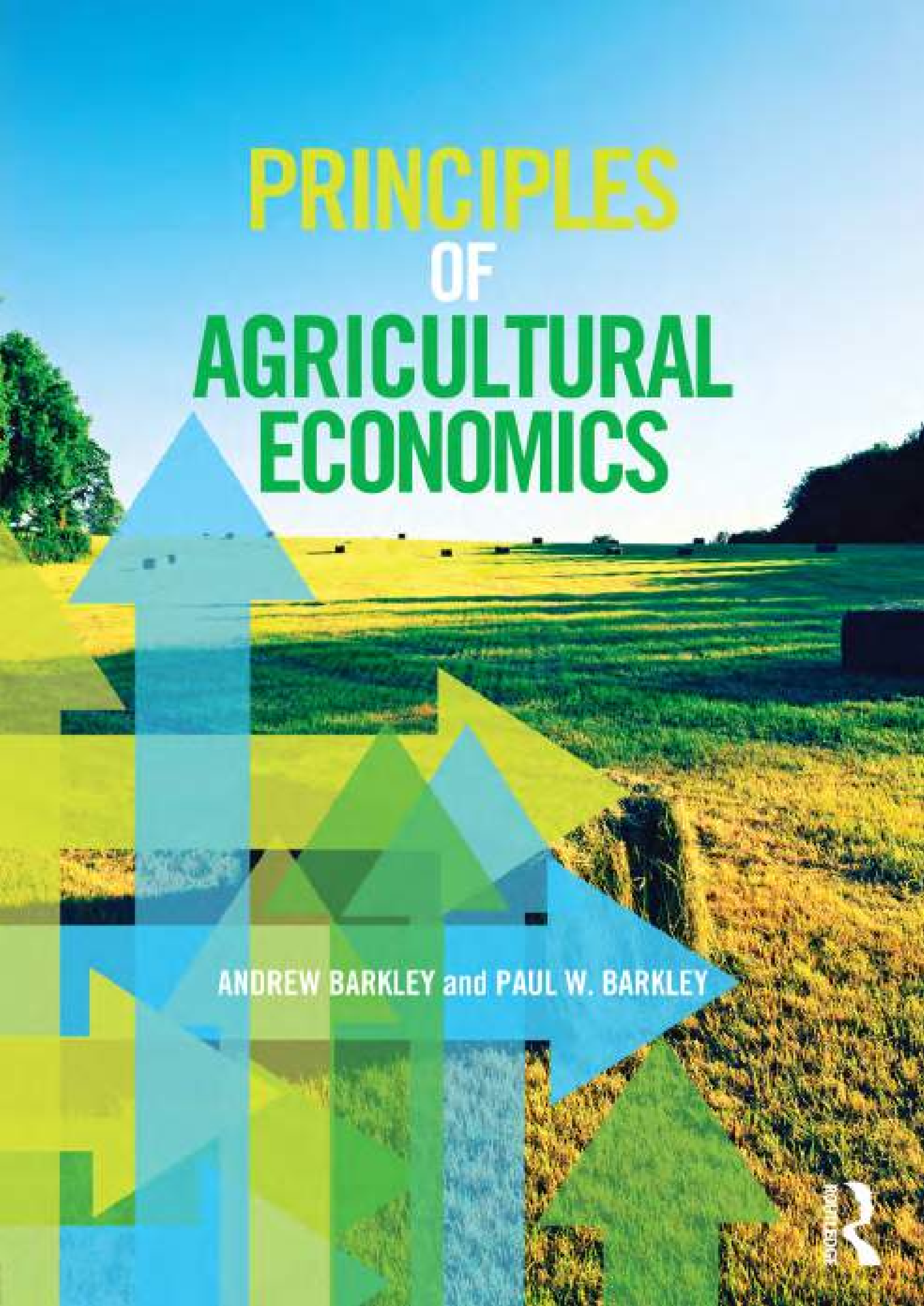
PRINCIPLES OF AGRICULTURAL ECONOMICS

ANDREW BARKLEY and PAUL W. BARKLEY



Principles of Agricultural Economics

This book showcases the power of economic principles to explain and predict issues and current events in the food, agricultural, agribusiness, international trade, natural resources, and other sectors.

The result is an agricultural economics textbook that provides students and instructors with a clear, up-to-date, and straightforward approach to learning how a market-based economy functions, and how to use simple economic principles for improved decision making.

While the primary focus of the book is on microeconomic aspects, agricultural economics has expanded over recent decades to include issues of macroeconomics, international trade, agribusiness, environmental economics, natural resources, and international development. Hence, these topics are also provided with significant coverage.

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Preface

The main objective of this book is to provide students and instructors with a clear, up-to-date, and straightforward approach to learning how a market-based economy functions, and how to use simple economic principles for improved decision making. Emphasis is placed on the intuition of profit maximization, and how the intuition can be used to improve both personal and professional decision making.

Together, we have many years of experience teaching economics to students who are majoring in fields related to agriculture. Our idea is that students will find economic principles more relevant if the examples were related to agriculture: bushels of wheat, pounds of hamburger, gallons of pesticides, acres of land. The theories, models, and concepts appropriate to studying economics do not vary when one moves from widgets to bushels, and the lessons become easier for the student interested in food, agriculture, and environmental issues.

The book began to take form when Andrew started teaching large classes of Kansas State University students who were new to economics. Andy kept his notes from one semester to the next and added, modified, corrected, and edited. After several years, the notes were almost in book form, and many teachers at K-State and at other institutions used the notes for their classes. This evolved into a plan to develop the notes as a full-blown, publishable manuscript. We decided to work together to broaden the base of experience and interest. The result of the collaboration is a useful and flexible microeconomics text that treats all of the essential topics at a comfortable level that uses words, graphs, and simple algebra to explain the major themes and examples.

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Abbreviations

ADM	Archer Daniels Midland
AFO	Animal Feeding Operation
bu	bushel
CA	Controlled Atmosphere
CAB	Certified Angus Beef
CAFO	Concentrated Animal Feeding Operation
CD	Compact Disk
CRP	Conservation Reserve Program
cwt	hundredweight
DDT	dichloro-diphenyl-trichloroethane
EPA	Environmental Protection Agency
EU	European Union
FTA	Free Trade Agreement
GATT	General Agreement on Tariffs and Trade
GIS	Geographical Information Systems
GPS	Global Positioning Systems
H	beef growth hormones
HFCS	High Fructose Corn Syrup
kwh	kilowatt hours
lb(s)	pound(s) [weight]
LEPA	Low Energy Precision Application
M	Meter
N	Nitrogen
NAFTA	North American Free Trade Agreement
NCBA	National Cattlemen's Beef Association
NYSE	New York Stock Exchange
OPEC	Organization of the Petroleum Exporting Countries
US	United States
USD	United States Dollars
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USSR	Former Soviet Union, Union of Soviet Socialist Republics
USTA	United States Tennis Association
WTO	World Trade Organization

Economic terminology

π	profits
π_A	accounting profits
π_E	economic profits
A	Land
AFC	Average Fixed Costs
APP	Average Physical Product
AR	Average Revenue
ARP	Average Revenue Product
ATC	Average Total Costs
AVC	Average Variable Costs
D	demand curve
E	equilibrium
E^d	price elasticity of demand
E^d_{Y1Y2}	cross price elasticity of demand
E^m	income elasticity of demand
E^s	elasticity of supply
E^s_{Y1Y2}	cross-price elasticity of supply
EP	expectations of future prices
IR	Immediate Run
K	Capital
L	Labor
LR	Long Run
M	Management
M	income
MC	Marginal Cost
MFC	Marginal Factor Cost
MPP	Marginal Physical Product
MR	Marginal Revenue
MRP	Marginal Revenue Product
MRPS	Marginal Rate of Product Substitution
MRS	Marginal Rate of Substitution
MRTS	Marginal Rate of Technical Substitution
MU	Marginal Utility
N	number of sellers
P	price of a good
P*	equilibrium price
P_i	input price
P_o	prices of other, related goods
P_{own}	own price of a good
Pop	population
$P_{related}$	price of related goods
P_X	input price
P_Y	output price
PPF	Production Possibilities Frontier
q	individual firm quantity
Q	market quantity

Q*	equilibrium quantity
q^d	individual firm quantity demanded
Q^d	market quantity demanded
q^s	individual firm quantity supplied
Q^s	market quantity supplied
SR	Short Run
t	per-unit tax
T	Technology
TC	Total costs
TC_A	Accounting Costs
TFC	Total Factor Costs
TFC	Total Fixed Costs
TP	Tastes and Preferences
TPP	Total Physical Product
TR	Total Revenues
TRP	Total Revenue Product
TU	Total Utility
TVC	Total Variable Costs
Y	quantity of a good; output

Mathematical notation

$\succ$	is preferred to
$\prec$	is less preferred to
$\sim$	is indifferent to
f	function
Δ	change
m	slope
$\Delta y/\Delta x$	slope
b	y-intercept
∞	infinity

Plate 1.1 Introduction to the economics of agriculture.
Source: April Cat/Shutterstock

1 Introduction to the economics of agriculture

Synopsis

This chapter explains why economics is important and interesting. It defines the study of economics, and discusses what it is about. We introduce and explain economic terms, including producers, consumers, macroeconomics, microeconomics, positive and normative economics, absolute prices, and relative prices. The major discussion explains why scarcity is the fundamental concept of economics. The chapter also introduces and explains economic organization, resources, trends in the agricultural economy, and a review of graphs and their construction.

1.0 Introduction

At the beginning of the twenty-first century, there were slightly more than 2.2 million farms in the United States (US). Missouri had the most with more than 100,000 Alaska came last with fewer than 1000. Taken together, these farms produced hundreds of crops, from apples to zucchini, from bees to turkeys, and hundreds of crops and animals in between. When sold, all products from all farms yielded a net farm income of nearly $100 billion in 2007. Today, each US farmer "supports" or "feeds" more than 150 non-farmers. It has not always been this way. As recently as 1975, each farmer provided goods and services for fewer than 100 people, and in the nation's early years, farmers were sometimes barely able to feed their own families.

At the beginning of the nation's history, nearly 90 percent of the population lived on farms. By the mid-1930s, there were approximately 6.5 million farms. Now, less than 2 percent of the population lives on farms. Farm output continues to grow while the farm population continues to decline.

The beginning of agriculture in the "New World" is difficult to trace. Many Native American tribes had progressed beyond hunting and gathering and were engaged in the cultivation of crops and the domestication of animals. The early settlers coming from Europe introduced agriculture similar to that of today to North America. Different objectives brought settlers to Jamestown Virginia (1607) and Plymouth Massachusetts (1620). Even so, their early efforts at agriculture or farming were very much alike. The Native Americans provided the knowledge and experience concerning how to clear the land, and the three-crop method of planting corn, beans, and squash in the same hills.

The Plymouth colony moved quickly into animal agriculture and survived by selling animal products to the rapidly growing urban population of the Northeast. The South was better suited for plantation farming and moved quickly to tobacco, rice, indigo, and cotton: all crops that required large labor forces and helped make slavery a prominent institution in the South.

When it became clear that the two early colonies were successful, land-poor immigrants began to arrive, mainly in the Northern port cities. The new arrivals sought land and moved west to find it in what is now known as the "corn belt." The migration continued westward through both the cotton-producing south and the grain-producing areas of the central and northern plains. From there, the westerly movement had to slow until irrigation water and transportation networks were developed. These came soon enough. With only a few areas that were too dry, too cold, or too high in the mountains, farm families covered the North American continent by the late 1800s. It was clear to everyone that the nation was well suited to growing food!

The problem was that it produced too much. No single farmer or group of farmers could solve the problem of low prices and low-income farm families. All producers had to take the offered price and the massive productive capacity of the huge land kept driving the price down. The federal government became involved with the plight of the agricultural industry. At first, it was felt that improved transportation would help carry the surpluses from low-price areas to high-price areas, or to port cities for shipment overseas. The government had no money for rail or canal construction, so it gave land (parts of the public domain) to the railroads that were quick to sell it to farmers. The farmers got their transportation, but the new land coming into production did little to increase the price of agricultural commodities: the farm population continued to live in poverty relative to the urban citizens of the US.

The first large land grant to a railroad came in 1862, a year filled with government activity on behalf of the farm population. The government also passed the Morrill Act and the Homestead Act in 1862. The Morrill Act gave large grants of land to individual states to use in developing the State Agricultural Colleges (Land Grant Colleges) to provide teaching, research, and off-campus education aimed to help rural residents. All three activities—teaching, research, and "extension"—helped farm operators to be more efficient, to keep accurate books, and to use more reliable information in their buying and selling activities.

The Homestead Act was an effort to allow people to settle the unclaimed parts of the United States that were still in public ownership. Eligible homesteaders paid a token price for 160 (sometimes 320) acres of land, made minimal improvements, and took full title after five years of residence on the land itself. Before Congress repealed the law in 1976, over 1.6 million individuals or families made application to obtain the land and more than 270 million acres (over 10 percent of the nation's total land area) passed into private ownership through homesteading.

A third federal action in 1862 put the US Department of Agriculture in place. This made agriculture the only industry to have its own federal agency; an agency devoted to research and improvement of the industry. Agricultural research has led to high and sustained levels of productivity enhancement in US food and fiber production. Enhanced output has resulted in continuous decreases in food prices. This ever-changing technology and financial situation in US agriculture makes it important for farmers, ranchers, and agribusiness managers to learn the rules of choice as propounded by economists, as reported in this book.

In many respects, the nation still divides into sections or regions similar to those of the early years of settlement by immigrants, primarily from Europe. The Midwest (the Corn Belt) is the main agricultural region in the country. Clustered around the Great Lakes and extending south to Missouri, this region produces huge amounts of corn and soybeans, small grains, and hogs. Yields are generally high and these crops move through the food chain to become an ingredient of many “table-ready” foods. Many of the farms in the region began as 160-acre units, but most have grown demonstrably since the time of settlement.

The vast, flat, and highly productive Great Plains lie to the west of the Corn Belt: mainly to the west of the Mississippi River and extending to the Rocky Mountains. The “Plains States” (the Dakotas, Nebraska, Kansas, Oklahoma, Texas, and parts of neighboring states) make an ideal garden for small grains. The region produces wheat, barley, oats, sunflower seeds, and many other crops. Most of the Plains States have only modest non-agricultural or industrial sectors so the populations are more dependent on agriculture relative to the rest of the US. Consequently, they watch government activity as it relates to their cropping plans. Efficiency in production has developed to the stage where the need for labor has diminished and continues to drop as new technologies are developed and put in use. This has led to population losses in many areas and to partially utilized schools, churches, and stores.

The irrigated Southwest or the Desert Southwest includes states from Texas in the east to parts of California in the west. The region has people and it has soils suitable for farming, but no farming is possible without irrigation. The Native Americans in the region grew corn (originally brought in from Mexico) for centuries. The early settlers streaming in from the east were well aware of the need for irrigation so the region developed as a cattle-producing area. By the closing years of the nineteenth century, small-scale irrigation was beginning on a farm-by-farm basis, and some groups of farmers began to cooperate and form irrigation districts. In 1902, the federal government stepped in with the Bureau of Reclamation and US Army Corps of Engineers to develop huge irrigation systems that transported water for hundreds of miles and changed the nature of crop production in many parts of the Desert Southwest. The newly irrigated areas produced cotton, citrus fruits, melons, and vegetables on some of the largest farms in the United States. As the years passed, irrigation moved north in California and eventually made the state a leader in the production of rice, tree fruits and nuts. Other parts of the state produced prodigious quantities of citrus fruits, vegetables, and a number of semi-tropical commodities that could not thrive in most other parts of the nation.

The Atlantic coastal area has been in farms for longer than any other part of the nation. As early as 1609, tobacco for export grew in parts of the Delmarva Peninsula, and it remains as an important crop in the region. Rice and indigo have also been the area’s important exports. Cotton sustained agriculture in the Deep South but has gradually migrated west to the irrigated portions of Texas, Arizona, and California.

The remaining areas in the United States are generally small and generally support highly specialized types of agriculture. Much of the old Cotton South is now producing timber for dimension lumber as well as for fiber. The Pacific Northwest has very productive valleys for berries, seed crops, and tree fruits, and the region remains an important area for timber harvests.

Livestock and the roughage crops needed to support it are grown throughout the nation. Dairies produce a product that requires special handling, so it is frequently found near population centers: New York State, Southern California, mid-state California, and the Great Lakes areas are all important producers of milk and its related products. Meat animals, especially cattle, are important enterprises throughout the states, but are most important in the western parts of the Great Plains states and the parts of the mountain states and Desert Southwest where soil is generally too poor to support cultivated farming. Hogs complement the corn produced in the Corn Belt; so much so that the region could easily be the “Hog Belt.”

Overall, the United States is a highly diverse and highly productive agricultural nation. In 2000, six crops (corn, soybeans, hay, wheat, cotton, and rice) brought cash receipts greater than USD one billion. Of these, cotton was most important. In that year, more than 400,000 farms harvested nearly 75 million acres of corn. Over 800,000 farms produced at least some beef.

Rapid technological change characterizes nearly all aspects of US agriculture. The profit margins on most commodities are quite small, so individual growers find it advantageous to adopt new methods as quickly as possible. These two factors, change and low profits, will continue to force farms to consolidate and to make the industry more concentrated. While this trend is in opposition to the tradition and the psychological urge for Americans to venerate the “family farm,” it is exactly this continued consolidation that helps keep food prices down and it is exactly this trend and these circumstances that make the economics of agriculture an important and an interesting subject for study, for use in day-to-day decision making, and for years of study as a career.

The changes affecting agriculture have been substantial. There have been changes in technology, changes in plant and animal breeding, changes in the diets of consumers, changes in food exports and imports, and changes in the way agriculture relates to the US government. Each change has required US farmers to ask a simple question: how should I respond to the change? Answering this question is what economics is about … but what is Economics?

Economics is a **Social Science**, meaning that it uses scientific methods to study the way people behave. The subject dates from antiquity, but economists have studied agriculture for about 150 years. Although economics is the theme of thousands of books, papers, laws, and regulations, its day-to-day use by economists interested in **Agriculture** centers on five very clear-cut questions that might be asked by a producer of agricultural goods, a consumer, or even an operator of a business that serves agriculture. The five questions may change slightly from person to person, but they always come back to:

- What (if anything) should I produce?
- How much should I produce?
- How should I produce it?
- When should I produce it?
- For whom should I produce it?

These basic questions form the foundation of the lessons and discussions in this book.

1.1 Economics is important and interesting!

Rapid changes in the agricultural industry make this an exciting time to study **Agricultural Economics**. Changes in the global economy and in the agricultural industry are occurring at a more rapid rate than at any other time in history, and these changes have huge implications for the entire domestic economy.

Some examples show how this happens. The United States has been at war in the Middle East for many years. Economics provides a useful tool for understanding why the wars have been undertaken, what the economic implications are, and how agricultural and food markets have been affected. Due to terrorism, the agricultural industry has increased the security of the nation’s food supply. Wheat (as well as other foodstuffs) has been airlifted to Afghanistan. Similarly, food of all kinds still helps the victims of hurricane Katrina in 2005, the massive earthquake in Haiti in 2010, and the starving citizens of Somalia.

Plate 1.2 Beef and rice consumption in Japan.
Source: Gresei/Shutterstock

Events that happen in other parts of the world often have a large impact on those who live in the agricultural regions of the United States. For example, the break-up of the former Soviet Union (USSR) in 1990 led to the formation of 15 separate nations of which Russia is the largest. This transition from a communist (centrally planned) economy to several capitalist (market-oriented) economies brought change, stress, and dislocation in the new nations. This resulted in low agricultural output. The poor performance of Russian agriculture resulted in the need for Russia to import wheat from the United States.

The rapid economic development of Japan in the years following World War II is another example of how international events affect US agriculture. For many centuries, rice was the staple food of the Japanese people. Even now, 60 percent of all Japanese people in Japan eat rice in some form every day. In the past few decades, rice consumption in Japan has declined, while beef consumption has increased dramatically. Today, the per-capita consumption of beef and coffee in Japan are much higher than they were in the 1950s. As the Japanese economy prospered in the years following World War II, the income levels of Japanese households increased, resulting in a shift away from rice consumption and toward more expensive foods such as beef and coffee. The change in Japanese eating habits has had an important impact on the US beef industry.

A similar shift in consumption habits is expected to occur in many developing countries. As income levels in low-income nations increase, individuals will likely shift from less expensive foods such as grains, and into more expensive foods such as beef. Understanding how and why consumers purchase goods provides information useful in improving decision making by persons employed in agriculture and agribusiness. Business decisions are not the only decisions affected by economic conditions. Similarly, they are not the only decisions more easily understood and even improved by using economic information and logic.

Since 1933, a devastating time for US agriculture, the US Congress has legislated "Agricultural Acts" (frequently referred to as "Farm Bills") that spell out the types of aid that the federal government will provide for the agricultural industry and other activities managed by the United States Department of Agriculture (USDA). Farm bills usually cover four to six years, depending on the economic condition of the industry and the composition of the Congress. The first such comprehensive law was simply the "Agricultural Adjustment Act of 1933." Six more Agricultural Acts came before the Congress between 1938 and 1971 and nine such "farm bills" have become law since 1970, with the most recent in 2008. The names of the recent legislation have broadened to indicate that agriculture is more than just food and farms. The 1990 law was called, "The Food, Agriculture, Conservation, and Trade Act," and the 2008 Act was the, "Food, Conservation, and Energy Act of 2008." Farm bills are usually controversial because they are expensive and they deal with subsidies, mandated payments, and regulations on what farmers can and cannot do.

Box 1.1 The United States Department of Agriculture (USDA)

In 1862, President Abraham Lincoln established the Department of Agriculture, which he called the "people's department," but the Department did not have Cabinet-level status. In 1889, President Grover Cleveland signed a bill that gave the Department of Agriculture Cabinet status. The Department was created to assist farmers by providing information, research, loans, and education for rural youth. Agriculture has changed a great deal since 1862, when over half of the nation's population lived on farms. However, the mission of the USDA has remained the same: "We provide leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management."

Currently, the USDA promotes the marketing of farm products overseas, promotes food safety and nutrition, provides marketing assistance to farmers, protects natural resources and the environment, conducts scientific research in agriculture, and promotes rural development. Today, the USDA has over 105,000 employees. Its annual budget is over USD 145 billion.

Source: USDA website. http://www.usda.gov/wps/portal/usda/usdahome?navid=ABOUT_USDA

The 1996 Farm Bill, officially named "The Federal Agriculture Improvement and Reform Act of 1996," drastically changed agricultural policy and the relationship between the federal government and individual farms. Beginning in 1933, agricultural producers received large subsidies (government payments) each year. The 1996 Farm Bill removed these subsidies in a movement toward free markets and free trade. The 2002 farm legislation, "The Farm Security and Rural Investment Act of 2002," reversed this course by increasing the role of the federal government in agricultural production decisions and payments. This policy shift angered some of the nation's trading partners, who had grown accustomed to lower prices for several commodities traded in world markets.

The 2008 Farm Bill, "Food, Conservation, and Energy Act of 2008" expires on September 30, 2012. At the time of this writing, the 2012 bill (the Agriculture Reform, Food, and Jobs Act of 2012) is in the process of being discussed, voted, and passed along to the president for veto or for signature. A farm bill is extremely complicated, costly, and highly political, especially in a general election year.

The proposed legislation of the 2012 Farm Bill has "titles" (subsections) devoted to commodities, loans, conservation (the environment), trade including gifts of commodities, nutrition, credit, rural development, research and extension, forestry, energy, horticulture, crop insurance, and a general title for "miscellaneous." In its present form (Senate version only) the proposed legislation stretches to nearly 1000 pages.

In a general sense, the proposed bill calls for reduced spending on agricultural activities and considerable reorganization aimed at achieving efficiency in administration of the programs. It also calls for individual farm operators to absorb additional risks in their farming activities. In most respects the proposed legislation makes relatively minor changes and government will remain a major presence in agricultural activities over the life of the Agriculture Reform, Food, and Jobs Act of 2012.

Economic principles help explain the reasons behind the changes in agricultural policy, and the impacts of the new policies as they are legislated and implemented. The remainder of this section provides short examples to reveal the nature of real-life economic problems and the importance of using economics to understand them.

Meat processing

The meat processing industry earns its profits by purchasing cattle and selling meat. Many years of consolidation through mergers and acquisitions have resulted in four beef packers (Tyson, Cargill, JBS USA, and National Beef) controlling over 80 percent of all beef sold in the United States. Many individuals and firms in the beef business would like to know if the "structure" of the beef industry (the number and size of the packing firms) has an effect on the profits of the livestock industry, as well as the cost of meat at local grocery outlets. With only four major packers, there may be less competition in buying cattle from livestock producers. This could result in downward pressure on the price of cattle. However, there are some positive price effects from having big packers. Large packing plants allow the meat production process to become more efficient, resulting in lower costs to consumers, who in turn purchase more meat. These increased meat sales place upward pressure on the price of livestock. Individuals who study this complicated issue say that the increased benefits (profits) and costs of the changing structure of the packing industry are not divided equitably among growers, packers, and consumers. The study of economics allows a deeper understanding of the causes and consequences of mergers and acquisitions in most any part of the agricultural and food industries.

Free trade among nations

Free trade agreements (FTAs) are formed to reduce or eliminate trade barriers between nations. Two of the most important FTAs are NAFTA (the North American Free Trade Agreement) and the WTO (the World Trade Organization, formerly called the GATT, the General Agreement on Tariffs and Trade). These agreements have had major consequences for agricultural producers and consumers in the United States and throughout the world. Trade barriers are laws that restrict the movement of goods across national borders. These **Free Trade Agreements** have opened the way for increased exports of US grain (wheat, corn, milo, and soybeans) by eliminating or reducing **Trade Barriers** such as tariffs, quotas, and harsh inspection criteria. The FTAs allow the United States to sell grain to Russia, Japan, Mexico, and other countries with fewer legal restrictions or taxes. This book demonstrates that the movement toward free trade generally has benefits for agricultural producers.

The trade agreements have caused some individuals and groups to question globalization and free trade. In 1999, serious and prolonged rioting occurred at World Trade Organization (WTO) meetings held in Seattle and in Washington, DC. The cause of the violence focused on the impact of world trade on agriculture and the environment. Two years later, in 2001, issues related to low incomes among farmers caused a breakdown of WTO trade negotiations held in Cancun, Mexico.

Box 1.2 Trade barriers

Nations around the world use laws and regulations to restrict imports, exports, or both. Three common barriers include:

TARIFFS: taxes paid before goods can be sold across a national border. For example, automobile consumers in the United States must pay a tariff when they purchase a car made in another country. In 2010, tariffs accounted for about 1.3 percent of the US government's revenue.

QUOTAS: restrictions on the quantity of goods allowed to enter the United States from another country. Quotas protect domestic producers from foreign-made products.

INSPECTION: the most subjective of the devices used to restrict imports. Inspection is used to prevent food items that are considered unsafe from entering the US economy.

Source: Economic Glossary. http://glossary.econguru.com/

The environment

Environmental issues play an increasingly important role in agriculture. A number of Midwestern states are well suited to growing corn (Iowa, Illinois, and Nebraska are typically the three leading states in corn production), but modern corn production often utilizes an herbicide called Atrazine to eliminate weeds. Atrazine provides large agronomic and economic benefits to corn farmers in this area. Unfortunately, the chemical is also associated with human health problems when it enters a domestic water supply.

The impacts of Atrazine are mixed. On the one hand, the chemical provides efficient control of weeds, resulting in higher yields and higher levels of profits for corn farmers. On the other hand, Atrazine contaminates the groundwater, possibly causing health problems for not only the corn farmers and their families, but also for all downstream water users. Economists use a number of analytical tools to sort out the effects of this tradeoff between economic benefits and environmental harm. Successful decision making for individuals, firms, and governments involves understanding how to choose the "optimal" level of Atrazine to apply to cornfields in the American Corn Belt.

Agricultural chemicals

The use of fertilizer and agricultural chemicals (such as Atrazine and other herbicides, pesticides, and fungicides) has increased dramatically in the last 50 years. Environmentalists and others who are concerned about chemical residues in the food supply and in the domestic water supply have criticized the widespread use of almost all types of agricultural chemicals. As a result, the large agrochemical companies (Monsanto, Dow, Novartis, Union Carbide, and others) are looking to the time when chemical use is likely to diminish in response to strengthened environmental laws. For example, in the period 2004–08, Monsanto, a multinational agricultural biotechnology corporation, purchased several large agricultural seed businesses to diversify its operations, and expand beyond agricultural chemicals, in the case that the chemical business is reduced due to enhanced regulations. This form of diversification is a prudent business strategy for a large chemical company, since environmental laws and regulations may impose high costs on the producers of agricultural chemicals in the future. As income levels increase, consumers are likely to become more interested in organic food, causing a major chemical company to switch from chemical production to biotechnology development, something that Monsanto has done. Environmental issues have an even longer reach. Recent growth in the consumption of food produced without chemicals has led to large investments in organic food products by several large agribusiness corporations including General Mills, Heinz, ConAgra, and Gerber.

Each of these examples presents an issue that affects the lives of all consumers. Economics can be helpful to those who want to understand the causes and consequences of these situations and events. These issues will be noted from time to time in later chapters. Economics helps provide improved understanding of our complex society, agriculture, and consumer choices. Economic principles and the framework of economic analysis lead to improved business, career, and personal decisions. The knowledge of just a few principles of economics eases the task of making decisions.

One goal of this book is to help readers to "think like an economist." Throughout the book, simple economic principles will be applied to events and issues that appear in newspapers, on television, and online. Success in the rapidly changing global agricultural economy requires accurate information and the ability to recognize how the changes shape people's lives. Understanding economics often provides a context for dealing with current events, career decisions, and personal situations in a clear and precise manner.

It is important to note that the human condition is characterized by complex and sustained difficulties and problems. Economics improves our decision making, but, to date, it has not solved the fundamental problems of disease, shortages, and limitations. However, many economists view recent history as a triumph of the economic way of thinking, and a huge improvement in how long humans live and how well off they are while they are alive. These trends are likely to continue, with solid economic decision making guiding the way.

1.2 What is economics, and what is it about?

As has been mentioned, **Economics** is a **Social Science** that centers on the study of humans as they act and interact in the marketplace. Economists study these actions and interactions. This section provides definitions and explanations of several economic concepts, then uses these ideas to provide a formal definition of economics.

Producers and consumers

Economists are particularly interested in how people produce and consume items such as food, clothing, housing, and a myriad of other things. Economists divide people into two broad groups, **Producers** and **Consumers**. Note, though, that many, perhaps most, people belong to both groups.

- ***Producer*** = an individual or firm that produces (makes; manufactures) a good or provides a service.

A **Good** is a physical product, and a **Service** is an intangible product such as a haircut, an insurance policy, or cell phone service.

- ***Consumer*** = an individual or household that purchases a good or a service.

These two groups of people are so important in economics that they have several names:

> ***Producers*** = firms = business firms = sellers,
> ***Consumers*** = households = customers = buyers.

Agricultural producers are individuals, families, or firms that grow and sell agricultural products. The products include field crops (including non-food products such as cotton, tobacco, flax, and hemp) and animal products (including milk products, meats, wool, furs, and pelts).

A consumer is any person, firm, corporation, or institution who buys something. Consumers buy food items, such as pepperoni pizza and milk. They also buy clothing, houses, cars, cell phones, computers, and real estate. Consumers drive the economy, since their purchases generate signals telling producers what products to place on the market.

Most individuals are simultaneously producers and consumers. A wheat producer in North Dakota produces wheat and sells it to make a living. This same wheat producer buys food at the grocery store (whole wheat bread), clothing (Wranglers), and perhaps a pick-up truck (Ford). Even though most individuals are both producers and consumers, the lessons of economics are much more easily understood if the two roles are studied one at a time.

Macroeconomics and microeconomics

Economics divides into two major categories: **Macroeconomics** and **Microeconomics**.

- ***Macroeconomics*** = the study of economy-wide activities such as economic growth, business fluctuations, inflation, unemployment, recession, depression, and booms.
- ***Microeconomics*** = the study of individual decision-making units such as individuals, households, and firms.

This book is directed mainly to microeconomic behavior, or the actions and choices of individuals and individual firms. It will consider issues surrounding how a feedlot owner reacts to a change in the price of cattle or the price of feed. This issue is a part of microeconomics, since the feedlot is an individual decision-making unit; in this case, a business firm.

Positive and normative economics

As a social science, economics deals with topics of major consequence to public policy. There are many divergent opinions about issues such as the minimum wage, availability of health care, affirmative action, NAFTA, welfare (including Social Security), animal rights, environmentalism, the War on Terrorism, and the like.

Since economics deals with all of these issues, it is important to distinguish between value judgments, which are opinion statements, and neutral statements, which are factual and descriptive. The two categories of economics that keep the opinions in one box and the facts in another are **Positive Economics** (facts) and **Normative Economics** (opinions).

- ***Positive Economics*** = based on factual statements. Such statements contain no value judgments. Positive statements describe "what is."
- ***Normative Economics*** = based on statements that contain opinions and/or value judgments. A normative statement contains a judgment about "what ought to be" or "what should be."

Quick Quiz 1.1

Examine the following statements and determine which statement or statements represent a positive and which represent a normative position or normative statement.

1. The market price of wheat is $3.82 per bushel.
2. The market price of cotton should be higher.
3. The market price of spinach should be higher.
4. Abortion is legal in the United States.
5. Environmentalists have an increasing voice in agricultural policy.
6. Abortion should be outlawed in the US.
7. Unemployment is a major economic issue.

Notice in the first three examples of Quick Quiz 1.1 that price changes can be both good and bad at the same time. A price increase makes the producer of that good better off, while the consumer of that good is worse off. Similarly, when the price of oil increases, oil companies earn higher levels of profits. Meanwhile, agricultural producers who must purchase oil and petroleum-based products (gasoline, diesel, fertilizer, chemicals, etc.) are made worse off. Thus, economists must be careful when making normative statements and normative judgments because "facts" have different implications for different persons. Economists attempt to eliminate normative statements from their economic discussions, because what is good for one individual can be bad for another.

