turn, impacts TR. Remember from the previous case study that $\% \triangle P = \lambda \times \% \triangle Q^D$, where λ is the price flexibility. This equation can be rewritten as a function of $\% \triangle P$ and the own price elasticity of demand, as well (η). That is $\% \triangle Q^D = \eta \times \% \triangle P$.

Considering the information above and that the own price elasticity of demand for parking permits is -0.25, consider a 10% increase in the price of parking permits for the following question.

For the following questions, refer to the original price of $200 and the original quantity demanded of 850 permits. Let's analyze how the 10% change in price would impact revenues earned by the parking services.

This case study shows how the own price elasticity of demand may provide insight into economic thinking and decisions in our everyday lives. University parking services usually deal with a demand for parking that is highly inelastic. In this situation, as the case study illustrates, by increasing the price of parking permits, parking services can substantially increase revenues earned, while still limiting the number of spots left unfilled.

3.3 Price Elasticities and Agricultural Land-Use

While much work is done using own price and cross price elasticities to examine the effects of price changes on the quantity demanded of goods and services, these elasticities play a role in examining the supply side of the market, as well. This case study will examine the use and interpretation of own price elasticities of supply, cross price elasticities of supply, and input price elasticities of supply. To be able to put these into context, we will examine the supply of corn from a land use perspective.



Corn Field [15]

Corn is one of the primary crops grown in Kansas and around the rest of the nation. In 2017, there were 5,200,000 acres of corn harvested in Kansas. This area represents a production of over 680 million bushels of corn [16]. The supply of corn in the Kansas market is a function of the (own) price of corn, the prices of other crops, and the prices of inputs. The Law of Supply indicates that as the (own) price of corn increases, the quantity supplied of corn will increase. This could be interpreted from a land use perspective too: as the price of corn increases, the amount of land devoted to corn production increases. In this respect, we can talk about the supply of corn based on the number of acres planted for corn. We can examine the responsiveness of corn supply in terms of acreage to a change in the price of corn using our **own price elasticity of (acreage) supply**. This elasticity measures the percentage change in the acreage supplied or planted given a 1 percentage change in the own price of corn. For example, if the own price elasticity of acreage supply is 0.8, then a 1% increase in the price of corn will increase the acreage planted to corn by 0.8%.

While a change in the (own) price of corn directly impacts the quantity supplied, changes in prices of related crops and inputs will cause supply to change. That is, the supply curve will shift as changes in these other prices change, as they are determinants of supply. Elasticities can be used here to examine the responsiveness of supply to changes in one of these other prices or determinants. Consider the two following concepts:

(i) **Cross price elasticity of acreage supply**: This elasticity measures the percentage change in acreage devoted to a given crop to a 1% change in the price of another crop. The crops can be complements or substitutes in production. For example, if the cross price elasticity of acreage supply for corn for the price of soybeans is 0.5, then a 1% increase in the price of soybeans will increase the acreage devoted to corn production by 0.5%. When these elasticities are positive, the two crops being considered are complements in production (e.g. they may be grown in rotation). When these elasticities are negative, the two crops being considered are substitutes in production (i.e. they compete for the same area of land).

(ii) **Input price elasticity of supply:** This elasticity measures the percentage change in the acreage devoted to a crop to a 1% change in the price (or cost) of an input to produce that crop. For example, if the input price elasticity of acreage supply for corn for the price of labor is 1.5, then a 1% increase in the wage rate paid for labor on the farm will result in a 1.5% decrease in the amount of land devoted to corn production.

All of these elasticities are calculated in the same manner as presented in section 2.0. The only difference for an acreage supply elasticity is that the change in quantity is the change in the amount of land devoted to the production of the crop.

To be able to illustrate the use of these concepts, let's consider the production of irrigated corn in western Kansas. Al-Sudani [17] did a statistical analysis of the factors influencing the amount of land devoted to irrigated corn production in western Kansas between 2003 and 2015. The focus on irrigated corn production was due to its crop revenue generation and scarcity of water for corn production in this region of the state. We will focus on the estimated acreage supply elasticities for corn for different prices found in the study.

Al-Sudani [17] estimated the following acreage elasticities:

· Own price elasticity of acreage supply for corn = 0.66;

· Cross price elasticity of acreage supply for corn with respect to sorghum = -0.38;

· Cross price elasticity of acreage supply for corn with respect to soybean = -0.03; and

· Input price elasticity of acreage supply for corn with respect to fertilize price = -1.19.

These elasticities can be used to explain how the amount of acreage devoted to corn production changes when different commodity and input prices change in the market. This information would be useful to industry (e.g. cooperatives, elevators, traders) and farmers for marketing and planning their next growing season. Use this information to answer the following questions about the likely impact of different changes in the market.

4.0 Concluding Remarks

Elasticity is an important economic measure and can be a highly influential factor and aid when making economic decisions. Elasticities provide a readily accessible way to conduct marginal analysis for a multitude of problem situations. Elasticity has applications ranging across all reaches of economics as illustrated by the examples and case studies examined in this chapter. We have gone over a few of the essential elasticities, however, there are many more that assist in helping to examine different relationships between economic variables. Elasticity is a useful tool to utilize for producers, consumers, and policy-makers and applies to our everyday lives.

5.0 References

[1] Image courtesy of Luke Erickson through Pixabay, under license CC0 1.0 Universal.

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[7] Image courtesy of Pexels, under their licensing agreement.

[8] Video courtesy of econom through Youtube, under license CC BY Attribution 3.0 Unported.

[9] InvestingAnswers, 2018. "Income Elasticity of Demand." Available at: http://www.investinganswers.com/inco...ty-demand-2906.

[10] Image courtesy of freddthompson through Wikimedia Commons, under license CC BY-SA 2.0.

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Marginal Analysis



Grains [1]

1.0 Introduction

Economics is the study of human decision-making and the allocation of scarce resources among competing ends. The choice to use more scarce resources to undertake an activity is made at the **margin**. For example, when allocating your time to study for an exam, you may decide to allocate an hour, initially. If you feel more time is needed to understand the material after an hour has passed, you may decide to study for an additional hour. These study decisions are made on the margin. On the margin, refers to the additional resources needed to make a choice, complete an activity, or take an action. The designated hour to study and the additional hour for studying are marginal decisions. Thinking on the margin is essential in understanding the impact of each additional resource consumed, sold, or gained. It is key to thinking like an economist! Foundational to a thorough understanding of economics is the idea of **marginal analysis**. This type of analysis is crucial in making informed decisions as a producer or consumer in any market. Marginal analysis is used to compare the additional benefits of an activity to the additional costs incurred by the same activity to meet specified objectives.

Marginal analysis comes into many of the decisions we make. Weighing the additional benefits and costs of making a decision is something that is experienced by everyone. This is the essence of marginal analysis! Whether you realize it or not, marginal analysis is something you do every single day, from deciding to eat that last slice of pizza to pushing yourself through one last rep on the bench with those heavy weights. We undertake marginal analysis in deciding whether or not to go to class each day, by deciding which is more essential at that given moment; another nap, lunch with your friends, a quick run, or learning the class material.

In addition to explicitly considering other alternatives, another benefit of learning marginal analysis more formally is learning you do not need to make decisions by starting from the beginning. Let's go back to the studying example. If you've been studying for an exam for 2 hours for your principles of economics course and you're weighing the decision of whether or not to study for another hour, you are utilizing marginal analysis. We don't decide every single hour whether or not we should study at all! Consider another example involving farmers, who use the same sort of logic. Assume a farmer is contemplating deciding to invest in more land for their farm. The farmer doesn't evaluate whether or not it would be profitable to farm their entire operation with the acquisition of the new land. The costs, revenues, and profit for the land the farmer already owns are known. It is the additional (or marginal) costs and revenues incurred by incorporating the new land into the farming operation that they would be concerned with.

The purpose of this chapter is to introduce you to the concept of **marginal analysis**, present different marginal concepts often used in economics, and begin to present to you how to think "on the margin". We define what "on the margin" means and alternative marginal concepts in the next section. In Section 3, we learn about marginal analysis and different techniques used to conduct marginal analysis. Finally, in Section 4, we present three case studies that apply the concepts and approaches used in the chapter to examine profit maximization for a firm, a problem of pollution abatement in the area of environmental economics, and an application of partial budgeting to the adoption of conservation practices on-farm.

1.1 Learning Objectives

At the end of this chapter you should be able to:

(1) *Define what "**on the margin**" means and identify alternative marginal concepts in economics;*

(2) *Calculate **marginal values** for different economic decision situations (e.g. for consuming and producing goods and services);* and

(3) *Conduct **marginal analysis** using optimization rules and partial budgeting.*

Throughout the chapter, there are many examples to illustrate the concepts we talk about and the case studies will provide in-depth examples that will allow you to walk through situations of calculating marginal values and conducting marginal analysis.

2.0 "On the Margin"



Tractor Production Line [3]

This section of the chapter will introduce the concept of "**on the margin**", its importance in economic analysis, and different marginal concepts often used in economics. The notion of "on the margin" is central to thinking like an economist.

2.1 What do “on the margin” and marginal mean?

The term **marginal** is used by economists to describe the additional benefits and costs incurred when one more unit or level of an activity or choice is made. For example, this could be eating one more piece of pizza, producing one more tractor, or studying for one more hour. Benefits and costs can include how "full" you feel, an increase in production costs, or your performance on an exam. “On the margin” is essentially a description of the change that occurs when the amount or level of a choice or activity is being changed incrementally. The marginal change is measured as the additional benefit or cost from the change in the amount or level of an activity or choice.

Marginal changes in economics are often illustrated as the change in the benefits or costs with a one-unit change in the amount or level of a choice or activity being undertaken. For example, consider a government deciding whether or not to build an additional nuclear power plant in their country. The capital required for this kind of decision usually only allows for a single unit of the good to be considered at a time. Marginal changes do not have to be in one-unit increments though. Consider the production of lollipops, which a candy producer may produce in the hundreds of thousands of units. Asking the question “Should I produce one more lollipop?” may seem ludicrous. However, the company may be interested in the marginal decision to open an additional production line to produce 100,000 lollipops and want to know what the additional or marginal cost would be of that decision. Thus, **"on the margin"** refers to the additional or incremental decrease or increase in benefits or costs from making an incremental change (i.e. one unit change) in a choice or activity. We will explore multiple marginal concepts in this chapter and examine how decisions can be made "on the margin" using *marginal analysis*.

2.1.1 The Difference Approach to Calculating Marginal Values

We can often calculate marginal changes quantitatively. Marginal changes are mathematically calculated by taking the incremental change in the value of the benefit or cost being examined over the incremental change in the value of the amount or level of the activity or choice being considered. (Mathematically, this ratio is the slope of the secant line between two points.) We call this the **difference method** for calculating marginal changes. An alternative and more exact approach would be to use the first derivative of a function measuring the benefit or cost as a function of the amount or level of the choice or activity being undertaken, which is addressed more in the aside below. The most important thing is to understand the distinction between the two. We will not have you calculate marginal values using the first derivative, but it is important to understand the difference. Both methods estimate marginal changes and both represent rates of change (or slopes) of a benefit or cost outcome (function) of interest. If you are curious or have taken calculus in the past, take a look at the aside below for more information on the marginal calculated using the first derivative.

Aside: For those of you who have taken calculus, the term "marginal" corresponds to the slope or the first derivative of a function. These derivatives are referred to as an "instantaneous rate of change", which is where the marginal concept arises from. Derivatives of a function are a fundamental part of understanding any type of function and its unique behavior. These derivatives are used in physics, engineering, economics, finance, mathematics, and many other fields. In economics, for example, functions capturing profit take on certain shapes. The shape of the profit function is determined by the costs and revenues of the operation, or the "costs and benefits". Analyzing the first derivative of the profit function gives us the contribution (whether positive or negative) of another unit of production to profit (i.e. marginal profit), which helps us determine the maximum profit for a firm and at what level of production it is achieved at. Mathematically, the derivative of a function $y = f(x)$ is represented as $\frac{\partial y}{\partial x} = \frac{\partial f(x)}{\partial x}$, where y is the outcome variable (e.g. benefit or cost), x is the independent variable (i.e. amount or level of activity or choice being made), and ∂ can be interpreted as the "the change in". The first derivative is the slope of the function, which can also be written as $f'(x)$, where the $'$ stands for the first derivative.