1.3 Scarcity

Economics is about **Scarcity**. Scarcity means that there is less than the desired quantity of something. Scarcity reflects the idea that we live in a world of finite resources and unlimited wants and desires. Humans typically want more than the available quantity of money, material goods such as cars, trucks, football championships, higher grades, and time. The notion of scarcity applies to both material goods (computers and smart phones) as well as intangible goods (fame, respect). The result is that humans want more than they have.

- ***Scarcity*** = because resources are limited, the goods and services produced from using these resources are also limited, which means consumers must make choices, or tradeoffs among different goods.

An interesting issue related to scarcity is that the major religions of the world (Judaism, Christianity, Islam, and Buddhism) suggest that it is better to give than to receive. This important ethical principle seems to be in direct contradiction with the economic principle that "people always desire more." Mother Teresa was a Roman Catholic nun who devoted her life to helping the poorest of the poor in Calcutta, India. Did Mother Teresa fall victim to the idea that "more is better than less?" Yes, even philanthropists would like to have more resources to feed the hungry and help the poor. The desire to have more than is currently available is a ubiquitous trait shared by peoples of all faiths and dispositions.

Economists talk extensively about "goods." If a good is scarce, it becomes an **Economic Good**. A good that is scarce is one for which there is an unfilled desire such as fine foods, clothes, houses, time, and vacations. **Noneconomic Goods** are not scarce: they are free goods available in any quantity to any people. A consumer can have as much as he or she wants at no cost. Watching a beautiful sunset is a noneconomic good, because it is free. Air is free because an unlimited quantity is available for all who want to consume it. However, air is not a free good in every circumstance. Mountain climbers, scuba divers, submariners, and test pilots would consume more air if it were free. Is the air in a lecture room totally free? Indirectly, it has a price since it requires heating or cooling before it reaches the lecture hall. Clean air is not always free: people who live in urban areas would like more clean air, if it were available.

The fundamental problem of economics is "**scarcity forces us to choose**." A frequently heard definition of **Economics** defines it as "the allocation of scarce resources among competing ends." Scarcity constantly forces choices between what goods to buy, how to spend time, and which career goals to pursue. Economics is about making informed decisions. The study and use of economics allows individuals to make more informed personal, career, and business decisions.

1.4 The economic organization of society

There are many different forms of economic organization, or different ways that a society (usually a nation) can use to organize its economic activity. Three fundamental ways of organizing an economy include: (1) a **Market Economy** (capitalism; free markets); (2) a **Command Economy** (dictatorship, communism); and (3) a **Mixed Economy** (a combination of a market economy and a command economy). These three forms of economic organization are described in this section. However, a quick diversion is needed to define and explain **Resources**.

Resources

An economy must find a suitable way to allocate resources. But, what qualifies as a resource that requires allocation? **Resources** are productive items used to produce the goods and services that satisfy human wants and needs. Resources, together with the letter abbreviation used by most economists, are classified and listed in Table 1.1. These groups of resources appear in every kind of economy.

A **Market Economy** is an economic organization in which prices determine how resources and goods are allocated. Consumers in a market economy make purchase decisions based on the price of goods and the money available to them. If the price of chicken increases, some consumers will eat fewer chicken products. Similarly, in a market economy, producers use prices to determine what to produce. If the price of wheat increases relative to

Table 1.1 Resource names and definitions

1. Land (A)	Natural and biological resources, climate.
2. Labor (L)	Human resources.
3. Capital (K)	Manufactured resources, which include buildings, machines, tools, and equipment.
4. Management (M)	The entrepreneur, or individual, who combines the other resources into inputs.

soybeans and corn, farmers will plant more acres to wheat than they did previously. In a market system, prices drive the entire economy by conveying value, or by telling how much things are worth to producers and consumers. In a free market economy (capitalism), resources are allocated to the use that brings the highest returns. Crops are grown in California's Great Central Valley, but in the bordering foothills of the Sierra-Nevada Mountains, the land is too rocky and too steep for crops. Instead, the foothill land is devoted to grazing, which provides the highest return to this rocky area. Prices allocate resources; prices affect the incentives and behavior of both producers and consumers.

In a **Command Economy**, resources do not automatically flow to the producer earning the highest return or to the consumer who can pay the most for the product. Resources are allocated by whoever is in charge. Examples of command economies include Cuba, where resources are allocated by a dictator, Raul Castro (brother of Fidel Castro), and the former Soviet Union, where high-ranking members of the Communist Party used an elaborate committee system to decide how resources would be allocated. In many socialist countries such as Sweden, resources are allocated by an elected group of decision makers. However, a dictator who has complete control of the economic system could direct the use of resources. In either case, resources are allocated according to the discretion of a generally small group of decision maker(s) and decisions are made by considerations other than price. Resources don't always flow to the use that brings the highest return. The people who live in a command economy may desire more fruits and vegetables. If the government's goals are different from the citizens' goals, then these fruits and vegetables will not be produced. The land, labor, and other resources may be used in the production of beef or pork, rather than fruits and vegetables. The economic returns to producing crops may be higher, but it is up to the decision-making group to decide whether to produce fruit, vegetables, or meat.

Examples of market-based economies that are characterized by both political and economic freedom include the US, Australia, Canada, Japan, and the members of the European Union (EU). Nations that do not share political and economic freedom include North Korea, Cuba, and China. China has been moving towards a market-based economy since the 1980s, but remains a nation without many political rights and freedoms.

Most economic systems are **Mixed Economies** that have elements of both market economies and command economies. The United States has many markets that are free from government intervention. However, industries such as agriculture, transportation, and banking are regulated and often subsidized. Therefore, the economy of the United States is a Mixed Economy, although the nation prides itself on being a capitalist democracy. For many years the former Soviet Union (now Russia) and China were both considered to be command economies, where elected officials planned what goods were to be produced and who would get the products. However, beginning in the 1980s, changes in both countries moved their economic systems towards free markets, particularly in agriculture. The economies of these two nations are mixed economies, with elements of both market economies and command economies.

So, all real-world economies are a mixture of free market and command economies. The lessons in this book are primarily oriented to markets, since markets organize and allocate most resources in the United States.

1.5 A model of an economy

The model developed here describes any economy: market, command, or mixed. The individuals in the economy are divided into two categories: Firms (producers) and Households (consumers). In a subsistence economy, like Robinson Crusoe stranded on a remote island, producers and consumers are the same people: they must consume only what they produce. If there is no trade, the individuals have to produce all of their own food, clothing, and housing.

The major feature of a market economy is voluntary exchange. Producers and consumers are not forced to buy or sell anything. Even though this is true, the goods and services that consumers wish to purchase and consume must be produced. Resources are used to produce output. **Resources** are also called **Inputs**, **Factors of Production**, or **Factors** (economists use these terms interchangeably).

Table 1.2 shows the resources used to produce agricultural products. The model shown in Figure 1.1 is a simplified version of the real world. The real world is extraordinarily complex, so we must simplify it to understand it. One of the key elements of science is simplification

Table 1.2 Agricultural resources

Inputs = Resources = Factors = Factors of Production	*Payments*
1. Land (A)	rent
2. Labor (L) = operators, family, hired	wages, salaries
3. Capital (K) = machines, buildings, tools and equipment	interest
4. Management (M)	profit

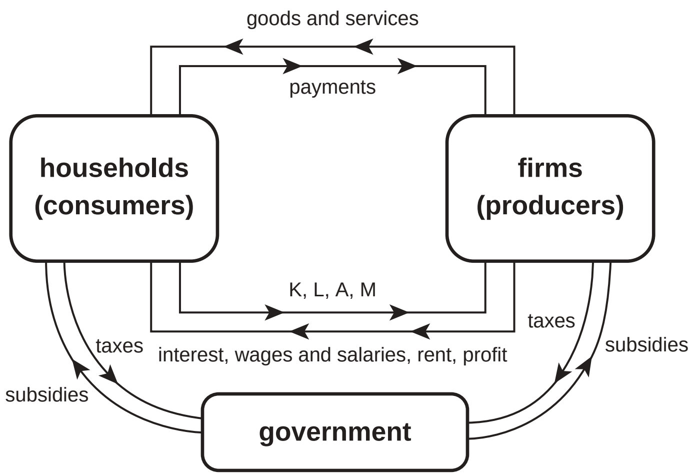

Figure 1.1 Circular flow diagram.

or modeling, also known as "reductionism." The model shown in Figure 1.1 fits with this need to use science to understand human behavior.

The arrows in Figure 1.1 show the flow of goods and services between households and firms. The two arrows across the top of the diagram show the movement of goods and services from producers (firms) to consumers (households). Households make payments to the firms to take possession of goods and services. In order to produce goods, firms must use **Inputs** (also called resources, factors, and factors of production). These resources are supplied by households, and include: **Capital** (K), **Labor** (L), **Land** (A), and **Management** (M). In economics, the term **Capital** refers to physical capital, such as machines, tools, buildings, and equipment. This contrasts with the typical use of the term, "capital," used to describe financial capital, which in most regards simply refers to money.

Firms make payments to households for the use of inputs. Interest pays for capital, wages and salaries pay for labor, rent pays for land, and profits are the payment to management.

If the lower box labeled "government" were omitted from Figure 1.1, the model would be one of a pure market economy. All real-world economies, however, include some form of government activity. Adding government to Figure 1.1 converts a market economy to a mixed economy. Both business firms and households must pay taxes to fund the government sector, and legislation allows the government to make payments to selected households and firms. These subsidies include payments to family farms, welfare checks to low-income households, schools, transportation, the postal system, and scores of other types of payments.

1.6 Trends in the agricultural economy

The main objective of this book is to show how economic knowledge (models, theories, and methods) can assist in the understanding of agriculture. Emphasis divides between learning economic principles and applying this knowledge to the agricultural sector. Some background information about modern agriculture in the United States is helpful.

Five trends affecting the agricultural industry are especially important and are presented before returning to the study of economics. Here is a synopsis.

Fewer and larger farms

Farm numbers continue to drop. The continuing consolidation of small farms into larger units is primarily due to technological change, including mechanization, the use of agricultural chemicals and fertilizers, and improved seeds. These changes allow for large farms to have lower costs per unit of production than small farms. Lower production costs on large-scale operations relative to small farms have resulted in huge consolidation of farms and changes in the structure of agriculture, especially during the past half-century. Farms have become fewer in number but larger and more productive.

Agriculture is not just farming

Production agriculture presently employs approximately 2 percent of the US workforce, but the food and fiber industry, which includes processing, transport, retailing, and dozens of other things, requires approximately 16 percent. Although it is true that "everyone eats food," the number of persons involved in production agriculture has decreased steadily over the last century.

Substitution of capital for labor

Over the past several decades, there has been an enormous movement toward mechanization, or replacing workers with machines. This trend stems from changes in relative prices. If it is less expensive to use machines than labor, machines will be used. For example, specialized machines are used to pick cotton. These are expensive machines, but using them is much less costly than using large crews of workers to pick the cotton by hand. The fast food giant McDonald's hires thousands of laborers at low wages. If there is an increase in the minimum wage, McDonald's will use more machinery, and hire fewer workers to operate the automatic French fry machines and drink dispensers.

Off-farm income for farm families has increased enormously

In earlier years, farming was the sole source, or at least the major source, of income for most farm families. In today's agricultural economy, most farm families rely not only on income from agricultural sources, but also on income from nonfarm jobs or investments. Typically, one individual in the family will do the farm work while another will work in a nonfarm position. With this arrangement, a farm family's total income will not be dependent on highly variable farm income alone. On average, farm families in the United States have higher levels of income and wealth than nonfarm families.

Exports are increasingly important to the agricultural sector

The nation's ability to produce ever-larger amounts of food has increased as a result of biological breakthroughs, mechanization, and improvements in management. The production of food has grown more rapidly than the domestic consumption of food. The United States has responded by exporting more and more food to consumers in other nations.

1.7 Using graphs

Graphs are often used to summarize and interpret economic information. Graphs can communicate a great deal of information in a small space, which makes them useful tools to see the most important aspects of a situation or decision. A graph is a "model," and economic analysis is often an exercise in modeling. Graphs simplify the presentation of data, and social scientists must simplify the real world in order to understand it.

Most graphs allow the viewer to look at the relationship between two variables while holding everything else constant. Holding all other things constant has a special name: ***Ceteris Paribus*** (Latin for "holding all else constant"). Much of economics has to do with understanding the relationship between two variables. The following demonstrates one of the most important concepts in economics: the demand curve. The demand curve shows the relationship between the price (P) and the quantity sold (Q) of an economic good. A graph isolates the relationship between price and quantity while all else (time, place, prices of other goods, income, etc.) is held constant (*ceteris paribus*). The two variables, price and quantity, can be shown simultaneously on a two-dimensional surface such as the chalkboard or a page in a notebook.

In economics, the horizontal axis along the bottom of a graph (the "x-axis") measures the value of one variable. In Figure 1.2, the quantity of a good (Q) is the measured variable on the x-axis. The numerical value of a second variable is measured from bottom to top along the vertical axis (the "y-axis") on the left-hand side of the graph.

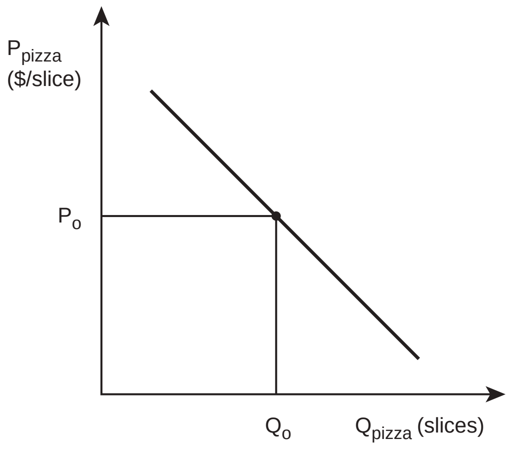

Figure 1.2 The demand for pizza.

The graph cannot be understood unless each axis has two items: **LABELS** and **UNITS**. In Figure 1.2, the label for quantity is Q (pizza), and the units are slices. The label for price is P and the units are ($/slice). Units are typically placed in parentheses.

To understand the graph, for a given number of pizza slices (Q_0), the price of pizza is equal to P_0. As the price of pizza increases, the quantity demanded of pizza decreases.

1.8 Absolute and relative prices

In a market economy, prices determine the decisions made by producers and consumers. Producers and consumers do not use a single price to make decisions, but rather it is the price of one good relative to the price of other goods that is important.

The difference between absolute and relative prices

- ***Absolute Price*** = a price in isolation, without reference to other prices. Example: The price of wheat is $3/bushel.
- ***Relative Prices*** = the prices of goods relative to each other. Example: The price of wheat increased relative to the price of corn.

The fact that the market price of wheat is equal to $3/bushel does not have much meaning when making a production decision about which crop to plant. Producers need to know the price of wheat relative to the price of alternative crops such as corn, cotton, and hay. This is because it is possible for the farmer to use the land to produce an alternative crop. The farmer desires to earn the highest possible level of profit on this land, so a good economic decision is one that takes into account the relative prices of all crops that can reasonably be grown on the land. In general, producers will react to a relative price increase by producing more of a good, since they will earn higher levels of profit by doing so. Consumers, on the other hand, will react to a price increase by buying less of a good.

Producer and consumer reactions to price changes are central to the lessons of economics. Later chapters will help explain how producers and consumers react to price changes. The following intuition will help in understanding economics.

> **Producers** prefer higher prices of the goods that they produce.
> **Consumers** prefer lower prices for the goods that they purchase.

Suppose that due to an increase in oil prices all crop prices increase by the same percentage. In this case, the relative prices for all crops remain the same, even though their absolute prices increase. All of the prices moved up together, so the relative prices all remained constant.

Consider the following statement: if all prices in an economy doubled, nothing would happen. At first glance, this does not seem to make sense. However, if it is known that all of the prices in the entire economy increased by the same percentage amount, in this case doubled, then relative prices remain constant, so producers and consumers would not change their decisions. Everything would cost the same relative to everything else.

Additional information suggests that if inflation were 10 percent for all goods in the economy, then the prices of everything would increase by 10 percent. This would be true for all goods, including labor services, so wages and salaries would increase by the same amount as the prices for goods. Nothing would happen, because all items in the economy would retain the same relative value. However, if oil prices were to increase due to a war in an oil-producing region near the Persian Gulf, then consumers would use less oil and more energy from other sources. To summarize, absolute prices are accounting devices, whereas relative prices are responsible for actual decisions.

Price units

The units used to express prices are crucial to understanding how producers and consumers behave. The price of a good is not just a number of dollars, it is dollars per unit ($/unit). The price of bread at Walmart is not just $1, but rather it is $1/loaf. The following list shows other examples.

Bread	$2/loaf
Wheat	$7/bushel
Pizza	$15/large pizza
Blue jeans	$60/pair
Car	$23,000/car

Prices are not expressed in dollars alone. Rather, prices are expressed in **DOLLARS PER UNIT**.

Constant-quality prices

The price of a good refers to constant-quality units. It means very little to say, "a pair of jeans," or "a large pizza." The statement must be more specific. Fortunately, specific qualities are often used in everyday conversation. For example, "I sold two pens of cattle," or "10,000 cars were sold today," or "five billion bushels of wheat were exported to Russia in February." Such specific statements tell exactly the type of good under discussion. Other examples are:

- "I sold two pens of heifers of average quality."
- "10,000 Jaguars were sold last month."
- "Five billion bushels of US #2 Hard Red Winter Wheat were exported in February."

Once again, a simplified real world describes what is happening.

1.9 Examples of graphs

A graph of the demand for hamburger in Miami, Florida

The demand (consumption) for hamburger is easily described using mathematics. How do consumers respond to a change in the price of hamburger in Miami, Florida? The numbers in the demand schedule in Table 1.3 show the relationship between the price of hamburger and the quantity of hamburger purchased in Miami's grocery stores.

The units are of constant quality. Specifying constant quality means that the entire quantity of hamburger in Table 1.3 is of the same quality. The units used for the hamburger price are dollars per pound (not just dollars) P = $/lb. In this example the units for the quantity of hamburger are assumed to be 1000 pounds, or Q = 1000 lbs. Figure 1.3 has both labels and units.

Quick Quiz 1.2

What are the labels and units in Figure 1.3?

As fewer pounds of hamburger are placed on the market in Miami, consumers are willing to pay a higher price for it. This is due to scarcity. The lower the availability of something, the more valuable that it is, *ceteris paribus*. Figure 1.3 demonstrates the relationship between the price and quantity of hamburger, and nothing else. Everything else is held constant.

Table 1.3 Hamburger demand schedule in Miami, Florida

Price ($/lb)	*Quantity Purchased (1000 lbs)*
2.30	0
2.10	20
1.90	40
1.70	60
1.50	80
1.30	100
1.10	120
0.90	140
0.70	160
0.50	180
0.30	200
0.10	220
0 (free!)	230

Plate 1.3 Hamburger demand in Miami, Florida.
Source: Shutterstock

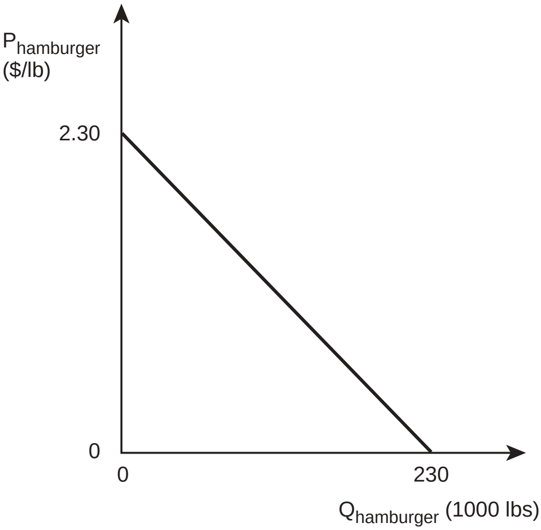

Figure 1.3 The demand for hamburger in Miami, Florida.

The graph simplifies the real world by omitting many otherwise important details. For example, if wages in Miami increase, will more hamburger be sold? Answering this question requires knowledge of income levels, and how they are associated with changes in the consumption of hamburger. In addition, the demand for hamburger is seasonal. People buy more hamburger during the summer months for outdoor cooking. This is ignored in the graph. In this example, as in other cases, simplification helps ease understanding.

The slope of a line

The same information can be viewed in a slightly different way using algebra. Remember that a **function** relates two variables, say x and y. The function y = f(x) reads as “y is a function of x.” The variable x is called the independent variable, since the value of x does not depend on any other variable. The y variable is called the dependent variable, since the value of y depends on the value that x takes. Restated, x causes y.

- x = independent variable
- y = dependent variable.

The expression y = f(x) is a general function that could take any form, linear or nonlinear. A more specific functional form is the linear form, which just means that the relationship between the two variables is a straight line. The linear functional form is:

$$y = b + mx. \tag{1.1}$$

This can be read, “y is a function of x, where b is the y-intercept, and m is the slope.” Armed with this simple algebra, the demand for hamburger in Miami becomes an equation, where P is the price of hamburger in dollars per pound, and Q is the number of 1000 lb units of hamburger purchased in Miami:

$$P = 2.30 - 0.01Q. \tag{1.2}$$

The demand for hamburger in Miami can be graphed using a different method. First, calculate the slope of hamburger demand in Miami. The slope is the rate at which a relationship increases or decreases. The slope is sometimes called the “rise over the run,” or the “change in y divided by the change in x.” In the hamburger case, the object is to find how much the price changes when the quantity of hamburger purchased changes. The symbol for change is a Greek letter delta: Δ. The slope is equal to:

$$\Delta y / \Delta x = \Delta P / \Delta Q. \tag{1.3}$$

In the case of hamburger in Miami in Figure 1.3, the slope equals: –2.30/230 = –0.01. Therefore, the slope of the demand line (m) equals –0.01, and the y-intercept (b) equals 2.30. This can be seen in the equation of the line, P = 2.30 – 0.01Q. The graph of this economic relationship can be derived from either the demand schedule or the equation of the line.

Example: veterinary clinic in Milwaukie, Wisconsin

Suppose a veterinarian charges $50 for a 60-minute appointment in her clinic next to the brewery in Milwaukie. The vet’s total revenue (TR) is equal to the number of appointments (Q) multiplied by the price of an appointment (P = $50/hour):

$$TR = P * Q = 50 * Q. \tag{1.4}$$

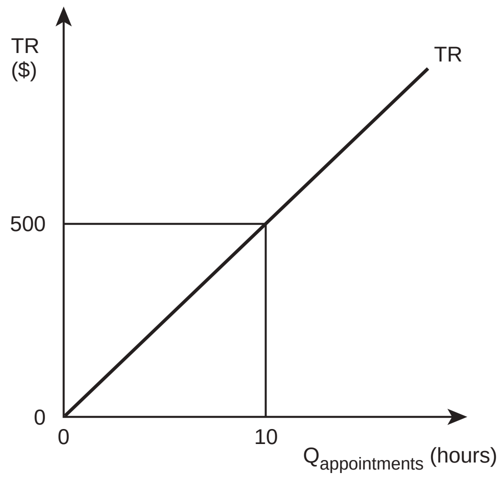

Figure 1.4 Total revenue for a veterinary clinic in Milwaukie, Wisconsin.

This economic relationship is a linear relationship. The slope of the line (m) equals 50, and the y-intercept equals zero.

The units for total revenue (TR) are in dollars because the price P is in dollars per hour ($/hr), and it has been multiplied times the quantity, in hours (hrs). The dollars represented by TR are the bills found in the clinic's cash register at the end of the working day.

When carefully drawn, graphs are useful tools to help organize thoughts about economic relationships. Good graphics require that every axis must include **labels** and **units**. Also, prices are always in $/unit, not just in dollars, and the units are constant-quality units. Several of the concepts discussed in this chapter will be used throughout the course. Since the content of this book is cumulative (all new concepts build on old concepts), students who learn each concept in the beginning will have a huge advantage as the book progresses. Chapter 2 introduces the concept of production, or how we turn inputs (resources) into economically useful outputs (goods).

1.10 Summary

1. Economics is important and interesting.
2. Economics helps us make better business, career, and personal decisions.
3. Goal of course: to learn to "think like an economist." Thinking like an economist provides a framework for understanding economic events, career decisions, and personal situations in a clear and precise manner.
4. Economics is a social science, which is the study of human behavior.
5. A producer is an individual or firm that produces (makes; manufactures) a product.
6. A consumer is an individual or household that purchases a product.
7. Individuals are both producers and consumers.
8. Macroeconomics is the study of economy-wide activities or events.
9. Microeconomics is the study of individual decision-making units.

10. Positive economics is based on statements that are factual and contain no value judgments ("what is").
11. Normative economics is based on statements that contain opinions or value judgments ("what should be").
12. Price increases help producers and hurt consumers, whereas price decreases help consumers and hurt producers.
13. Economics is about scarcity. Scarcity means that there is less of something than is desired.
14. An economic good is any good whose quantity cannot expand without an increase in price.
15. A noneconomic good is a good that is not scarce (a free good).
16. Scarcity forces us to choose. We can't have everything that we want.
17. Economics is the allocation of scarce resources among competing ends.
18. A market economy is an economic organization in which prices determine how resources and goods are allocated (capitalism; free markets).
19. A command economy is an economic organization in which resource allocation is determined by whoever is in charge (dictatorship; communism; socialism).
20. A mixed economy has elements of both a market economy and a command economy.
21. Resources are productive items used to produce goods and services to satisfy human wants and desires. Resources include land (A), labor (L), capital (K), and management (M).
22. Firms combine resources (K, L, A, and M) to produce goods and services. Consumers make payments to firms to obtain goods and services.
23. The agricultural economy is changing rapidly. Important trends include: (1) fewer and larger farms, (2) agriculture is not just farming, (3) substitution of capital for labor, (4) increases in off-farm income, and (5) exports are increasingly important.
24. Graphs are useful tools to summarize and interpret information.
25. Absolute prices refer to a single price level, whereas relative prices refer to the prices of goods relative to (compared to) each other. The economic decisions of producers and consumers depend on relative prices.
26. Prices of goods are expressed in constant-quality prices.
27. Every graph must have units and labels on each axis.

1.11 Glossary

Absolute Price. A price in isolation, without reference to other prices. Example: The price of wheat is $3/bushel (see **Relative Price**).

Agricultural Economics. Economics applied to agriculture and rural areas.

Agriculture. The science, art, and business of cultivating the soil, producing crops, and raising livestock useful to humans. Farming.

Capital. Physical capital: machinery, buildings, tools, and equipment.

Ceteris Paribus. Latin for "holding all else constant." An assumption used to simplify the real world.

Command Economy. A form of economic organization where resources are allocated by whoever is in charge, such as a dictator or an elected group of officials (see **Market Economy** and **Mixed Economy**).

Consumer. An individual or household that purchases a good or a service.

Economic Good. A good that is Scarce (see **Noneconomic Good**).

Economics. The study of the allocation of scarce resources among competing ends.

Free Trade Agreement. An agreement between nations to reduce or eliminate **Trade Barriers**.

Good. An **Economic Good**.

Macroeconomics. The study of economy-wide activities such as economic growth, business fluctuations, inflation, unemployment, recession, depression, and booms (see **Microeconomics**).

Market Economy. A form of economic organization in which resources are allocated by relative prices. Resources flow to the highest returns in a free market system (see **Command Economy** and **Mixed Economy**).

Microeconomics. The study of the behavior of individual decision-making units such as individuals, households, and firms (see **Macroeconomics**).

Mixed Economy. A form of economic organization that has elements of both a **Market Economy** and a **Command Economy**.

Noneconomic Good. A good that is not scarce; there is as much of this good to meet any demand for it. A free good (see **Economic Good**).

Normative Economics. Based on statements that contain opinions and/or value judgments. A normative statement contains a judgment about "what ought to be" or "what should be" (see **Positive Economics**).

Positive Economics. Based on factual statements. Such statements contain no value judgments. Positive statements describe "what is" (see **Normative Economics**).

Producer. An individual or firm that produces (makes; manufactures) a good or provides a service.

Relative Prices. The prices of goods relative to each other. Example: The price of wheat increased relative to the price of corn (see **Absolute Price**).

Resources. Inputs provided by nature and modified by humans who use technology to produce goods and services that satisfy human wants and desires. Also called **Inputs**, **Factors of Production**, or **Factors**. Resources include **Capital** (K), **Labor** (L), **Land** (A), and **Management** (M).

Scarcity. Because resources are limited, the goods and services produced from using those resources are also limited, which means consumers must make choices, or tradeoffs among different goods.

Service. A type of economic good that is not physical. For example, a haircut or a phone call is a service, whereas a car or a shirt is a good.

Social Science. The study of society and of individual relationships in and to society, generally regarded as including sociology, psychology, anthropology, economics, political science, and history.

Trade Barriers. Laws and regulations to restrict the flow of goods and services across international borders, including tariffs, duties, quotas, and import and export subsidies.

1.12 Review questions

1. Economics is:
   a. an agricultural science
   b. a social science
   c. a physical science
   d. not a science, but a field of study

2. A producer is:
   a. a person who purchases a product
   b. the seller of a product
   c. the buyer of a product
   d. a good sow
3. A consumer is all of the following except:
   a. a buyer
   b. a household
   c. a customer
   d. a firm
4. A North Dakota wheat farmer is an example of:
   a. a producer
   b. a consumer
   c. both a and b
   d. neither a nor b
5. The study of growth in Mexico's level of living is an example of:
   a. macroeconomics
   b. microeconomics
   c. political science
   d. consumer behavior
6. The study of how a single beef producer uses growth hormones is an example of:
   a. macroeconomics
   b. microeconomics
   c. biological science
   d. consumer behavior
7. The statement, "the market price of soybeans is $4.50 per bushel" is an example of:
   a. positive economics
   b. normative economics
   c. a value judgment
   d. consumer behavior
8. The statement, "the price of wheat should be higher" is an example of:
   a. positive economics
   b. normative economics
   c. a factual statement
   d. consumer behavior
9. If the price of wheat rises, who is made better off?
   a. producers
   b. consumers
   c. both a and b
   d. neither a nor b
10. An increase in the price of wheat is good for:
    a. wheat producers
    b. milling and baking firms
    c. bread consumers
    d. cattle producers
11. Scarcity affects:
    a. industrial firms
    b. agricultural producers

c. Internet users
d. everyone

12. Scarcity:
a. reflects limited resources and unlimited desires
b. affects religious persons
c. forces us to choose
d. all of the other three answers

13. An example of an economic good is:
a. a cookie
b. pollution
c. garbage
d. disease

14. The following is a noneconomic good:
a. a cookie
b. a sunset
c. a football
d. a Lexus automobile

15. In a market economy, resources are allocated by:
a. prices
b. whoever is in charge
c. an elected group of officials
d. a disaster

16. The United States is an example of:
a. a command economy
b. a market economy
c. a mixed economy
d. none of the other three answers

17. What percent of the US population is engaged in production agriculture?
a. 16
b. 3
c. 2
d. 25

18. If the price of corn increases relative to the price of other crops:
a. farmers will plant more corn
b. farmers will plant less corn
c. farmers will plant the same amount of corn
d. a corn consumer will purchase more corn

19. If the price of all crops increases, then:
a. farmers will plant more corn
b. farmers will plant less corn
c. farmers will plant the same amount of corn
d. a corn consumer will purchase more corn

20. The price of corn is written in which form?
a. $2
b. $2/bushel
c. 2 bushels
d. 2 bushels/$

Plate 2.1 The economics of production.

Source: Satin/Shutterstock

2 The economics of production

Synopsis

This chapter explores the physical production process. That is, it describes the physical relationship between inputs and outputs, and describes the economics of transforming inputs into products; resources into goods. The production function is defined and explained. Next, the effect of time on production is investigated by defining the immediate, short, and long runs. The role of physical production relationships is highlighted, with definitions for constant, increasing, and decreasing returns. Technological change and the law of diminishing marginal returns are used to enhance understanding of examples from food and agriculture.

2.1 The production function

The production of goods and services is a logical place to begin studying the economics of agricultural production. During the production process, firms, or producers, combine inputs into outputs for sale to consumers. The process can be quite complex, so the next several chapters discuss the production activities undertaken by firms. The discussion then shifts to the behavior of consumers, or households. All of this leads to consideration of the interactions of consumers and producers in markets.

Production is the process of producing goods and services. This process requires scarce resources. As shown in Chapter 1, inputs have several different names:

$$\text{Inputs} = \text{factors} = \text{factors of production} = \text{resources} = A,\ L,\ K,\ M \tag{2.1}$$

> **Quick Quiz 2.1**
>
> What do the letters A, L, K, and M refer to?

Wheat production in the high plains of North Dakota

Consider a wheat producer in North Dakota, a leading wheat producing state in most years. Let Y = output = wheat, measured in bushels (bu), where f = the mathematical relationship between inputs and output:

$$\text{Output} = f(\text{inputs}), \tag{2.2}$$

$$Y = f(\text{inputs}),\ \text{or} \tag{2.3}$$

$$Y = f(K,\ L,\ A,\ M). \tag{2.4}$$

The North Dakota wheat producer uses the inputs K, L, A, and M to produce wheat (Y). Chapter 1 included a short discussion of the need to simplify this complex relationship in order to understand real-world production. Graphs will lead to fuller understanding, but a two-dimensional graph is possible only if the number of inputs allowed to vary is reduced to one. Consider the relationship between inputs and outputs, and concentrate on just one input. In this case, the choice of capital is entirely arbitrary, since any one of the inputs could fit into the example.

Quick Quiz 2.2

How is capital defined in economics?
What four types of capital are included in this definition?

As in Chapter 1, the *ceteris paribus* assumption isolates the relationship between output and the single input, capital.

Quick Quiz 2.3

What does *ceteris paribus* mean?

Adopting a convention used by mathematicians helps clarify what is happening. A mathematician writes an equation to say that the variable Y is related to, or depends on other variables $x_1, x_2, \ldots, x_n$. The equation is written as:

$$Y = f(x_1,\ x_2, \ldots, x_n). \tag{2.5}$$

Box 2.1 The North American northern high plains region

Although the area has no precise definition, the North American High Plains encompass the Missouri River drainage, and parts of the states that lie east of the Mississippi River. The northern part of this region, including North Dakota, South Dakota, Nebraska, Kansas, Montana, Wyoming, and Colorado, is sparsely populated and is used primarily for farming and ranching. In 1910, the area supported nearly 550,000 farms. By the year 2010, the number had dropped to approximately 250,000 farms, a 55.4 percent decrease! Rainfall is scarce, so the farms of this region are devoted primarily to the production of small grains: wheat, barley, some corn, sunflower seeds, rye, and soybeans. Irrigation provides water for high-value crops in areas located above the Ogallala Aquifer. Hay grown in the region, primarily in Nebraska, Kansas, Oklahoma, and Texas, provides winter feed for large cattle herds. In 2010, these states produced 56.7 percent of the nation's wheat, 58 percent of its barley, 89.4 percent of its sunflower seeds, 41 percent of its cattle raised for beef, 24 percent of the corn, 21.8 percent of the hay, 21 percent of the soybeans, 56.3 percent of the nation's grain sorghum, and over 90 percent of the canola.

Source: USDA/NASS. http://www.nass.usda.gov/

Following mathematical convention, the variable "x_1" to the left of the vertical bar is free to vary, but all variables to the right of the vertical bar, in this case, $x_2,..., x_n$, are held constant:

$$Y = f(x_1 \mid x_2,...,x_n). \tag{2.6}$$

In this example of wheat production in North Dakota, only the variable to the left of the vertical bar (K) varies. The variables to the right of the vertical bar (L, A, and M) are held fixed, or constant. This enables the use of a graph to describe the multidimensional relationship on a two-dimensional surface. Real physical production is a complicated biological process. Therefore, one input at a time must be isolated:

$$Y = f(K \mid L,\ A,\ M). \tag{2.7}$$

This equation is what mathematicians refer to as a function. Economists provide a more descriptive term by calling it a "**Production Function**."

- ***Production Function*** = the physical relationship between inputs and outputs.

The production function is a purely physical relationship used to describe the quantity of inputs required to produce a given quantity of output. Since there are no dollar values associated with it, it is not an economic relationship.

Real-world production processes can be very complicated, making it difficult to understand the relationships among the constantly changing variables. Working with one variable at a time offers an approach to this problem. To determine the optimal use of the fertilizer nitrogen on wheat fields, agronomists can run controlled experiments to determine what happens to wheat yields as the amount of nitrogen is changed: either increased or decreased. They do this type of experiment on test plots, or small wheat fields that are typically adjacent to each other to keep constant the weather, growing conditions, and soil conditions across all of the plots. The idea behind the controlled experiment is to hold all inputs constant except for nitrogen, and measure how the different levels of nitrogen affect the wheat yields. The wheat production function would look like this:

$$Y = f(x_1,\ x_2,...,x_n). \tag{2.8}$$

Where Y is wheat output, measured in bushels (bu), f is the production function, or the physical relationship between inputs and output, and the x_i are inputs, which include land, labor, machinery, seed, and nitrogen. Specifying each input makes it possible to write the production function as:

$$Y = f(N,\ L,\ K,\ M,\ A). \tag{2.9}$$

Quick Quiz 2.4

What does each of the letters in this production function stand for?

To isolate the relationship between nitrogen and wheat yields, the agronomists (or other biophysical scientists) will hold constant all inputs other than the one that they are isolating, in this case nitrogen.

> **Quick Quiz 2.5**
>
> What is the term economists use for "holding all else constant?"

$$Y = f(N \mid L, K, M, A). \tag{2.10}$$

Knowledge of this relationship allows agronomists to identify the relationship between nitrogen and wheat growth. This relationship is highly important, since too little nitrogen means the yields will be lower than the potential, and too much nitrogen will "burn" the crop, causing smaller yields. Figure 2.1 shows the connection between nitrogen applications and wheat yields.

Here is a major lesson: the point of maximum physical wheat yield (N*) is not always the optimal economic wheat yield. This is because nitrogen is a scarce resource, and costs money to purchase. In fact, fertilizer is one of the major costs of production for farmers in most agricultural regions in the United States. If nitrogen were free, then the optimal application to a wheat field would always be N* in Figure 2.1, since this is the level of nitrogen that maximizes production. However, since it costs money to purchase and use fertilizer, the farmer will stop applying it at a point to the left of N*. Finding the optimal amount of nitrogen to apply requires application of economic principles. Economic reasoning will help determine the exact point where the benefits of using N minus the costs are maximized. For now, note that producers will not maximize production, because it costs too much. Instead, they will maximize profits. This problem will return for added explanation in Chapter 4.

A second example of a production function is a controlled experiment to find the impact of growth hormones (H) on beef production (Figure 2.2). Growth hormones are controversial since some consumers believe that the hormones are unhealthy for human consumption. Belief in this possibility is so intense that Europeans do not import American beef. Even so, cattle producers continue to use the hormones because they increase output significantly, and a vast majority of consumers in the US have not objected. A production function for beef can be written: Y = f(H, K, L, A, M).

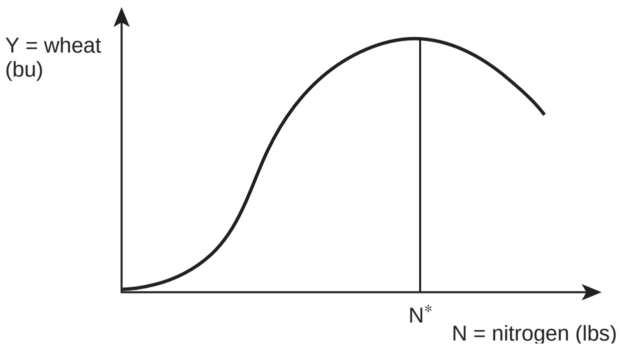

Figure 2.1 Wheat yield as a function of nitrogen application.

Quick Quiz 2.6

What do each of these letters stand for?
How are the growth hormones isolated in a scientific experiment?

Box 2.2 Nitrogen fertilizer use in US Agriculture

Fertilizer is an organic or inorganic material, of natural or synthetic origin, that is added to soil as a nutrient to promote plant growth. Recent studies have found that a large percentage of crop yields are attributable to commercial fertilizer use, causing a large percentage of the population to rely on synthetic nitrogen fertilizer.

Mined inorganic fertilizers have been used for many centuries. Chemical, synthesized inorganic fertilizers were developed during the industrial revolution leading to the British Agricultural Revolution, and the industrial Green Revolution of the twentieth century. Nitrogen fertilizers are made using the Haber-Bosch process (1915), which combines natural gas and nitrogen gas with a catalyst at elevated temperature and pressure to produce ammonia. Ammonia is then converted into nitrogen fertilizers such as anhydrous ammonium nitrate and urea.

The use of commercial inorganic fertilizers has increased rapidly in the last 50 years, rising almost 20-fold to the current rate of 100 million tons of nitrogen per year. In the United States, use of nitrogen in agriculture has increased steadily from 2.7 million nutrient tons in 1960 to over 12.2 million nutrient tons in 2010. Corn is the biggest user of nitrogen in US agriculture, with 5.6 million nutrient tons used in 2010, followed by wheat at 1.3 million nutrient tons, and cotton at 0.4 million nutrient tons.

Applying excessive amounts of fertilizer has negative environmental effects, and wastes the growers' time and money. Negative environmental effects can include eutrophication, or serious oxygen depletion, in the ocean, especially in coastal zones, and lakes, causing the inability to sustain aquatic wildlife. As a result, application of nitrogen fertilizer is monitored and regulated in the United States. Agricultural runoff into groundwater has also been linked to "blue baby syndrome," and soil acidification. Another concern is global warming, resulting from increased levels of nitrous oxide, the third most important greenhouse gas after carbon dioxide and methane. Since the benefits of using nitrogen fertilizer are large and significant to feeding a growing world population, nations and groups will need to compare carefully these benefits of increased food production with the potential environmental costs.

Source: Stewart, W.M., Dibb, D.W., Johnston, A.E., and Smyth, T.J. (2005). "The Contribution of Commercial Fertilizer Nutrients to Food Production." *Agronomy Journal* 97: 1–6.

Box 2.3 US beef production and consumption

Humans have consumed beef since prehistoric times. Globally, it is the third most common meat after pork and poultry. Domestication of cattle began around 8000 BC to provide a source of meat, milk, and leather. Cattle were also draft animals until mechanization began to occur in the sixteenth and seventeenth centuries AD. Now, in the twenty-first century, the United States, Brazil, and the People's Republic of China are the world's three largest consumers of beef.

Beef production occurs using two major methods: grass-fed on pastures, and grain-fed in confined pens, or feedlots. Feedlots, or concentrated animal feeding operations (CAFOs), typically feed cattle a ration of grain, protein, roughage, vitamins, and minerals. The world's largest exporters of beef are Brazil, Australia, and the United States. Beef production is also important to the economies of Paraguay, Argentina, Ireland, Mexico, New Zealand, Nicaragua, Russia, and Uruguay.

Beef is an excellent source of protein and minerals such as zinc, selenium, phosphorus, iron, and B vitamins. Recent health concerns from beef consumption include cancer, cardiovascular disease and coronary heart disease, dioxins from cattle raised in the United States fed on pastures fertilized with sewage sludge, E. coli contamination, and bovine spongiform encephalopathy (BSE or, colloquially, mad cow disease). Given the importance of beef in the US diet, consumers will need to continue to weigh the culinary and nutritional advantages of beef consumption with the food safety, environmental, and health concerns that arise because of modern, concentrated beef production.

Source: USDA/FAS. http://www.fas.usda.gov/psdonline/

The controlled experiment would use several pens of cattle with identical inputs (feed, water, temperature, bedding, etc.) except the level of growth hormone (H). The scientists would carefully measure and record the weight of each animal, and find the physical relationship between the growth hormone and the amount of muscle on the animal.

The shape of the graph in Figure 2.2 is similar to the graph of the wheat experiment shown in Figure 2.1. There is an "optimal" level of growth hormone for cattle production. Larger amounts of input will increase output only up to a certain point. After that, the high dose hormone input becomes toxic, and causes production to decrease.

The study of production functions applies to many situations, events, and circumstances. A student studying for an exam is involved with a kind of production. In this situation output (= Y) might be test performance, or grade, and the input (= X) is the number of hours that

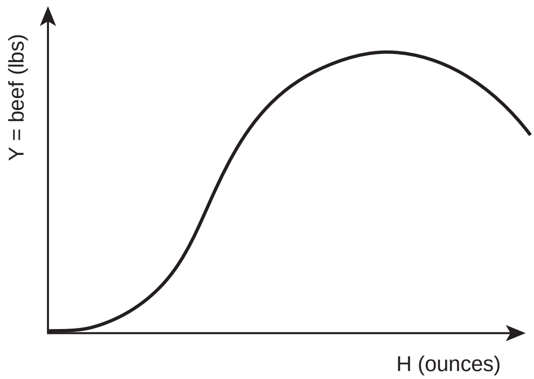

Figure 2.2 Beef output as a function of hormone use.

Plate 2.2 Hormone use in beef production.

Source: Sergey Goruppa/Shutterstock

Quick Quiz 2.7

Will the cattle producer use the level of growth hormones that maximizes production? Why or why not?

the student studies. The output of this production process will depend on how many hours the student studies and other factors, such as intelligence and previous knowledge. However, if the student constantly drinks coffee (or Mountain Dew) and stays up all night, the test performance may actually fall. Too much studying can result in too little sleep, which in turn results in poor test performance. Thus, the relationship between the number of hours studied and the grade on a test (Figure 2.3) will have the same general shape as the graphs for wheat production (Figure 2.1) and beef production (Figure 2.2). Because of differences in intelligence,

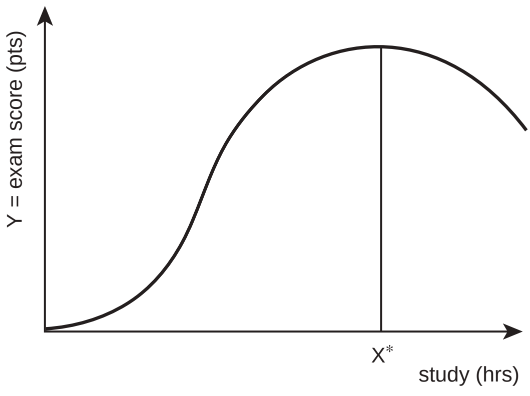

Figure 2.3 Grade as a function of study time.

preparation, alertness, and academic ability, each individual student will have a different "production function" for the examination.

Profit maximization

Economists build models on the assumption that all producers want to maximize profits. This is a simplification of the real world, since there may be producers who have other goals, such as a nice lifestyle, a clean environment, world peace, political power, or to pay employees more than the market wage rate. Although there are many producers who may not do everything in their power to maximize profits, this profit-maximization goal is a good first approximation. Why? Because any business owner who does not pay attention to potential profits is unlikely to remain in business for long in a market economy.

Profits, denoted by the symbol π (the Greek letter pi), have special meaning and importance in economics. Here, profits are defined as total revenue (TR) minus total costs (TC):

$$\pi = TR - TC. \quad (2.11)$$

- ***Profits* [π]** = total revenue minus total costs: $\pi = TR - TC$. The value of production sold minus the cost of producing that output.

Total revenue is simply the dollars earned from the sale of a good. Let the quantity of a good sold be given by Q units, and the price of the good by P dollars per unit. Then, the total revenue earned by the producing firm is equal to TR = P*Q. The units for total revenue are in dollars, since P is in (dollars/unit) and Q is in (lbs, bushels, dozens, or some other appropriate measure), when P is multiplied times Q, the units cancel and TR is in (dollars). Total costs represent the costs of production of the good, and are also in dollar units.

Producers of goods and services alter their production and marketing activities in a never-ending effort to maximize profits. The ability of business firms to make changes in how they produce and sell goods depends on the product that they produce. If the product is corn, major adjustments are possible at least once each year with a small number of changes occurring throughout the year. If the product is walnuts, major production decisions come only once in a generation, or even longer, but a small number of minor adjustments are possible during each growing season. If the product is lettuce grown in greenhouses, major adjustments occur almost continually. Time and timing are the critical issues. Length of time is of great importance in making profit-maximizing decisions.

2.2 Length of time: immediate run, short run, and long run

Radio announcers, politicians, and people on the street speak casually and knowingly about the "long run" and the "short run." In economics, however, these terms have specific meanings, but not meanings related to a specific length of time such as minutes, days, or weeks. The length of the long run, the short run, and the immediate run depend on the specific situation, as defined and explained in the next section.

Immediate, short, and long runs

The **Immediate Run** is a period of time during which all of the inputs available to a producer are fixed and cannot be changed. The producer cannot change the quantity of any input. A wheat producer purchases land, labor, seed, machinery, fertilizer, and chemicals. After the planting season, the producer is unlikely to be able to alter or use either more or less of the quantity of these inputs to affect the progress of the crop. This situation defines the immediate run.

- ***Immediate Run [IR]*** = a period of time in which all inputs are fixed.

As time passes, the producer will have more flexibility to change the quantities of inputs. In a three-month period, this producer is able to alter the number of hours of work hired, but cannot change the number of acres of land that are in production or, after a certain period, add more fertilizer. This situation is called the **Short Run**, defined as a period when some inputs are fixed (the quantities of inputs used cannot be altered) and some inputs are variable (the quantities of inputs can be changed).

- ***Short Run [SR]*** = a time span during which some factors are variable and some factors are fixed.

The quantities of some agricultural inputs are not easy to change in the short run. Land is a common example. Most producers cannot acquire more land in a short length of time. Therefore, the acres of land available to one producer remain fixed in the Short Run (SR). Similarly, machinery and equipment (combines, tractors, and plows) are very expensive, and many producers cannot rapidly increase or decrease the number of these inputs. During that period when a farmer is unable to alter the quantity of inputs, the inputs are fixed, and the farmer is in the Short Run (SR). However, in the short run, some inputs are variable. For example, the producer could alter the level of chemicals, fertilizer, labor, or management.

In the **Long Run** (LR), all inputs are variable.

- ***Long Run [LR]*** = a time span during which no inputs are fixed; all inputs are variable.

Over a longer period, a producer may buy or sell machinery or land. Producers can adjust the size of their farm. An agribusiness example is the agricultural implement manufacturer, John Deere, of Moline, Illinois. In the short run, "Deere" cannot build a plant to produce more combines since this would require purchasing land, building a factory, and training a labor force. However, in the long run (several years), Deere can build a new factory and start production of an expanded line of farm machinery. The crucial aspect regarding the short run and long run is that there is not a set length of time for the long run: the long run is however long it takes to adjust the levels of inputs. This differs from farm to farm and from business to business.

Now suppose that a farmer in the Northern Plains is able to increase his land holding in only two weeks (he is also a real estate broker). If all of the inputs on this farm are variable in a two-week time period, then the length of the long run is only two weeks. The length of time that defines the long run depends on the situation, and the willingness of the neighbors to sell land. Most farmers face a much different situation, as it can take many years to acquire new land.

A lemonade stand set up by the children living on a residential street provides a sharp contrast. In the lemonade business, the long run is very short. The children can alter the quantities of all inputs (water, glasses, lemonade mix, and stirring spoon) very quickly by running into the house. The long run may only last five minutes.

Box 2.4 Business cycles and agriculture

John Maynard Keynes (1883–1946) was a British economist whose ideas concerning the role of government spending made a large impact on macroeconomics and public policy. Famously, Keynes stated, “The long run is a misleading guide to current affairs. In the long run we are all dead.” Keynes was suggesting that government policy was more important in the short run, in the midst of an economic downturn. A major feature of market economies is that they are subject to periods of expansion and contraction. Economists call the fluctuations in the level of economic activity that occur over a long period of time, “business cycles.”

Early economists believed that these economic cycles were a regular and predictable feature of a market economy. In 1860, French economist Clement Juglar identified economic cycles that were 8 to 11 years long. In 1939, Austrian Joseph Schumpeter expanded this idea by identifying four stages in each cycle: expansion, crisis, recession, and recovery. In 1935, Russian economist Nikolai Kondratiev identified a long wave cycle of high growth and slow growth, lasting 45–60 years.

Modern-day macroeconomists now believe that fluctuations in the overall level of economic activity are not regular, and are less predictable than earlier cycle scholars thought. Contemporary business cycle scholars believe that economic growth and business fluctuations are not separate, unrelated events. Instead, they believe that business cycles result from shocks, such as new technology, which regularly affect most economies.

Recent research by Da-Rocha and Restuccia has shown that business fluctuations are related to the share of agriculture in the economy. Nations with higher percentages of agricultural employment are characterized by greater fluctuations in national output. However, the agriculture-based nations have lower volatility of employment. These authors also found that agriculture fluctuates more than the rest of the economy. Interestingly, the agricultural economy is not related to the overall economy, a result that is not surprising, since agriculture is small relative to the overall economy. Lastly, the authors found that the level of economic activity and the level of employment are not correlated in agriculture, but are correlated in the overall economy.

Sources: Cooley, T.F., Ed. (1995). *Frontiers of Business Cycle Research*. Princeton University Press.
Da-Rocha, J.M., and Restuccia, D. (2006). “The Role of Agriculture in Aggregate Business Cycles.” *Review of Economic Dynamics* 9: 455–482.
Kondratiev, Nikolai D. (1935). “The Long Waves in Economic Life,” *Review of Economic Statistics* 17(6) Nov.

Quick Quiz 2.8

How long are the short run and the immediate run for the lemonade stand?

Fixed and variable inputs

The discussion above provides the background necessary for the definitions of fixed and variable inputs.

- ***Fixed Input*** = an input whose quantity does not vary with the level of output.

The idea of a fixed input is a short run concept, because in the long run, all inputs are variable.

- ***Variable Input*** = a variable input is one that when changed, affects the level of output.

Quick Quiz 2.9

Are nitrogen and growth hormones fixed or variable inputs in the above examples?

2.3 Physical production relationships

Understanding the production function requires discussion of transforming inputs into outputs. Suppose a corn farmer in Iowa uses capital, labor, land, and management to produce corn. The generalized production function for his farming activity is:

$$Y = f(L, K, A, M). \tag{2.12}$$

Box 2.5 Iowa corn

Corn, wheat, and rice are the world's three leading grain crops. Corn as we know it descended from the plant "teosinte" in Mexico. Today, Iowa is the leading corn producing state, and Iowa, Illinois, Nebraska and Minnesota account for over 50 percent of the corn grown in the US. The "Corn Belt" includes these four states, together with Indiana, Ohio, Wisconsin, South Dakota, Michigan, Missouri, Kansas, and Kentucky. The story of corn is one of success: the original corn ears were only a few inches long, but centuries of plant breeding, first by Native Americans, then by early settlers and modern scientists, have resulted in larger ears, more kernels per ear, and more ears per plant. In 1900, corn yields in Iowa averaged about 40 bushels per acre. Iowa corn yields increased to about 50 bu/acre in 1950, and 90 bu/acre in 1970. In 2011, Iowa corn growers harvested an average of 172 bushels per acre. The national average in that year was 147 bushels per acre.

Corn is used for many purposes, the most important being livestock feeding, where one bushel of corn converts to about 5.6 pounds of retail beef, 13 pounds of retail pork, 28 pounds of catfish, or 32 pounds of chicken. An American grocery store contains several thousand products that list corn ingredients on the label. Iowa's corn is also processed into starches, oil, sweeteners, and ethanol. Iowa leads the nation in ethanol production, producing nearly 30 percent of all ethanol, and more than 3.6 billion gallons annually, using over 1.1 billion bushels of corn. One bushel of corn can produce 2.8 gallons of ethanol. Nearly one-third of the US corn crop goes to other nations including Japan, Mexico, Korea, Taiwan, and Egypt.

Source: Iowa Corn. http://www.iowacorn.org/

Understanding the impact of labor on corn output requires holding the levels of all other inputs constant:

$$Y = f(L \mid K, A, M). \tag{2.13}$$

The production function in equation (2.13) leads to an understanding of production efficiency, the topic of the next section.

Constant, increasing, decreasing, and negative returns

The level of inputs as reported in the production function determines the level of output (the production function describes the physical relationship between inputs and output). The production process can take on different forms: **Constant Returns**, **Increasing Returns**, **Decreasing Returns**, and **Negative Returns**. The word "returns" refers to changes in output that occur as quantities of inputs increase incrementally. Think of increasing the level of inputs by one unit at a time, and measuring how output responds to each change. This incremental way of approaching a problem is one cornerstone of "thinking like an economist."

In a production process characterized by **Constant Returns**, each additional unit of input is equally as productive as all other units of input.

- ***Constant Returns*** = when each additional unit of input added to the production process yields a constant level of output relative to the previous unit of input. Output increases at a constant rate.

Consider the number of cattle it takes to produce cattle hides: one animal produces one hide, no more, no less (Figure 2.4). Since each additional unit of input (in this case steers) produces exactly one additional hide, the slope of the production function for leather hides (= ΔY/ΔX) remains constant as more inputs are used, graphically demonstrating the concept of constant returns. The Greek letter Delta (Δ) refers to a small change.

Y = leather (hides)	X = cattle (steers)	Added Output (ΔY/ΔX)
0	0	–
1	1	1
2	2	1
3	3	1
4	4	1
5	5	1

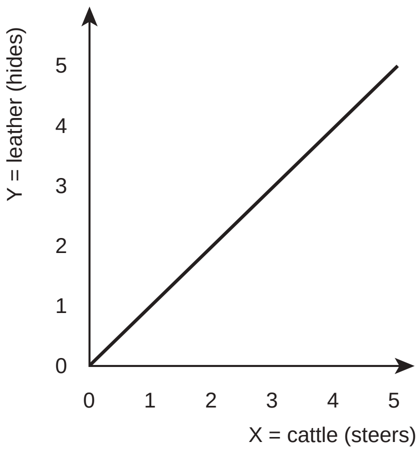

Figure 2.4 Leather production: constant returns.

- ***Increasing Returns*** = when each additional unit of input added to the production process yields an increasing level of output relative to the previous unit of input. Output increases at an increasing rate.

Managers of business firms look favorably upon this type of production process, since each additional unit of input is more productive than the one just before it. For example, if only one person tries to run both the combine and the truck during wheat harvest, the production process is inefficient. When a second worker drives the truck, the first person can spend all of her time operating the combine. As more workers join the harvest crew, holding all other inputs constant, the output increases at an increasing rate, as depicted in Figure 2.5. When **Increasing Returns** are present, each additional unit of input causes the level of output to increase more relative to the previous unit of input.

Quick Quiz 2.10

The production functions depicted in Figures 2.4 and 2.5 show an upward slope. Which of the graphs demonstrates increasing returns? How did you arrive at this conclusion?

Decreasing Returns occur when the addition of one more unit of input results in a smaller increase in output than the previous unit.

- ***Decreasing Returns*** = when each additional unit of input added to the production process yields less additional output relative to the previous unit of input. Output increases at a decreasing rate.

Figure 2.6 illustrates a production function that exhibits decreasing returns. Suppose the example takes place in a kitchen. As more chefs appear, the productivity of the cooks increases, but at a decreasing rate. The first cook is the most productive, but adding more

Y = wheat (bu)	X = workers (persons)	Added Output ($\Delta Y/\Delta X$)
0	0	–
10	1	10
30	2	20
60	3	30
100	4	40
150	5	50

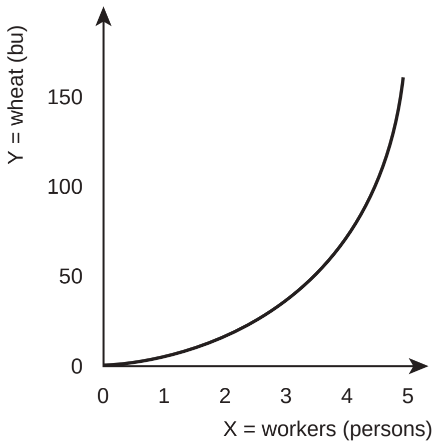

Figure 2.5 Wheat production: increasing returns.

cooks causes the additional productivity to decline. Why? They get in each other's way and compete for use of the kitchen equipment. **Negative Returns** occur when an additional unit of input actually decreases total output. In this situation the added input is harming the production process. The cooks in the kitchen example indicate how this can happen. If the kitchen is very small, the addition of the second cook lowers cook number one's ability to prepare meals. In many situations, adding inputs results in a loss in output. Applying too much fertilizer "burns" the wheat plants, and lowers the yield. Too heavy a dose of growth hormones lowers the weight gain in steers. Figure 2.7 illustrates negative returns.

- ***Negative Returns*** = when each additional unit of input added to the production process results in lower total output relative to the previous unit of input. Output decreases.

Y = prepared food (meals)	X = cooks (persons)	Added Output (ΔY/ΔX)
0	0	–
10	1	10
18	2	8
24	3	6
28	4	4
30	5	2

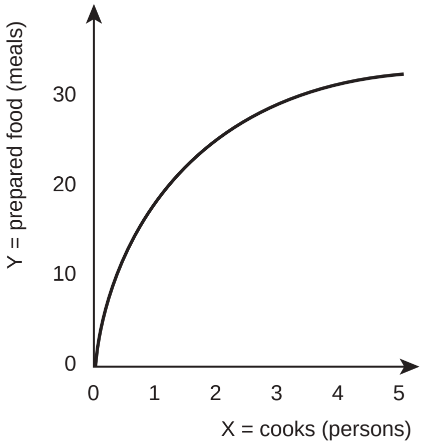

Figure 2.6 Food production: decreasing returns.

Y = prepared food (meals)	X = cooks (persons)	Added Output (ΔY/ΔX)
0	0	–
10	1	10
9	2	–1
7	3	–2
4	4	–3
1	5	–3

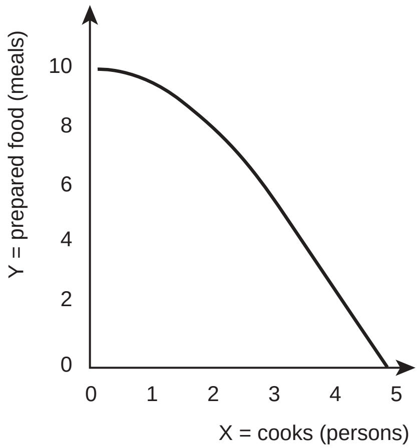

Figure 2.7 Food production: negative returns.

Plate 2.3 Negative returns: too many cooks in the kitchen.
Source: Robert Adrian Hillman/Shutterstock

The negative slope in Figure 2.7 corresponds to a production function characterized by negative returns. A situation of negative returns develops any time there is "too much of something."

A typical production function

Most production processes display stages of Increasing Returns, Decreasing Returns, and then Negative Returns. Why is this pattern so prevalent? Remember, the production function characterizes the physical relationship between output (Y) and a single input (X), *ceteris paribus* (holding all else constant).

The wheat farmer in North Dakota used land, labor, capital, and management to produce wheat. Suppose that this farmer has several thousand acres of wheat (farms of this size are not unusual in North Dakota), and holds all inputs constant except one: the number of combines. During harvest time, the first combine will allow this farmer to produce a large amount of grain. In fact, the mechanized combine got its name because it combined the reaping function (cutting and shocking the grain) with the threshing function (separating the wheat kernels from the straw and chaff). When compared to harvesting wheat by hand, even the earliest combines boosted production enormously.

The first combine can process a very large amount of output. A second combine will be helpful, and will allow the farmer to take advantage of having two combines working in the same field at the same time. This can actually increase production by even more than the first combine can, as efficiencies are gained with the logistics of the field and the trucks needed to haul the grain to the elevator.

This may remain true for the first several combines. However, after several combines appear for use in the same field, the efficiency begins to fall. Decreasing returns set in, as combines begin to get in each other's way. When many combines are used, production can

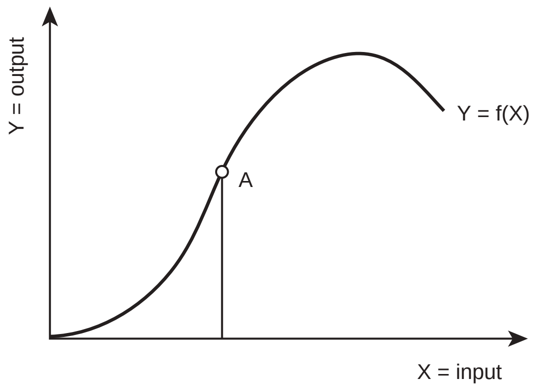

Figure 2.8 The typical production function and diminishing returns.

actually decrease, since the farm operator must manage too many machines for a given plot of land. Figure 2.8 shows the typical production function. Notice that this function has the same shape as the earlier examples in Figures 2.1 to 2.3.

In real-world production processes, this "typical" production function usually holds. As a single input is increased, holding all other inputs constant, the productivity will typically increase with the addition of more units of input. At a certain point, adding more of the input will still yield an increase in productivity but at a decreasing rate. This is the point in the graph where the slope of the production function turns from increasing to decreasing (point A).

Total physical product

The **Total Physical Product** (TPP) is the relationship between output (in this case corn) and one variable input (labor), holding all other inputs constant (Figure 2.9). The TPP of corn, typically measured in bushels, represents the maximum output for each level of input use. A table and graph of the TPP relationship for a corn farmer in Iowa appear in Figure 2.9.

- ***Total Physical Product [TPP]*** = the relationship between output and one variable input, holding all other inputs constant.

Average physical product

The **Average Physical Product** (APP) refers to the average productivity of each unit of variable input used (Figure 2.10). Dividing the quantity of output by the quantity of input (Y/X) yields the APP that tells the number of bushels produced by each individual unit across the entire quantity of input.

- ***Average Physical Product [APP]*** = the average productivity of each unit of variable input used [= Y/X].

Different graphs must be used for TPP (Figure 2.9) and APP (Figure 2.10), since they are expressed in different units. Specifically, TPP is in units of output, whereas APP is expressed in units of output per unit of input.

Labor (workers)	TPP = corn (bu)
0	0
1	10
2	21
3	33
4	40
5	45
6	48
7	42

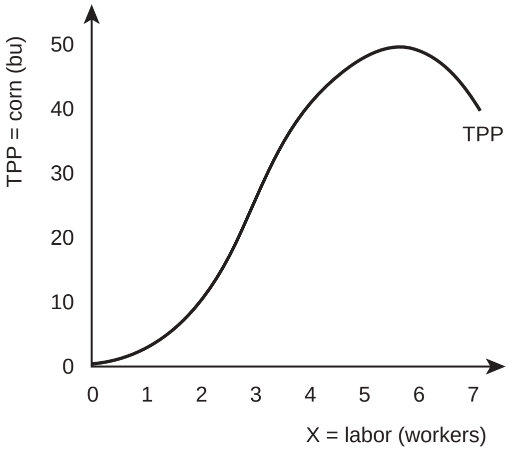

Figure 2.9 Corn production: total physical product.

Labor (wkrs)	TPP (bu)	APP (bu/wkr)	MPP (bu/wkr)
0	0	–	–
1	10	10	10
2	21	10.5	11
3	33	11	12
4	40	10	7
5	45	9	5
6	48	8	3
7	42	6	–6

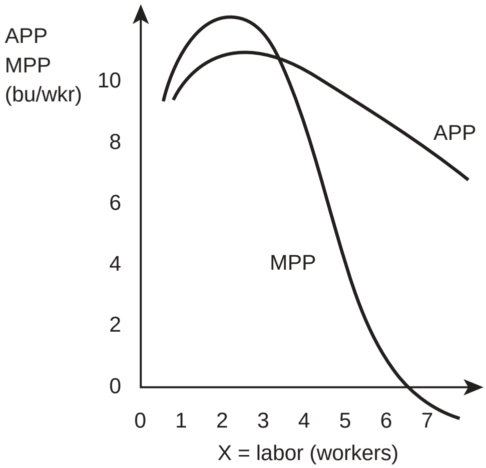

Figure 2.10 Physical product of corn: average and marginal product.