The **difference approach**, which is what we will predominantly use here, utilizes what's known as the secant line between two points on a function (or curve on a graph) to calculate the marginal change between those two points. The secant line is the line that passes through the two points of interest. The difference method estimates marginal changes by calculating the slope of the secant line, which may be a crude estimate at times. Using the difference approach, marginal changes or values are calculated as the change in the outcome variable (Y) divided by the change in the independent variable (X) (i.e. activity or choice) using the formula:

$$\frac{change\ in\ Y}{change\ in\ X} = \frac{\triangle Y}{\triangle X} = \frac{Y_1 - Y_2}{X_1 - X_2} \tag{1}$$

where $\triangle$ represents the "change in" and (X_1, Y_1) and (X_2, Y_2) are two data points needed to perform the calculation. It is heavily advised that you become as familiar with this equation as you can, as it is commonly used in many economics classes. For those of you who may be curious or have taken calculus in the past, take a look at the following aside for some more information on the difference between the difference approach and the derivative approach.

Aside: Typically, for calculating marginal changes, the difference approach (which uses the slope of the secant line) is less exact than the derivative approach (which uses the slope of the line tangent to the function at the point of interest). However, mathematically, as the two points used to calculate the difference approach become arbitrarily closer together, the estimates between the two methods will become closer in value. You may think of this as the secant line itself becoming closer and closer (as you choose points closer and closer together on the function) to the line of tangency at the point where the derivative method is used to calculate the slope of a function. Another note to consider is the notation contrast between the two. The difference approach utilizes the capital Greek letter delta, $\triangle$, which means "change in", while the derivative approach utilizes a script d (∂) (which can be pronounced several ways, but includes the name "dee" and "dabba") which means an "infinitesimally small change in" [5].

2.2 Aspects of Thinking "On the Margin"

Marginal analysis is a fundamental and important economic concept that is used in explaining how individuals and entities make decisions. There are a few key aspects encompassing marginal analysis that are important to take into consideration. Understanding the difference between average and marginal concepts, as well as understanding the properties of curves used in marginal analysis are important and will come up in this chapter.

2.2.1 Average vs Marginal

One of the single most important distinctions in economics is understanding the difference between the concepts of *average* and *marginal*. While both can be helpful in understanding production, costs, revenues, profits, consumption, and a host of other decision-making contexts, they are quite distinct in their interpretation. Mathematically, an *average* is just a sum of the items under consideration in a set divided by the count (or number of items) in the set. Economists use an average to determine average production, costs, revenues, and profits to examine the efficiency of a process. That is, how efficient is the process under consideration over a set amount of time and/or space. For example, in physical production, the average tells us how much output we are able to obtain from a unit of input considering the entire production process over a set amount of time or space. In contrast, *marginal* refers to an incremental step and does not look at the entire process under consideration. Marginal changes focus on what is needed to obtain the next step or produce the next unit. Continuing the physical production example, in production, marginal changes may focus on how much additional output can be produced from a single unit of input. In production, marginal changes provide a way to assess the productivity of the physical production process under consideration.

2.2.2 Tendencies of Marginal Curves.

Marginal curves are governed by certain tendencies in economics. By knowing the general tendency of a marginal curve, economists can use their judgment to quickly ascertain the nature of whatever they are studying. Oftentimes, marginal changes within a process can be represented as a function or curve on a graph. We call these *marginal curves*, which can be linear or nonlinear. A linear marginal curve (a straight line) will have a constant slope or rate of change. When the marginal curve is nonlinear, then the marginal change will differ from point to point as you move along the curve. For example, a typical production function will change on the margin as you adjust the level of inputs. A typical representation of a production function (top graph in Figure 1) and other related curves are provided in Figure 1 below.

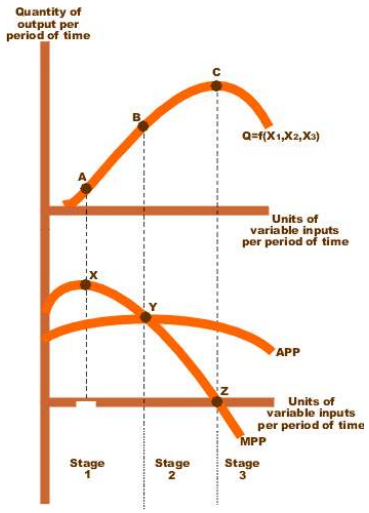


Figure 1: Production Function and Related Curves [5]

As seen in Figure 1, the typical production function is nonlinear. Thus, the marginal change in output as input use is increased will change as you move along the curve from right to left. Also shown in Figure 1, is the marginal curve, denoted here as the MPP curve. The MPP curve here is nonlinear and not constant due to the nonlinear nature of the production function in the top graph. A marginal curve that arises from a nonlinear curve can increase or decrease at certain points. For a production process, note that the MPP curve first increases and then decreases, meaning the productivity of the production process is changing as more input is added to the production process (i.e. as you move from left to right in the graph).

Taking things one step further, we can look at the rate of change (or slope of the) marginal curve. (If you were understanding the marginal before as a slope of a curve, then the tendency would then be the "slope of the slope".) Now, instead of saying a marginal curve is increasing, we can go a step further and say the process being presented is increasing at an increasing or decreasing rate. For example, go back to Figure 1 and the generic physical production process being considered. Notice, that the marginal curve (the MPP curve) first increases, then decreases. Thus, the slope of the marginal curve is first positive (i.e. increasing rate) and then becomes negative (decreasing rate). When the slope of the MPP curve is positive, we say that the production process or production function is increasing at an increasing rate. When the slope of the MPP curve is negative, but above zero, we say that the production process or production function is increasing at a decreasing rate. When the slope of the MPP curve is negative (< 0), we say that the production process or production function is decreasing at an increasing rate. These tendencies allow us to talk about economic processes in more detailed ways, providing useful information about productivity and efficiency.

2.3 Marginal Concepts Used in Economics

Marginal analysis can be applied to nearly every single decision we make, but it is perhaps most useful when we can quantify the marginal benefits and marginal costs under consideration. This subsection examines different marginal concepts used in economics, which include marginal concepts related to production, profit, revenue, utility, amongst others. It is important to emphasize that, marginal benefits and marginal costs will be dependent on the situation or decision under consideration, but the concepts here can be useful for decision-making in a number of different contexts.

2.3.1 Marginal Benefit

In general, a *marginal benefit* is the additional (or incremental) benefit from making a choice or decision. In economics, marginal benefit is often the additional benefit (e.g. revenue or satisfaction) from an additional unit of an input, output, good or service that is used in consumption or production by a person or firm. Marginal benefits are “situationally dependent” and are often based entirely on an individual’s perceived benefits. For example, the marginal benefit or additional satisfaction someone receives from consuming an additional slice of pizza will be dependent on how much they like pizza and their own anatomy. We can quantify marginal benefit at times too. For example, marginal benefits can include the additional revenue or profit a firm receives from producing and selling another unit of a good or service. Other examples of marginal benefits include the marginal benefit derived by a firm from the income they earn over capital within a given quarter or from a rise in the worth of their stock. There are times when it may be difficult to quantify marginal benefits. For individuals, marginal benefits may only be portrayed by emotions and not directly measurable, such as feeling good for doing a good deed or helping a person in need. Thus, the measure for marginal benefits varies widely, depending on the question being asked. In this chapter, we will focus on marginal benefits that are primarily quantifiable.

2.3.2 Marginal Revenue

Marginal revenue (MR) is a type of marginal benefit. Marginal revenue is defined as the additional revenue earned by a firm from selling an additional unit of a good or service. It can be calculated as:

$$MR = \frac{\Delta TR}{\Delta Q}$$, where TR = total revenue, and Q = total quantity.

Consider a firm that operates in a perfectly competitive market (like some farmers and ranchers). These firms are known as *price takers*. That is, they have no control over the market price for the sale of their commodities or output and must accept the market price as given. A perfectly competitive wheat

farmer would not be able to negotiate with their local coop or grain elevator for a higher price for their wheat, but would instead take the given market price when they sell their wheat. Thus, firms in a perfectly competitive market will receive a constant marginal revenue, the market price. For perfectly competitive firms, $MR = P$, where P is the market price for the good being considered. For every unit of good that is produced and sold by a perfectly competitive firm, the firm will receive the market price of that good, which will be its marginal revenue. Although total revenue will increase with each additional unit of output, marginal revenue remains constant.

Let's look at an example to look at the concept of marginal revenue. Consider Farmer Jane, who is looking at selling her corn at market price, which has been quoted at $3.71/bu. Assume Farmer Jane is a perfectly competitive corn producer. The table below provides the output from corn production in bushels, market price in dollars per bushel, total revenue from selling different levels of output, and the marginal revenue from selling each additional bushel of corn. You see that the marginal revenue of selling each additional bushel of corn is equal to the market price for a bushel of corn in this example.

Output (Bu)	Price ($/bu)	Total Revenue	Marginal Revenue
1	$3.71	$3.71	$3.71
2	$3.71	$7.42	$3.71
3	$3.71	$11.13	$3.71

Marginal revenue in a perfectly competitive market is quite literally, the market price for the good. This will not be the case when firms begin to exhibit market power or the ability to influence the market price. Markets with different organizational structures (such as monopolies) will have firms with marginal revenues that will be influenced by their level of market power.

2.3.3 Marginal Product

Firms are interested in the productivity of their production processes for goods and services. This productivity can be measured by the *marginal product* of the production process at a given point in time. Marginal Product (or MP) is defined as the additional output (i.e. good or service) produced from one additional unit of input. It is sometimes also referred to as marginal physical product (or MPP), as well. Mathematically, the marginal product is:

$$MP = \frac{\Delta Y}{\Delta X}, \text{ where } Y \text{ is a given output and } X \text{ is a given input.}$$

Marginal product is typically associated with a given input and we often refer to the marginal product of that input. For example, we could be interested in the marginal product of labor (or MP_L) or the marginal product of capital (or MP_K), which are used to evaluate the productivity of increasing or decreasing labor or machinery (capital) in a production process. The marginal products of labor and capital can be mathematically defined as:

$$MP_L = \frac{\Delta Output}{\Delta Labor}, \text{ and } MP_K = \frac{\Delta Output}{\Delta Captial}$$

To help put this into practice, consider the following example. Assume you are a producer of no-till planters. The primary input into the production of planters is steel. Assume that if you increase the amount of steel used in the production process from 100 to 150 tons, then the number of no-till planters that can be produced will increase by 100 units. What is the marginal product of steel for the additional 100 tons of steel used in the production of no-till planters? Recall, $MP = \frac{\Delta Y}{\Delta X}$. We are told the change in output, $\Delta Y = 100$ no-till planters. The increase in the amount of input used is $\Delta X = 150 - 100 = 50$ tons of steel. Then the marginal product of steel, $MP_{Steel} = \frac{100}{50} = 2$ no-till planters per ton of steel added to the production process. Notice that the units for the marginal product are per unit of input. Put another way, each ton of steel added to the production process between 100 and 150 tons, increases the number of no-till planters produced by 2.

A concept that combines marginal revenue and marginal product is *marginal revenue product* or MRP. The marginal revenue product is the additional revenue generated from the output sold as a result of adding one more unit of input to the production process. That is, if you increase the amount of input used by one unit, then output will increase. If you then sell that additional output, you will gain additional revenue, which is the MRP. The marginal revenue product can be defined as:

$$MRP = \frac{\Delta TR}{\Delta X} (= MR \times MP = \frac{\Delta TR}{\Delta Y} \times \frac{\Delta Y}{\Delta X} = \frac{\Delta TR}{\Delta X}),$$

where TR is total revenue, Y is output and X is input. The relationship in parentheses emphasizes how MRP is connected directly to marginal revenue and marginal product.

A final aspect of marginal product relates to a very important property of production processes in economics. This is the ***Law of Diminishing Marginal Returns***. This law states that holding all other inputs constant, at some point in a production process, the additional output produced from adding additional units of a specific input will decrease. That is, the marginal product of the production process will decline. An example of this economic law in action is a farmer hiring additional workers without buying more equipment for them to use. Each additional laborer added to their operation costs the same amount of money, while the amount of work to be done does not increase, due to the lack of additional equipment. Thus, the productivity of each additional worker is lower, until theoretically, the marginal product of labor of the next worker is zero, and perhaps negative. (A negative marginal product may arise here as employees demotivate each other or argue over use of the equipment to get their jobs done.) This concept has a broader application too. Consider what happens as you increase the consumption of a good. While the marginal benefit received by that good may increase initially, eventually, at some point the marginal returns from consuming that good will decrease with each additional unit consumed. We refer to this in economics as the *Law of Diminishing Marginal Utility*, which is very similar to the Law of Diminishing Marginal returns, but describes an aspect of consumption of a good or service. We can see this in everyday life when we sit down for lunch. Consider purchasing a 12-inch sub at a sandwich store. While the first bite of your sandwich may be

"to die for," and the next bite is still very good, each additional bite isn't as good as the first. By the time you get to the end of your sandwich, you may start to wonder whether or not it was worth the $8.00 you paid.