Marginal physical product

The **Marginal Physical Product** (MPP) is the physical product obtained from using one additional (marginal) unit of variable input (Figure 2.10). This concept tells how much more output comes from the last, or marginal, unit of input. Economists use the word, "marginal," to refer to the last, or additional, or extra unit of input or output. The term appears throughout the remainder of the book. Using mathematical notation, marginal refers to a "small change," symbolized by the Greek letter delta (Δ). The MPP is the change in output (ΔY) brought about by a change in input (ΔX).

$$MPP = \Delta Y / \Delta X. \quad (2.14)$$

- ***Marginal Physical Product [MPP]*** = the additional amount of total physical product obtained from using an additional, or marginal, unit of variable input [= ΔY/ΔX].

Figure 2.10 shows the Average Physical Product (APP) and Marginal Physical Product derived from the information related to inputs (X) and outputs (Y). Output is TPP (in this case bushels of corn). To derive APP, divide TPP (in the second column) by the number of workers found in the first column. In the first row, note that if there are zero workers, no corn is produced (TPP = 0). To calculate APP for the first row, divide TPP (= 0) by the number of workers (= 0), which is not possible, since a number divided by zero is undefined. Show this by placing a dash in the first row for APP. In the second row, divide TPP = 10 by X = 1 to get APP = 10. Similarly for the remaining rows: average productivity equals Y divided by X [APP = Y/X]. The graph shows that APP increases up to a given level, then decreases. Remember that the APP refers to the average productivity of all inputs used. Notice that the TPP curve must be graphed separately from the APP and MPP curves, since the units are different: TPP is in units of output, and APP and MPP are in units of output per unit of input.

Calculate Marginal Physical Product (MPP) in a similar fashion. The MPP is the change in output given a small change in input (ΔY/ΔX). To calculate MPP, look at a change in the input level, and calculate how much the output level changed as a result of the input change.

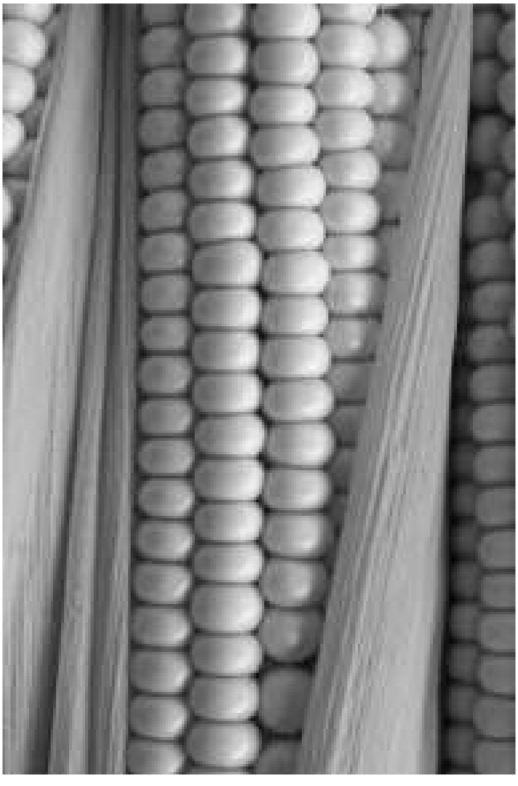

Plate 2.4 Corn production.
Source: Fonats/Shutterstock

Figure 2.10 shows that when the number of workers increases from zero to one [$\Delta X = 1 - 0 = 1$], output increases from zero bushels to 10 bushels of corn [$\Delta Y = 10 - 0 = 10$]. By definition, MPP = $\Delta Y/\Delta X = 10/1 = 10$, seen in the first entry in the MPP column in the table. The MPP refers to the productivity of the last unit of input, or the additional unit of input. Calculating MPP provides the answer to the question, "How much more output will be produced by adding one more unit of input?"

Look at the MPP of using a second worker. The change in input is one [$\Delta X = 2 - 1 = 1$], and the change in output is 11 [$\Delta Y = 21 - 10 = 11$]. The marginal productivity of labor increased with the addition of a second worker.

Quick Quiz 2.11

Calculate the APP and MPP from data in Table 2.1 for a beef producer. In this example, the input is bushels of corn fed to cattle and the output is meat in pounds.

The relationship between average and marginal physical product

The APP and MPP are both derived from TPP, and therefore have a direct relationship. The relationship is worth noting:

- If MPP > APP, then APP is increasing,
- If MPP < APP, then APP is decreasing.

An easy way to remember this is "Average Chases the Marginal." Figure 2.11 shows this in the graph of the APP and MPP data for output (wheat in bushels) per input (workers).

Grades in a university-level class show the same characteristic. When each test score appears, it is the marginal (or additional) grade. The average grade is the total number of points from all tests divided by the number of exams. Suppose that a student has taken two exams, and has an average grade of 80. If this student gets a perfect score of 100 on the next, marginal, exam the average grade moves up to 86.7. The average has followed the marginal to a higher level. Similarly, a professional basketball player who has a great night will pull his average points per game up.

When the marginal physical product is greater than the average physical product, the APP is increasing. In the case of a cattle feedlot, the production process is to add pounds of muscle to a steer by feeding it corn.

Table 2.1 Data for Quick Quiz 2.11

Corn (bu)	*TPP (lb)*	*APP (units =?)*	*MPP (units =?)*
0	0		
10	10		
20	40		
30	65		
40	80		
50	90		
60	80		

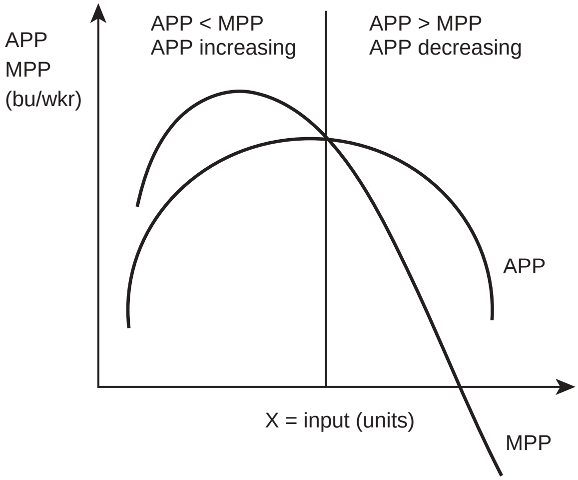

Figure 2.11 The relationship between average and marginal.

TPP = Total Physical Product
= Y = beef (lbs)
APP = Average Physical Product
= Y/X = beef/corn (lbs/bu)
MPP = Marginal Physical Product
= $\Delta Y/\Delta X$ = Δbeef/Δcorn (lbs/bu)

Quick Quiz 2.12

Draw the TPP, APP, and MPP graphs for the feedlot example in Table 2.1.

Technological change

The knowledge of productivity and the production function can help in understanding an important issue: **Technological Change**. An amazing number of technologies have appeared in the past decade or two: computers, software, cell phones, space travel, and health care. The Internet and the information age have all occurred recently, and have literally changed the world. Technological change allows production processes to become more efficient.

- ***Technological Change*** = change that allows the same level of inputs to produce a greater level of output. Alternatively, technological change allows production of the same level of output with a smaller number of inputs.

Graphically, technological change is an upward shift in the production function, as in Figure 2.12. Technological change shifts the wheat production function from Y_0 to Y_1.

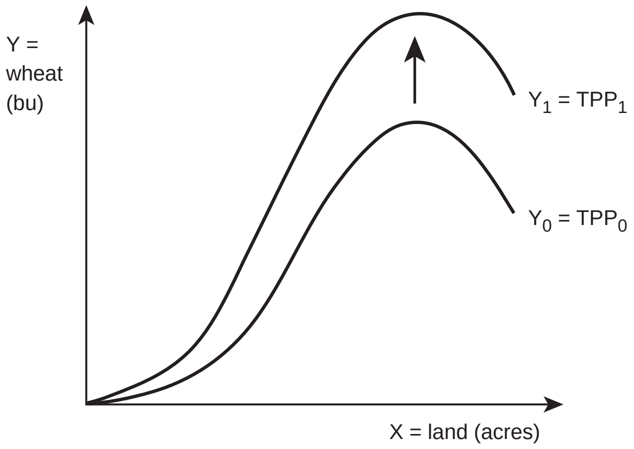

Figure 2.12 Technological change.

Box 2.6 Green revolution in India

Since the 1960s and 1970s, the term "Green Revolution" has described the development and adoption of high-yielding seed varieties in agricultural nations. The Green Revolution enhanced agricultural productivity enormously, and allowed India, food-short for decades, to become self-sufficient in food grains: wheat and rice. In the early 1960s, India endured a number of famines. After that, during the period from 1960 to 1990, Green Revolution techniques helped rice yields in India increase from 2 tons per hectare to 6 tons per hectare. Rice became more affordable, with rice prices dropping from over $550 per ton in the 1970s to a low of less than $200 per ton in 2001.

Norman Borlaug, an American agronomist named the "Father" of the Green Revolution, is credited with saving over a billion people from starvation through the development of high-yielding, or modern, varieties of cereal grains. These new varieties required irrigation, and application of agricultural chemicals and pesticides. This resulted in industrial growth to produce these inputs, providing more jobs in the Indian economy.

The Green Revolution provided large amounts of food that allowed India and other nations to feed a rapidly growing population. However, Indian agriculture faces future challenges. The modern varieties of rice and wheat require more water, and the water table is falling in some regions. As wells are dug deeper, salinity becomes a larger problem. The use of chemicals and fertilizer has resulted in an environmental challenge, and the purchase of modern inputs requires efficient sources of credit. As India moves forward, it will continue to evolve and solve these issues, making agriculture more productive, and feeding a growing world population.

Sources: Barta, P. (2007). "Feeding Billions, a Grain at a Time." *Wall Street Journal*, July 28: p. A1.
Zwerdling, Daniel (2009). "'Green Revolution' Trapping India's Farmers in Debt." National Public Radio. April 14. http://www.npr.org/templates/story/story.php?storyId=102944731. Retrieved July 25, 2012.

Technological change in cotton production is exemplified by the success of the cotton-breeding activities carried out by scientists in cotton-producing states. Using genetic selection and biotechnology, cotton breeders have been able to develop new varieties of seeds that result in higher cotton yields. Even holding all other inputs used in cotton production (land, chemicals, fertilizer, labor, etc.) constant, the new seed varieties result in higher yields. Technological change of this kind is not limited to cotton. Output per unit of input in nearly all aspects of agriculture continues to increase as new methods of farming and raising animals for food are developed and adopted.

Box 2.7 Cotton in Mississippi

Cotton is a major crop in Mississippi. It ranks third behind poultry and forestry in state commodities with nearly $600 million of revenue produced each year. Mississippi producers plant approximately 1.1 million acres of cotton annually. This number fluctuates, depending on weather and relative prices. In recent years, corn production has replaced some cotton acres in the Mississippi Delta Region. The highest acreage recorded in Mississippi was in 1930, when 4.163 million acres were planted to cotton. The highest production year was 1937 when 2.692 million bales were produced on 3.421 million acres. The highest cotton yields came in 2004 with 1034 pounds of lint produced per acre. This same year there were 2.346 million bales produced, almost as much as in 1937 with one-third of the acreage. This yield surpassed the previous yield of 934 lbs in 2003.

The production function for cotton has shifted greatly in the past few years, due to technological change. Advancements in cotton production include successful eradication of Boll Weevils, a major pest in cotton fields. The use of transgenic cotton varieties has increased, and a majority of Mississippi cotton producers now use transgenic varieties that eliminate some pests and save production costs. Reduced tillage techniques have enhanced cotton yields and increased profits.

Source: Cotton Production in Mississippi. http://msucares.com/crops/cotton/

2.4 The Law of Diminishing Marginal Returns

Knowledge of relationships between inputs and outputs allows examination of an economic "law" (meaning that the production relationship is universal). The name of this law is the **Law of Diminishing Marginal Returns**. Simply stated, this law means that as more of a single input is applied, the marginal increase in productivity will eventually decline.

- ***Law of Diminishing Marginal Returns*** = as additional units of one input are combined with a fixed amount of other inputs, a point is always reached at which the additional output produced from the last unit of added input will decline.

The "truth" in this law stems from one of the foundations of economics: scarcity. Adding more of a single input to a fixed quantity of other inputs means there are not enough of the other inputs to make effective use of the addition. Adding too much fertilizer to a potted houseplant does little good: the plant already has enough resources.

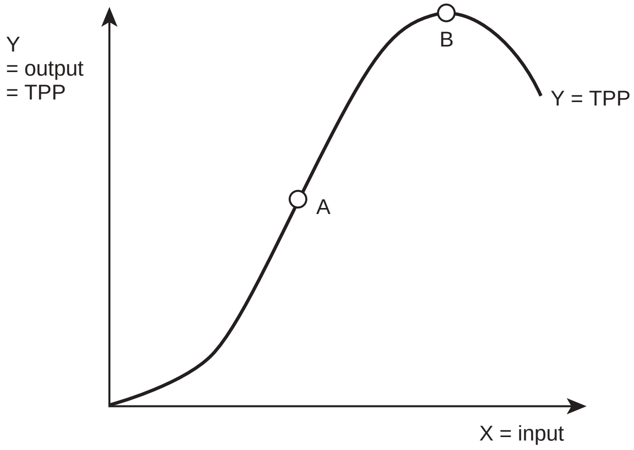

Figure 2.13 Diminishing returns.

If scarcity did not exist, adding inputs would allow the production of more and more goods and services. In this case, every consumer would have everything that he or she desired.

Other examples of the Law of Diminishing Marginal Returns are not hard to find. The first hour of studying is the most productive. After studying for several hours, a student's energy runs low, and productivity declines. This holds true for all productive activities. Crop production in the United States follows the same rule. When the European settlers reached North America, the most productive lands were cleared and planted first, because these lands produced the largest quantity of food. As more acres of land came into production, productivity per acre fell, because of the poor quality of the remaining land. This is in accordance with the Law of Diminishing Marginal Returns. Note that productivity need not be negative for the Law to hold, as is shown in Figure 2.13.

Diminishing Returns begin when the rate of productivity per unit of input begins to fall (point A in Figure 2.13). Put another way, diminishing returns set in when increasing returns are exhausted. Notice: a common mistake is to think that the Law of Diminishing Marginal Returns means that the returns to adding one additional unit of input are negative. The Law says that additional productivity must eventually decline.

2.5 The three stages of production

These concepts come together to provide a large amount of information regarding the economics of production processes. Assume that producers are "rational," which simply means that they desire to maximize profits associated with their production activity. If this is so, the lessons of this chapter show that a producer will always operate within a certain range of input use. Stage I of production is defined by a level of input use that is to the left of point A in Figure 2.14, where APP = MPP. Stage I is an "irrational" stage of production, in the sense that the producer can become more efficient if he or she increases the quantity of input used. The APP curve in Stage I shows this. The APP curve represents the average productivity of the production process. Since the average productivity is increasing, the producer could

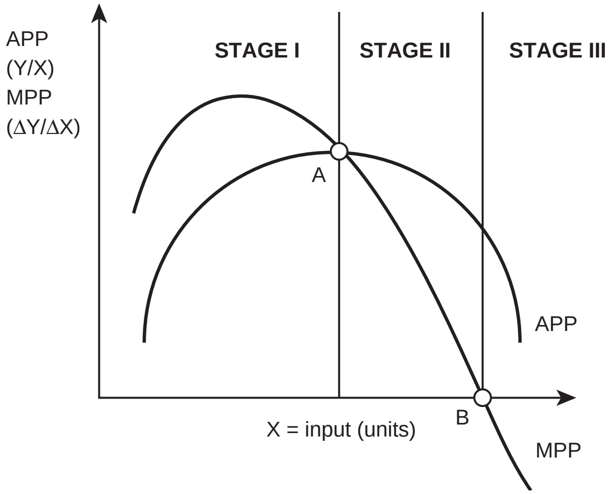

Figure 2.14 The stages of production.

become more productive by increasing the level of input use. Therefore, the rational producer will never locate in Stage I, because productivity could increase by using more inputs.

Stage III is also an irrational stage of production. The third stage of production includes all input levels greater than the point at which MPP becomes negative (point B in Figure 2.14). In Stage III, the producer is using too much input, since total productivity diminishes with each additional unit of input use. Total output would increase if the quantity of inputs were decreased. In other words, higher levels of productivity are possible at lower levels of input use (too many cooks in the kitchen lower the number of meals cooked). Stage II, the stage between Stage I and Stage III, is the "rational" stage of production, since the producer is operating in the region of input use that is most productive. The exact point of input use that is "optimal," or profit maximizing, depends on the price of the input, or the cost of acquiring the productive resource. This profit-maximizing point is the theme of Chapter 4.

2.6 Summary

1. Production is the process of combining scarce resources into outputs.
2. A production function shows the physical relationship between inputs and outputs.
3. The point of maximum physical output is not always the optimal economic level of output.
4. A two-dimensional graph of a production function shows the relationship between one input and one output, if all else remains constant.
5. Economists assume that the goal of all producers is to maximize profits. Profits are equal to total revenue (the value of production sold) minus total costs of production.
6. The immediate run is a period of time in which all inputs are fixed. In the short run, at least one input is fixed. The long run is a period of time during which all inputs are variable.

7. The length of the long run depends on the specific situation: it is the length of time that it takes for all inputs to become variable.
8. A fixed input does not vary with the level of output. A variable input does vary with the level of output.
9. A constant returns production function shows output increasing at a constant rate for each additional unit of input used. Increasing returns occur when an additional unit of input results in more additional output than the previous unit of input. A production function characterized by decreasing returns is one where each additional unit of input increases output, but at a smaller rate than the previous unit. Negative returns occur when total output decreases as a result of adding more units of input.
10. A typical production process passes through stages characterized by increasing returns, decreasing returns, and then negative returns.
11. Total Physical Product (TPP) is the relationship between output and one variable input, holding all other inputs constant. Average Physical Product (APP) is the average productivity of each unit of variable input (Y/X). Marginal Physical Product (MPP) is the amount of additional, or marginal physical product obtained from using an additional, or marginal, unit of variable input.
12. If MPP is greater than APP, then APP is increasing; if MPP is less than APP, then APP is decreasing. The average chases the marginal.
13. Technological change results in an upward shift in the production function. Technological change allows producing more output with the same level of inputs.
14. Stage I occurs when APP < MPP, or when APP is increasing. It is an irrational stage of production, since productivity increases with the increased use of input. Stage II occurs when MPP < APP, and MPP > 0. This is the rational stage of production. Stage III occurs when MPP < 0. Stage III is an irrational stage, since increased input use results in lower levels of total output. The rational producer will locate input use in Stage II.

2.7 Glossary

Average Physical Product [APP]. The average productivity of each unit of variable input used [= Y/X].

Constant Returns. When each additional unit of input added to the production process yields a constant level of output relative to the previous unit of input. Total output increases at a constant rate.

Decreasing Returns. When each additional unit of input added to the production process yields less additional output relative to the previous unit of input. Output increases at a decreasing rate.

Fixed Input. An input whose quantity does not vary with the level of output.

Immediate Run [IR]. A period of time in which all inputs are fixed.

Increasing Returns. When each additional unit of input added to the production process yields an increasing level of output relative to the previous unit of input. Output increases at an increasing rate.

Law of Diminishing Marginal Returns. As additional units of one input are combined with a fixed amount of other inputs, a point is always reached at which the additional output produced from the last unit of added input will decline.

Long Run [LR]. A time span during which no inputs are fixed; all inputs are variable.

Marginal Physical Product [MPP]. The additional amount of total physical product obtained from using an additional, or marginal, unit of variable input [= $\Delta Y/\Delta X$].

Negative Returns. When each additional unit of input added to the production process results in lower total output relative to the previous unit of input. Output decreases.

Production Function. The physical relationship between inputs and outputs.

Profits [π]. Total revenue minus total costs: $\pi = TR - TC$. The value of production sold minus the cost of producing that output.

Short Run [SR]. A time span during which some factors are variable and some factors are fixed.

Technological Change. Change that allows the same level of inputs to produce a greater level of output. Alternatively, technological change allows production of the same level of output with a smaller number of inputs.

Total Physical Product [TPP]. The relationship between output and one variable input, holding all other inputs constant.

Variable Input. A variable input is one that when changed, affects the level of output.

2.8 Review questions

1. The production function is:
   a. an economic relationship
   b. a physical relationship
   c. a mathematical property
   d. a party for producers
2. In the following production function, $Y = f(L| K, A, M)$:
   a. *ceteris paribus* does not hold
   b. labor is held constant
   c. land is allowed to vary
   d. labor is allowed to vary
3. Economists assume that producers attempt to:
   a. do the best that they can to get by
   b. maximize profits
   c. feed the world
   d. produce enough food to feed their family
4. Profits are equal to:
   a. costs of production minus revenue
   b. total revenue minus total costs
   c. average revenue minus average costs
   d. marginal revenue minus marginal costs
5. The long run is defined as:
   a. ten years
   b. one year
   c. depends on the situation
   d. when at least one input is fixed
6. If all inputs are variable except land for a wheat producer, then:
   a. the firm is in the short run
   b. the firm is in the long run
   c. the firm is in the immediate run
   d. the firm is not in production

7. A variable input is one that:
   a. changes with the weather
   b. moves up and down
   c. varies with the level of output
   d. varies with the level of other inputs
8. In decreasing returns, an additional unit of input added to a production process:
   a. increases output at an increasing rate
   b. decreases output
   c. increases output, but at a decreasing rate
   d. does not change output
9. When too much of an input is used, and output decreases, the production process results in:
   a. constant returns
   b. increasing returns
   c. decreasing returns
   d. negative returns
10. If average productivity is 20 bu/acre, and marginal productivity is 30 bu/acre then:
    a. average productivity is increasing
    b. average productivity is decreasing
    c. average productivity is constant
    d. average productivity is negative
11. The relationship between average and marginal is:
    a. average causes marginal
    b. marginal causes average
    c. average chases marginal
    d. marginal chases average

Plate 3.1 The costs of production.

Source: Cosma/Shutterstock

3 The costs of production

Synopsis

This chapter discusses the major motivating force behind all market-based economic behavior: profits. The economic concept of opportunity cost is highlighted, with examples of the next-best alternative in professional and personal decision making. A clear distinction between accounting profits and economic profits is explained. Special attention is given to cost relationships, including constant, decreasing, and increasing cost curves, and how they relate to production in real-world examples such as Walmart, feedlots, forestry, and packing plants.

3.1 Profits

The study of production assumed that the goal of a business enterprise in a market-based economy is to maximize profits. This assumption applies to all firms, whether they are large multinational corporations such as Microsoft or Cargill, or small family-owned businesses such as a family farm in Delaware or a family restaurant in Salem, Oregon. The study of costs of production begins with a simple definition of profits and how the level of profits relates to the costs of production. In the simplest possible form,

$$\pi = TR - TC \qquad (3.1)$$

Total Revenue (TR) refers to how much money a firm earns from the sale of its output (Y). Multiplying the number of units of output (Y) by the per-unit price of the output (P) yields total revenue:

$$TR = P * Y \qquad (3.2)$$

The units for TR are in dollars, since output (Y) times price ($/Y) is in terms of dollars. The units of output cancel each other.

The level of **Total Costs** (TC) measures the payments that a firm must make to purchase the factors of production. The production of a good or service transforms inputs into outputs. These inputs are not free, but require payments, because they are scarce. The sum of all of the payments for inputs describes the total costs that a firm must pay to produce a given quantity of a good.

Quick Quiz 3.1

Define scarcity. What implications does scarcity have for the production process?

Many commodity promotion associations present an award to the corn or wheat producer whose fields produce the highest yield per acre in the county or state. The award winner typically wins a cash prize, publicity in the local newspaper, recognition at the county fair, and Internet coverage. These contests and awards are interesting and even fun, but economists and agricultural economists who deal with commodity production are more interested in finding ways to help producers understand that the maximum level of profits differs from the highest level of production.

A yield contest encourages farmers to produce the maximum level of output. This requires large amounts of scarce inputs, and can be a costly activity. The contest winner will have total costs (the costs of the scarce inputs) that may be much higher than the market value of the crop. A simple graph of total revenue and total costs helps illustrate this.

In Figure 3.1, the vertical distance between the TR curve and the TC curve indicates the profits (π) accruing at each level of output. Total revenue, defined as price times output, is an increasing function of output (measured on the horizontal axis of Figure 3.1). Total revenue is a linear function of output, since the price of output is constant ($/Y). The more output that the firm produces and sells, the higher the level of TR.

Total costs also rise with increasing levels of output, but due to the law of diminishing marginal returns, the costs rise at an increasing rate. This means that the production process will at some point become less productive and more costly. What does this say about county yield contests? This careful look indicates that a farmer could very well be spending too much money on the inputs just to win the award.

From an economist's point of view, the emphasis should center on profits rather than yields. An economist would advise the producer to weigh the benefits and the costs of producing a higher yield with a full understanding that the maximum yield does not automatically bring the highest level of profits. It costs too much to achieve the maximum yield.

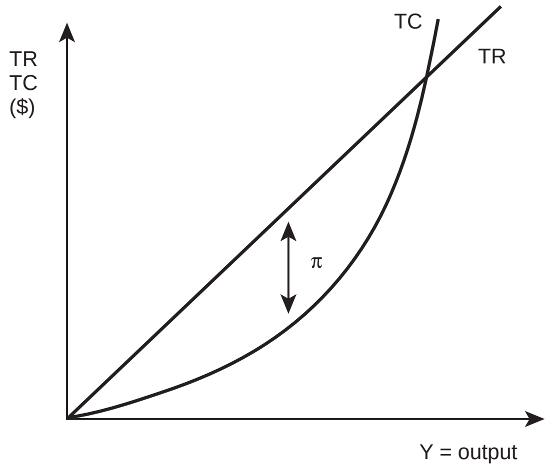

Figure 3.1 Total revenues, total costs, and profits.

To win the award, the farmer is spending too much on inputs. The producer may be better off backing away from thoughts relating to production and awards and looking at both the benefits and the costs of each activity or each level of one activity.

An economist would tell the producer to determine the level of input use and compare the benefits of the input to the costs of purchasing and applying it. If the benefits of using one more unit of input are greater than the cost of the input, it is profitable to use it. The producer, however, should not purchase the input if it costs more than the benefits that stem from its use.

The comparison of benefits and costs is one of the most important "take home lessons" from this course. In every activity, an economist will ask the question, "Do the benefits of this activity outweigh the costs?" If the rewards of the activity are larger than the costs, then the activity should be undertaken. This is true for producers deciding how much fertilizer to apply to their fields, or how much corn to produce, or for consumers trying to decide how many slices of pizza to eat, or for students deciding how many hours to study for an upcoming test.

This approach to decision making is enormously useful, and the approach is valuable. The salaries of Agricultural Economics and Agribusiness majors provide evidence that this is true: learning to think like an economist can provide many rewards in life, including greater financial rewards, improved personal decision making, and more career choices. The study of the costs of production will help students gain a better understanding of how to make solid decisions.

3.2 Opportunity costs

The entire issue surrounding cost takes on a new and slightly different complexion in economics. Because of this, there is a need to specify exactly what is meant by the term, "costs." Total costs include two types of costs: **Accounting Costs** and **Opportunity Costs**. Accounting costs are explicit costs, or payments that a business firm must actually make in order to obtain factors of production.

- ***Accounting Costs*** = explicit costs of production; costs for which payments are required.

Bookkeepers and accountants consider only accounting costs. Economists include opportunity costs, which are the value of a resource in its next-best use.

- ***Opportunity Costs*** = the value of a resource in its next-best use. What an individual or firm must give up in order to do something.

Opportunity costs exist for every human activity. By studying economics, a student gives up the opportunity to study the "next-best alternative," which might be studying biology, listening to music, partying, or seeing a movie. When individuals decide to become farm operators, they give up the opportunity to be a professor, or a mechanic, or whatever their next-best occupational choice might be.

Suppose a college student cannot decide between studying to be a soil scientist or a veterinarian. The trouble is the student cannot be both. If he becomes a soil scientist, his opportunity cost would be how much income he was giving up by not being a veterinarian. At another level, suppose that Jay-Z, who likely makes a fortune with his personality as an entertainer, actually would prefer to be a social worker. The opportunity cost of his being a social worker is what he would have to give up from his entertainment career: surely millions of dollars. Apparently, he prefers the millions to what might be a more satisfying life as a social worker. This concept of opportunity cost is quite powerful, and is useful in explaining both economic and noneconomic behavior.

All resources (and all occupational choices) have opportunity costs associated with them. The opportunity cost of planting one acre of land to cotton is the money lost by not planting the next-best alternative crop on that acre of land. Every resource has a "next-best use," so every resource has an opportunity cost. The key idea is that in economics, total costs (TC) always include both the accounting (or explicit) costs, and the opportunity costs, or what must be given up to use the resource. The following examples may help provide more confidence with this concept.

Profits (again!)

The definition of profit is $\pi = TR - TC$. Although correct, this definition says nothing about the categories of costs included in the definition. Some simple definitions and examples help clarify the issue.

Accounting profits

Accounting Profits are revenue minus only explicit costs. These profits are what accountants calculate, and reflect only the revenue and explicit monetary costs of producing and selling a good.

- ***Accounting Profits*** **[π_A]** = total revenue minus explicit costs. $\pi_A = TR - TC_A$.

Accounting profits do not consider opportunity costs. When opportunity costs are included as a cost item, the profit line shows economic profits, the pure profit left over after the opportunity costs of all inputs are subtracted from total revenue.

Economic profits

- ***Economic Profits*** **[π_E]** = total revenue minus both explicit and opportunity costs. $\pi_E = TR - TC_A$ – opportunity costs.

The opportunity cost of a wheat grower near Tulsa, Oklahoma

Consider a wheat farmer near Tulsa, Oklahoma. In this example, we will clarify the difference between accounting profit and economic profit. In Case One, suppose that this producer grows and sells 25,000 bushels of wheat at a price of $4/bu. Also assume that wheat production requires 10 months of managerial labor each year.

> **Quick Quiz 3.2**
>
> Define a production function.

Table 3.1 Oklahoma wheat producer production costs

Input	*CASE ONE (\$)*	*CASE TWO (\$)*
Chemicals	20,000	20,000
Machinery	20,000	20,000
Seed, Fertilizer	20,000	20,000
Land (rent)	20,000	20,000
Hired Labor	10,000	15,000
Total Accounting Costs	90,000	95,000
Opportunity Costs	10,000	10,000
Total Economic Costs	100,000	105,000
Total Revenues	100,000	100,000
Accounting Profits	10,000	5,000
Economic Profits	0	5,000

An easy calculation can be made to find that TR = \$100,000, as reported in Table 3.1.

> **Quick Quiz 3.3**
>
> Write out the steps taken in making this calculation.

The costs of production reported here are in round numbers to simplify the example. Actual cost data can be quite complicated. First, the explicit, or accounting costs only, are shown in the first column of numbers in Table 3.1, labeled Case One.

Continuing the story, suppose that an accountant adds up all of the accounting costs (explicit costs, which are the costs on the books) for this wheat producer. The total accounting costs (TC_A) are equal to \$90,000, the sum of all of the payments made for the inputs used in wheat production in Case One.

Calculating accounting profits yields (Table 3.1):

$$\pi_A = TR - TC_A = \$100{,}000 - \$90{,}000 = \$10{,}000 \quad (3.3)$$

Next, calculate the level of economic profits, and compare the results to accounting profits. Economic profit is what is left over after all costs including opportunity costs are deducted (π_E = TR – TC_A – opportunity costs). Restated, economic costs include both accounting costs and opportunity costs. Use the following formula to calculate economic costs:

$$TC_E = TC_A + \text{opportunity costs} = \$90{,}000 + \text{opportunity costs} \quad (3.4)$$

Opportunity costs are the value of a resource in its next-best use. Suppose that the Tulsa wheat producer could earn \$1,000/month in town as a salesperson with a farm implement dealer. In this case, the opportunity cost of this individual being a wheat producer:

$$\text{Opportunity cost} = 10 \text{ months} * \$1{,}000/\text{month} = \$10{,}000 \quad (3.5)$$

The levels of economic costs and economic profits for Case One (Table 3.1):

$$TC_E = \$90,000(\text{accounting costs}) + \$10,000(\text{opportunity costs}) = \$100,000, \tag{3.6}$$

$$\pi_E = TR - TC_E = \$100,000 - \$100,000 = 0. \tag{3.7}$$

At first glance, it appears that this wheat producer is not doing very well, since her economic profits are equal to zero. In reality, this is not a bad thing. The farmer is earning exactly what she is worth, or exactly her opportunity cost. The farmer's accounting profits are positive (= $10,000), which is exactly what she could be making in her next-best alternative job. So, oddly enough, when economic profits equal zero, all resources earn exactly what they are worth.

Box 3.1 Oklahoma wheat

Around 9000 years ago, domestic wheat originated in the Fertile Crescent, the area that includes the modern nations of Syria, Jordan, Turkey, Armenia, and Iraq. Wheat has been a crop in the United States since colonial times, but production expanded rapidly after 1870, when Russian immigrants brought Turkey Red wheat seed with them to Kansas. Wheat is the number one crop grown in Oklahoma. Most of the wheat grown there is a descendent of Turkey Red winter wheat and is used to make bread. This variety of wheat grows best in the harsh, dry climate of the Southern Great Plains in Oklahoma and Texas. Wheat is well adapted to harsh environments, and is a common crop in windswept areas too dry and too cold for rice, corn, or cotton.

Wheat is grown on more land area worldwide than any other crop, and is a close third to rice and corn in total world production. World leaders in wheat production include China, India, the United States, Russia, France, and Australia. Wheat supplies about 20 percent of the food calories for the world's people and is a staple in many countries. The per capita consumption of wheat in the United States exceeds that of any other single food staple.

Both whole wheat flour and all-purpose (white) flour are made from wheat kernels. A wheat kernel is divided into three major parts: bran, endosperm, and germ. All-purpose flour is made from only ground endosperm. Whole wheat flour is made by grinding the entire wheat kernel. A bushel of wheat weighs about 60 pounds, and yields about 42 pounds of white flour or 60 pounds of whole wheat flour.