Watch the following video to help better understand the concepts learned here.



Diminishing Marginal Returns [https://www.youtube.com/watch?v=xLSRMt-wWAM]

Use the video to answer the following question.

2.3.4 Marginal Cost

In general, *marginal cost* is the additional cost that is incurred from making a decision or choice "on the margin". We are often able to calculate a quantitative value for marginal cost in dollars. Marginal costs are just the opposite of marginal benefits, and likewise, are situationally dependent. Marginal costs are often characterized in financial terms, such as the marginal cost of production or consumption of goods and services. However, marginal costs can be based entirely on an individual's perceived costs. Opportunity cost can be realized through marginal terms, as well. Participating in an activity will incur certain costs at the margin, and some of those costs are characterized by the lost opportunity to participate in another activity. Thus, opportunity costs can be viewed as a type of marginal cost.



Marginal Cost of spraying herbicides on an additional crop field [6]

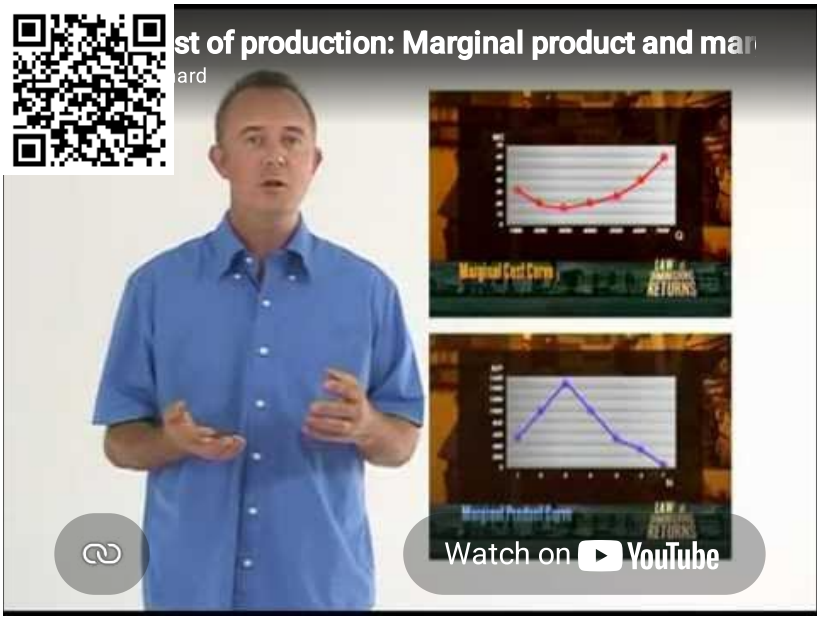
From a production standpoint, marginal cost is the change in total cost from producing an additional unit of output. Marginal cost can be mathematically defined as:

$MC = \frac{\Delta TC}{\Delta Y}$, where TC is total cost and Y is output.

Consider the production of sprayers used on a farm to apply herbicides. Assume a manufacturer of sprayers increases production per day from 100 units to 150 units. The total cost of 100 units is equal to $3 million, while the total cost of producing 150 units is $5 million. What is the marginal cost of each sprayer for producing the next 50 sprayers? Using the formula above, $\Delta TC = \$5,000,000 - \$3,000,000 = \$2,000,000$ and $\Delta Y = 150 - 100 = 50$, so that $MC = \frac{\$2,000,000}{50} = \$40,000$ per sprayer. You should recognize that marginal cost here is reported per unit of output.

Now consider the following question:

From a production standpoint, marginal product and marginal cost are related. Marginal product shows the marginal or additional gain in output as more input is used for production, while marginal cost shows the additional cost of producing an additional unit of output. Note that marginal cost is defined in terms of changes in output. We can look at marginal cost from a change in input use in the production process too. For this, we use the concept of marginal factor cost (MFC). $MFC = \frac{\Delta TC}{\Delta X}$, where X is the input being examined. The relationship between marginal cost and marginal product of a production process is explored more in the following video.



Marginal Product and Marginal Cost [7]

Answer the following question after watching the video.

Let's now consider another example using marginal cost. Consider the firm "AGSPI", which is interested in entering the market for commercial drones that are specifically used in agriculture (e.g. remote sensing and crop mapping). After consulting with another prominent firm in the market, they have been able to determine the expected costs of production for drones. These costs are given in the table below.

Output	Total Cost	Average Total Cost	Marginal Cost
1	580.30	580.30	560.90
5	2537.50	507.50	422.50
10	4300	430.00	290.00
15	5512.50	367.50	202.50
20	6400	320.00	160.00
25	7187.50	287.50	162.50
30	8100	270.00	210.00
35	9362.50	267.50	302.50
40	11200	280.00	440.00
45	13837.50	307.50	622.50
50	17500	350.00	850.00

Notice that the total cost (2nd column) will increase with each set of 5 additional drones produced. Average Total Cost (3rd column) is the total cost divided by the level of output. For example, at a production level of 15 drones, the average cost will be $\frac{\$5512.50}{15} = \$367.50$ per drone. Of interest here is the behavior of Total Cost and Marginal Cost as output increases. Recall, that all production processes will exhibit the Law of Diminishing Marginal Returns, which tells us as production continues to increase, productivity (measured as marginal product) will decrease. In essence, this means that as more output is produced, it takes more and more input to produce each additional unit of output. This implies that the marginal cost of that additional unit of output will increase, as well. Remember, the use of more input means higher costs to produce each unit of output. Notice as total output increases, marginal cost is increasing. This is due to declining productivity (i.e. the Law of Diminishing Marginal Returns). The impact on the total cost of production is that total costs are increasing at an increasing rate. Use all this information to consider the following questions.

Understanding the nature of marginal cost and marginal revenue is tremendously important in the next section, in which we will cover marginal profit. If you have struggled with the previous sections concerning marginal cost and marginal revenue, you may want to review them before moving on to the marginal analysis and case study sections of this chapter.

2.3.5 Marginal Profit

In doing economic analysis we are often interested in the net benefit of making a choice. In general, the net benefit of a decision *on the margin* is the difference between the marginal benefit and the marginal cost of that decision. For a profit-maximizing firm, the net benefit can be characterized by *marginal profit*, which is defined as the following:

$Marginal/profit = \frac{\Delta \pi}{\Delta Y}$, where π denotes firm profit, and Y is output.

Marginal Profit is the profit received from producing an additional unit of output of a good or service. Marginal profit is often strictly interpreted in terms of currency. This contrasts with marginal benefits and costs, which can be measured in a variety of ways. For a firm, marginal profit from producing an additional unit of output is the difference between the marginal revenue and marginal cost of that unit of output. That is:

$$Marginal/profit = MR - MC \tag{2}$$

Similar to the derivation of marginal costs and marginal revenues, marginal profit is the slope or first derivative of the profit function for the firm. Knowledge of the marginal profit of a good or service can be very useful in a firm's decision-making process. It can help to identify when it is no longer profitable to produce or shut-down, which occurs when a firm can no longer cover its fixed costs in the short-run. This is illustrated in the example below.

Let's go back to our example concerning drone production by "AGSPI". We will assume AGSPI operates in a perfectly competitive market, where they have no market power and take the market price for drones as given. That is, AGSPI is a price-taker. The market price for a drone is $350. Using this information, AGSPI asks their finance department to examine the drone production process and they estimate the following cost and revenue information that is provided in the table below.

Output	Total Cost ($)	Total Revenue ($)	Marginal Cost ($)	Marginal Revenue ($)	Marginal Profit ($)
1	580.30	350.00	580.30	350.00	-230.30
5	2537.50	1750.00	489.30	350.00	-139.30
10	4300.00	3500.00	352.50	350.00	-2.50
15	5512.50	5250.00	242.50	350.00	107.50
20	6400.00	7000.00		350.00	172.50
25	7187.50	8750.00	157.50	350.00	192.50
30	8100.00	10500.00	182.50	350.00	167.50
35	9362.50	12250.00	252.50	350.00	97.50
40	11200.00	14000.00	367.50	350.00	-17.50
45	13837.50	15750.00	527.50	350.00	-177.50
50	17500	17500.00	732.50		-382.50

Use the above information to answer the following questions.

When looking at the marginal profits in the table for AGSPI, you will notice at first marginal profit is negative, which may be the case for specific firms due to high fixed costs, resulting in high average fixed costs at the start of production. Thus, at first, AGSPI is earning an economic loss (negative profit). After 10 drones have been built though, the marginal profit becomes positive. Thus, for each drone produced, the total profit is increasing by the amount of marginal profit. Total profit for the firm is maximized up to the point that marginal profit becomes zero (or negative again in the table). Use this information to answer the following question.

2.3.6 Marginal Rate of Substitution

The last marginal concept we will examine in this section is the *marginal rate of substitution* (*MRS*). From a production perspective, the marginal rate of substitution is a measure used by economists to examine the tradeoff between producing two goods (e.g. minivans versus full-size vans) or the substitutability between different inputs (e.g. machinery and labor), among other uses. From a consumption perspective, the marginal rate of substitution examines the tradeoff between the consumption of goods that a consumer can choose between (e.g. breakfast cereal and oatmeal) and maintain the same level of satisfaction from the consumption of those goods. Mathematically, the marginal rate of substitution is given by:

$$MRS = \frac{\Delta X_1}{\Delta X_2} \tag{3}$$

where X_1 is the first good or input being considered and X_2 is the second good or input being considered. From a production perspective, MRS measures the amount of good (or input) X_1 that can be produced (or substituted) by giving up one unit of good (or input) X_2. From a consumption perspective, the

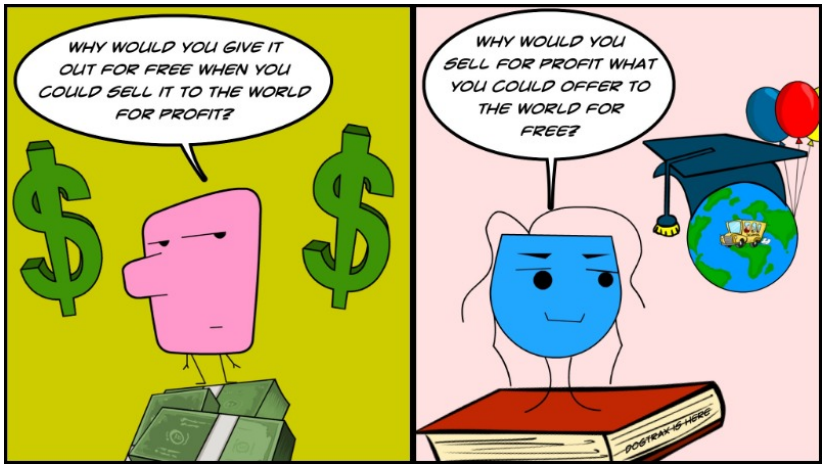
MRS measures the amount of good X_1 that can be substituted by giving up one unit of good X_2. Let's look at an example from a production perspective using inputs.

Consider a livestock producer who is preparing feed rations for his cattle. The farmer has two inputs that he can substitute between for part of the rations, soybean (X_1) and distillers dried grains (DDGs) (X_2) (both measured in lbs), to provide additional protein for the ration. Assume, the marginal rate of substitution between the two is 0.75. The MRS tells us that the livestock producer can substitute 1 lb of DDGs for 0.75 lbs of soybeans and maintain the same level of protein in the ration. Now answer the following question.

3.0 Marginal Analysis

This section of the chapter examines how to use the marginal concepts presented in the previous section to conduct *marginal analysis*. Recall from earlier in the chapter, that marginal analysis is used to compare the additional benefits of an activity to the additional costs incurred by the same activity to meet specified objectives. We will examine two approaches often used in economics to conduct marginal analysis. The first is based on *optimization rules* and the second is *partial budgeting*.

3.1 Marginal Benefit (MB) versus Marginal Cost (MC)



Profit or Not [8]

Economists recommend that individuals, firms, and/or organizations consider both the positive attributes or marginal benefits (MB) and negative attributes or marginal costs (MC) of decisions or choices they are faced with. Such consideration means weighing the marginal benefits against the marginal costs of that choice or decision. Individuals and firms should consider all relevant benefits and costs, whether they directly or indirectly impact the individual or firm. Even when an individual or entity has an opportunity to largely benefit directly without much internal cost, there can be *externalities* involved. Externalities are impacting third parties who do not have direct involvement in the choice, decision, or action being taken. Externalities can be positive and negative, meaning other external benefits and costs may result from a given choice or decision, which should also be considered. In addition, decision-makers want to take account of *opportunity costs or* the next best thing they could do with the resources they are using for the decision or choice being made.

Thus, all relevant additional benefits and costs of a choice or decision should be considered by individuals, firms, and organizations in their decision-making processes. To help guide these decisions, economists will often employ *optimization rules*. Optimization rules can be mathematically derived from optimization-type problems, such as firms trying to maximize profit or minimize cost when producing their goods and services, but these derivations are well beyond the scope of this chapter.

In this subsection, we will focus on a general rule for comparing MB and MC. An individual, firm, or organization should consider enacting a choice or decision as long as the marginal benefits outweigh the marginal costs. Mathematically, this can be represented as:

$$MB >= MC \tag{4}$$

That is, if the marginal benefits are greater than or equal to the marginal costs of the choice or decision then an individual, firm, or organization should, from an economic perspective, make that choice or decision.

To explore this consider the following situation: You have to make an effort each morning to go to class during the week. Pick one weekday this coming week. Now consider the following questions.

The optimization rules considered in the next two subsections will be based on this general optimization rule but will allow for the numerical computation of MB and MC.

3.2 Profit Maximization

In economics, we often assume that firms are profit maximizers. The assumption can be justified by the fact that firms must earn profit to remain in business. However, it is important to recognize that this may not be the firm's only objective. Other motives that drive firms include minimizing risk, cost

minimization, promoting environmental sustainability, and charity.

The assumption of profit maximization provides for a relatively strong optimization rule for production decisions made by firms. That is, can a profit-maximizing rule be determined that helps a firm decide how much to produce in the short-run? First, let's present the rule and then we will discuss it. **A firm will maximize profit in the short-run by producing up to the point where (1) marginal revenue (MR) equals marginal cost (MC), and (2) marginal cost cuts marginal revenue from below**.

The second condition helps to make sure that the firm gets through the initial phase of production where marginal profits may be negative. That is, firms may have high fixed costs, which can result in significantly higher marginal costs at the start of production that only begin to decrease as production increases (i.e. as average fixed costs decline). Thus, marginal profit ($MR - MC$) at the beginning or in the initial stages of production may be negative, but will likely become positive as the level of production increases (as seen in the example with AGSPI in section 2.3.5). So in the initial stages of production, a firm will try to produce until $MarginalProfit > 0$. (If the firm is unable to reach a point in the production process where marginal profit is positive, then it will have to shut down and stop production.)

Now let's turn our attention to the first and most significant part of this optimization rule for profit maximization, that a firm will produce up to the point where $MR = MC$. To begin to explain why the above optimization rule works, first remember that for a firm selling a single unit of output, the marginal benefit (MB) is the marginal revenue (MR) or price they receive for selling that unit of output. The marginal cost (MC) of producing the unit of output will be the actual marginal cost in dollars (which includes variable cost, fixed cost and opportunity cost for that unit of output). Marginal profit for the unit is then $MR - MC$. If a firm is a profit maximizer, then it will produce and sell an additional unit of output if the marginal profit for that unit is greater than or equal to zero, i.e.

$$MarginalProfit \geq 0 \tag{5}$$

Remember, that $MarginalProfit = MR - MC$, so the above rule, implies that the profit-maximizing firm will want to produce and sell an additional unit of output, if:

$$MR - MC \geq 0 \tag{6}$$

This implies a firm should produce as long as $MR \geq MC$ (i.e. they are still earning money on the additional unit of output being produced).

To dive a bit deeper, assume the firm is at a point of production in the short-run, where marginal profit is positive. The firm wants to determine the level of output to produce that will maximize its total profit. As long as marginal profit is positive, total profit will increase. It is only when marginal profit becomes negative that the firm will stop increasing production, as total profit will decrease. Thus, the firm will want to produce as long as the marginal profit is positive, but not when the marginal profit is negative. This condition suggests the firm will want to produce up to the point where $MarginalProfit = 0$. At this point, the firm is making no additional profit from producing more output. That is, the additional profit from the next unit of output is zero. If they go past this point in the production process, marginal profit will become negative, decreasing total profit. Given that $MarginalProfit = MR - MC$, a profit-maximizing firm should produce up to the point where $MR - MC = 0$ or:

$$MR = MC \tag{7}$$

which is our optimization rule given by (1). The profit-maximizing optimization rule can be applied to many types of firms in many types of markets.

Let us return to the AGSPI example previously explored, considering the production of agricultural drones. The table below provides information about Total Cost, Total Revenue, Marginal Cost, Marginal Revenue, and Marginal Profit for different levels of output (or production) for AGSPI. Now let's use this information to apply the profit maximization rule.

Output	Total Cost ($)	Total Revenue ($)	Marginal Cost ($)	Marginal Revenue($)	Marginal Profit ($)
1	580.30	350.00	580.30	350.00	-230.30
5	2537.50	1750.00	489.30	350.00	-139.30
10	4300.00	3500.00	352.50	350.00	-2.50
15	5512.50	5250.00	242.50	350.00	107.50
20	6400.00	7000.00		350.00	172.50
25	7187.50	8750.00	157.50	350.00	192.50
30	8100.00	10500.00	182.50	350.00	167.50
35	9362.50	12250.00	252.50	350.00	97.50
40	11200.00	14000.00	367.50	350.00	-17.50
45	13837.50	15750.00	527.50	350.00	-177.50
50	17500	17500.00	732.50		-382.50

Type caption for table (optional)

We already had you explore in section 2.3.5 how many drones AGSPI should produce. Let's see if you were correct (see Question 13). Using the profit-maximizing optimization rule for a firm, according to condition (2), AGSPI should produce at least 15 drones, as this is the point where they begin to earn a positive marginal level of profit per drone. Now we turn to condition (1), which states we should produce up to the point where $MR = MC$ and not beyond (i.e. as long as $MR \geq MC$). If we look at the table, marginal profit remains positive up to the production of 35 drones. At this point $MR > MC$. If AGSPI produces 40 drones, then marginal profit becomes negative, reducing total profit, because $MR > MC$. While in the table we do not have a level of production given where $MR = MC$, we want to make sure we do not choose a level of production past this point where marginal profits become negative. In many examples using tables with production, cost, and revenue information, this will likely be the case. Thus, we want to find the highest level of production where $MR \geq MC$ (i.e. marginal revenue is still greater than marginal cost) or marginal profit is positive, which occurs for AGSPI at a production level of 35 drones. Thus, AGSPI's profit-maximizing level of production is 35 drones.

To see an additional example, view the following video below.



Apple Orchard Profit Max Example [9]

Use the video to answer the following two questions.



Farmer Decisions [10]

Making decisions as a manager will often have an impact on the bottom line. Thus, managers must consider the impacts of their decisions on marginal benefits or revenue and marginal cost. Thus, we have to consider how each decision will impact the profitability of our firm or operation. A very useful technique known as ***partial budgeting*** exists to aid in the making of these decisions and incorporates many of the marginal concepts we discussed in this chapter**.** Partial budgeting is a technique that provides a formal way to estimate the expected marginal change in profit from a particular decision for a firm or operation [11]. For example, partial budgeting can be used to assess the impacts of proposed changes in crop rotations or livestock enterprises on a farm or ranch. Partial budgeting can be viewed as a formal way to conduct profitability analysis by allowing for the comparison of multiple decisions or changes in a production system, providing the manager guidance on how to best maximize profit or meet their goals. In addition, if you consider the profitability of the next best alternative not made, then partial budgeting can also provide one way to estimate the *opportunity cost* of a given decision.

Partial budgets only consider (i) *marginal revenues* or changes in revenue and (ii) *marginal cost*s or changes in production costs or expenses of a decision, management changes, or technology adoption. Given that we are often in the midst of production or activity when making decisions, aspects of the production situation or activity ***not*** affected by the decision being assessed are excluded from the partial budget. The goal of using partial budgeting is to determine if the proposed decision or change will result in a positive marginal change in profitability. The approach “tallies” the net change based on marginal changes in revenues (benefits) and costs [11-12].

In addition to the financial or monetary estimates that can be derived using partial budgets, personal and social factors can also be incorporated. These factors can include level of risk; desire for personal time for leisure and family; workload on employees; equitability; impacts on the environment; and other factors that are difficult to quantify but are important to the overall firm or operation [11]. Personal and social factors are included in the partial budgets as qualitative components and should also be considered in the marginal decision-making process.

To complete a partial budget, a decision-maker can use the following six steps that are adapted from Kay et al. [11] and Bergtold et al. [12]. The steps are as follows:

Step 1: Identify the proposed change in the production system, activity, or operation. For example, on a farm, the proposed change might be to change crop varieties, adopt no-till, or increase herd size. If you are considering multiple changes, then prepare a separate partial budget for each.

Step 2: Positive Marginal Revenue Changes: Record additional revenues (i.e. changes in marginal revenue). List marginal increases in current revenues and/or new revenue sources generated from the decision being considered.

Step 3: Marginal Cost Reductions: Record marginal decreases or reductions in production or other monetary costs (e.g. cost-savings) from the decision being considered.

Step 4: Marginal Cost Increases: Record marginal increases in or new costs from the decision(s) being considered.

Step 5: Reductions in Marginal Revenue: Record marginal decreases or reductions in revenue, as well as lost revenue sources from the decision being considered.

Step 6: Calculate the marginal change in profit (or net return or other objective measure) by subtracting the negative marginal changes (Step 4 and Step 5) from the positive marginal changes (Step 2 and Step 3). If the difference is positive, there is a net economic benefit or marginal gain from adopting the change or making the decision. If the difference is negative, there is a net economic loss or marginal loss. If the marginal change is zero, the decision to adopt the change may be based on the significance of the personal or social factors being considered.

These changes can be put into a partial budgeting form, which is provided below. A case study example illustrating the use of partial budgets will be provided in the case study section of the chapter.

PARTIAL BUDGET	
Decision being considered: (*Step 1*)	
Additional (Marginal) Costs: (*Step 4*)	Additional (Marginal) Revenue: (*Step 2*)
Lost (Marginal) Revenue: (*Step 5*)	Lower (Marginal) Costs/Cost-Savings: (*Step 3*)
(A) Total additional costs and lost revenue: $_____	**(B) Total additional revenue and lower cost/cost-savings:** $_____
Net Marginal Change in Profit (B minus A): (*Step 6*) $_____	

4.0 Case Studies

Marginal analysis can aid in making decisions at both the individual and firm level. This section will provide you with a set of case studies using marginal analysis in a variety of topics and will apply what you have learned in this chapter. An emphasis on understanding the material will be important for these applied problems.

4.1 Profit Maximization in Production from an Input Perspective

The purpose of this case study is to examine profit maximization for a firm but from an input perspective. That is, how much input should the firm apply to maximize output. The optimization rule here is based on the general profit maximization rule for determining the optimal level of output for a firm, producing up to the level of production where $MR = MC$. For our purposes, in this case study, we will modify this optimization rule for the input perspective. As examined in section 2.3.3, the marginal revenue from the additional use of one unit of input is referred to as the marginal revenue product (MRP). MRP will replace MR in the optimization rule. The additional cost of one unit of input is called the marginal factor cost (MFC) and this will replace MC in the optimization rule. Thus, for a firm that wants to maximize profit from production from an *input perspective*, the firm will produce as long as $MRP \geq MFC$ or up to the point or level of production where:

$$MRP = MFC \tag{8}$$

The logic behind this optimization rule is very similar to that for the output perspective as presented in section 3.2.



Fertilizer Application [13]

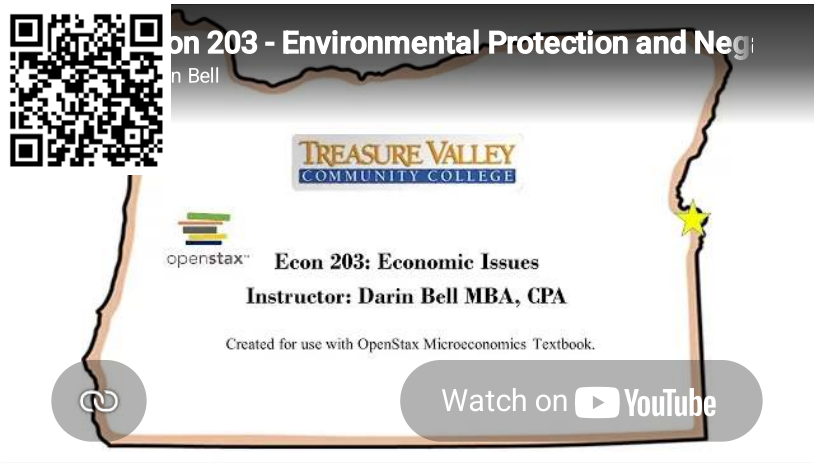
The applied example here will examine the economic optimal level of nitrogen fertilizer to apply to maximize return (or profit) for a corn crop being produced by a farmer. The example will utilize corn production data from Debertin [14] with some modifications.