Unlike most other crops, hard red winter wheat is planted in the fall and harvested in the spring. In summer, wheat producers prepare the soil for planting, and then plant the seed. The wheat plant will grow about six inches before the frost comes. When the weather gets cold the wheat plant will stop growing, beginning the dormant period. On most farms in Oklahoma, cattle feed, or graze, on the young wheat plants while they are in their dormant period. In the spring, warm weather causes the wheat plants to grow quickly. Some varieties of wheat grow as tall as seven feet, but most are between two and four feet tall. During the early summer, the plants begin to fade from dark green to tan and then to a golden brown. Then the wheat is ripe and nearly ready for harvest. Now the wheat producer must avoid rain, hail, and lightening to harvest the wheat. The farmer drives a combine across the fields to harvest the grain. When the storage bin of the combine is full, it is emptied into a truck. The truck is driven to the grain elevator in town. It takes a combine nine seconds to harvest enough wheat to make 70 loaves of bread.

Source: Oklahoma Ag in the Classroom. Wheat Facts. http://oklahoma4h.okstate.edu/aitc/lessons/extras/facts/wheat.html

Plate 3.2 Wheat production costs.
Source: Yaroslava/Shutterstock

A second situation, Case Two, assumes that the farmer continues to grow and sell 25,000 bushels of wheat at the prevailing market price of \$4/bu. Therefore, total revenue (TR) remains the same at \$100,000. However, in this case, suppose that the federal government increases the minimum wage, so that the wages paid to the hired help increase. Now, the cost of hired workers to help with wheat harvest increases to \$15,000, as shown in Table 3.1. To keep the example simple, assume that the increase in the minimum wage is the only change in the firm's costs of production. If all of this is true, then TR = \$100,000, and Case Two profits are reported in Table 3.1:

$$\pi_A = \$100,000 - \$95,000 = \$5,000, \tag{3.8}$$

$$\pi_1 = \$100{,}000 - \$95{,}000 - \$10{,}000 = -\$5{,}000. \quad (3.9)$$

In this case, the increase in the minimum wage results in negative economic profit. Interestingly, the farmer might stay in business. Why? Many farmers have strong ties to agriculture, and will try to stay in farming even if they earn negative economic profits. This is possible because the accounting profits are positive, so the bills are paid. As before, the farmer is giving up the possibility of earning more money in her next-best job. She gives up \$5,000 to remain in agriculture. This is a very realistic scenario for many persons employed in jobs such as agricultural production or teaching, where income levels are often low but the work is compelling, satisfying, or both.

If the farmer remains in agriculture with negative economic profits, she is violating the assumption that the objective of all producers is to maximize profits. Many individuals are content to work in a job that has rewards other than money. In the current study of economics, the assumption of profit maximization is maintained to simplify the analysis. The major conclusions of economics remain the same with or without the assumption.

ECONOMIC COSTS INCLUDE OPPORTUNITY COSTS!

Another example of economic costs relates to the full costs of attending college or a university. The explicit, or accounting, costs of attending school include tuition, fees, room and board, textbooks, football tickets, and the like. The opportunity cost is the value of a resource in its next-best use. In this case, the student is the resource and the opportunity cost is how much that student could earn in another field without a university-level education. Therefore, the full economic cost of attending college is not just the high cost of paying for the undergraduate education. It also includes the sacrifice of a salary and benefits that go with the job not taken in order to attend an institution of higher learning.

3.3 Costs and output

This section explores the relationship between the level of output produced by a firm and the costs of producing that output. Total costs will increase with increased output, since this increase requires additional levels of input. The added inputs are scarce and incur costs.

Quick Quiz 3.4

Should a firm always strive to produce the highest level of output?

Recall the definition of the short run. It is a period of time during which the quantity of at least one input cannot change. The number of acres of cropland in a farm provides an example. It is often difficult to change the size of a farm in a short period of time. Similarly, it may be difficult to change the size of any of the several small specialty shops or restaurants that seem to surround major university campuses. In each case, the availability of suitable land (space) seems to be the limiting factor. Each of these examples demonstrates that some inputs cannot adjust in the short run. They are "fixed."

Quantities of other inputs are variable in the short run, which means that their quantity is adjustable. For an Oklahoma wheat farm, variable inputs might include chemicals, labor, fertilizer, seed, machinery, and other items (Table 3.1). The items in this list are easy to change, even in a short period of time. Some inputs are fixed and some are variable, so costs break down into two categories: fixed costs and variable costs.

- ***Total Fixed Costs [TFC]*** = the total costs of inputs that do not vary with the level of output.
- ***Total Variable Costs [TVC]*** = the total costs of inputs that vary with the level of output.
- ***Total Costs [TC]*** = the sum of all payments that a firm must make to purchase the factors of production. The sum of **Total Fixed Costs** and **Total Variable Costs**. TC = TFC + TVC.

Fixed costs are payments to factors such as land or machines that are fixed in quantity in the short run. Variable costs are payments to factors whose quantity may change in the short run. Chemicals, labor, and fuel are included in this category.

Quick Quiz 3.5

How long is the long run?

In the long run, all factors are variable. This is because over a longer period of time, a producer can buy more machines and more land. Producers can adjust the size of their farm. There is no set number of years for the long run; it depends on the situation (the answer to Quick Quiz 3.5).

Since fixed factors do not vary with output, they must be paid in full, regardless of the level of output. Examples include (1) rent to the landlord that must be paid no matter what, (2) a payment to the bank for a loan taken out to purchase machines, (3) insurance on the buildings, and (4) property taxes. The key thing to remember about fixed costs is that they do not vary with output (Figure 3.2). Restating for emphasis:

FIXED COSTS DO NOT VARY WITH THE LEVEL OF OUTPUT.

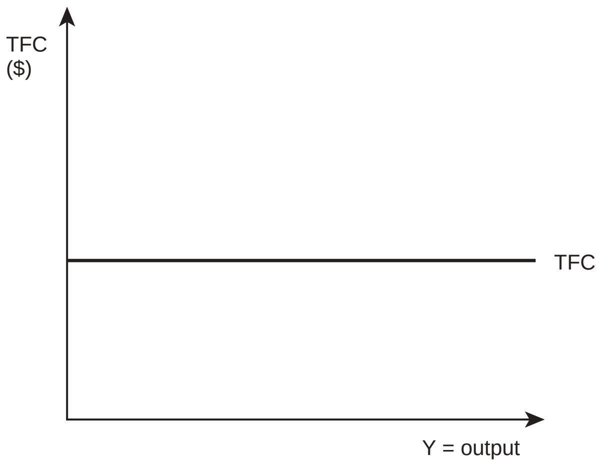

Figure 3.2 Total fixed costs (TFC).

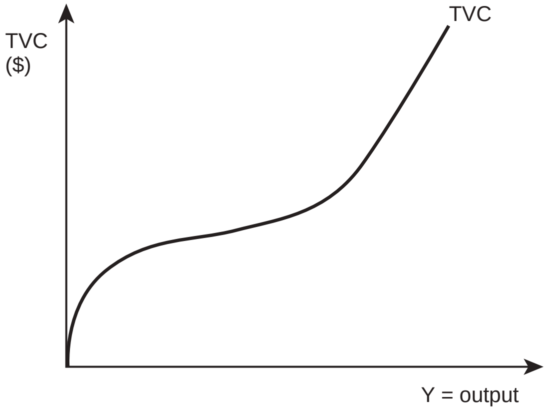

Figure 3.3 Total variable costs (TVC).

Variable costs are somewhat more intuitive: they vary with the level of output. In particular, they increase with the level of output, because producing firms must purchase more of these resources to increase the quantity of production. This is shown in Figure 3.3.

These costs increase for a wheat farmer, for example, because more labor and more chemicals are required to increase the production of the crop. The interesting shape of the TVC curve is due to the "typical" shape of the production function discussed in Chapter 2. The slope of the TVC curve is positive, but the slope decreases in the range of output near the origin. This reflects the increasing productivity of a production process as more inputs are added. Further to the right, the slope of the total variable cost curve begins to increase at an increasing rate, indicating its adherence to the law of diminishing marginal returns.

Quick Quiz 3.6

State the Law of Diminishing Marginal Returns, and explain the shape of the TVC curve.

Cost curves

Total costs (TC) are the sum of total fixed costs (TFC) and total variable costs (TVC). Graphically, this results in cost curves as shown in Figure 3.4, where TFC and TVC are added vertically to get the total cost curve (TC).

In addition to total costs, the average, or per-unit, costs of producing goods are of interest. Dividing the total costs (TC) by the level of output (Y) yields average costs: AC = TC/Y. Average total costs (ATC) provides the calculation of the average cost of producing a single unit of output. Calculating average fixed costs (AFC) and average variable costs (AVC) use the same steps:

- ***Average Fixed Costs [AFC]*** = the average cost of the fixed costs per unit of output. AFC = TFC/Y.

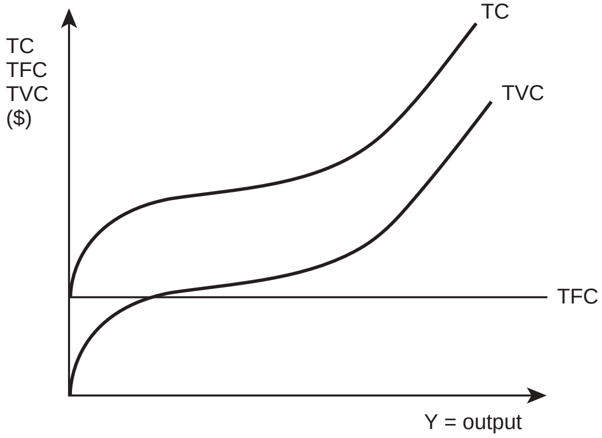

Figure 3.4 Total cost, total fixed costs, and total variable costs.

- ***Average Variable Costs [AVC]*** = the average cost of the variable inputs per unit of output. AVC = TVC/Y.
- ***Average Total Costs [ATC]*** = the average total cost per unit of output. ATC = TC/Y. Note that **Average Costs** (AC) are identical to **Average Total Costs** (ATC).

Marginal cost is the added cost of producing one more unit of output. The marginal, or incremental, costs help answer the question: "Do the benefits of producing one more unit of output outweigh the added costs?" The next chapter emphasizes this issue.

- ***Marginal Costs [MC]*** = the increase in total costs due to the production of one more unit of output. MC = ΔTC/ΔY.

The average, or per-unit, costs and marginal costs are shown on the same graph in Figure 3.5. This is possible because they share the same units: dollar per unit of output. Similarly, the total cost curves (TC, TFC, and TVC) are on the same graph (Figure 3.4) because all of these costs are in dollars.

The per-unit cost curves shown in Figure 3.5 are closely related to the total cost curves in Figure 3.4. These curves are the "typical" cost curves for a business firm that has the "typical" production function of increasing followed by decreasing returns. In Figure 3.5, the average total costs decrease, reflecting an increase in productivity, then increase, due to decreasing returns. The marginal cost curve cuts (from below) through the minimum points on the AVC curve and ATC curve.

3.4 Cost curve example: Vermont dairy farmer

A Vermont dairy farm provides a quantitative example, using cost curves similar to those introduced in the previous section. The fixed costs paid by the operator might include a rental payment to the landowner, or a payment to the bank for a loan on milking machines.

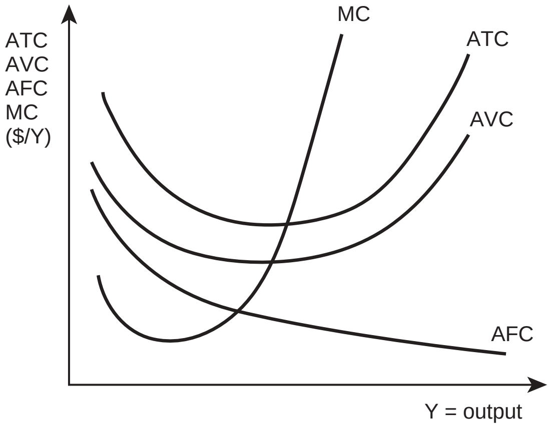

Figure 3.5 Average and marginal costs.

Quick Quiz 3.7

What are fixed costs? Why would a loan payment be a fixed cost? List one more input for this dairy that could be a fixed cost.

Plate 3.3 Vermont dairy cow.

Source: Len Green/Shutterstock

Variable costs might include payments for replacement cows, feed, veterinary services, medicine, electricity, and the like.

Quick Quiz 3.8

What are variable costs? Why would a loan payment be a variable cost? List one more input for this dairy that could be a variable cost.

The definitions of costs given above allow calculation of the total, average, and marginal costs for the dairy farmer. The total fixed costs are the payments for pasture rent, and the loan payment to the bank. Suppose that each of these payments is equal to \$5, so TFC = \$10, as seen in Table 3.2.

Box 3.2 Dairy farming in Vermont

European settlers brought dairy cows and sheep to Vermont from the Plymouth Colony in the 1600s. The period 1850 to 1880 was the greatest period of growth in Vermont agriculture, and dairy products became the foundation of Vermont's agriculture. In a time before refrigeration, dairymen frequently turned their milk into cheese or butter before it spoiled. The first vacuum-type milking machine appeared in 1865, but did not become commercially viable until the 1920s. The Vermont Dairyman's Association, formed in 1868, became a vocal and successful advocate for scientific breeding practices and the development of new technology. Vermont dairies produced high quality butter, primarily because of the continuous improvement in the dairy herd.

Though some farmers kept Holstein and Ayrshire herds, the Jersey breed predominated in Vermont because the high level of butterfat in their milk was desired for making butter. Mechanization and rural electrification in the first half of the twentieth century allowed for larger farms. Homogenization and pasteurization increased milk safety and consumer confidence, and by the 1950s, nearly all of Vermont's milk was pasteurized. Major advancements in refrigeration and transportation made Vermont the leading supplier of fluid milk to Boston. By 1915, there were nearly 300 butter factories in Vermont.

In 1937, the federal government established a milk pricing system to maintain a stable milk supply and in 1949, a support price system was established for dairy farmers. Through 1950–70, this system worked well for Vermont. The problem came as productivity increased at a more rapid pace than in other industrial sectors of the economy and production outpaced demands. The government programs could not continue to maintain a floor price without controlling the increased production. The government policy makers replaced the support price with a market-driven price.

Additional productivity increases came from conversion from milk cans to bulk storage, and from consolidation. Many small dairy farms went out of business as larger farms invested in new technology and grew. Fewer milk producers remained, but those that did, produced more milk.

Source: http://www.vermontdairy.com/learn/history/

Quick Quiz 3.9

If the dairy were to shut down in the short run, what would the fixed costs be? If the dairy were to double the number of cows milked in the short run, what would the fixed costs be?

The cost curve definitions and a table of costs appear in Table 3.2. The first three columns on the left side of the table (Y, TFC, and TVC) provide the basic data for completing the other columns.

$$TC = TFC + TVC \tag{3.10a}$$

$$ATC = TC / Y \tag{3.10b}$$

$$AVC = TVC / Y \tag{3.10c}$$

$$MC = \Delta TC / \Delta Y. \tag{3.10d}$$

Note that the units of output for the Vermont dairy farm are 1000 pounds of milk. Each unit of Y is equal to one thousand pounds of milk.

The first column in Table 3.2 is output (Y) in units of 1000 pounds. The second column is total fixed costs (TFC), which, by definition, do not vary with output. The TFC are constant at $10 for all units of milk produced.

Quick Quiz 3.10

Why do fixed costs not vary with the level of output? What do the fixed costs for this Vermont dairy farmer represent?

Total variable costs (TVC) appear in the third column. Variable costs change with the level of output, and increase as output increases. If the firm has the "typical" production process, the total variable costs increase at a decreasing rate, then at an increasing rate. Total costs

Table 3.2 Vermont dairy farm production costs

Y = milk (1000 lbs)	*TFC ($)*	*TVC ($)*	*TC ($)*	*ATC ($/Y)*	*AVC ($/Y)*	*AFC ($/Y)*	*MC ($/Y)*
0	10	0	10	–	–	–	–
1	10	10	20	20	10	10	10
2	10	18	28	14	9	5	8
3	10	23	33	11	7.67	3.33	5
4	10	30	40	10	7.5	2.5	7
5	10	40	50	10	8	2	10
6	10	56	66	11	9.33	1.67	16
7	10	74	84	12	10.6	1.43	18

(TC) are simply the sum of the total fixed costs and total variable costs (TC = TFC + TVC). All of the total costs (TC, TFC, and TVC) are in units of dollars.

Average total costs (ATC) are total costs divided by the farm's entire output (TC/Y). These per-unit costs decrease, then increase. Average variable costs are the total variable costs (TVC) divided by the level of output (TVC/Y). The AVC curve follows the same pattern as the ATC curve. The next column is AFC, or average fixed costs. This represents the payments to fixed factors per unit of output, found by dividing total fixed costs by the amount of milk produced (AFC = TFC/Y). Average fixed costs decline as more output is produced, because the dairy farmer is spreading the fixed payments (a constant numerator) over more units of output (an increasing denominator). Therefore, average fixed costs decline with larger quantities of milk produced. This provides an explanation about why many large agribusiness firms continue to increase in size: more output results in lower per-unit costs. Expansion of output can lower per-unit costs in many circumstances. This theme will appear often in the remaining chapters. Graphing these costs will provide a better understanding of their shapes and meaning.

Quick Quiz 3.11

Calculate the total, average, and marginal costs for the Vermont dairy farm in Table 3.2.

Total cost curves for the Vermont dairy farmer are shown in Figure 3.6.

Quick Quiz 3.12

Why are total, average, and marginal costs all shown in Table 3.2, but separate graphs are required for (1) total, (2) average, and (3) marginal costs?

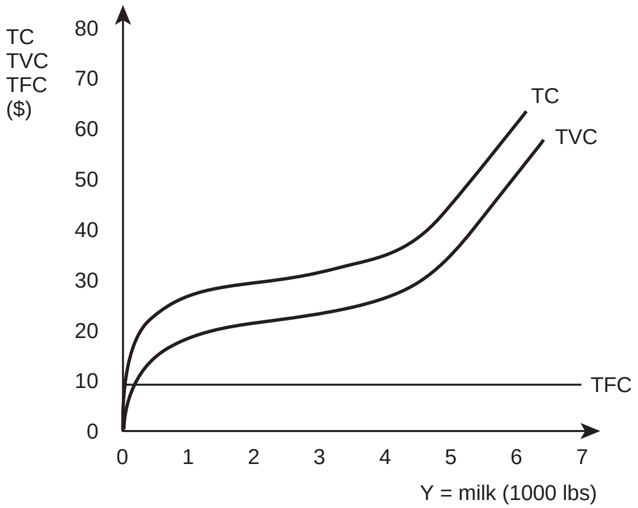

Figure 3.6 Total costs for Vermont dairy farm.

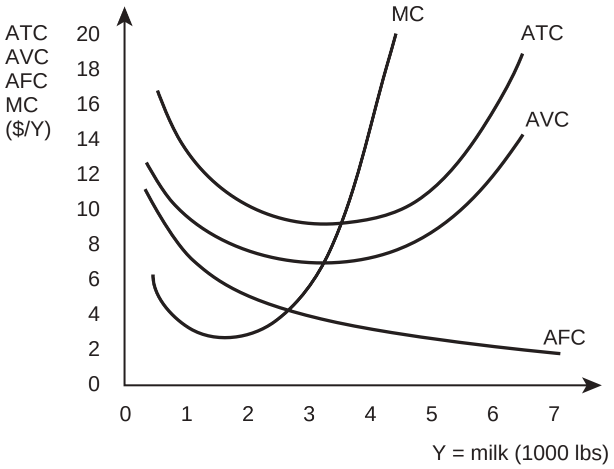

Figure 3.7 Per-unit costs for Vermont dairy farm.

> **Quick Quiz 3.13**
>
> Explain the shapes of the cost curves in Figures 3.6 and 3.7.

The cost curves for the Vermont dairy farm have the same shape as the cost curves derived above in Figures 3.4 and 3.5.

3.5 Where do cost curves come from?

The costs of production are directly related to the productivity of a firm. By most definitions, an efficient firm will have lower per-unit costs of production. This section makes the connection between the physical product curves (from Chapter 2) and the cost curves introduced in this chapter. Recall that the production function is the physical relationship between inputs (X) and output (Y), as in equation (3.11).

$$Y = f(X_1, X_2, \ldots, X_n). \tag{3.11}$$

Since graphs and paper have only two dimensions, the relationship between one input and output is isolated and graphed while holding all other inputs constant.

$$Y = f(X_1 \mid X_2, \ldots, X_n). \tag{3.12}$$

Figure 3.8 is a graph of the typical production relationship of increasing then decreasing returns in production, together with cost curves that are increasing at a decreasing rate, then increasing at an increasing rate.

The relationship between physical product curves and cost curves is shown in the per-unit graph in Figure 3.9. The average and marginal product curves in the top half of the diagram

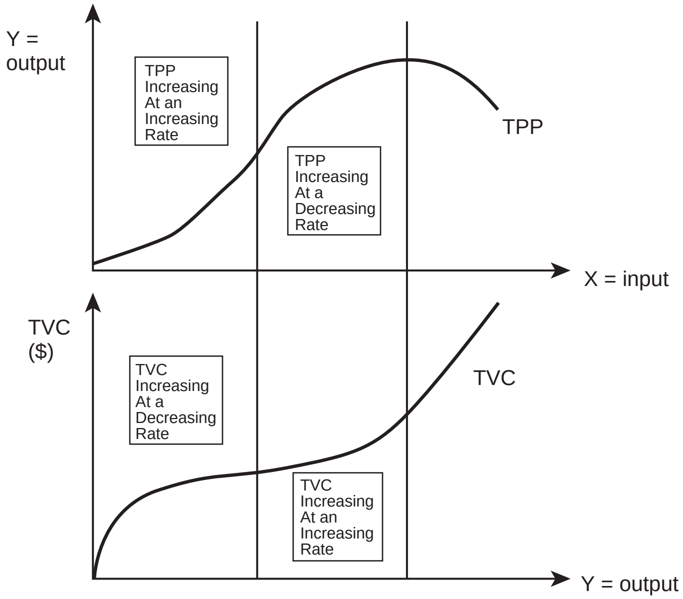

Figure 3.8 The relationship between total costs and total productivity.

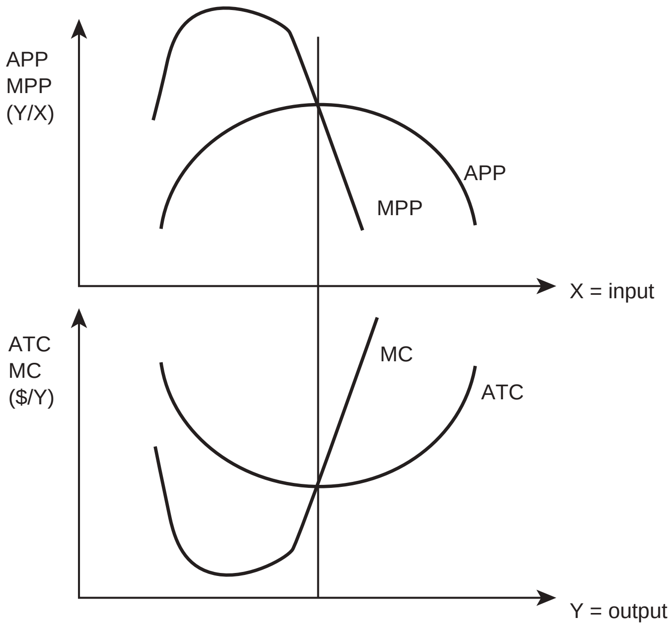

Figure 3.9 The relationship between per-unit costs and per-unit productivity.

are a mirror image of the average and marginal cost curves in the bottom half of the diagram. Mathematically, this inverse relationship demonstrates that the total variable costs of a firm are the payments made to the variable inputs. In this case, input X_1 is variable, with all other inputs held constant. Let P_1 be the price of input X_1.

$$TVC = P_1 * X \tag{3.13a}$$

$$AVC = TVC/Y \tag{3.13b}$$

$$APP = Y/X_1 \tag{3.13c}$$

Simple substitution allows for the following result:

$$AVC = TVC/Y = P_1 * X_1/Y = P_1 *(X_1/Y) = P_1/[Y/X_1] = P_1/APP. \tag{3.13d}$$

This result shows that the AVC curve is inversely related to the APP curve, as in Figure 3.9. Similarly, the marginal cost curve is inversely related to the MPP curve:

$$MC = \Delta TC/\Delta Y = \Delta(P_1 * X_1)/\Delta Y = P_1 *(\Delta X_1/\Delta Y) = P_1/[\Delta Y/\Delta X_1] = P_1/MPP. \tag{3.14}$$

This result shows that marginal costs and marginal physical product are inversely related. Figure 3.9 summarizes the close connection between physical product curves and cost curves: an increase in productivity (increase in APP) occurs along with a decrease in costs (decrease in ATC). The relationship between average and marginal costs is the same as the relationship between average and marginal physical products.

The relationship between average and marginal costs

As noted in Chapter 2, "The average chases the marginal." This means that:

If MC > AC, then AC is increasing, and (3.15a)

If MC < AC, then AC is decreasing. (3.15b)

Here, average costs (AC) can refer to either average total costs (ATC) or average variable costs (AVC). The result above occurs because the marginal cost is the additional cost associated with producing one additional unit of output. If this marginal cost is larger than the average, it "pulls" the average up. If MC, the additional costs of producing the last unit, is smaller than the average, it "pulls" the average down.

This relationship between average and marginal: "average chases marginal," is true for many examples: grades, costs, and revenue.

Quick Quiz 3.14

Graph the relationship between average and marginal grades.

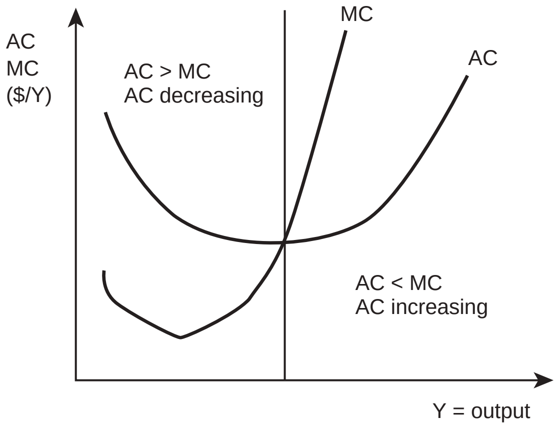

Figure 3.10 The relationship between average costs and marginal costs.

3.6 Constant, decreasing, and increasing cost curves

Four types of cost curves are possible: constant, decreasing, and increasing cost structures, as well as the "typical" cost curves explained above.

Constant cost firm

A constant cost firm is one that faces constant production costs for all units of output produced. In such a firm, the first unit of output produced costs the same as the last unit of output produced. An example is a feedlot. The operators fatten cattle until they are ready for slaughter.

Plate 3.4 Cattle feedlot.

Source: Tyler Olsen/Shutterstock

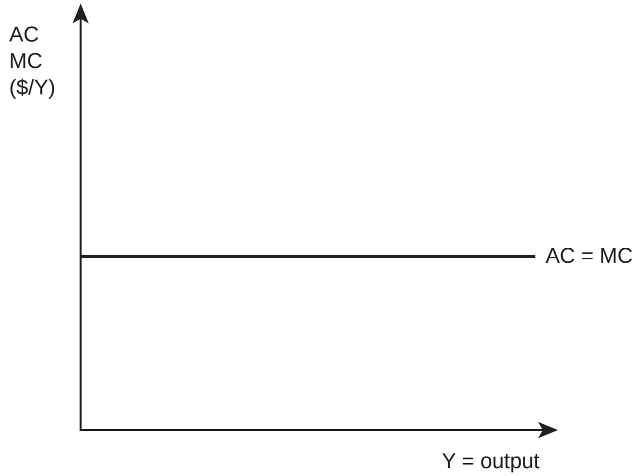

Figure 3.11 A constant cost firm.

The fattening process is one of feeding the cattle large quantities of feed (corn, sorghum, and soybean meal) together with some vitamins and nutritional supplements. A typical feedlot pays the same amount for each bushel of feed, no matter how many steers are in the lot. Figure 3.11 shows that the firm pays the same amount for inputs.

Regardless of the number of units produced, the per-unit cost is the same at a given point in time. Since the marginal cost of producing a unit of output is fixed (constant), then MC is horizontal and AC = MC. The average chases the marginal, but in this specific case, it has "caught" it! For a constant cost firm, the average costs (AC) equal the marginal costs (MC), as shown above.

Decreasing cost firm

Decreasing costs occur when the per-unit cost of a firm's output declines as output increases. An example of a decreasing cost firm is the meat packing plant in Nebraska. Packing plants, also called slaughterhouses, convert the fattened cattle into steaks, hamburger, and leather. These are often very large facilities, with enormous electricity, water, and labor requirements. Because of this huge size, each additional pound of meat can be produced at a lower per-unit cost, since the large fixed costs (the electricity, water, and labor) are spread over more units of output. Since MC < AC, AC is decreasing. The huge fixed costs mean that greater productivity comes at lower costs per unit of output, as shown in Figure 3.12.

Other examples of decreasing cost industries include Walmart and social networks. In a decreasing cost firm, the MC curve always lies below the AC curve, and the AC curve is declining. Other examples of declining cost firms include power generating plants, cable television companies, and city water systems. These examples are all firms that require a huge network, or distribution system. The high costs of installing power generators and power lines to every house in the network region result in a decreasing cost structure for an electricity plant. This also holds true for cable television companies, which must invest large amounts of money to develop the cable network throughout town. The more customers who

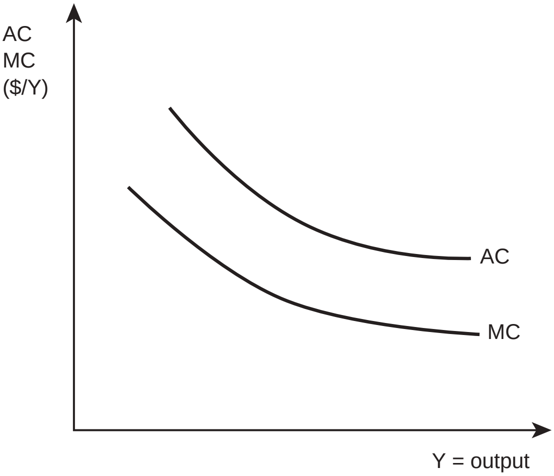

Figure 3.12 A decreasing cost firm.

Box 3.3 Walmart

Walmart is the largest retailer in world history, with millions of global customers. Sam Walton, founder, opened his first Walmart discount store in 1962, with the vision to save customers money, and to help them live better. According to the Walmart website, Sam's secret was simple: give your customers what they want. From a single store in Rodgers, Arkansas, Walmart has grown to over 10,000 stores in 27 countries, employing over 2.2 million workers, and serving over 176 million customers a year. The size of an average store is 108,000 square feet. Each store employs about 225 people.

One important feature of Walmart's success is logistics: how to transport goods from producers to customers throughout the globe. Walmart has one of the largest private distribution operations in the world, with over 40 Regional Distribution Centers. Each one is over one million square feet in size, and operates around the clock, supporting between 75 and 100 stores within a 250-mile radius. Walmart's innovations in transportation and logistics allowed the retailer to lower costs through expansion of the distribution network, resulting in low-cost products for customers. A second major factor behind Walmart's success is the development and use of technology to track its inventory, causing reduced supply chain costs.

Source: Walmart*Corporate. http://www.walmartstores.com/AboutUs

Box 3.4 Network economies

A relatively new concept in economics is "network economies," which describe networks and services that become more valuable as they are more widely used. Social network software such as Facebook and Twitter are the most obvious examples. As more individuals use these services, the more valuable they become to each individual user. Other examples of network economies include common language, common currencies such as the Euro, online auctions like eBay, and air transport networks. The rapid expansion of e-commerce is another example of the use of network economies of scale by Internet merchants.

A formal definition of network economies is a good or service where the marginal cost of adding one more user to the network is nearly zero, but the resulting benefits may be large. The large benefits are due to the ability of the network adopter to interact and/or trade with all of the existing members or parts of the network. Network economies have interesting economic characteristics, and interesting business challenges. For example, publishing a book or a song online fundamentally changes the use of property rights to protect writers and composers. In many cases, ownership is not valued, so revenue is collected through user fees. Businesses such as book and music publishers are in the process of changing longstanding business practices to keep up with the huge advantages of the information age and network economies.

Source: Shapiro, Carl and Varian, Hal R. (1998). *Information Rules: A Strategic Guide to the Network Economy*. Harvard Business Review Press.

purchase electricity and cable television, the lower the per-unit costs of production and distribution will be.

Increasing cost firm

An increasing cost firm is one whose per-unit cost of production increases with increases in output. Firms that extract fixed natural resources, such as oil, timber, or coal, typically have increasing cost structures because a fixed resource (e.g., the coal in the mine) becomes increasingly scarce as more coal is extracted. This causes the per-unit cost of production to increase along with increases in output. Figure 3.13 shows the cost structure of an increasing cost firm.

For increasing cost industries, the cost of extracting the resource increases as extraction increases. This is because the lowest-cost resources are used first, with costs increasing as more resource is extracted or used. For example, the costs of digging a mine deeper, or hauling lumber farther, increase as more coal is extracted or more trees are cut. In this case, the MC curve is everywhere above the AC curve, and the AC curve continues to increase (average chases the marginal).

Typical cost curves revisited

The typical cost curves involve all three types of costs: decreasing AC, constant AC, and increasing AC, as illustrated in Figure 3.14. These cost curves will help find the profit-maximizing point, the topic of the next chapter.

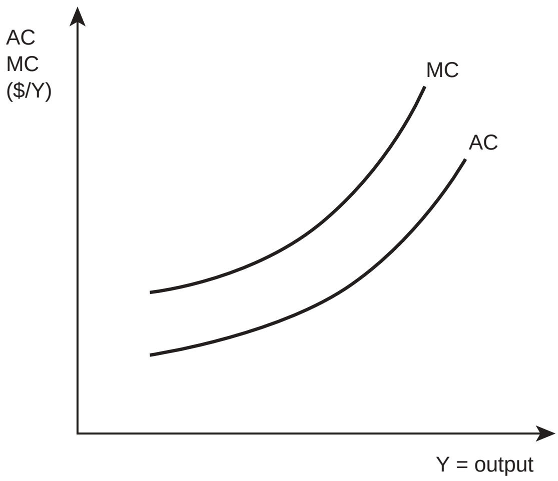

Figure 3.13 An increasing cost firm.

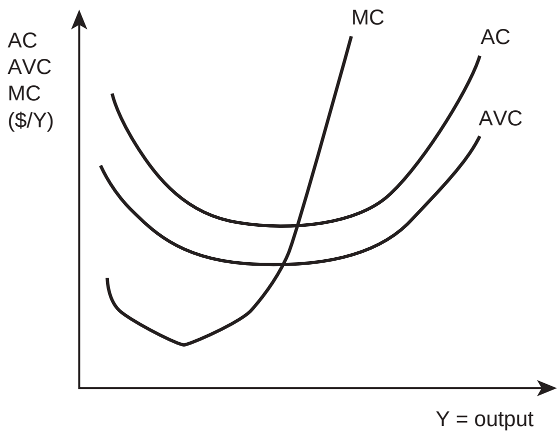

Figure 3.14 Typical cost curves.

3.7 Summary

1. Profits equal total revenue minus total costs. Total revenue equals the product price times the level of output. Total costs are the payments paid to acquire factors of production.
2. Accounting costs are the explicit costs of production. Opportunity costs are the value of a resource in its next-best use.
3. Accounting profits are total revenue minus explicit costs. Economic profits are total revenue minus explicit and opportunity costs.
4. When all resources are earning their opportunity costs, economic profits are equal to zero, and the resources are earning as much as they are worth.

5. Some farmers and ranchers remain in agriculture, even if they are earning negative economic profits, since they prefer a career in farming or ranching, even if it pays less than what they could earn in a different occupation.
6. Total fixed costs do not vary with the level of output.
7. Average fixed costs are fixed costs per unit of output. Average variable costs are variable costs divided by the level of output. Average total costs are total costs divided by the level of output.
8. Marginal cost is the additional cost of producing one more unit of output.
9. A typical total cost curve increases at a decreasing rate, and then increases at an increasing rate, as diminishing marginal returns set in.
10. If MC > AC, the average costs are increasing; if MC < AC, then average costs are decreasing.
11. A firm's cost curves reflect the firm's productivity: an increase in productivity is identical to a decrease in per-unit costs.
12. A constant cost firm faces constant production costs for all units of output produced.
13. A decreasing cost firm has per-unit costs that decrease as output increases.
14. An increasing cost firm has increasing per-unit costs as output increases.
15. A firm with "typical" cost curves is one whose average costs decrease then increase.

3.8 Glossary

Accounting Costs. Explicit costs of production; costs for which payments are required.

Accounting Profits [π_A]. Total revenue minus explicit costs. $\pi_A = TR - TC_A$ (see **Economic Profits**).

Average Costs [AC]. Total costs per unit of output. AC = TC/Y. Note that **Average Costs** (AC) are identical to **Average Total Costs** (ATC).

Average Fixed Costs [AFC]. The average cost of the fixed costs per unit of output. AFC = TFC/Y.

Average Total Costs [ATC]. The average total cost per unit of output. ATC = TC/Y. Note that **Average Costs** (AC) are identical to **Average Total Costs** (ATC).

Average Variable Costs [AVC]. The average cost of the variable costs per unit of output. AVC = TVC/Y.

Costs of Production. The payments that a firm must make to purchase inputs (resources, factors).

Economic Profits [π_E]. Total revenue minus both explicit and opportunity costs. $\pi_E = TR - TC_A -$ opportunity costs (see **Accounting Profits**).

Fixed Costs. Those costs that do not vary with the level of output; the costs associated with the fixed factors of production.

Marginal Costs [MC]. The increase in total costs due to the production of one more unit of output. $MC = \Delta TC/\Delta Y$.

Opportunity Costs. The value of a resource in its next-best use. What an individual or firm must give up to do something.

Profits [π]. Total revenue minus total costs. $\pi = TR - TC$. The value of production sold minus the cost of producing that output (see **Accounting Profits** and **Economic Profits**).

Total Costs [TC]. The sum of all payments that a firm must make to purchase the factors of production. The sum of **Total Fixed Costs** and **Total Variable Costs**. TC = TFC + TVC.

Total Fixed Costs [TFC]. The total costs of inputs that do not vary with the level of output.

Total Revenue [TR]. The amount of money received when the producer sells the product. $TR = P_Y*Y$.

Total Variable Costs [TVC]. The total costs of inputs that vary with the level of output.

Variable Costs. Those costs that vary with the level of output; the costs associated with the variable factors of production.

3.9 Review questions

1. Corn producers interested in maximizing profits should:
   a. maximize yield
   b. maximize revenue
   c. consider both costs and revenue
   d. minimize costs
2. Accounting costs include all of the following except:
   a. electricity payment
   b. payment to hired workers
   c. how much money the operator could earn as a plumber
   d. fertilizer costs
3. Opportunity costs are:
   a. explicit costs
   b. the value of a resource in its current use
   c. implicit costs
   d. the value of a resource in its previous use
4. Economic profits are:
   a. accounting profits
   b. total revenue minus accounting costs
   c. total revenue minus accounting costs and opportunity costs
   d. total revenue minus marginal costs
5. When economic profits equal zero:
   a. the firm should shut down
   b. the firm must increase profits
   c. the resources employed by the firm are underpaid
   d. resources are earning exactly what they are worth
6. In a situation of negative economic profits:
   a. the costs of production cannot be paid
   b. accounting profits are negative
   c. accounting profits could be positive or negative
   d. the firm will shut down
7. In the short run:
   a. only fixed costs exist
   b. only variable costs exist
   c. both fixed and variable costs are present
   d. neither fixed nor variable costs are present
8. Variable costs:
   a. do not change with the level of output
   b. increase with the level of output
   c. decrease with the level of output
   d. fluctuate in a manner unrelated to the level of output

9. Total variable costs divided by output equal:
   a. average variable costs
   b. marginal costs
   c. average fixed costs
   d. total fixed costs
10. If MC > ATC, then:
    a. ATC are increasing
    b. ATC are decreasing
    c. ATC are constant
    d. cannot be determined from the information given
11. All of the following are typical variable costs for a small business except:
    a. electricity
    b. hired labor
    c. paper
    d. rental payment
12. For a firm with typical cost curves:
    a. the ATC increase then decrease
    b. the ATC decrease then increase
    c. MC is greater than ATC
    d. ATC is greater than MC
13. A public utility such as Kansas Power and Light (KPL) is:
    a. an increasing cost firm
    b. a decreasing cost firm
    c. a constant cost firm
    d. cannot be determined from the information given
14. A coal mining company is:
    a. an increasing cost firm
    b. a decreasing cost firm
    c. a constant cost firm
    d. cannot be determined from the information given

Plate 4.1 Profit maximization.

Source: Thoma/Shutterstock

4 Profit maximization

Synopsis

This chapter explores the profit-maximizing level of inputs and outputs for a firm in a competitive industry. It defines and explains perfect competition and clarifies the economic approach of comparing benefits and costs in decision making. Graphs are used to explain the optimal levels of input use and output. This chapter emphasizes the intuitive appeal of profit maximization and the rationale for using profits and losses to help determine a firm's break-even and shutdown points. It is a comprehensive treatment of the heart of microeconomics.

4.0 Introduction

The lessons regarding good economic decisions continue in this chapter. The materials presented here are important in economic decision making, and provide a comprehensive way of looking at the world. The "economic way of thinking" is based on comparing the benefits and costs of every human activity. It applies to purchasing a new pickup truck, attending college, or studying late. The **Marginal Analysis** used here is also an important tool of microeconomics that focuses attention on the advantages and disadvantages of each decision.

- ***Marginal Analysis*** = comparing the benefits and costs of a decision incrementally, one unit at a time.

The following paragraphs show that marginal analysis, or the economic approach to decision making, applies to a great number of decisions, choices, and issues.

4.1 Perfect competition

To determine the profit-maximizing levels of inputs and outputs, we will use the concepts introduced in the preceding chapters and an additional piece of information, the price of the product (P_Y). This price is the market price received by producers when they sell their output (Y). The units of the output price are in dollars per unit of output ($/Y).

The term, "output price" requires additional assumptions (simplifications) about the structure of the market in which the firm operates. The assumptions simplify the analysis in order to make some important tools of economics into something easily learned and used in the quest for the profit-maximizing levels of inputs and outputs. The major simplification is that the firm under study is in an **Industry** characterized by **Perfect Competition**. An "industry" is a group of firms that produce and sell the same product.

- ***Industry*** = a group of firms that all produce and sell the same product.

Perfect Competition means something very specific. It means that the industry has four characteristics, as specified in the formal definition.

- ***Perfect Competition*** = a market or industry with four characteristics: (1) a large number of buyers and sellers, (2) a homogeneous product, (3) freedom of entry and exit, and (4) perfect information.

Large number of buyers and sellers

This condition states that there are so many firms selling a product, and so many consumers who purchase it, that each individual firm is so small relative to the market that it cannot affect the price. Since numerous firms produce the same product, if one firm raises the price of the product above the price charged by the other firms, no buyers would pay the higher price and all of the customers would go to other firms.

UNDER PERFECT COMPETITION, INPUT AND OUTPUT PRICES ARE FIXED AND GIVEN.

In a perfectly competitive market, no individual firm can influence the price charged for the industry's product. The product price is a constant. This refers to a price at a given place and at a given point in time. This is true in an industry as diverse as agriculture. On a given day, all strawberry growers receive the same price for berries and all dairy producers receive the same price for their milk.

Quick Quiz 4.1

Does agriculture have a "large number of buyers and sellers?"

Constant prices also hold true in the input markets that sell resources to a competitive industry. In a perfectly competitive economy, firms hire as many inputs as required without affecting the price, since there are numerous buyers and sellers of inputs. Restated, each individual firm is so small relative to the market that it cannot influence factor prices. In addition, all competitive firms have access to as few or as many factors (labor, land, capital, and management) as needed. There are no additional (hidden) costs of hiring more of any input. Meeting this assumption is not always possible in the real world. If the computer industry desired to double the number of hired programmers, the wages of programmers would rise in locations such as Silicon Valley (San Jose, California) and the Seattle area where Microsoft is located. Hiring more agricultural workers in remote rural areas often requires that farmers and ranchers increase wage levels to attract enough workers, violating the assumption of perfect factor mobility. In a competitive industry, resources flow without cost to the desired jobs and locations. This is a simplifying assumption, used to make the analysis easier.

Homogeneous product

The homogeneous product assumption states that one firm's product is identical to the product sold by all other firms in the industry.

- ***Homogeneous Product*** = a product that is the same no matter which producer produces it. The producer of a good cannot be identified by the consumer.

The key idea is that a consumer is indifferent regarding which firm produced the good. Many agricultural products have this characteristic. Consider a truckload of wheat. A buyer could not determine who produced the crop. The same is true for a dozen eggs, or a bunch of carrots, or two pounds of cooking apples.

Quick Quiz 4.2

Are cattle an example of a homogeneous good? Is meat?

Freedom of entry and exit

Freedom to enter and exit an industry means that there are no "barriers to entry." Any firm can enter or leave the industry without encountering any special government obstacles, or financial limitations. Most small businesses, including farming, have freedom of entry and exit. A counter example is a public utility, such as the local producer and distributor of electric power. This industry usually requires a government permit to enter. Even with the permit, the huge financial requirements for generators, power lines, and installation costs may deter entry. Medical doctors, dentists, electricians, accountants, and many other professionals are required to obtain a license or some kind of certification in order to practice their craft. In a competitive industry, a firm can enter and exit with ease. Although entry into agricultural production may be difficult due to high costs of land and equipment, this lack of financial ability is not considered a rigid barrier to entry. A qualified and competent individual could acquire the necessary financial resources to enter agriculture. Barriers to entry refer to legal or government restrictions.

Quick Quiz 4.3

Do farmers in the United States generally have freedom of entry and exit?

Perfect information

Information is required in any business firm. A successful firm must know the prices and availability of output and all inputs. If a single firm had "inside information" about movements in future prices, that firm would have a distinct advantage over other firms, and would be able to earn higher profit levels. This form of cheating is illegal in the United States. In a perfectly competitive industry, all buyers and sellers know all prices, quantities, qualities, and technologies that they use. There are no informational advantages in an industry characterized by perfect competition.

- ***Perfect Information*** = a situation where all buyers and sellers in a market have complete access to technological information and all input and output prices.

Quick Quiz 4.4

How realistic is the assumption of perfect information?

The four characteristics of a perfectly competitive industry are unlikely to hold completely in the real world. However, the assumptions serve as guides to further knowledge. Entrepreneurs, scholars, business leaders, and common citizens use these and other assumptions as a starting point, then later relax them while adding complexity to the problems they must analyze. The major point to remember about perfect competition is that in the short run, prices paid by buyers and sellers are constant.

PERFECT COMPETITION = FIXED, CONSTANT PRICES

A competitive firm is a **Price Taker** since at any given moment it must take prices as fixed and given. The firm cannot change the price. Firms in market structures other than competition may be able to influence the market price of a good. If so, they are **Price Makers**. Competitive firms that meet the criteria listed above have no influence on prices, and will always be price takers.

- ***Price Taker*** = a firm so small relative to the industry that the price of output is fixed and given, no matter how large or how small the quantity of output it sells.
- ***Price Maker*** = a firm characterized by market power, or the ability to influence the price of output. A firm facing a downward-sloping demand curve.

The specific assumptions of perfect competition appear in later chapters. They are, however, particularly important in this chapter on profit maximization.

4.2 The profit-maximizing level of input

Maximizing profits is a fundamental concept in nearly all of microeconomics. It helps to review the economic approach to decision making before facing the problem of profit maximization.

Economics: how to make better decisions

Economists look at business and personal decisions in a special way. In most every decision-making situation, an economist will compare possible benefits with probable costs. If the projected benefits are greater than the anticipated costs, the activity should be undertaken. Similarly, if the satisfaction gained from eating a slice of pizza is greater than the cost of the pizza, purchasing and eating the pizza is rational. This logic is sound and it applies over a wide range of possible situations. This usefulness comes from the fact that decisions often come one at a time. The decision pondered right now is based on all the decisions that came before. This means that decision making occurs "at the margin," or as an increment to behavior. Put another way, marginal decision making looks at the benefits and costs of each additional unit (or each additional decision). Marginal decision making allows determination of the profit-maximizing levels of inputs and outputs, one unit at a time. The next section uses an example from the livestock industry to make these ideas explicit.

A feedlot in Abilene, Texas: physical production

A feedlot is a business firm that purchases livestock and feeds the animals until they are ready for slaughter. The output (Y) of a feedlot is beef in pounds, and the output price (P_Y) is the price of beef in dollars per pound:

$$Y = \text{beef (lbs)}. \qquad (4.1)$$

P_y = price of beef = \$1/lb. (4.2)

Quick Quiz 4.5

Why use the economic term "holding all else constant" in this case?

Box 4.1 Feedlot

A feedlot or feed yard is a type of animal feeding operation (AFO) used for finishing beef cattle prior to slaughter. The very large beef feedlots, referred to as concentrated animal feeding operations (CAFOs), have thousands of animals in pens. Regardless of the size of the facility, the animals eat a diet composed mostly of grain.

The first known feedlot, designed and built by Gustavus Swift in 1876 on the south side of Chicago, was followed by hundreds of similar facilities in the 1950s and 1960s when feed became widely available, and lower transportation costs allowed feedlots to be located on grain farms. In the 1980s, the meatpackers located their plants next to the feedlots in the Central and Southern Great Plains.

Cattle feed on pasture for the first 12 to 18 months of their life, until they weigh about 650 pounds. At that time, they transfer to a feedlot, where they continue to grow (they are fattened) for approximately three to four months, gaining up to 400 additional pounds before slaughter. The grain diet provides marbling, or fat deposits desired by consumers. However, a high grain diet lowers the acidity in the animal's rumen, and antibiotics are necessary to maintain animal health.

Feedlot operators have become increasingly attentive to the environment. Odor, water quality, air quality, and land utilization are all factors that feedlot operators must consider. Most feedlots require some type of governmental permit and must have plans in place to deal with the large amount of waste that they generate. The Environmental Protection Agency (EPA) has authority under the Clean Water Act to regulate all animal feeding operations in the US. In some cases this authority is delegated to individual states. Feedlots contribute to greenhouse gases, due to the methane produced by the animals. Feedlot operators also consider animal welfare through attention to practices considered sound from a moral and economic standpoint.

Source: National Cattlemen's Beef Association. Fact Sheet: Feedlot Finishing Cattle. http://www.beefusa.org/uDocs/Feedlot%20finishing%20fact%20sheet%20FINAL_4%20(2).pdf

The price of beef in this example is \$1/lb. The assumption of perfect competition says that no matter how many pounds of beef that this feedlot sells, it will always sell for one dollar per pound. The inputs in the feedlot's production process include animals, feed, water, medicine, hormones, etc. The production function for beef fattened (fed) on this feedlot then becomes:

$$Y = f(\text{labor, feed, steers, water, medicine, hormones, ...}) \quad (4.3)$$

Focusing on the profit-maximizing level of feed requires isolating the relationship between beef and feed, while holding everything else constant.

$$Y = f(\text{feed} \mid \text{steers, labor, water, medicine, hormones, } \ldots) \quad (4.4)$$

Recall that everything to the left of the vertical bar is a variable input, and everything to the right of the bar is fixed. Let X refer to the feed input, in bushels of feed. The feed price is P_X, in dollars per bushel of feed.

$$X = \text{feed (bu)} \quad (4.5)$$

$$P_X = \text{price of feed} = \$5/\text{bu} \quad (4.6)$$

$$P_Y = \text{price of beef} = \$1/\text{lb.} \quad (4.7)$$

Finding the profit-maximizing level of inputs is difficult because of the need to be aware of all information related to inputs, outputs, and prices. The actual physical production process is a reminder of what the feedlot is all about: $Y = f(X)$, where Y is weight gained, or fattened beef ready for slaughter, and X is the feed input. Table 4.1 includes the physical product relationships introduced in Chapter 2.

Quick Quiz 4.6

Define TPP, and define the term "production function." Define APP and MPP.

The term APP refers to average physical product or the average per-unit productivity of all units of feed already used. It is the average productivity of all of the inputs. The MPP, or marginal physical product, is the productivity of the last unit of feed used. If the output generated by the last unit of input is more valuable than what the input cost, purchasing and using it in the production process is an appropriate economic decision.

Table 4.1 Midland feedlot production process

X	*Y*	*APP*	*MPP*
(feed bu)	*(beef lb)*	*= Y/X (lb/bu)*	*= ΔY/ΔX (lb/bu)*
0	0		
1	10	10	10
2	30	15	20
3	60	20	30
4	80	20	20
5	90	18	10
6	96	16	6
7	98	14	2
8	96	12	−2

Quick Quiz 4.7

Could you graph the TPP, APP, and MPP curves on the same graph? Why or why not?

The graphs in Figures 4.1 and 4.2 show physical relationships between inputs and outputs, or the production side of the feedlot in Abilene based on the production function in Table 4.1.

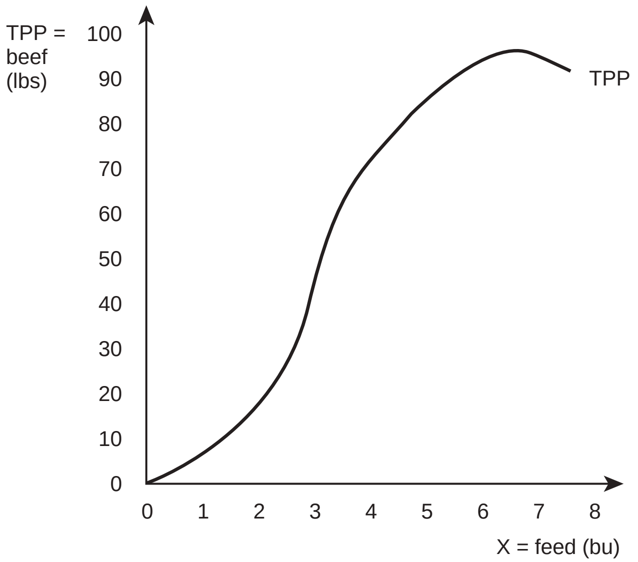

Figure 4.1 Total physical product for Abilene feedlot.

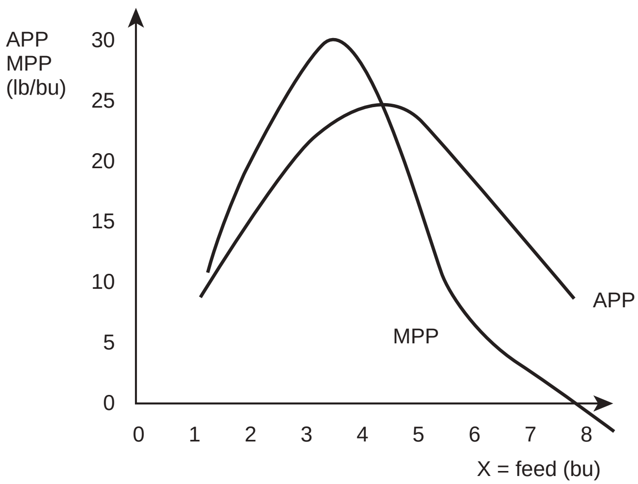

Figure 4.2 Average and marginal physical product for Abilene feedlot.

Feedlot in Abilene, Texas: value of production

The major activities of business firms break down into two categories: (1) production, and (2) marketing. The previous section described production; the marketing function comes next. When the steers reach a certain weight, the feedlot operator converts physical units of output (pounds of beef) into values (dollars) by selling the cattle to the packing plant, or slaughterhouse. This analysis is a simple calculation based on the prices of the input (the price of feed, P_X), and the price of output (the price of beef, P_Y). The assumed prices are:

$$\mathbf{P_Y = \$1/lb, and} \tag{4.8}$$

$$\mathbf{P_X = \$5/bu.} \tag{4.9}$$

A new term, **Total Revenue Product (TRP)** represents the total value of the firm's production. TRP converts output from physical units (pounds of beef) to dollar values.

- *Total Revenue Product [TRP]* = the dollar value of output produced at a given level of variable inputs. TRP = TPP*P_Y

Multiplying the total physical product (pounds of beef) by the price of output ($1 pound of beef) yields the total revenue product, in units of dollars:

$$TRP = TPP(lb)*P_Y(\$/lb) = (\$). \tag{4.10}$$

As before, economic decision making is about comparing the benefits with the costs of any activity. The benefit of feeding cattle in the feedlot is the revenue received from selling beef after production has occurred, or the TRP. The costs of feeding cattle are the **Total Factor Cost (TFC)** calculated assuming that all inputs other than feed are fixed, or held constant.

- *Total Factor Cost [TFC]* = the total cost of a factor, or input. TFC = P_X*X

Using this definition, and under these assumptions, the costs are the total variable costs stemming from the use of the purchased feed.

$$TFC = P_X * X. \tag{4.11}$$

The TFC are also in dollar units since they come from multiplying the quantity of the input (bushels of feed) by the unit price of the input (the price of feed, in dollars per bushel):

$$TFC = P_X(\$/bu)*X(bu) = (\$) \tag{4.12}$$

Table 4.2 shows the benefits and costs for the Abilene feedlot. The left column shows the number of units of input (X). The next column, TPP, is the number of units of output produced with the level of inputs shown in the first column. The first two columns represent the production function shown in Table 4.1 and Figures 4.1 and 4.2. The table and the two figures relate to the physical relationship between inputs and outputs. Multiplying output by price converts the physical relationship into an economic (TRP) relationship shown in the third column. In this particular example, TRP has the same numerical values as TPP, because the price of output is P_Y = $1/lb.

Table 4.2 Profit maximization for Abilene feedlot: P_Y = \$1/lb, P_X = \$5/bu

X	*Y*			*Profits*
= feed (bu)	*= TPP (lb)*	*TRP (\$)*	*TFC (\$)*	*= π (\$)*
0	0	0	0	0
1	10	10	5	5
2	30	30	10	20
3	60	60	15	45
4	80	80	20	60
5	90	90	25	65
6	96	96	30	66
7	98	98	35	63
8	96	96	40	56

Quick Quiz 4.8

Calculate TRP if the price of beef was \$2/lb. How about \$0.50/lb?

The next column shows TFC, or the feedlot's cost of production. By assumption, all costs other than the cost of feed are assumed to be fixed, or constant. Multiplying the left column by the input price gives the total amount that the feedlot pays for feed.

The goal is to find the profit-maximizing, or optimal, level of input to purchase. To do this, calculate the profits in the last column by subtracting the total factor costs (TFC) from the total revenue product (TRP) for each level of input (X). The profits are the amount of money left over after the inputs are paid for (π = TR – TC = TRP – TFC). A quick look at the profit column shows the highest profit occurs at \$66, when the feedlot uses six bushels of feed. This straightforward calculation allows identification of the profit-maximizing level of input for a business firm. Economists working in the real world, however, would use the real cost and revenue data supplied by the firm, but the procedure is identical.

Feedlot in Abilene, Texas: marginal analysis

The main idea behind economic analysis is to find the optimal (profit-maximizing) point by looking at input use one input at a time, to find if the benefits of one additional unit of this input are greater than the costs. We do this with the help of two new concepts: the **Marginal Revenue Product (MRP)** and the **Marginal Factor Cost (MFC)**.

- ***Marginal Revenue Product [MRP]*** = the additional (marginal) value of output obtained from each additional (marginal) unit of the variable input. MRP = MPP* P_Y.

The units for MRP are in dollars per unit of input. MPP is the per-unit quantity of output (lbs of beef per bu of feed), and the price of output is dollars per pound of beef.

$$MRP = MPP [lbs/bu] * P_Y [\$/lb] = [\$/bu]. \quad (4.13)$$

Marginal Factor Cost (MFC) is the additional cost of one more unit of input.

- *Marginal Factor Cost (MFC)* = the cost of an additional (marginal) unit of input: the amount added to total cost by using one more unit of input. $MFC = \Delta TC/\Delta X$.

The same information is contained in the marginal revenue and marginal cost concepts as in the total revenue and total cost concepts. The marginal concepts are derived from the total concepts. Therefore, the marginal analysis shown here yields the same profit-maximizing solution described in the previous section. Verify this by looking at the marginal analysis for the feedlot in Table 4.3.

The first two columns of Table 4.3 repeat the input and TRP data from Table 4.2. The changes in TRP associated with each change in input use yields the MRP ($MRP = \Delta TRP/\Delta X$). Calculating this change for each additional unit of feed used by the feedlot yields data needed to develop the entire MRP column in Table 4.3.

A second method of calculating MRP is to calculate MPP as in Table 4.1, and multiply MPP by the output price. This follows from the definitions of MRP and TRP:

$$MRP = \Delta TRP/\Delta X = \Delta(TPP * P_Y)/\Delta X = (\Delta TPP/\Delta X) * P_Y = MPP * P_Y. \quad (4.14)$$

> **Quick Quiz 4.9**
>
> As a check, calculate the MRP using the definition: $MRP = MPP*P_Y$.

In the case shown here, the numerical values of MRP are equal to MPP, since the output price is \$1/lb. To find the profit-maximizing level of input use, the feedlot operator will continue to increase feed use for the animals as long as the benefits outweigh the costs. The marginal costs of purchasing a unit of feed are equal to the price of feed, (P_X = \$5/bu). The feedlot is assumed to operate in a perfectly competitive industry, so the price of feed is fixed and constant at five dollars per bushel for every bushel the feedlot purchases.

Table 4.3 Profit maximization using marginal analysis for Alberta feedlot

X (bu)	*TRP ($)*	*MRP ($/bu)*	*MFC ($/bu)*
0	0		
1	10	10	5
2	30	20	5
3	60	30	5
4	80	20	5
5	90	10	5
6	96	6	5
7	98	2	5
8	96	−2	5

Quick Quiz 4.10

Why does perfect competition result in constant prices for an individual firm?

An economic advisor will tell a firm (in this case, the feedlot operator) to continue with any activity (adding more feed) as long as the marginal benefits are greater than the marginal costs. Comparing the MRP and MFC columns in Table 4.3 shows the optimal number of bushels to feed. The comparison tells the feedlot operators to continue to buy feed as long as MRP is greater than MFC. The MRP is larger than the MFC for the first six bushels of feed. Good economic advice says that it is economically sound to continue feeding additional feed until MRP = MFC.

Once the marginal benefits (MRP) fall below the marginal costs (MFC), the feed input costs more than it returns. Marginal productivity eventually declines with more feed.

Feedlot in Abilene, Texas: change in input price

In the real world, the market prices of inputs and outputs change continuously, so the manager stays busy continuously recalculating the optimal level of feed inputs. An illustration shows how the optimal feed decision changes when the price of the feed input changes. Suppose an early frost damages the corn and milo crops, resulting in a short supply of feed, and an increase in the price of feed from \$5/bu to \$10/bu. The feedlot operator must now recalculate the profit-maximizing level of feed to purchase.

Table 4.4 shows that the feedlot will reduce the level of feed to five bushels: the sixth bushel would cost ten dollars, but would only increase the value of output by six dollars. The firm would continue to feed more input until reaching the profit-maximizing condition (MRP = MFC) at five bushels of feed.

Not only is this a profit-maximizing result for the feedlot operator, who is increasing the feedlot's profitability, but it is also important from an economic perspective. Predictions about the agricultural economy are now possible. When the price of an input (P_X) increases, the quantity demanded of that input will decrease because profit-maximizing operators will reduce the level of use of this high-priced input. This is due to the "Law of Demand," the topic studied in Chapter 8.

Another important and interesting outcome of this model is that the number of pounds of beef that are sold to the packing plant will drop from 96 pounds to 90 pounds.

Table 4.4 Profit maximization using marginal analysis: P_X = \$10/bu

X (bu)	*TRP (\$)*	*MRP (\$/bu)*	*MFC (\$/bu)*
0	0	–	–
1	10	10	10
2	30	20	10
3	60	30	10
4	80	20	10
5	90	10	10
6	96	6	10
7	98	2	10
8	96	−2	10

Beef consumers will find less meat available in the grocery meat case, which will in turn lead to an increase in the price of meat. When the costs of production of a good increase, an increase in the price of the good will result.

This explains why oil is such an important feature of the US economy. Petroleum products are direct or indirect inputs to the production of almost every good and service. Because of this, an increase in the price of petroleum products causes the price of all goods produced with oil inputs to increase. Agricultural production is particularly sensitive to the price of oil, since farming requires large amounts of gasoline, diesel, oil, and other lubricants. Not only do tractors need fuel, but also fertilizer and agrochemicals are nearly all petroleum-based products. Changes in the price of oil (petroleum products) have a major effect on farmers and on all of agriculture.

Feedlot in Abilene, Texas: change in output price

The analysis of input use can also provide insight into how producers will react to changes in output prices. Suppose that the National Cattlemen's Beef Association (NCBA) is able to forge a trade pact with Russia to increase beef exports. This would increase the price of beef in the US from, say, one dollar per pound to three dollars per pound. Table 4.5 shows the results facing the feedlot when the output price increases to P_Y = \$3/lb.

The first two columns of Table 4.5 remain unchanged when the price of beef increases to \$3/lb. The total revenue product (TRP), however, is increased by a factor of three, since TRP = TPP*P_Y. Locating the profit-maximizing (optimal) level of input use, requires calculating the profit level (π = TRP – TFC) for each level of input use. The highest profit level is \$259, when the feedlot uses seven bushels of feed.

The result shows that when the output price increases, a business firm will increase the use of inputs. This makes perfect sense. A business firm will earn higher levels of profits at higher output prices, because the firm will typically find it optimal to increase the amount of output it places on the market.

Higher levels of production require higher levels of input use [recall the production function: Y = f(X)]. Therefore, a major result of this analysis is that when output prices increase, profit-maximizing firms will purchase more inputs.

Table 4.5 Profit maximization for Abilene feedlot: P_Y = \$3/lb

X	*Y*			*Profits*
= feed (bu)	*= TPP (lb)*	*TRP (\$)*	*TFC (\$)*	*= π (\$)*
0	0	0	0	0
1	10	30	5	25
2	30	90	10	80
3	60	180	15	165
4	80	240	20	220
5	90	270	25	245
6	96	288	30	258
7	98	294	35	259
8	96	288	40	248

Box 4.2 European price supports and the environment

Beginning after World War II, the Common Agricultural Policy (CAP) of the European Community (EC), later the European Union (EU), used high price supports for agricultural commodities to ensure enough food for European nations. The price supports worked well: Europe was transformed from a large food importer to a large food exporter in the decades 1950–90. However, the price supports had an unintended consequence on the environment. Higher prices resulted in greater input use, including agricultural chemicals and fertilizers, which can result in damage to the environment and human health.

A comparison of France, an EU member, and the United States provides an example. France and the US are both characterized by diverse and productive agricultural sectors. Both nations have modern, efficient production practices and produce similar crops and meat products. Both nations have large government subsidies for farmers. However, the EU had larger commodity subsidies, which led to greater input use. France has approximately 19.6 million hectares of arable land, compared to 179 million hectares in the US. The arable land in France represents 33.6 percent of the total land area, and in the US, arable land represents 19 percent.

France's higher subsidy levels have led to greater production per land area: France produced 105,000 metric tons of cereals, and the US produced 117,000 metric tons. Importantly, the higher prices resulted in a French wheat yield in 2003/04 equal to 6.23 metric tons per hectare, compared to the US 2.97 metric tons per hectare. In 2000, France had fertilizer usage of 211.7 kilograms per hectare (kg/ha), whereas the US used fertilizer at less than half that rate: 103.4 kg/ha. Pesticide usage was 4.43 kg/ha in France, and 1.66 kg/ha in the US.