Consider a farmer who is planting corn on a field in the Corn Belt. The farmer is trying to determine how much fertilizer to apply to maximize her profit on that field from corn production. The farmer has worked with her local extension agents at the nearby land grant university to assemble the information in the table below. The first column indicates the potential amount of nitrogen in lbs that can be applied to the corn crop. The second column provides the expected corn yield at the given level of nitrogen. The first two columns represent the expected corn production schedule for the farmer. Each row represents the agronomic and economic effect of applying an additional 20 lbs of nitrogen to the corn crop. The third column provides the marginal product of fertilizer ($MP_{fertilizer}$) for each additional pound of fertilizer applied to the corn crop at that level of production. The fourth column is the expected price of corn at harvest. The fifth column is the marginal revenue product from fertilizer application ($MP_{fertilizer}$). The fifth column is the marginal factor cost of nitrogen MFC or the cost of nitrogen per pound, which is assumed to be $0.55 per pound. The last column is the marginal profit from applying an additional pound of nitrogen and is calculated as the $MRP_{fertilizer} - MFC$. Use this information to answer the following questions. The blanks in the table are left for you to fill in (i.e. on a separate piece of paper).

Nitrogen (lbs)	Corn Yield (bu/ac)	Marginal Product of Fertilizer (bu/lb)	Corn Price ($/bu)	Marginal Revenue Product of Fertilizer ($/lb)	Marginal Factor Cost of Nitrogen ($/lb)	Marginal Profit ($/lb)
0	0	---	$4.50	---	---	---
20	16	0.80	$4.50	$3.60	$0.55	$3.05
40	35	0.95	$4.50	$4.28	$0.55	$3.73
60	55	1.00	$4.50	$4.50	$0.55	$3.95
80	76	1.05	$4.50		$0.55	
100	94	0.90	$4.50		$0.55	
120	111	0.85	$4.50		$0.55	
140	124	0.65	$4.50		$0.55	
160	133	0.45	$4.50		$0.55	
180	137	0.20	$4.50		$0.55	
200	138	0.05	$4.50		$0.55	
220	135	-0.15	$4.50		$0.55	
240	104	-1.55	$4.50	-$6.98	$0.55	-$7.53

4.2 Environmental Economics and Pollution Abatement

In economics, market transactions or decisions (e.g. driving to work or planting a crop) may not take account of the full impact of the transaction or decision on society or the environment. That is, individuals and businesses may engage in economic activity (consuming and producing goods and services) without considering the impact this has on the rest of society. If this activity has a negative impact on society or the environment, then we say that this economic activity may result in a *negative externality*. We define a *negative externality* as a situation where the parties in the market transaction or decision being considered (through the market price) do not fully account for all the costs of the market activity on society (or third parties), such as health impacts, pollution, etc. [15]. The impact on society or a third party includes potential harm or loss of welfare, which is uncompensated. Of particular interest in this case study is the ability to use *marginal analysis* in examining the economics of negative externalities. That is, we can use the notions of marginal benefit and marginal cost to examine when it is economically optimal to take account of negative externalities in society. The following video provides additional information on externalities.



Externalities Video [16]

We will use the case of water pollution as our example. Consider a farmer who plants a majority of their peanut crop next to a river. The farmer has not yet adopted conservation practices, such as vegetative or field buffers, that would prevent run-off from their crop field from flowing into the river. The farmer bases their peanut production system on what his parents did in the 1990s, given that his parents earned a good income producing peanuts. The production of peanuts requires a significant application of pesticides that may potentially leach or run-off the field after application into the river and other streams or lakes [17,18]. Downstream is a small town that uses the river for drinking water and recreation (swimming and fishing). Local environmental safety officials have tested the water and found that current water levels contain an unsafe level of pesticides that make it hazardous for residents to use. The local officials have determined that the primary source of the pollution originates from the farmer's peanut field upstream. After consulting with the local town council, they want to try to find a way to encourage the farmer to reduce their use of pesticides or put in conservation measures, such as conservation buffers, to make the water safe again. The conservation buffer, also known as a field buffer or vegetative strip helps to absorb some of the excess pesticides that may run off the field. They decide to look for and consult an environmental economics professor at the local university for an answer.

The environmental economics professor tries to explain the problem from an economic point of view to the local environmental safety officials. She indicates that the decision to reduce pollution to an "economically optimal level" is determined using marginal analysis. She indicates that it is unlikely an optimal solution from a market perspective will eliminate all of the pollution too. She explains that, first, one must consider the marginal benefit of the economic activity undertaken by the farmer. That is, for each unit of pesticide applied to the peanut crop by the farmer, the farmer will earn additional benefit (e.g. from higher crop yields), but it is likely the case that this marginal benefit will decrease as more pesticide is applied due to the *Law of Diminishing Marginal Return*, (see section 2.3.3 for more information on this concept). Decreasing marginal yields from additional pesticide applications or higher rates means that a farmer is marginally earning less revenue with each additional unit of pesticide applied, assuming crop prices are constant. This change is similar to marginal revenue but is referred to as *marginal revenue product* $\boldsymbol{MRP}$ or the marginal change in total revenue from a one-unit change in pesticide use (i.e. $\boldsymbol{MRP} = \frac{\Delta TR}{\Delta X}$). Assume the cost of a unit of pesticide is $\$\boldsymbol{W}$. Then the marginal cost of a unit of pesticide, known as the *marginal factor cost* $\boldsymbol{MFC}$ is $\$\boldsymbol{W}$ (*i*.e. $\boldsymbol{MFC} = \frac{\Delta TC}{\Delta X} = \$\boldsymbol{W}$).

She goes on to discuss that the concepts in the prior paragraph can now be used to help determine the marginal benefit, or what we will call the *marginal net private benefit (*$\boldsymbol{MNPB}$) to the farmer growing the peanut crop. The marginal net private benefit or $\boldsymbol{MNPB}$ is in essence the marginal profit from using an additional unit of pesticides or $\boldsymbol{MNPB} = \boldsymbol{MRP} - \boldsymbol{MFC}$ [19]. Given that $\boldsymbol{MRP}$ is likely decreasing as more pesticide is applied and $\boldsymbol{MFC}$ is constant (e.g. $\$\boldsymbol{W}$), then $\boldsymbol{MNPB}$ will be decreasing, as well. The $\boldsymbol{MNPB}$ Curve is illustrated in Figure 1. As crop output increases with additional pesticide use, $\boldsymbol{MNPB}$ decreases. So due to the Law of Diminishing Marginal Returns, $\boldsymbol{MNPB}$ will be decreasing for the farmer with additional application of pesticides due to less yield from each additional unit of pesticide being applied.

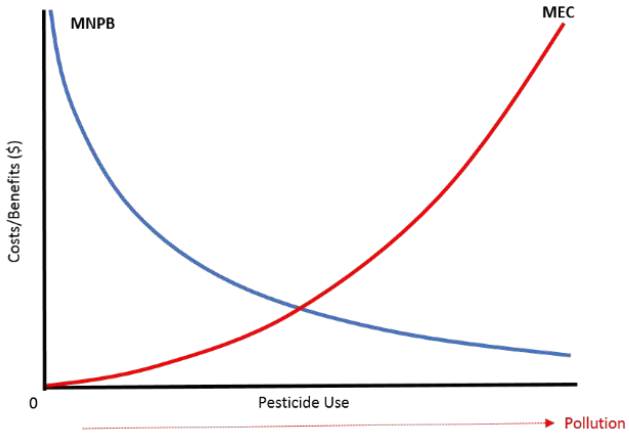


Figure 1: Marginal Net Private Benefit (MNPB) and Marginal External Cost (MEC) Curves for the Farmer Pesticide Problem.

It is important to note that $MNPB$ does not take into account any costs to society or third parties. These costs, known as negative externalities, are characterized in this example by health impacts and loss of recreation felt along the river downstream. In addition, it is emphasized that there is no direct economic incentive in the market for the farmer to adjust their behavior.

The other curve in Figure 1 is the Marginal External Cost (MEC) curve [19]. As crop output increases, driven by the increasing use of pesticides by the farmer (holding all else constant), the amount of pesticide leaching or running off the field increases. This type of leaching or run-off that impacts the river and the small town downstream is known as *non-point source pollution*, as it is usually difficult for environmental safety officials to pinpoint the exact source of the pollution (e.g. the starting point). Thus, as shown in Figure 1, as pesticide use increases, so does the nonpoint source pollution (designated by the red arrow below the X-axis). The increased pollution in the water leads to water quality problems for residents using the water for drinking water and watering livestock, as well as the lost recreational use of the small river due to potential health hazards. These problems can be assigned a monetary cost, which could be equal to actual health costs; the cost of buying bottled water or filters; the cost of lost recreational income from use of the river; etc. We refer to the costs as *external costs*. These external costs increase with the level of pollution. Each additional unit of pesticide use increases the external cost to society, which we refer to as the *marginal external cost*, represented by the MEC curve in Figure 1 [19].

The economist points out that the environment can deal with some level of pollution or waste through natural processes. Thus, it may not be economically optimal to prevent all pollution or eliminate all waste from production processes. So at what point, from an economic point of view, is the *optimal level of pollution*? This point occurs where $MNPB = MEC$, that is where the marginal net private benefit is equal to the marginal external cost. This occurs where an additional unit of pesticide results in an increase in marginal net private benefit to the farmer equal to the marginal external cost to society (or the citizens of the small town). In this sense, it may be *socially optimal* to make sure that the gains from private production are not at the expense or greater than the costs to society. This occurs where $MNPB = MEC$. Thus, the optimal level of pollution here may be economically and socially optimal, maximizing the net welfare of society (or all residents of the local community). It should be noted, that there are other ways and criteria used to assess the impacts on society and its welfare, as well.

The condition that $MNPB = MEC$ is an equilibrium condition. That is, from an economic point of view there is not an incentive for society to move away from this point. To see this, consider the following questions that explore what would likely happen if $MNPB$ was not equal to MEC.

Many conservation programs exist at the local, state, and federal governmental level. For example, the USDA Natural Resource Conservation Service (USDA- NRCS) administers the Environmental Quality Incentives Program (EQIP) to incentivize farmers to adopt and add conservation practices on their farms to improve soil health, reduce soil erosion, improve water quality, sequester carbon, etc. USDA-NRCS incentivizes farmers by offering monetary incentives to adopt conservation practices in their farming operations. (For more information on this program see: https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/.) One practice that can help to reduce run-off from fields that may result in pesticides getting into water bodies, such as a river, is vegetative or field buffers. USDA-NRCS refers to these as conservation buffers, which they define as: “small areas or strips of land in permanent vegetation, designed to intercept pollutants and manage other environmental concerns” [20].

Consider the situation where the small town decides to incentivize the peanut farmer to install conservation buffers along their fields adjacent to the river and the farmer agrees to do this. Assume there is no net change to $MNPB$ for the farmer (assuming the cost-share covers the cost of installation). For the small town, for each unit of pesticide applied to the fields adjacent to the river, less pollution now runs-off into the river. This results in lower marginal external costs. Thus, the adoption of conservation practices can help to potentially increase the net benefit of private production to society by potentially reducing external costs to society overall.

4.3 Partial Budgeting and Conservation Adoption

Partial budgeting provides a very organized and formal way of conducting marginal analysis of decisions using monetary values. To illustrate the use of this technique, let’s consider a farming example that is adapted from Bergtold et al. [12]. Farmer Jane farms 600 acres of cotton conventionally in

Southeast Kansas. A long-term goal is to move to a conservation tillage system (utilizing no-tillage equipment and management). No-tillage is defined as a crop production system in which seeds are planted into soil that has not been tilled. No-tillage practices are also known as no-till, zero tillage, and direct seeding. No-tillage systems may require equipment modifications and weeds are controlled using herbicides rather than cultivation [21].