These data are a simple case study of the impact of higher output prices on agricultural inputs and outputs: higher output prices result in higher Marginal Revenue Products, which result in greater levels of input use. More inputs result in higher crop yields, and higher levels of output. Both the EU and the US have become increasingly concerned about the impact of chemicals and fertilizer on the environment. Agricultural policies in both the EU and the US are moving rapidly away from commodity subsidies and toward environmental "green" payments to farmers.

Sources: FAOSTAT. FAO Statistics Division 2012. Retrieved July 23, 2012.

Johnson, R., Hanrahan, C.E., and Schnepf, R. (2010). Comparing U.S. and EU Program Support for Farm Commodities and Conservation. January 26. Congressional Research Service 7-5700. www.crs.gov R40539. Retrieved July 23, 2012.

Quick Quiz 4.11

If the price of wheat increases, do wheat producers purchase more inputs? Explain why.

Graphs of optimal input use

The above analysis shows that a firm will respond to price changes by selecting the optimal level of input use. The firm will purchase inputs as long as the benefits (the increase in

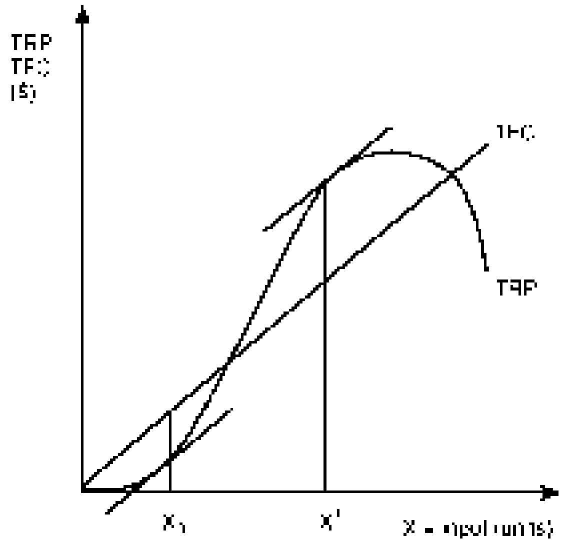

Figure 4.3 The profit-maximizing level of input: total revenue and cost.

revenue brought about by using one more unit of input) are larger than the costs (the payment required to purchase the input). This result is easily shown using graphs when the TRP and TFC functions appear on the same graph. Figure 4.3 is an example.

The profit-maximizing level of input use for a firm occurs where the vertical distance between total revenue product (TRP) and total factor cost (TFC) is the largest. This optimal point is where the slope of the TRP function equals the slope of the TFC function. To see this, draw a line parallel (of equal slope) to the TFC line and just tangent (barely touching) the TRP line, as shown at X* in Figure 4.3. The profit level is the highest at point X*. By moving either to the right or the left of X*, the distance between TRP and TFC decreases, reflecting lower levels of profits at any point other than X*.

There are two points where the slopes of the two functions are equal, so care is required to select the correct profit-maximizing point. At point X_1, the slopes of the two functions are equal to each other, but this is not a desirable point for the firm to locate. Why? Because TFC > TRP, which means that the costs of production are greater than the revenue. At this point, the firm is maximizing its losses.

The marginal analysis shown in Figure 4.4 reveals the same result that was found with the total functions in Figure 4.3. The information contained in the marginal cost and revenue functions came directly from the total functions. It is helpful to recall the definitions of marginal revenue product (MRP) and marginal factor cost (MFC):

$$MRP = MPP * P_Y = \Delta TRP/\Delta X, \text{ and} \tag{4.15}$$

$$MFC = \Delta TFC/\Delta X. \tag{4.16}$$

The definitions show that the MRP is the slope, or rate of change, of TRP, and the MFC is the slope of TFC. The profit-maximizing rule of input use is to continue buying inputs until MRP = MFC (Figure 4.4), or when the slopes of TRP and TFC are equal (Figure 4.3).

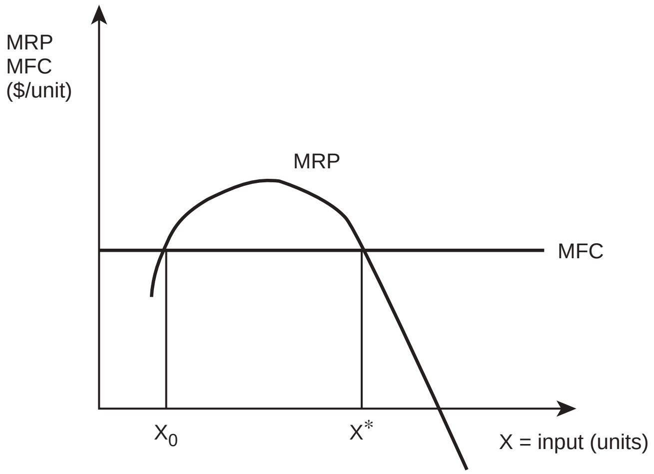

Figure 4.4 The profit-maximizing level of input: marginal revenue and cost.

Quick Quiz 4.12

Why does the feedlot not use a production plan based on point X_0, where MRP = MFC?

Tax on the agrochemical Atrazine

A study of input use can be useful in predicting how firms will respond to changes in input and output prices. One timely and important application of this analysis relates to the study of public (government) policies regarding the use of agrochemicals. Chapter 1 included a brief mention of Atrazine, a common herbicide used to kill weeds in corn production. Chemical residues from Atrazine appear in water supplies in areas where the chemical is used. These residues can have an adverse effect on human health.

The chemical enjoys extensive use in nearly all parts of the Corn Belt. In some cases, the level of Atrazine residue is higher than the United States Environmental Protection Agency (USEPA) recommended maximum safe level. Suppose that the government imposed a tax on Atrazine as a means of reducing its use. The tax would make the chemical more expensive to farmers, who would reduce their use of the input. The reduction in use would have the desired result of lowering the residue levels in the area's drinking water.

Further, suppose that the United States Department of Agriculture (USDA) asks an economist to predict the impact of the tax on Atrazine. We know that profit-maximizing producers will use the profit-maximizing level of Atrazine, found where MRP = MFC. The per-unit tax (t) would increase the cost of each additional ounce of Atrazine by t dollars:

$$\text{MFC} = P_X + t. \tag{4.17}$$

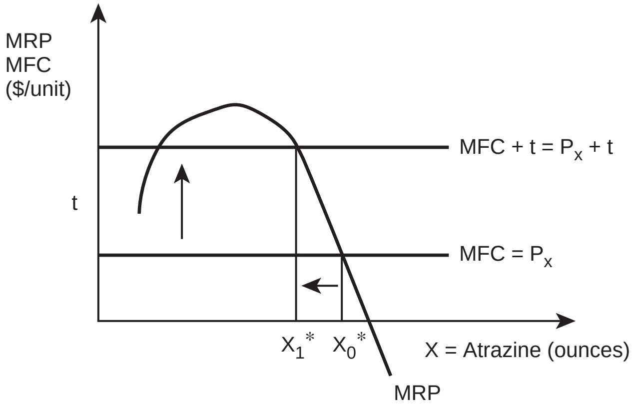

Figure 4.5 Impact of a tax on Atrazine.

Figure 4.5 shows the impact of the tax. It increases the cost of purchasing the input from P_X to (P_X + t). This raises the MFC by the amount of the tax, and reduces the profit-maximizing level of Atrazine from X_0* to X_1*.

By imposing the tax, the government has made it more costly to use an input that has economic benefits, but potential environmental costs. Adjusting the tax rate can bring the level of Atrazine residues to a targeted and safe level. Governments tax many goods considered to have adverse effects in a similar manner to those in Atrazine: cigarettes, gasoline, lottery tickets, alcohol, etc.

Quick Quiz 4.13

Use a graph to show the impact of a gasoline tax on agricultural production in the US. Will such a tax affect consumers of agricultural products?

4.3 The profit-maximizing level of output

This section discusses the optimal, profit-maximizing level of output for a business firm. The concepts and ideas presented here are applicable to a large number of business decisions, career choices, and personal issues.

CONTINUE ANY ACTIVITY AS LONG AS BENEFITS OUTWEIGH COSTS!

Consider the output decision on a farm or for any business. Important questions include “How much wheat (or corn, potatoes, strawberries, or wool, for example) should I produce this year?” and “What is the optimal herd size for my dairy (or my hog enterprise, or my poultry flock)?” Economic analysis can be useful in providing answers to these questions.

Profit maximization using total revenue and total cost curves

The questions have something in common: they all require use of the assumptions used earlier and the general assumption of the profit-maximizing firm. Now, though, attention focuses on profits, defined as total revenue (TR) minus total costs (TC).

$$\pi = TR - TC, \text{ where} \tag{4.18}$$

- ***Total Costs [TC]*** = the sum of all payments that a firm must make to purchase the factors of production. The sum of **Total Fixed Costs** and **Total Variable Costs**. TC = TFC + TVC.
- ***Total Revenue [TR]*** = the amount of money received when the producer sells the product. $TR = TPP*P_Y$.

Total revenue is the amount of money earned from the production and sale of a good.

$TR = TPP * P_Y = Y * P_Y$, where Y is output and P_Y = price of output ($/unit).

(4.19)

Total costs are the costs of production, including both fixed and variable costs. All units are in dollars.

Quick Quiz 4.14

Are the costs in TC economic costs or accounting costs? Are the profits economic profits or accounting profits? Are opportunity costs included?

What are the costs facing this firm? There are both fixed and variable costs, and the total costs will increase with output.

$$\pi = TR - TC \tag{4.20}$$

$$\pi = P_Y * Y - TC(Y) \quad (TC \text{ is a function of } Y) \tag{4.21}$$

The equation above shows that both TR and TC are functions of the quantity produced (Y). The firm will continue to increase its level of output as long as the additional revenue brought in from the production and sale of the good is greater than the additional costs of production incurred when producing an additional unit of output.

A graph of total costs and total revenue often helps understanding. The total revenue curve (TR) will be a straight line, since the price of output, P_Y, is fixed and constant. Multiplying a constant by the variable, Y yields a straight line as shown in Figure 4.6. The total cost (TC) curve has the "typical" shape, showing costs increasing at a decreasing rate, and then increasing at an increasing rate.

In Figure 4.6, the vertical distance between the TR and TC functions represents profits (π = TR – TC). The firm's objective is to maximize this distance. A line parallel to TR and tangent to the TC curve identifies this maximum distance. The point of tangency is the

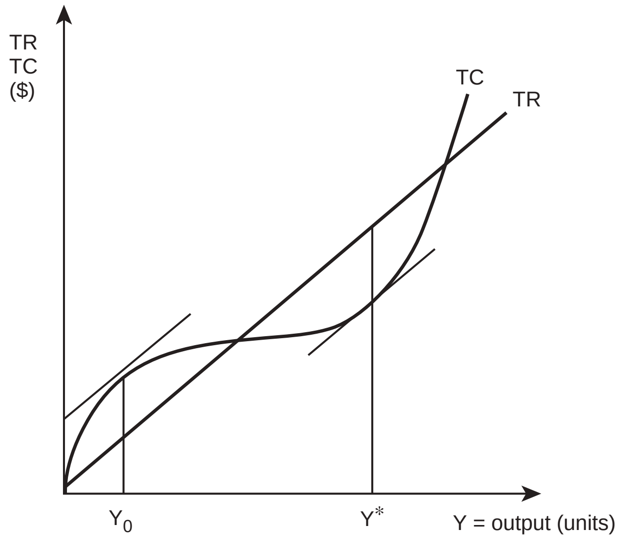

Figure 4.6 The profit-maximizing level of output: total revenue and cost.

output level consistent with maximum profit. It occurs at output level Y*. Geometrically, this is the point where the slope of TR is equal to the slope TC (or MR = MC). Any movement to the right or left of Y* will result in a decrease in the vertical distance between TR and TC, or a reduction in profits.

As in the input case, note that there are two points in Figure 4.6 where the slope of TR is equal to the slope of TC. The firm must be sure to maximize, rather than minimize, profit. The point Y* is profit maximizing, since MR = MC and TR > TC. The first condition for profit maximization occurs at point Y_0, but this point is a cost-maximization point, since at Y_0, TR < TC.

Profit maximization using marginal revenue and marginal cost curves

The definitions of marginal revenue (MR) and marginal costs (MC) help summarize the profit-maximization process:

- ***Marginal Revenue [MR] =*** the addition to total revenue from selling one more unit of output. MR = ΔTR/ΔY.
- ***Marginal Cost [MC]*** = the increase in total costs due to the producion of one more unit of output. MC = ΔTC/ΔY.

These terms are analogous to the marginal terms in the section relating to a firm's decision relating to the use of inputs: marginal revenue product (MRP) and marginal factor cost (MFC). The marginal analysis presented here uses plots of the same information used in the total analysis.

Marginal revenue is the slope, or rate of change, in total revenue: MR = ΔTR/ΔY (Figure 4.7). TR is a constant. Therefore, MR is constant for every level of output. This is

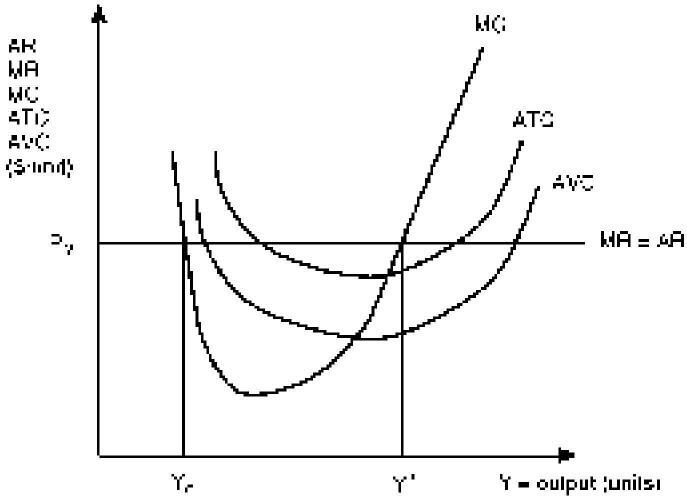

Figure 4.7 The profit-maximizing level of output: marginal revenue and cost

also in the formula for total revenue, TR = P_Y * Y. Any change in TR comes from a change in output, Y.

$$\Delta TR = \Delta(P_Y * Y) = P_Y(\Delta Y). \qquad (4.22)$$

Substituting this into the definition of marginal revenue yields:

$$MR = \Delta TR / \Delta Y = \left[P_Y(\Delta Y)\right] / \Delta Y = P_Y, \qquad (4.23)$$

which is why the MR line in Figure 4.7 is labeled P_Y.

Average Revenue (AR) is the per-unit revenue that the firm earns from the production and sale of a good.

- ***Average Revenue (AR)*** = the average dollar amount received per unit of output sold. AR = TR/Y.

Average revenue is also constant at the output price, since AR = TR/Y = (P_Y*Y)/Y = P_Y. Since MR and AR are constant, MR = AR.

> **Quick Quiz 4.15**
>
> What is the relationship between average and marginal? Does the relationship hold in this case?

To find the profit-maximizing level of output, the firm sets MR = MC, or P_Y = MC. This condition occurs at two points in Figure 4.7: Y_0 and Y*. These two points in Figure 4.7 are identical to the points with the same labels in Figure 4.6, since the information contained in both graphs is identical. The optimal, profit-maximizing point is Y*, at that point TR > TC. Because of this, the profit-maximizing condition has two parts.

PROFIT-MAXIMIZING CONDITION:
1. MR = MC
2. MC must cut MR from below.

This condition is important to economics. It reiterates a theme that has already appeared several times in this and earlier chapters. It comes back to the notion of how to make better decisions, whether as an economist, or a manager in a business situation, or a person planning activities for the day. In summary form, it says that what a manager (farmer, planner, teacher, student, army general, US Senator) needs to do to make good decisions, is that he or she must continue any activity as long as the benefits exceed the costs. The two conditions given above guarantee that the additional benefits are greater than the additional costs.

4.4 Profits and losses, break even, and shutdown points

When is the firm earning profits or incurring losses? All of the graphs in the preceding sections show when profits were present and maximized. Moreover, the search was geared toward economic profits, rather than accounting profits.

Quick Quiz 4.16

What is the difference between economic profits and accounting profits?

The cost curves depicted here include both explicit and opportunity costs. This section expands the definition of profit using both algebra and graphs to reveal the differences between maximization with and without the inclusion of opportunity costs. The explicit definition of profit is:

$$\pi = \text{TR} - \text{TC}, \text{ where} \qquad (4.24)$$

$$\text{TR} = \text{TPP} * \text{P}_{\text{Y}} = \text{Y} * \text{P}_{\text{Y}} = \text{Y} * \text{MR}, \text{ and} \qquad (4.25)$$

$$\text{TC} = \text{Y} * \text{ATC}, \text{(from the definition of average total costs, ATC = TC/Y).} \qquad (4.26)$$

Total revenue (TR) is simply the level of output (Y) times the output price (P_Y). The output price is constant in a perfectly competitive industry, so P_Y = MR = AR. In Figure 4.8, the firm maximizes profits by setting MR = MC, where MC cuts MR from below. Graphically, total revenue is the rectangular area defined by the horizontal distance 0Y*, and the vertical distance $0P_Y$. A similar rectangle identifies total costs as the per-unit costs (ATC*) times the level of output (Y*). This is the smaller rectangle bounded by the horizontal distance 0Y* and the vertical distance 0ATC*.

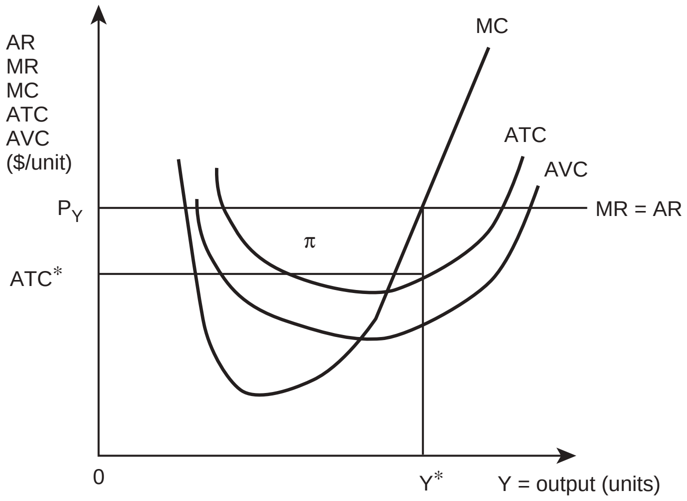

Figure 4.8 Positive economic profits.

Profits are defined as total revenue minus total costs (π = TR – TC), the rectangle identified in Figure 4.8. In the case in Figure 4.8, profits are positive ($\pi > 0$) because the price line (P_Y = MR = AR) is above the average total cost curve (P_Y > ATC). The firm will earn positive profits when this condition holds. If the price falls below the ATC curve, the firm will earn negative profits. In Figure 4.9, the price has fallen below the ATC curve (P_Y < ATC). The firm continues to maximize profits by setting MR = MC, where MC cuts MR from below. However, in this case, profits are negative ($\pi < 0$), and the firm is earning less than the opportunity costs of its inputs. Total revenue (TR) is the rectangle defined by the horizontal distance (0Y*) and the vertical distance ($0P_Y$). Total costs (TC) are the larger rectangle defined by a base of (0Y*) and a height of (0ATC*).

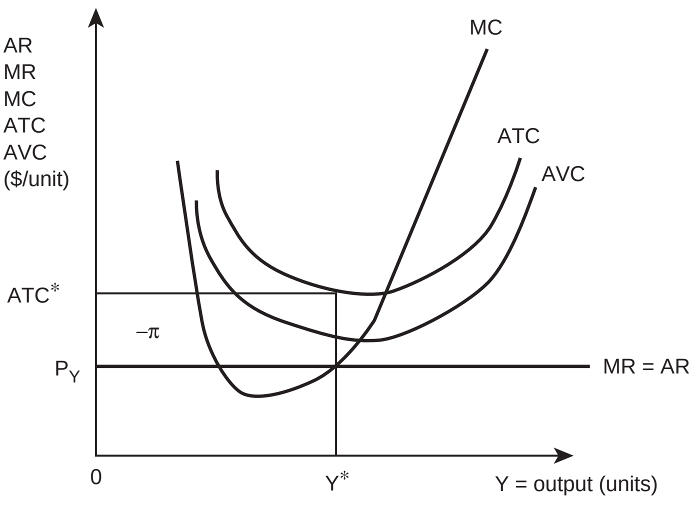

Figure 4.9 Negative economic profits.

The rectangle identified in Figure 4.9 shows negative profits (losses). If the firm were to maximize profits, it would switch activities and use its productive inputs in their next-best use. The results above show that a firm could quickly determine if profits are positive or negative by noting the following rule:

> If $P_Y > ATC$, then profits are positive, and
> if $P_Y < ATC$, then profits are negative.

When the output price is exactly equal to the per-unit costs, the firm is just "breaking even." Economic profits are equal to zero, but no economic losses appear.

> **Quick Quiz 4.17**
>
> When economic profits equal zero, is this good or bad for the firm?

The Break-Even Point

The **Break-Even Point** occurs when $P_Y = MC$ at the minimum point on the ATC. At the break-even point, there are no economic profits or losses, as in Figure 4.10.

- ***Break-Even Point*** = the point on a graph that shows that total revenue (TR) is equal to total cost (TC).

It may seem as if a firm should shut down, since profits are equal to zero. However, this is the difference between accounting profits and economic profits. The cost curves take into account (include) the salaries still earned by the owners of the firm. Even though profits equal zero, the returns to the owners are as high as what they could be earning in their next-best use. At the break-even point, the following condition holds:

$$P_Y = ATC = MC = AR = MR. \tag{4.27}$$

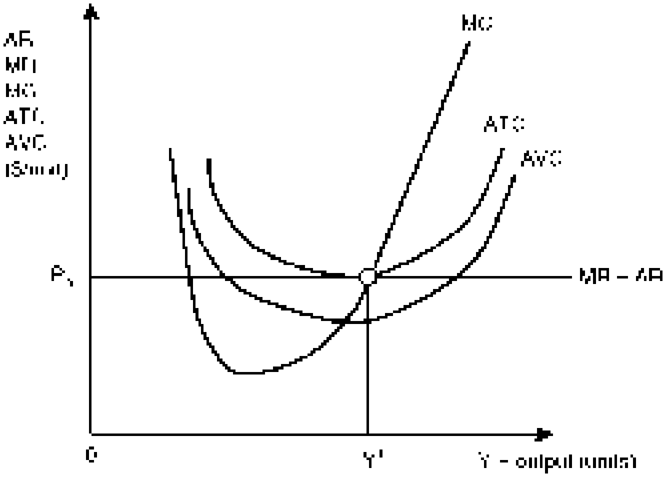

Figure 4.10 The break-even point.

Since the firm's revenue is exactly equal to the firm's costs, profits equal zero ($\pi = 0$). If the price falls below the ATC curve, economic profits become negative. Under certain conditions, a firm may remain in business even though it is earning negative economic profits, as is explained in the next section.

The shutdown point

Logic says that a firm should shut down when profits are negative, but there is a good reason why the firm will remain in production when the price falls below the ATC curve. In the short run, some of the inputs are fixed, and the firm must pay the fixed costs, no matter how much is produced. If the output price falls below per-unit costs, the firm cannot cover its total costs. Since the firm is not earning enough to pay its costs of production, it might shut down. If it does shut down, it must continue to pay all of the fixed costs. For example, even if a business in a small town closes its doors, it will still have to pay the taxes, rent, and likely some utility bills. The firm might be better off remaining in business in order to pay at least part of its fixed costs. Expanded definitions of total costs help explain why:

$$\text{TC} = \text{TFC} + \text{TVC}. \tag{4.28}$$

Dividing all three terms by the level of output, changes the equation to:

$$\text{ATC} = \text{AFC} + \text{AVC}. \tag{4.29}$$

In the short run, a firm will have both fixed and variable costs. Fixed costs do not vary with the level of output. They require payment no matter what the level of output. In Figure 4.10, the vertical distance between the ATC and AVC curves is equal to the level of fixed costs (AFC = ATC – AVC).

Plate 4.2 The shutdown point.

Source: Mark Winfrey/Shutterstock

In the long run, all fixed costs become variable: the ATC curve is the same as the AVC curve, and fixed costs disappear (making ATC = AVC, and AFC = 0).

Quick Quiz 4.18

Why do the fixed costs become variable in the long run?

If the output price lies between average total costs and average variable costs (ATC > P_Y > AVC), then the firm is covering all of its variable costs, and part of the fixed costs. Remaining in business is a better choice than closing down and owing all of the fixed costs. Therefore, the firm remains in business with negative profits to minimize costs. This is the optimal, profit-maximizing (cost-minimizing) solution.

If the output price falls below the average variable cost curve (P_Y < AVC), then the firm will shut down. Since it cannot meet even its variable costs of production, it is losing money on each unit of output that it produces. Figure 4.11 clarifies the concept of the **Shutdown Point**.

- ***Shutdown Point*** = the level of output at which marginal revenue (MR) is equal to average variable costs (AVC).

At any price level above the shutdown point (P_Y > AVC), the firm will remain in business. This is because the firm can meet all of its variable costs and at least part of its fixed costs. At any price level below the shutdown point (P_Y < AVC), the firm will shut down. This is because the firm cannot meet its variable costs of production. The firm minimizes losses by producing where MR = MC, which is where the price line intersects the MC curve, and the MC curve cuts the price line from below. At this point, total costs exceed total revenue, but as long as the firm is covering its variable costs, the firm will set MR = MC and continue producing.

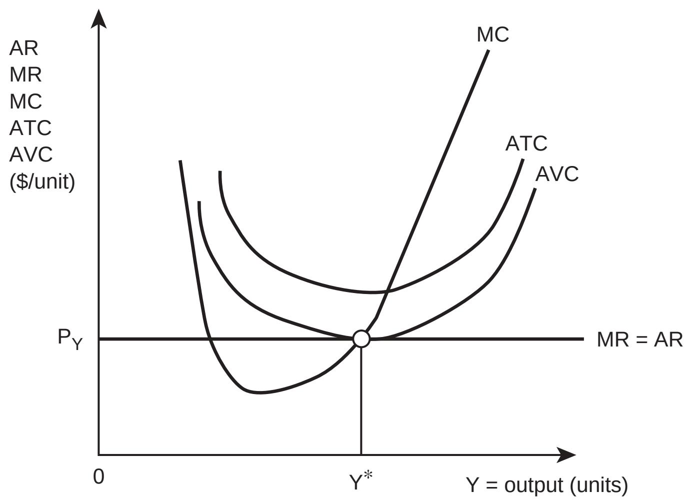

Figure 4.11 The shutdown point.

Plate 4.3 Catfish dinner.
Source: HLPhoto/Shutterstock

Example: Profit maximization for a catfish producer in Mississippi

Consider a commercial catfish producer as an example of a profit-maximizing firm.

$$TC = TFC + TVC. \tag{4.30}$$

Dividing these three terms by the level of output (Y), converts the total costs into average, or per-unit, costs.

$$ATC = AFC + AVC. \tag{4.31}$$

Recall that fixed costs are payments to inputs that do not vary with output. Restated, the land and building inputs remain at the same level whether the firm produces 0, or 1000, or 1,000,000 catfish. Regardless of level of output, the fixed costs require payment. Fixed costs represent the vertical distance between the ATC and AVC curves in Figure 4.12.

In the long run, all of the fixed inputs become variable: TC = TVC, and TFC = 0. Graphically, the long run curves reflect the variability of all inputs, as in Figure 4.13.

The firm can use either the total or the marginal graphs to find its profit-maximizing level of catfish production. In the total graph (the left side of Figure 4.14), the catfish firm will find the number of catfish (Y*) that will maximize the vertical distance between the TR and TC

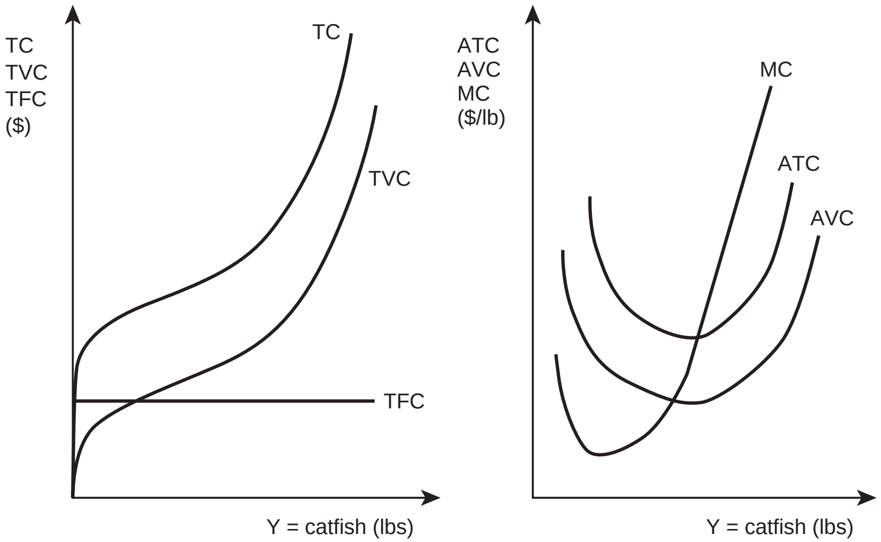

Figure 4.12 Short run cost curves: Mississippi catfish producer.

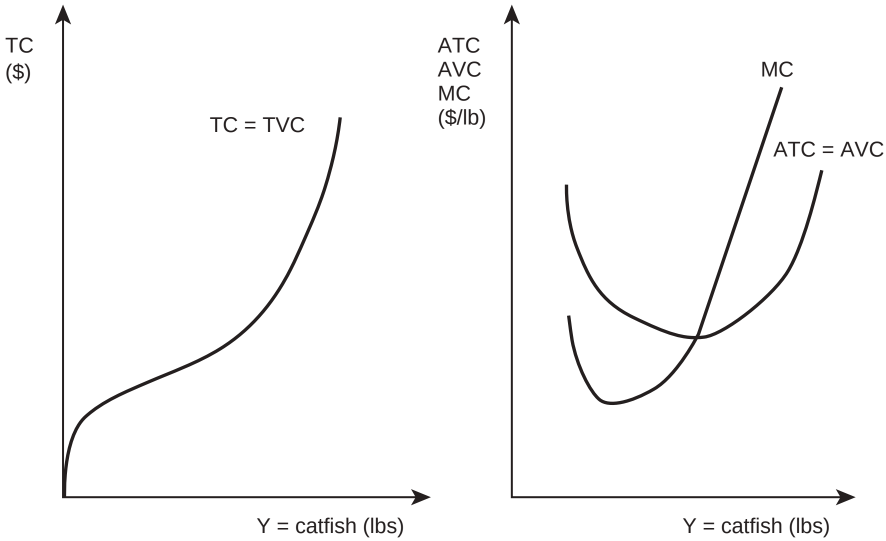

Figure 4.13 Long run cost curves: Mississippi catfish producer.

Box 4.3 Catfish in Mississippi

Catfish production represents over 46 percent of the value of aquaculture production in the United States, making it the number one source of aquaculture revenue. Commercial catfish production began in the 1960s, and catfish production has grown rapidly to reach annual sales of 660 million pounds in 2003. The value of the catfish crop in the US reached $425 million in 2003. Mississippi reported the greatest value.

The rapid growth of the catfish industry in the 1980s and 1990s led it to become one of the most important agricultural activities in states such as Mississippi, Arkansas, Alabama, and Louisiana. The combined production acreage of these four states makes up 94 percent of all catfish production acreage. Mississippi has had more acreage in catfish production than the other three states combined and has held this position since the late 1980s. The catfish industry generates an economic impact of billions of dollars and is the primary source of economic activity and employment in a number of Mississippi counties, primarily in the Mississippi Delta region.

Source: Commercial Catfish Production. Msucares.com. Mississippi State University. http://msucares.com/aquaculture/catfish/index.html

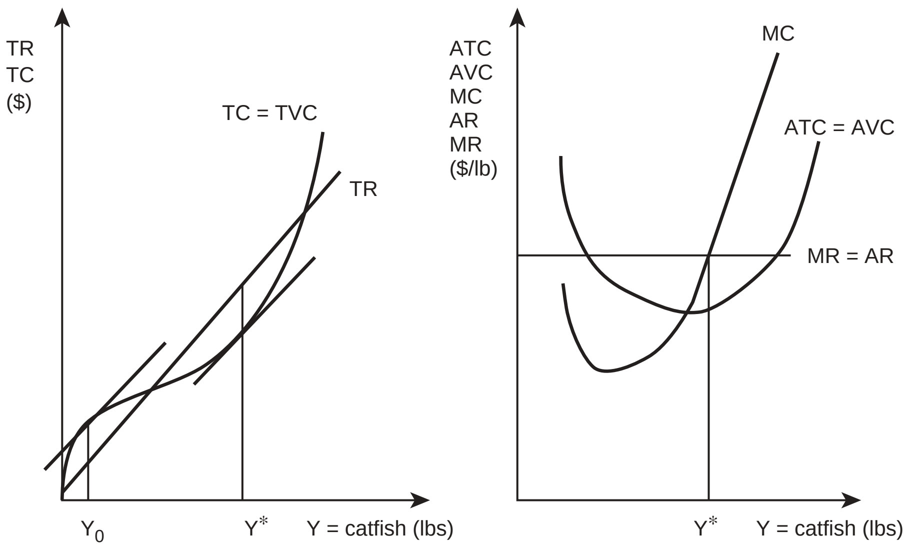

Figure 4.14 Profit maximization for Mississippi catfish producer.

curves (π = TR – TC). The firm must make sure that the second condition of profit-maximization (TR > TC) holds. Maximum costs occur at point Y_0. In the marginal graph (the right side of Figure 4.14), the firm will find the optimal, profit-maximizing point (Y*) by finding the point where (1) MR = MC, and (2) MC cuts MR from below. The profit-maximizing level of output is the same in both graphs.