No-Till [2]

To assess the transition from a conventional to a no-tillage system, Jane looks for data online and finds studies providing cotton yield differences between conventional and no-tillage production. Jane determines that transitioning to no-tillage from conventional tillage will result in a 60-pound-per-acre increase in cotton yield. After talking with her local farm dealer, she is also able to purchase a slightly used no-till planter costing $15,000. The useful life of the planter is expected to be seven years with a $1,000 salvage value. Jane can take out a loan to purchase the planter with an annual interest rate of 5 percent. Additionally, Jane can determine that repair and insurance rates should be 2 and 2.5 percent, respectively, of the net value of the used planter, $14,000; (the net value is the actual cost minus salvage value). Below is a partial budget chart outlining the partial budgeting analysis for this case study. The cost of the new planter is expected to be $5.63 per acre, which is equal to the interest cost of $1.25 per acre ($\frac{\$15,000 \times 0.05}{600}$), plus repair costs of $0.47 per acre ($\frac{\$14,000 \times .02}{600}$), plus insurance costs of $0.58 per acre ($\frac{\$14,000 \times 0.025}{600}$), as well as depreciation costs of $3.33 per acre ($\frac{\$15,000 - \$1000}{7 \times 600}$).

Assume that the price of cotton lint (which is the yield from cotton that is sold) is $0.85 per pound.

Converting to no-tillage can help farmers reduce costs by reducing the number of passes made across the field for tillage operations no longer performed (like disking, harrowing, cultivation, plowing, etc.). Let's assume, that Jane can eliminate two tillage passes (a disking and deep tillage operation) each year on her 600 acres of cotton. The production cost savings is estimated to be $20 per acre. Given that Jane is in southeast Kansas, she wants to further protect and enhance the productivity of the soil in her new no-tillage crop production system, so Jane decides to plant a cover crop at a cost of $25 per acre. Cover crops are crops planted between regular cash crops in rotation to provide mulch to cover the soil, enhance soil fertility, and help suppress weeds. The cover crop is not expected to change cotton yield but will help maintain soil fertility and reduce soil erosion.

Given that cultivation will no longer be used to control weeds in the field, the no-tillage system will require the use of herbicides with additional passes for herbicide applications during the growing season. The expected cost of the additional herbicide applications is $18 per acre, which includes cover crop termination in the spring and weed control during the summer months.

The partial budgeting table below is partially filled out. The questions will guide you through the analysis and filling out of this Table. It could be useful to print out the Table (copy and paste to a word processor) and use it to guide you through the questions.

PARTIAL BUDGET	
Decision being considered: Transitions from a conservation tillage cotton production system to no-tillage cotton production system with a cover crop.	
Additional (Marginal) Costs: (*Step 4*) **$/acre** No-Till Planter Cost (per year per acre) Cover Crop Cost per acre. Herbicide Application Cost per acre. Lost (Marginal) Revenue: (*Step 5*) **$/acre**	Additional (Marginal) Revenue: (*Step 2*) **$/acre** Increase in cotton yield per acre. Lower (Marginal) Costs/Cost-Savings: (*Step 3*) **$/acre** Reductions in tillage passes.
(A) Total additional costs and lost revenue: $_____	**(B) Total additional revenue and lower cost/cost-savings: $_____**
Net Marginal Change in Profit (B minus A) $_____	

5.0 Concluding Remarks

In this chapter, we introduced you to the marginal concepts that are central to an economic way of thinking, including marginal benefit, marginal revenue, marginal cost, and marginal profit, among others. These concepts are used in conducting marginal analysis, which can be done using different methods. Two presented here are the use of optimization rules, such as a firm maximizing profit for the production of a single good up to the point where $MR = MC$ and MC cuts MR from below. Another important and useful tool presented was partial budgeting, which is a tool used by many firms and producers today. Finally, you were presented with some case studies to expand on these topics and present how they can be used in analyzing decisions.

6.0 References

[1] Image courtesy through Pixabay, within the public domain. (Grain)

[2] Image courtesy of Wikimedia Commons, under the Creative Commons Attribution-Share Alike 2.0 Generic License (No-till)

[3] Image courtesy of Homoatrox through Wikimedia Commons, under license CC BY-SA 4.

[4] Wikipedia. "∂∂". Available online at: https://en.Wikipedia.org/wiki/%E2%88%82.

[5] Image courtesy of Mydogategodshat through Wikimedia Commons, under license CC BY-SA 3.0.

[6] Image courtesy of barskefrank through Pixabay, under license by Pixabay.

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Agricultural Economics: Prohibition



Prohibition Agents Destroying Barrels of Liquor in 1921 [1]

1.0 Introduction

In certain situations, to protect citizens and the social welfare of its people, governments may decide to *prohibit* the consumption or production of a good. *Prohibition* is a type of *command-and-control policy* that is used by governments to limit the consumption and/or production of a good or service for different reasons. The prohibition of goods and services has occurred throughout history for different reasons. The most notable example in U.S. history was the prohibition of alcohol in the 1920's. Other examples include the prohibition of drugs; legal ages for drinking and smoking; banning of plastic bags and straws; limiting or eliminating the presence of trans fats in foods; and the protection of endangered species... This chapter will explore what prohibition is, different examples of prohibition, and an in-depth agricultural example involving the prohibition of margarine in the U.S. In this exploration of prohibition, we will examine the economics of prohibition, the formation of black markets, and the unintended consequences of prohibition policies.

1.1 Learning Objectives

By the end of the chapter, you should be able to:

(i) Define and understand what prohibition is;

(ii) Recognize the use of prohibition policies by government in different circumstances; and

(iii) Understand and assess the economic implications of prohibiting the production or consumption of a good or service in the market.

This chapter will provide a rich set of historical and present examples about prohibition to help you understand the breadth of prohibition policies, how they are used, and the potential economic impacts of these policies. A detailed case study involving the prohibition of margarine is used to illustrate the economics of prohibition and provide a contextual situation for you to examine the effects of prohibition in an agricultural commodity market.

2.0 What is Prohibition?



Smoking Prohibition [3]

While the word "prohibition" may bring to mind images like the picture on the right, prohibition has been a subject of much economic debate in topics spanning from alcohol and smoking to environmental protection. By legal definition, ***prohibition*** is the ceasing or restraining of action by a stated party by the authority of a legitimate legal authority [2]. That is, prohibition is a law or legal requirement that requires individuals or groups to cease a particular activity or stop the production or consumption of a good or service. These laws are usually governmental policies enacted at the local, state, or federal level. There exists a wide range of prohibition laws and policies that have been put into place in history in many countries. Below we provide some examples and assessments of the prohibition of goods in the U.S. from the past to the present day.

2.1 Accounts of Prohibition

Prohibition policies have been used for many reasons, including making harmful products, such as alcohol and cigarettes, illegal; protecting the environment and endangered species; reducing the effects of pollution; protecting consumers (e.g. ban on trans fats); to promoting consumer safety; among other reasons. This section of the chapter will examine four different historical and current cases of prohibition of goods in different contexts and will highlight some of the different aspects of prohibition in each.

2.1.1. Alcohol Prohibition and the Volstead Act

The first account of prohibition we will examine is the most recognized prohibition policy in the U.S., alcohol prohibition. When we even think of the word "prohibition" in the U.S. or search for it online, we are most likely to think of this event in history. Thus, we examine the economic and policy impacts of U.S. alcohol prohibition.

Fueled by temperance groups like the Anti-Saloon League of America and the Woman’s Christian Temperance Union (WCTU), the "war on liquor" began in the late 1800s in the United States. Beliefs about alcohol and the “evil” that it wrought on society were accepted by a large percentage of the public, as well as by women’s groups, church groups, and politicians by the early 1900s. Alcohol had become increasingly popular since the 1850s, and by the early 1900s, more than 50 million barrels of beer were being produced in the U.S. [4] Views about the havoc that saloons in particular had upon society were becoming well-established lines of thought across the nation. The picture below provides one-way alcohol consumption was viewed during this time period. Alcohol prohibition may have made its way to the center stage sooner but was slow to come to fruition due to constraints on temperance groups, which were made up of a large population of women. During this time, women were not allowed to vote and thus had to act through other means to influence public opinion. In many cases, women were the ones witnessing what alcohol was doing to their families [4].



The Drunkards' Progress [5]

It wasn't until January of 1919 when the 18th Amendment to the Constitution was passed that alcohol prohibition became a reality. The 18th Amendment prohibited the "production, sale, and transport" of "intoxicating liquors", but did not define "intoxicating liquors" nor provide penalties. By October of the same year, the Volstead Act was passed, enforcing the 18th Amendment. The Volstead Act defined "intoxicating liquors" as any beverage containing more than 0.5% alcohol by volume and provided further that "no person shall manufacture, sell, barter, transport, import, export, deliver, or furnish any intoxicating liquor" [6]. Neither the 18th Amendment nor the Volstead Act included prohibiting the *consumption* of alcohol.

While many would argue that the 18th Amendment to the Constitution was highly debated and opposed, it was adopted much more quickly than other constitutional amendments. The Volstead Act was passed rather quickly itself (even after a presidential veto) and took effect in October 1919. Those who supported alcohol prohibition expected crime levels to drop in the years following the passing of the law. However, the prohibition of alcohol was especially difficult to enforce and failed to eliminate crime as expected. In fact, the 18th amendment may have led to a rise in organized crime across the country, as bootlegging of alcohol became even more profitable under a black market [7]. The consumption of alcohol dropped dramatically, and so in that way, prohibition was effective. Unfortunately, crime levels increased dramatically due to the large demand for alcohol and organized crime centered around the production and provision of illegal alcohol.



Raid at Elk Lake [8]

Proponents of prohibition continued to fully support the amendment during the time of alcohol prohibition. In the following quote by The Federal Council of Churches, church officials speak on the evils of alcohol.

> *"If serious evils have sprung up since prohibition, they are far less than the evils which arose from the liquor traffic prior to the amendment. The liquor traffic with the accompanying saloon was allied with political corruption, crime, gambling, and prostitution. It meant the wreckage of men and the degradation of families, which social workers and ministers saw constantly in their daily work." [9]*

While these impacts did occur, many would argue that the rise and impacts of organized crime, like Al Capone and his gang, were far worse than what prohibition set out to mend.

While prohibition was effective in reducing the consumption of alcohol, the continued demand for alcohol provided a strong incentive to produce alcohol on the black market. Due to the high transaction costs (e.g. fines, imprisonment, risk, etc.) of producing alcohol illegally, producers (also known as bootleggers) could charge significantly higher prices than before. The dissipation of the legal market via the 18th Amendment and the Volstead Act meant a surge of consumers willing to purchase alcohol illegally. The Volstead Act, created to enforce the 18th Amendment, was much more difficult to enforce than expected; as such, law-abiding citizens would break the law to obtain alcohol [7].

Under prohibition, many proponents of prohibition expected demand for clothing and household goods (such as soft drinks and candy) to increase, and developers expected rents and land values to increase as bars and saloons closed, improving living conditions in neighborhood communities. Theaters and other entertainment industries expected increases in ticket sales, as well. Throughout the prohibition period though, none of this occurred. In fact, revenues in the amusement and entertainment industries fell across the United States. Furthermore, restaurants failed as they could no longer provide alcohol. Overall, the economic impact of alcohol prohibition was negative, eliminating thousands of jobs in the alcohol and related industries, as well as a decrease in revenues and profits for the food, entertainment, and amusement industries [10]. A significant impact of prohibition on local, state, and federal governments was the significant loss in government revenues from taxation of alcohol, which many states relied upon to fund their budgets, by as much as 75%. The prohibition cost the federal government $11 billion in lost tax revenue. The impact of this lost revenue was a shift from using alcohol tax revenue to fund budgets to relying upon higher income taxes to fund government activities, which continues to this day [10].



Al Capone Mugshot [11]

Due to the inability of the Volstead Act to effectively enforce alcohol prohibition, organized crime increased. Where saloons once operated, now there existed speakeasies, as well as increases in political corruption [12]. In 1932, a wealthy industrialist by the name of John D. Rockefeller, Jr. stated in a letter:

> *"When Prohibition was introduced, I hoped that it would be widely supported by public opinion and the day would soon come when the evil effects of alcohol would be recognized. I have slowly and reluctantly come to believe that this has not been the result. Instead, drinking has generally increased; the speakeasy has replaced the saloon; a vast army of lawbreakers has appeared; many of our best citizens have openly ignored Prohibition; respect for the law has been greatly lessened; and crime has increased to a level never seen before." [12]*

The American people as a majority had begun to oppose the 18th Amendment by the end of the 1920s, and by the early 1930s a large political movement formed in opposition to prohibition.

By December of 1933, the 21st Amendment to the constitution was adopted, with a single purpose, to repeal the 18th Amendment. The 21st Amendment is considered unique. It is the only amendment to the Constitution with the sole purpose of repealing a prior amendment. While prohibition at the federal level ended in 1933, state prohibition of alcohol continued across the country. Mississippi was the last to repeal prohibition in 1966, while Kansas continued to prohibit public bars until 1987 [12].

While the alcohol prohibition ended in 1933, policies still exist that are influenced by alcohol prohibition. These policies include bans on sales of alcohol at supermarkets in certain states; state-controlled alcohol monopolies; regulations on shipping alcohol across state borders; alcohol franchise laws; and restricted sales of alcohol on Sundays [13].

2.1.2 Endangered Species Act

The Endangered Species Act (ESA) was a piece of legislation passed by Congress and signed into law in 1973. The purpose of the act was to conserve and protect plants and animals (and their habitats) that are determined to be endangered or threatened by extinction. [14-15]. A plant or animal is considered to be endangered if: (i) there is threat to their habitat that would cause the plant or animal to not be able to survive; (ii) the plant or animal species has been over-utilized for commercial, research or other purposes; (iii) the species is heading toward extinction due to diseases or threats by other predators; (iv) the animal or plant species is not adequately protected by existing policies or laws; or (v) natural or man-made factors are threatening the continued survival of the plant or animal species [15]. Habitat loss is considered the greatest threat to endangered species, so the ESA protects critical habitats of endangered animals and plants, which includes the land, water, and air necessary for the plant and animal's survival and recovery [15-16]. The following video provides some history and more information about the ESA.



Endangered Species Act [17]

The ESA is a type of *prohibition* in that it prevents individuals, firms and groups from trading, hunting, disturbing, or harming endangered and threatened plants and animals, as well as protecting all lands, water, and air designated as their critical habitat. One of the most referenced cases for the ESA is the Northern Spotted Owl. This owl species was listed as threatened under the ESA in 1990 [18]. The Northern Spotted Owl is primarily located in the old-growth forests of the Pacific Northwest from Northern California to British Columbia. Each owl pair requires up to 4200 acres of old-growth forest in Washington and 2300 acres of old-growth forest in Oregon and California to survive [19-20]. Logging was and has been a significant economic enterprise in regions of old-growth forest, where the Northern Spotted Owl resides. The presence of the logging industry and the listing of the Northern Spotted Owl as threatened has created significant controversy. This is evidenced by the fact that 60% of the habitat for the Northern Spotted Owl is available for logging or timber production [20]. There were suggestions of setting aside 8 million acres of land as critical habitat for the owl, which some projected could put 12,000 to 50,000 individuals out of work, which would amount to a loss of $470 million to $2 billion in income for these individuals [20-22] Thus, a significant economic conflict exists regarding the protection of this species and economic welfare of firms and individuals working in the logging and timber industry. While this example illustrates the economic issues that can arise from prohibition, it provides an example of the potential unintended consequences of prohibition.



Northern Spotted Owl [23]

One of the other potential unintended consequences of protecting the critical habitats of the Northern Spotted Owl is that it prevents timber harvest and clearing of the old-growth forests, increasing wildfire risk and damage. The Stewards of the Sierra National Forest indicate that protection of the Northern Spotted Owl under the ESA in California has reduced timber harvesting by as much as 90% in some areas. It was the timber harvesting, which is usually done by thinning the forest, that provided a significant mechanism in removing tinder that helped to reduce the impact of wildfires in these forests. The organization now argues that tree density in the Sierra National Forest in California is now 10 times what it should be due to the lack of thinning and harvesting of timber. When coupled with the extreme droughts California has faced in the recent past, this leads to increased risks of highly explosive and destructive wildfires that are harder to control. Furthermore, with the significant decrease in timber harvesting, the number of lumber mills has drastically decreased, meaning current resources or logistics to provide the needed thinning of the forests are not available [24].

2.1.3 Banning Plastic Straws



Plastic Straw [28]

A more recent example of prohibition is the movement by cities (e.g. Seattle and San Francisco) and some countries (e.g. England) to ban or prohibit the use of plastic straws. The movement to ban plastic straws started as a grassroots movement. As it grew, businesses, such as Starbucks, got involved and decided to stop using or supplying plastic straws. Eventually, governments started considering instituting policies to prohibit their use, as well [25].

Why plastic straws? Plastic consumption around the globe was over 300 million metric tons in 2015. Put another way, that amounts to about 25 metric tons of plastic used per person for the world's 7.6 billion people [25]. The campaign to ban plastic straws is born out of a larger goal to reduce our dependence on the use of plastic, which has had a significant impact on our environment. Plastic straws were targeted because they are an item that many individuals are exposed to and use every day that connects them to plastic [26]. Many people are advocating for going back to paper straws or abandoning the use of straws altogether. One potential side effect of the ban is that persons with disabilities may need the use of these straws, as some have argued that there are not enough alternatives or substitutes readily available in the market [27].

The prohibition on plastic straws stems from the same principles as the prohibition on plastic bags, to reduce our use of single-use plastics and plastic consumption. The video below is an advertisement released in the city of Seattle about going strawless. The video represents part of the marketing campaign to reduce plastic consumption, which comes at a cost to produce, representing one type of cost (i.e. marketing and promotion of the prohibition policy or movement) it takes to make prohibition an effective policy.

Click the link to watch the video below:

https://vimeo.com/229148052

Straw Ban Advertisement in Seattle [43]

2.1.4 Marijuana Prohibition and Legalization



Hempseed [30]

Use of hemp in the U.S. spans back as far as Jamestown and the early settlers of the American Colony. Hemp is a fiber used to make sails, clothing, and rope. Hemp is the male orientation of the cannabis plant. Marijuana is derived from the flowers of the female orientation of the plant and is used for recreational and medicinal purposes. In 1619, King James I declared that the American colonies would need to do more to support England. This decree required all Jamestown owners to grow and export 100 hemp plants each. The growth of hemp eventually became pivotal to the growth of the United States. In fact, as late as 1900, hemp appeared on the 10-dollar bill of the U.S. [29]. In 1970, President Nixon signed the Controlled Substances Act, making not only marijuana illegal, but regular hemp, one of the world's oldest domesticated crops, illegal, as well [31].

By 1850, marijuana was being used medicinally across the United States after its introduction in medicine a decade prior. Recreational marijuana use followed close behind, although mainly outside of the United States. Marijuana cigarettes were used by Mexican soldiers as early as 1874. At the same time, laws started being passed regulating pharmaceuticals and product labeling requirements started to arise. In 1905, the USDA identified 29 states that were labeling marijuana as “poison”. By 1906, the Pure Food and Drug Act was passed in Congress, requiring the accurate labeling of certain drugs, including marijuana. By 1910, revisions in legislation focused on labeling all narcotics as poisons and limiting the sale of marijuana by pharmacies to those customers with a doctor’s prescription. In 1938, the Federal Pure Food, Drug, and Cosmetics Act was passed, which remains in effect today, providing a specific framework for how prescription and non-prescription drugs and food are handled. Marijuana is still considered a dangerous drug under this act [29].



Marijuana Prohibition [32]

Successful in their campaign against alcohol, temperance groups began focusing their efforts on opiate drugs and marijuana. Between the years 1914 and 1925, twenty-six states passed laws prohibiting marijuana. The marijuana prohibition laws were uncontroversial and passed without much debate [33]. By the early 1930's, prohibition of alcohol was repealed via the 21st amendment of the constitution, although prohibition on drugs across the U.S. remained in effect. Marijuana and other drugs were blamed for crime, murders, suicides, robberies, and more. Much as proponents for alcohol prohibition focused on alcohol as the cause of these negative social impacts, proponents for marijuana prohibition blamed all of these social impacts on marijuana. Thus, the prohibition of drugs continued long after alcohol prohibition was repealed. Proponents of marijuana prohibition relied on fear tactics at times to continue this campaign. By the 1950s, there was no effort to distinguish between different types of drugs. All drugs were considered dangerous and addictive [33].

By the 1960's, views on marijuana prohibition began to change. Mainly due to the increase in the number of college students smoking marijuana, the number of incarcerations due to illegal drug use increased tenfold between 1965 and 1970. Thus, people began to question the penalties associated with marijuana use. It seemed to be rather extreme by certain groups to incarcerate some of the best and brightest minds in the country attending college for such a small offense as marijuana use [33]. Disregarding this change in attitude, marijuana was further restricted under the Comprehensive Drug Abuse Prevention and Control Act of the 1970s, which put marijuana in the most restrictive group of narcotics, prohibited even from medical use [33].



Elvis Presley meets President Nixon – 1970 [42]

President Nixon spent most of his time in office continuing his anti-marijuana campaign as part of the "War on Drugs." Nixon's director of the Narcotics Treatment Administration recalled that when he joined the administration the president told him, "You're the drug expert, not me, on every issue but one, and that's decriminalization of marijuana. If you make any hint of supporting decriminalization, you are history. Everything else, you figure it out. But that one, I'm telling you, that's the deal.'" President Nixon ironically recruited Elvis Presley as a spokesperson for the War on Drugs circa 1970 [33].

Despite Nixon's continued push to keep marijuana illegal and the continued push for the "War on Drugs", more and more people were beginning to think that the harsh penalties applied to those who were caught using drugs were contrary to society's best interest. Thus, advocates for the legalization of marijuana have focused not on "drugs" but on the medical uses of marijuana and the social costs to the country from the prohibition of marijuana [33]. The "War on Drugs" continued for the next 40 years, with some relaxation of laws and enforcement. For example, in 1996, California passed the Compassionate Use Act, which made California the first state to legally allow the use of marijuana for medical purposes [31]. As of January 2018, nine states have legalized marijuana for recreational use to some degree, including Colorado, Washington, Alaska, California, Maine, Massachusetts, Nevada, Vermont and Oregon. While it is legal at the state level, it is still illegal under federal law [43]. Other states are now considering legalization and the federal government is considering how to deal with the situation.

The video below provides a perspective between two communities on the legalization of recreational use of marijuana in Colorado. The video presents some aspects of both sides of the current debate.

Click the link to watch the video below:

https://vimeo.com/108670571

The Marijuana Divide [34]

2.2 Economic Analysis

Governments at times wish to regulate the trade of goods through different means, such as taxes. A more dramatic approach is to **prohibit** the consumption, production, or trade of a good or service [35]. Prohibition itself is often a policy tool used on the supply side of the market, but it can be used to restrict demand if consumption is prohibited, but this is usually much more difficult to control and enforce. Our focus in the economic analysis of prohibition will be to examine the impact of prohibition policies and laws on the supply side of the market, the impact of prohibition type policies on consumption of prohibited goods, and the political economy of prohibition.

2.2.1 Prohibition, Supply and Black Markets

Prohibition is often a supply-side reduction policy, due to the better likelihood of enforcement of the prohibition (e.g. there are usually a much smaller number of producers than consumers in the market) [36]. Prohibition makes the production of the prohibited good illegal, but typically is not able to curtail all the production in the market [35]. That is, a ***black-market*** forms where the product is produced and sometimes consumed illegally. During alcohol prohibition, it was illegal to produce alcohol, but not illegal to consume. Prohibitions are enforced through fines, confiscation of resources used for production, jail terms, etc. These enforcement mechanisms come at a cost to the producer. That is, the cost of production for producers increases, usually dramatically, due to an increase in *transaction costs.* These transaction costs can include paying fines, higher costs for resources to produce the prohibited good, monies for bribes, potential loss of production, etc., all because the production of the good is now illegal. Thus, the prohibition policy acts as a *determinant of supply,* causing the supply curve to shift to the left due to the increase in the cost of production [36]. This shift is illustrated in Figure 1 below.

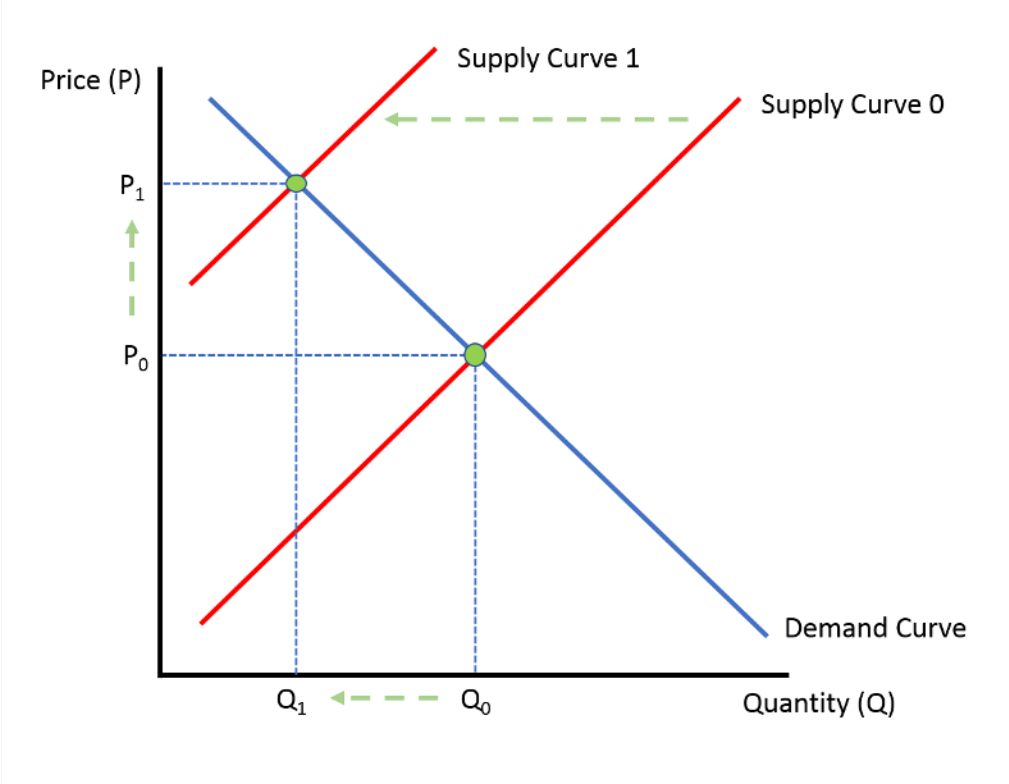


Figure 1: Supply-Side of Prohibition Market Effect

The significant shift in the supply curve from Supply Curve 0 to Supply Curve 1 is due to the high transaction costs. The market equilibrium moves from Q_0, P_0 to Q_1, P_1. This results in a significant increase in the equilibrium price and decrease in the equilibrium quantity in the market for the prohibited good. The *black market* is represented by the shift in the supply curve to the left. That is, the legal market becomes a black market after the shift, as all the production represented by Supply Curve 1 is illegal. In this case, there is no assumed change in the demand for the prohibited good. Overall, under prohibition, both consumers and producers are worse off. Consumers lose utility and must substitute goods that they likely feel may be inferior, while producers lose profit and employment [36].

2.2.2 Policy Considerations and Demand

As mentioned earlier, prohibition typically fails to eliminate the market for the prohibited good, giving rise to illegal production and potentially illegal consumption. In the U.S., many drugs are illegal to produce and consume. A prohibition-like policy that could be used to help curb consumption is to place a significant tax on the consumption of the good that you want to prohibit. In this sense, you avoid the direct prohibition of the good but may achieve a significant reduction in the consumption of that good [35]. This result arises from the fact that the tax increases the price of the good to consumers. According to the *Law of Demand*, as the price of a good in the market increases, the consumption of the good (or quantity demanded) will decrease. The tax is further enhanced by another property of demanded goods, the *Law of Diminishing Marginal Utility*. This law states that the more you consume a good, the less satisfaction (or utility) you receive for that good [36]. Thus, the tax may have the effect of essentially "pricing" some people out of the market, providing the same benefit as the prohibition. The tax is a *market-based* policy, in that it does not distort the market, making economic transactions illegal, resulting in a black market like prohibition policies can. The impact of the tax policy will be dependent on how elastic demand is. That is, how much consumption of the good that you want to prohibit (or reduce consumption of) is responsive to price. To see this, let's consider an example.

Assume that the government wants to institute a policy to prohibit the production of textbooks for undergraduates, due to the large use of wood pulp to produce them and their impact on the environment (through say deforestation). Assume that the own price elasticity of demand (η) for these textbooks is $\eta = -0.4$, which is inelastic. Recall, the own price elasticity of demand for textbooks tells us that a 1 % increase in the price of textbooks will decrease the quantity demanded of textbooks by 0.4%. Now assume, the government, in a push to get textbooks off the market, puts a consumption tax on textbooks, which consumers will have to pay when they buy a textbook. The tax comes in the form of an *ad valorem tax*. Assume the tax is 200%. That is, consumers will have to pay the price of a textbook, plus 200% of its value in taxes. If a textbook was $100, the tax would be $200, making the total cost to the consumer $300 for the textbook. What will be the impact of the 200% ad valorem tax on textbook consumption?

To answer the above question, remember the own price elasticity of demand for textbooks tells us what happens if the price of textbooks increases. The imposition of the tax is like a 200% increase in the price of a textbook. Now, recall from past chapters, that $\eta = -$ $\eta = -$. We can now use this formula to solve for the or percent change in the quantity of textbooks consumed. Using the information provided: \(%△Q^D =η/times{%△P} =−0.4\times 200 = −80\) or an 80% decrease in the consumption of textbooks.

Would you need as large a tax if demand was elastic or responsive to price? Consider the situation now when the own price elasticity of demand for textbooks is $\eta = -2.0$. Use this and the above information to answer the following question about how a lower ad valorem tariff could achieve the same effect in the market if the good is elastic.

2.2.3 Political Economy and other aspects of Prohibition

In this subsection, we want to touch on two other aspects of the economic analysis of prohibition briefly. These two aspects involve the political economy of prohibition and optimal level of enforcement.

Political Economy of Prohibition - In some instances, the prohibition of a good or service is a result of the government's response to strong or influential interest groups. As will be discussed in detail below, the prohibition on margarine in the late 1800s and early 1900s was primarily due to interests groups lobbying government to prohibit the good. The theory underlying why this may occur is the economic theory of regulation proposed by George Stigler [37]. The idea is that politicians are heavily influenced by the interests of the people they represent, their constituents, especially their best-organized constituents. In addition, politicians will likely favor policies that benefit not only their constituents but well-organized and influential interest groups, as it lowers the costs of supporting that policy and can provide political dividends. Policies that only have the support of the general public are usually not as well supported politically, as the political pay-off is not as high as those that are supported by well-organized and influential

interest groups [38]. Thus, prohibition policies many times, as seen in the above examples and below, are enacted due to the interests of certain groups, which may not represent what the majority of individuals feel about the policy.

Optimal Enforcement of Prohibition: A significant issue for policymakers to consider when looking to enact a prohibition policy or law is how to optimally enforce the policy. The government needs to determine at what point the marginal benefit or return from enforcement is equal to the cost of enforcement. Theoretically, at this point, the net gain from enforcement will be maximized. That is, enforcement will achieve the greatest reductions in production and/or consumption of the prohibited good in the most cost-effective manner. The benefits from prohibition include reductions in consumption or production, as well as the value of reductions in harmful impacts that are alleviated due to the consumption or production of the prohibited good. The costs of total enforcement of a prohibition usually far outweigh any benefits achieved [36].

3.0 Case Study – Prohibition of Margarine in the U.S.

We now present a case study to conduct an applied example of the economic assessment of prohibition policies on the market for a good. In this case study we examine the prohibition of margarine in the U.S.

3.1 Historical Background

Margarine was introduced in 1869 by the French chemist Mége-Mouries under Napoleon III. Made from animal fats (as a by-product of the slaughterhouse) or from plant fats (such as cottonseed oil), margarine could be made much cheaper and sold for half the price of conventional butter. The introduction of margarine in the U.S. led dairy interest groups to push for legislation to ban this new product, which would be prohibited in different ways in the U.S. until the mid-twentieth century [39].



Butter [40]

Margarine first arrived in the U.S in the 1870's, much to the dismay of dairy producers. Butter had never had much competition, but the introduction of margarine had the potential to adversely affect dairy producers, reducing the producers' and processors' profits made from producing butter. As a cheap substitute to butter, margarine was readily adopted by consumers across the country, sparking a considerable shift in consumer demand from higher priced butter to lower priced margarine. The market shift to margarine was viewed as being detrimental to the health of the dairy industry and a strong push was made to heavily tax margarine at a discriminatory rate relative to butter. By 1886, 27 states had introduced legislation on margarine production and sale; 20 regulated the labeling and packaging of margarine; and 7 states prohibited its manufacture and sale. [38-39]. Following legislation passed by state governments, the federal government felt the need to step in to help enforcement of state laws. Congress passed the Oleomargarine Bill, imposing a manufacturing tax of 2 cents per pound on margarine and a requirement for annual license fees for all producers in the margarine supply chain. Because of this new legislation, margarine was often sold as butter. Both products were sold in large quantities, and it was very hard to tell the difference between the two by examination. In reaction, the government instituted policies requiring the proper labeling of margarine to be able to identify it clearly and as different from butter. Instead of solving the problem of margarine disguised as butter, it made the situation even more complicated. With further pressure from interest groups, legislation was passed that focused regulation on the color of margarine, which was naturally a white blend and had been artificially died yellow to match the color of butter. By the 20th century, 32 states had passed legislation to prohibit the yellow coloring of margarine, "the most bizarre certainly being Vermont's in 1884, and New Hampshire's and West Virginia's in 1891 requiring that it be colored pink" [38].



Oleomargarine [41]

By the late 1800s and early 1900s, mounting pressures from interest groups and industry got federal legislation to regulate colored margarine in states where the colored product was still not banned. “The manufacturing tax was raised to 10 cents per pound on colored margarine and lowered to one-fourth cent per pound on the uncolored product” [38-39]. Licensing fees for selling and manufacturing uncolored margarine were also reduced considerably. By 1914, nearly all retailers and wholesalers were selling uncolored margarine [38].

Margarine had been the key focus of lobby and interest groups associated with the dairy industry. The interests of these groups though was up against other significant interest groups, such as those supporting manufactured food products, livestock groups and crop groups (e.g. for cotton) that all shared in the profits from the sale of margarine. Butter was a natural product produced from dairies, while margarine was one of the first manufactured products, but was viewed with suspicion as it was not seen as natural [38-39].

The restriction in the sale of yellow margarine continued until the end of World War 2, when butter prices significantly increased in 1947. The general public and interest groups sought to eliminate the restrictions placed on margarine, a much cheaper substitute during this time. By 1950, the Oleomargarine Bill was repealed. State legislation wasn’t far behind in most states, although it wasn’t until 1967 when restrictions on colored margarine finally disappeared in the primary dairy states of Minnesota and Wisconsin [38].

3.2 Market Analysis – Supply and Demand in the Margarine and Butter Markets

This section will ask you to examine the potential impacts of margarine prohibition on the market for margarine in the U.S. In addition, it is important to take into account the impact margarine prohibition had on the market for butter.

Following the introduction of margarine in the United States, dairy producers across the country lobbying for legislation of margarine production; and by 1886, seven states had prohibited the manufacturing or sale of the good, stabilizing the market for butter, with another 20 states regulating the sale of margarine in some way [38-39].

Just as prohibition throughout history has never been entirely successful at eliminating the supply of prohibited goods, the supply of margarine continued to be available, albeit through illegal ways. There are records of trucks carrying margarine across the borders at night into Wisconsin to sell to consumers [35].

3.3 Policy Implications

While it may be a simple economic analysis to look at prohibition in the few states that banned its production outright, this was not the case for much of the United States. In fact, the passing of the Oleomargarine Bill in 1902 was not to completely eliminate the

supply of margarine in the U.S. through outright prohibition. Rather, the Oleomargarine Bill was put in place to achieve one particular goal, artificially raising the costs of producing margarine and thus the market price of the good through taxation [38-39].

By imposing a tax on the production of margarine, legislation was created to specifically target the cheaper price of margarine in the market, thus helping to increase the demand for butter. Assume the own price elasticity of colored margarine is $\eta = -0.8$. The tax on margarine set by federal policy increased the price of colored margarine by 50%. Use this information to answer the following question.

By the 1960s much of the legislation passed to prohibit or reduce the consumption of butter was repealed. This had the effect of reducing the price of margarine to the consumer. Now assume that preferences have changed and the own price elasticity of margarine is now $\eta = -0.4$.

Now assume the cross price elasticity of butter for margarine is equal to $\sigma = 0.7$. Use this information to answer the next question.

4.0 Concluding Remarks

This chapter introduced you to the concept of prohibition, examined its historical and present significance as a policy tool, and the economic impacts that prohibition policies may have. When we think of prohibition, we tend to think of alcohol prohibition, but alcohol prohibition was not the only significant prohibition policy in our country's past. We are still engaged in the "War on Drugs" and we commonly see prohibition of products in the market to protect human safety, just to name a couple of examples. Prohibition will decrease the production and/or consumption of the prohibited good, but it is likely to give rise to black markets and potentially other social and economic hardships. Policymakers have tried to use other market-based tools, such as taxes, to achieve the same effect as prohibition, but try to avoid the other hardships mentioned.

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