If the catfish firm is a part of a competitive industry, the price of the output (P_Y) is constant. This is why the TR function is a straight line in Figure 4.14 (TR = P_Y*Y), and the MR function is constant (P_Y = MR = AR). Marginal analysis for a catfish producer involves starting at a low level of output, and asking the question, "Should I produce one more unit of output?" The answer is "yes," as long as the marginal revenue (benefit) is greater than the marginal costs (loss).

The catfish producer will continue to produce more catfish until point Y* is reached. At that point, one more unit of output would raise production costs to a higher level than the price of catfish. Any point to the left or right of the profit-maximizing point (Y*) will result in lower profits for the catfish firm. This chapter has demonstrated how to find the profit-maximizing point of both input use and output. The next chapter focuses on finding the profit-maximizing combination of inputs.

4.5 Summary

1. Marginal analysis compares the benefits and costs of every activity, one unit at a time.
2. An industry is a group of firms that produce and sell the same product.
3. Perfect competition is defined by: (1) a large number of buyers and sellers, (2) a homogeneous product, (3) freedom of entry and exit, and (4) perfect information.
4. In a perfectly competitive industry, the output price is fixed and given to a firm.
5. Total revenue product (TRP) is the dollar value of output produced from alternative levels of variable input (TRP = TPP*P_Y).
6. Total factor cost (TFC) is the total cost of an input (TFC = P_X*X).
7. Marginal revenue product (MRP) is the additional value of output obtained from each additional unit of a variable input.
8. Marginal factor cost (MFC) is the cost of an additional unit of input.
9. Marginal analysis suggests that an individual should continue any activity as long as the marginal (incremental) benefits are greater than the marginal (incremental) costs.
10. The profit-maximizing level of input use can be found by setting MRP = MFC.
11. When the price of an input increases, the quantity demanded of that input will decrease.
12. When the output price increases, a business firm will increase the amount of input that it uses.
13. A tax placed on an input will cause a business firm to purchase less of that input.
14. The profit-maximizing level of output can be found where MR = MC.
15. When the output price is greater than average total costs, profits are positive. When the output price is below the average total costs, profits are negative. When the output price is equal to the average total costs, then the firm is breaking even and earning zero economic profits.
16. The break-even point occurs where P_Y = MC at the minimum ATC point. Economic profits are equal to zero at the break-even point.

17. The shutdown point occurs where MR equals minimum AVC. At output prices above the shutdown point, the firm will remain in production. At output prices below the shutdown point, the firm will shut down.
18. Graphically, the profit-maximizing level of output can be found by locating the maximum vertical distance between the TR and TC curves. The profit-maximizing level of output can also be found by locating the point where (1) MR = MC, and (2) MC cuts MR from below.

4.6 Glossary

Average Revenue [AR]. The average dollar amount received per unit of output sold. AR = TR/Y.

Average Revenue Product [ARP]. The average value of output per unit of input at each input use level. ARP = APP*P_Y.

Break-Even Point. The point on a graph that shows that total revenue (TR) is equal to total cost (TC).

Homogeneous Product. A product that is the same no matter which producer produces it. The producer of a good cannot be identified by the consumer.

Industry. A group of firms that all produce and sell the same product.

Marginal Analysis. Comparing the benefits and costs of a decision incrementally, one unit at a time.

Marginal Cost [MC]. The increase in total costs due to the producion of one more unit of output. MC = ΔTC/ΔY.

Marginal Factor Cost [MFC]. The cost of an additional (marginal) unit of input; the amount added to total cost of using one more unit of input. MFC = ΔTC/ΔX.

Marginal Revenue [MR]. The addition to total revenue from selling one more unit of output. MR = ΔTR/ΔY.

Marginal Revenue Product [MRP]. The additional (marginal) value of output obtained from each additional (marginal) unit of the variable input. MRP = MPP* P_Y.

Perfect Competition. A market or industry with four characteristics: (1) a large number of buyers and sellers, (2) a homogeneous product, (3) freedom of entry and exit, and (4) perfect information.

Perfect Information. A situation where all buyers and sellers in a market have complete access to technological information and all input and output prices.

Price Maker. A firm characterized by market power, or the ability to influence the price of output. A firm facing a downward-sloping demand curve.

Price Taker. A firm so small relative to the industry that the price of output is fixed and given, no matter how large or how small quantity of output it sells.

Shutdown Point. The point on a graph where marginal revenue (MR) is equal to average variable costs (AVC).

Total Costs [TC]. The sum of all payments that a firm must make to purchase the factors of production. The sum of **Total Fixed Costs** and **Total Variable Costs**. TC = TFC + TVC.

Total Factor Cost [TFC]. The total cost of a factor, or input. TFC = P_X*X.

Total Revenue [TR]. The amount of money received when the producer sells the product. TR = TPP*P_Y.

Total Revenue Product [TRP]. The dollar value of output produced at a given level of variable inputs. TRP = TPP*P_Y.

4.7 Review questions

1. A large number of buyers and sellers results in:
   a. a homogeneous product
   b. a fixed and constant price
   c. freedom of entry and exit
   d. perfect information
2. All of the following have freedom of entry and exit except:
   a. gas station
   b. copy store
   c. cable television
   d. clothing store
3. Which physical product curves can be graphed on the same graph?
   a. TPP and APP
   b. APP and MPP
   c. TPP and MPP
   d. TPP, APP, and MPP
4. The cost of an additional unit of input is:
   a. Total Revenue Product
   b. Marginal Factor Cost
   c. Marginal Revenue Product
   d. Total Factor Cost
5. A firm will continue to purchase more input until:
   a. MPP = MFC
   b. MRP = P_Y
   c. TRP = TFC
   d. MRP = MFC
6. When the price of corn increases, feedlots will:
   a. purchase more corn
   b. purchase less corn
   c. purchase same corn amount
   d. cannot tell
7. When the price of automobiles increases, Ford Motor Company will purchase:
   a. more glass, steel, and rubber
   b. less glass, steel, and rubber
   c. the same amount of glass, steel, and rubber
   d. cannot tell from the information given
8. If a tax is placed on gasoline, then a wheat producer will produce:
   a. more wheat
   b. less wheat
   c. the same amount of wheat
   d. cannot tell from the information given
9. The profit-maximizing level of output can be found where:
   a. MR = MC, and MC cuts MR from below
   b. MR = MC, and MC cuts MR from above
   c. TR = TC
   d. the horizontal distance between TR and TC is largest

10. The shutdown point occurs where:
    a. P = min ATC
    b. P = min AVC
    c. ATC = AVC
    d. MR = MC
11. The break-even point occurs where:
    a. P = MR = MC = ATC
    b. P = min AVC
    c. AVC = ATC
    d. P = MC

Plate 5.1 Optimal input selection.
Source: Zeljko Radojko/Shutterstock

5 Optimal input selection

Synopsis

This chapter explains how business firms use relative prices when selecting which inputs to use. The relationship between inputs is discussed in detail, illuminating how the choice of techniques depends on relative prices. Isoquants are defined, and described for several input types: perfect substitutes, perfect complements, and imperfect substitutes. Real-world examples provide insight into optimal input decisions. The marginal rate of technical substitution and the slope of the isocost line, more tools of economic analysis, help identify optimal responses to price changes. Emphasis is on how relative prices allocate resources in a market-based economy.

5.0 Introduction

Chapter 2 introduced the physical production process, Chapter 3 covered costs of production, and Chapter 4 dealt with selecting the profit-maximizing levels of inputs and outputs. The next step asks how inputs relate to each other in the production process. In many, perhaps most, production processes, several different combinations of inputs will yield a specified level of output. For example, farm equipment can be built for use by skilled workers (labor intensive), or by highly specialized robots (capital intensive), or by many combinations of the two.

This chapter examines the selection of the optimal, profit-maximizing combination of inputs. The major message is that a firm will select inputs based on relative prices. In low-income nations where labor is inexpensive, business firms most often employ a labor-intensive production process, whereas in high-income nations, labor is often expensive, and capital-intensive production processes are used. Think of the comparison of agricultural production practices in the Great Plains portions of the United States compared to production practices in Africa. In the Great Plains, large, expensive machines till the soil, plant the crop, harvest the crop, and transport it to market. In Africa, manual labor often performs these same activities. Given the prices of labor and machinery in the two areas, farms in both areas are making rational economic decisions, even though they employ vastly different production processes.

5.1 The relationship between inputs

As in earlier chapters, the study of different combinations of inputs begins with the production function:

$$Y = f(A, L, K, M). \tag{5.1}$$

Quick Quiz 5.1

Define a production function, and explain what the letters Y, f, A, L, K, and M stand for.

Chapter 2 analyzed the relationship between one input and one output, when all else is held constant. The quantity of one input (labor) varied, while quantities of all other inputs remained constant:

$$Y = f(L \mid A, K, M). \tag{5.2}$$

Quick Quiz 5.2

Explain how this production function determines whether the firm is operating in the short run or the long run.

The production function captures the physical relationship between inputs (X) and output (Y). The physical product functions (TPP, APP, and MPP) all used the same data.

Quick Quiz 5.3

Define the physical product terms TPP, APP, and MPP. Draw a hypothetical graph showing each function.

Emphasis now shifts to consider the relationship between two variable inputs and the firm's output. In equation 5.3, a production function is shown where two variable inputs (L and K) are to the left of the *ceteris paribus* line, while A and M remain constant, and are to the right of the line:

$$Y = f(L, K \mid A, M). \tag{5.3}$$

A major trend affecting US agriculture is the substitution of capital for labor (Chapter 1). Over the past several decades, the nation's agricultural sector has replaced millions of agricultural laborers with highly productive and expensive machinery. The analysis here explains why this occurred, and shows how to find and measure the optimal rate of substitution of machines for labor.

A flour mill in Chicago, Illinois, provides an idea of how to determine the best combination of inputs. The term capital refers to physical capital, and includes: (1) machines,

Plate 5.2 Grinding wheat into flour.
Source: Mikus, Jo./Shutterstock

(2) buildings, (3) tools, and (4) equipment. Capital (machinery) often substitutes for labor, or workers.

A flour mill can use many possible combinations of machines and labor to grind wheat (or other grains) into flour. For example, the mill can use four workers and one machine (4 L, 1 K), or two workers and two machines (2 L, 2 K) to produce 100 five-pound bags of flour during a regular working day, as in equation 5.4:

$$Y = f(L, K \mid A, M). \tag{5.4}$$

The mill manager must hire workers and a mill (a location and machinery) to produce flour from wheat. The key idea here is that there are several possible production processes for producing flour.

Figure 5.1 shows two different production practices, and is different from the graphs shown in earlier chapters. The earlier graphs showed input on the horizontal axis and output on the vertical axis. In Figure 5.1, each axis represents one input in the production process. Points within the quadrant represent output, and help answer a different question about production. The issue centers on selecting the profit-maximizing combination of two inputs, rather than the optimal level of one input.

5.2 Isoquants

The two points shown in Figure 5.1 can represent two points on an **Isoquant**, which relates two variable inputs to a given level of output.

- ***Isoquant*** = a line indicating all combinations of two variable inputs that will produce a given level of output.

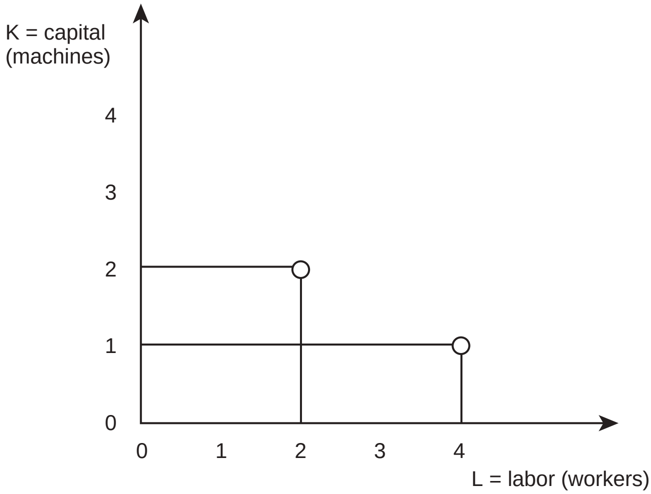

Figure 5.1 Production process for a flour mill in Chicago, Illinois.

The prefix "iso" refers to "same, or equal," and "quant" refers to the numerical value of output. Therefore, the term isoquant means, "equal quantity of output," and an isoquant is a line on which every point refers to the same level of output. Figure 5.1 shows two possible production methods for the flour mill. Suppose that there are several other combinations of labor and capital that could produce the same level of output, as shown in Figure 5.2.

Every point on the isoquant, the curved line in Figure 5.2, represents the same level of output, Y_1 (100 5-lb bags of flour). The isoquant shows that capital and labor are substitutable: a flour mill can use any combination of K and L on the isoquant to produce the same quantity of flour. Efficient firm managers will recognize the potential for substitution among inputs, and will select the profit-maximizing combination of inputs.

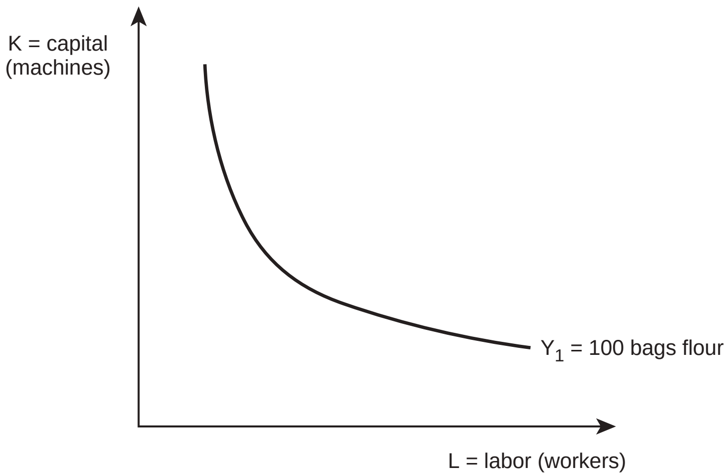

Figure 5.2 Isoquant for a flour mill in Chicago, Illinois.

Examples of isoquants

Numerous combinations of inputs can produce a given quantity of most agricultural products. Corn and soybean producers in Iowa can use different combinations of land, machinery, chemicals, and labor to produce given quantities of corn and soybeans. Wheat producers make choices when selecting the appropriate amount of machinery to use. Figure 5.3 introduces another feature of isoquants. Several isoquants, each representing a different level of output, are often drawn together as a "map."

The isoquants farther from the origin represent larger outputs than the ones that are close to the origin. Moving outward from the origin and passing through isoquants shows this increase in output and also the combination of inputs needed to produce each level of product. Output increases with movement to the northeast in the graphs, since more inputs result in more outputs [Y = f(X)].

5.3 Relative prices

Different agricultural production techniques stem from different levels of technology. Agricultural producers can select between labor-intensive methods or capital-intensive technology, as shown in Figure 5.4.

The production technology represented by point A in Figure 5.4 shows a relatively large amount of labor and small amount of capital (L_A, K_A). Producers in many low-income nations may use this labor-intensive technology. Producers in high-income nations typically use a capital-intensive production process in agriculture (L_B, K_B), as shown at point B in Figure 5.4. Why do producers in different nations use drastically different types of technology? The answer is relative prices. In regions where labor is less expensive than capital, more labor is used. In areas where labor is expensive, machines and chemicals substitute for labor because they can produce agricultural products in a less expensive manner.

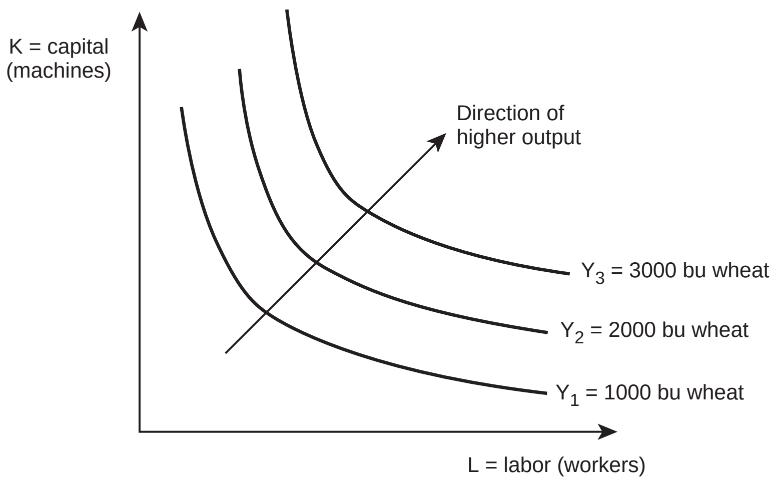

Figure 5.3 Isoquant map for an Oklahoma wheat farm.

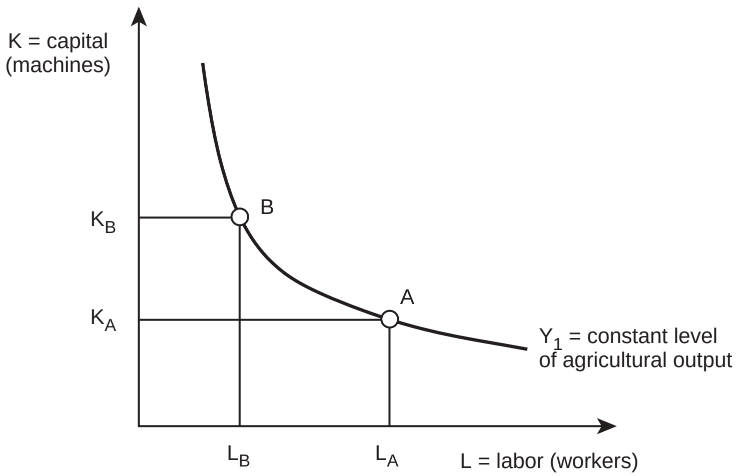

Figure 5.4 Isoquant for a hypothetical agricultural product.

Agricultural policy in the United States has paid direct subsidies to agricultural producers since 1933. Maintaining family farms has been one major goal of this policy. This policy has resulted in an agriculture that is more labor-intensive than it would be without the subsidies. Why? Because the subsidies keep some small family farms in business, which prevents more labor from migrating out of agriculture and into other pursuits.

Several forces push businesses to different points on the isoquant. Lack of financial resources pushes toward more labor and less machinery. The advance of technology encourages the adoption of the newest machine and the newest variety of insecticide. Where does the adoption and substitution stop? Relative prices define the end of the struggle. Agricultural producers ask, "How much does it cost to buy labor and capital?" They select the optimal combination of inputs based on these relative prices.

American agricultural firms are therefore likely to move toward using capital-intensive production techniques such as GIS (Geographical Information Systems, a satellite system) and computerized combines. In Africa, labor is relatively less expensive than capital. The opportunity cost of labor in many Sub-Saharan African nations is quite low, near zero in some places. Job opportunities are not high for a relatively unskilled and uneducated workforce. Therefore, the low-income nations of Africa, as well as low-income nations in other parts of the world, typically use labor-intensive techniques such as hand plowing, hoeing, weeding, and harvesting. This sounds inefficient to American producers, but these labor-intensive techniques can still be optimal, since relative prices guide the decision (Figure 5.5).

Figure 5.5 helps explain the ongoing migration of labor out of agriculture in high-income nations. As labor has become more expensive over time due to increases in productivity and education levels, agricultural producers have replaced labor by increasing their use of machinery. This is the major result of the analysis to this point:

THE CHOICE OF TECHNIQUES DEPENDS ON RELATIVE PRICES.

Plate 5.3 Labor-intensive potato harvest.
Source: Usosr/Shutterstock

Agribusiness firms will use relative prices when choosing combinations of inputs that minimize their costs of production.

Examples: choosing the right production techniques

Car washes are different in different parts of the country. In rural areas and in small towns like Bozeman, Montana, car washes use capital-intensive production techniques. There are few workers, and fully automated machines do the work of cleaning the car. In urban areas such as New York City or Chicago, people, not machines, often wash a dirty car. This is due

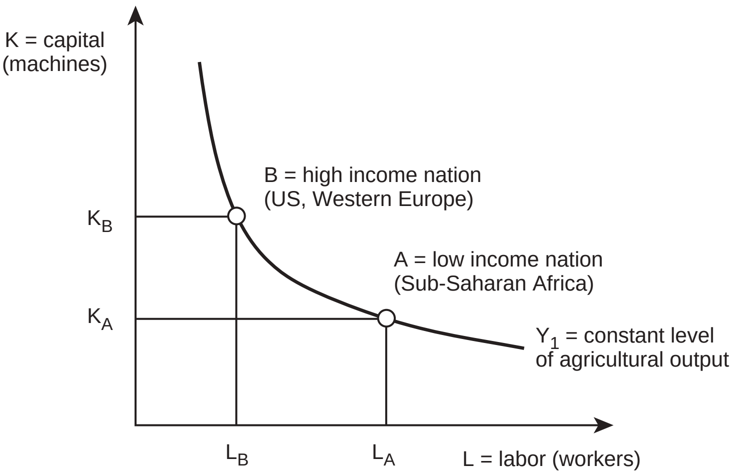

Figure 5.5 Isoquant location comparison across nations.

to relative prices. Labor is cheaper and more abundant in urban areas, so many of the car washes hire the low-skilled labor. If the price of labor increases over time, car wash owners would shift to more machines and less labor. Why? Because of the shift in relative prices.

Quick Quiz 5.4

How will McDonald's respond to changes in relative prices?

If the minimum wage increases, McDonald's must pay a higher price for labor, and the fast food company will substitute out of labor and use more machines. Could a fast food restaurant really do this? Yes, the decision depends on relative prices.

Quick Quiz 5.5

Explain how an automatic drink dispenser at a fast food restaurant, and agricultural tractors and combines that are driven by technology, are the result of relative prices.

Agricultural producers and agribusinesses make choices regarding the degree of mechanization based on relative costs. In the Great Plains, farming is practiced on a very large scale, with huge machines (tractors, combines, seed drills) working on thousands of acres. Contrast this with smaller farms in New England and California that have more labor available to them.

5.4 Isoquant types

The production processes of firms are highly diverse: contrast the lemonade stands run by neighborhood children with the production of a good as complex as a John Deere combine. The relationships between inputs and outputs are varied and complex. This section describes several possible types of isoquants, which reflect the variety of ways that agricultural producers and agribusinesses convert inputs into output.

Perfect substitutes

Perfect Substitutes are interchangeable inputs. High Fructose Corn Syrup (HFCS) is a perfect substitute for sucrose (sugar) in soda. Soda producers such as Coca-Cola and Pepsi can use either sweetener without any noticeable effect on the product.

- ***Perfect Substitutes*** = inputs that are completely substitutable in the production process (see **Substitutes**).

The graph in Figure 5.6 shows an isoquant for perfect substitutes. The isoquant is a straight line, since the two inputs substitute without impact.

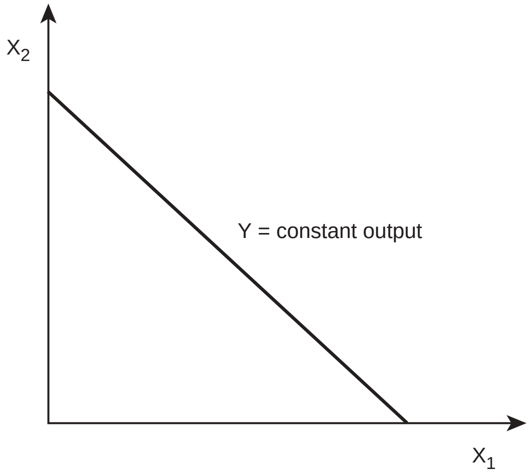

Figure 5.6 Isoquant for perfect substitutes.

Other perfect or nearly perfect substitutes include: (1) cane sugar and beet sugar (no difference in the chemical composition), (2) bag seed and bulk seed, (3) 5-lb bags of flour and 10-lb bags of flour.

Quick Quiz 5.6

Are John Deere combines and CASE-IH combines perfect substitutes?

Box 5.1 John Deere

Deere & Company, known by its brand name John Deere, was founded by John Deere in 1837 and is headquartered in Moline, Illinois. John Deere is the world's leading manufacturer of agricultural machinery. In 2010, it was listed as 107th in the Fortune 500 ranking. Deere & Company agricultural products, sold under the John Deere name, include agricultural equipment: tractors, combine harvesters, cotton harvesters, balers, planters, and sprayers. The company also produces construction equipment, forestry equipment, diesel engines, lawn mowers, and snow blowers. John Deere also provides financial services and other related activities. The company employs over 55,000 persons, earns revenue of $26 billion (2010), and has a net income of $3.9 billion (2010). The company's products are recognized by green color, with yellow trim, and the deer logo.

Sources: John Deere. http://www.deere.com. Fortune 500. http://money.cnn.com
"2010 Form 10-K, Deere & Company." United States Securities and Exchange Commission.

Perfect complements

Perfect Complements are resources that must be used together. Some examples come close. Think of a tractor and a plow: the plow is worthless without the tractor to pull it. The tractor is more versatile, so the complementarity is not perfect. Shoes are another example: except in very rare cases, the left shoe needs to complement the right shoe. Nuts and bolts are often perfect complements.

- ***Perfect Complements*** = Goods that are produced together using the same collection of resources (beef and hides) or inputs that must be used together in a fixed ratio (one tractor and one plow).

The isoquant of perfect complements is a right angle, showing that extra units of one input are not useful if not paired with the other input. The right angles in Figure 5.7 are isoquants. Every point on the vertical portion of each isoquant produces the same level of output. Similarly, every point on the horizontal part of an isoquant refers to the same level of output. Adding more of one of the two inputs will have no effect on the output levels. If an extra unit of X_1 is added, it must be accompanied by one unit of X_2 before it becomes a useful input. Using X_1 and X_2 together increase the total product and movement to a higher isoquant.

All points on an isoquant represent the same level of output. If an agricultural producer has only one tractor, it doesn't matter how many plows he or she has: the tractor can only pull one plow. Similarly, if there were only one plow, any additional tractors would be wasted, as depicted in Figure 5.7.

Imperfect substitutes

Imperfect Substitutes are the "typical" case. They are inputs that can be substituted one for another, but not perfectly. Skilled and unskilled labor are examples. These two inputs are useful in many parts of a production process, but they are not perfect substitutes.

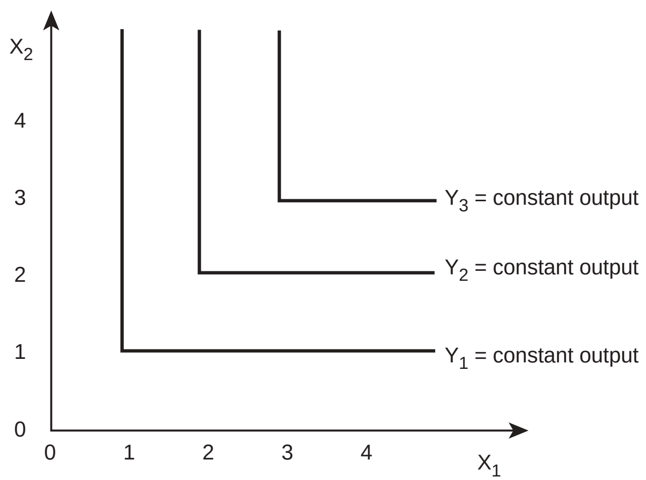

Figure 5.7 Isoquant for perfect complements.

- ***Imperfect Substitutes*** = inputs that are incomplete substitutes for each other in the production process (see **Substitutes**).

Due to the Law of Diminishing Marginal Returns, it takes larger and larger amounts of one input to substitute for equal reductions of the other inputs. This gives the isoquant a shape that is convex (bowed toward the origin).

At point A in Figure 5.8, a firm has many workers, but only one machine. Suppose that output would remain constant if the firm purchased one more machine and used three fewer workers. At point B (Figure 5.8) a firm has many machines, but only one worker. At this point, the firm could replace several machines by hiring one additional worker and output would be unchanged. Imperfect substitutes provide the ability to substitute between inputs. Because there are many different ways of producing goods, firm managers can select the optimal combination based on relative prices of the inputs.

Imperfect substitutes example

Soil and chemicals are imperfect substitutes when used in crop production. Many individuals believe that soil is necessary for the commercial production of food and fiber. In fact, crops can grow without soil using water in which an appropriate mix of chemicals has been dissolved. Soil and agrochemicals are close to perfect substitutes because producers can use chemicals to replace soil.

This should not be surprising to anyone who has visited Epcot Center at Disney World in Florida, where a small number of crops grow hydroponically (in chemical-infused water). It should also not surprise anyone familiar with agriculture in the vast open spaces of the US: the Great Plains, California's Central Valley, or the Great Basin. Large parts of these areas use sand with very little soil to grow crops. With modern irrigation technology, producers can use center-pivot irrigation systems to drip nutrients into the sand (these are the big circles seen from an airplane). Figure 5.9 shows an isoquant and substitution possibilities between imperfect substitutes: soil and chemicals.

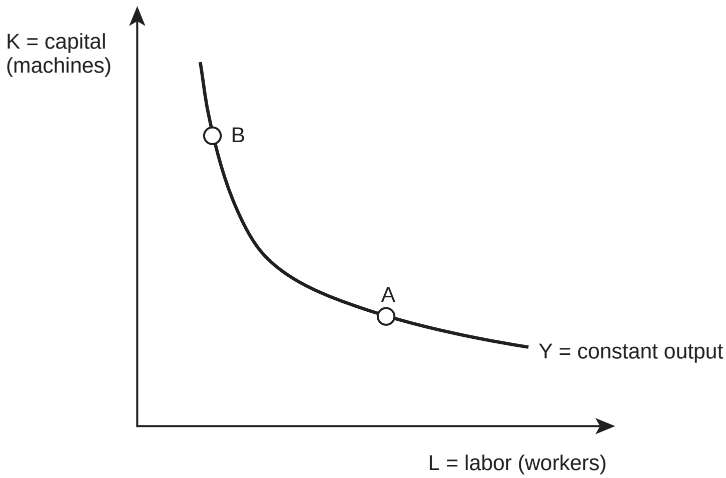

Figure 5.8 Isoquant for imperfect substitutes.

Box 5.2 Center-pivot irrigation

Center-pivot irrigation is a method of watering crops by using a sprinkler that rotates around a pivot. Center-pivot irrigation was invented in 1949 by farmer Frank Zybach, of Dalhart, Texas. The center pivot consists of segments of galvanized steel or aluminum pipe, joined together and supported by trusses, mounted on wheeled towers, with sprinklers positioned along its length. The machine moves in a circular pattern and is fed with water under pressure from the pivot point at the center of the circle. One complete rotation typically requires three days.

Center pivots are usually less than 500 meters (1640 feet) in length (circle radius) with the most common size being the standard 1/4 mile (400 m) machine. Most center pivot systems now have drops with sprinkler heads positioned close to the crop, thus limiting evaporative losses and wind drift. Drops can also be used with drag hoses or bubblers that deposit the water directly on the ground between crops. This type of system is known as LEPA (Low Energy Precision Application).

For center-pivot irrigation to be used, the field needs to be relatively flat. However, one major advantage of center pivots over alternative systems is the ability to function in undulating country. This advantage has resulted in increased irrigated acreage and water use in hilly areas, including parts of the United States, Australia, New Zealand, Brazil, the Sahara, and the Middle East.

Sources: “Center-Pivot Irrigation System Modification to Provide Variable Water Application Depths.” ddr.nal.usda.gov
NASA/Goddard Space Flight Center. (April 28, 2012). “NASA’s Landsat Satellites See Texas Crop Circles—Of the Irrigation Kind.” ScienceDaily. Retrieved April 28, 2012.

Plate 5.4 Center-pivot irrigation.

Source: B Brown/Shutterstock

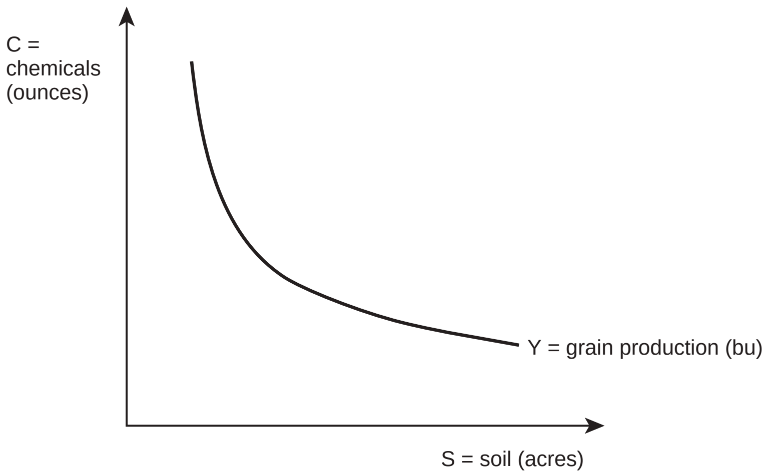

Figure 5.9 Substitutability of soil and chemicals in grain production.

Many forces cause movements along this isoquant. Soil erosion is a big issue in agriculture, since cultivating the soil increases soil loss from wind and water erosion. Severe soil loss has caused producers in some areas to switch out of soil replacing it with chemicals (hydroponic agriculture). New technologies such as "low-till" and "no-till" planting systems help reduce the threat of erosion and allow grain to be planted without having to plow the soil. These new technologies allow for the use of more soil, but often require higher chemical use.

Box 5.3 No-till agriculture

No-till farming is a technique of growing crops without tilling the soil. No-till is used to increase the amount of water and organic matter (nutrients) in the soil, and decrease erosion. It increases the amount and variety of life in and on the soil but often requires increased chemical use for weed control.

In no-till farming the seeds are directly deposited into untilled soil which has retained the previous crop residues. Special no-till seeding equipment opens a narrow slot into the residue-covered soil. The slot is just wide enough to put the seeds into the ground and cover them with soil. The aim is to move as little soil as possible in order not to bring weed seeds to the surface and not stimulating them to germinate. No other soil tillage is done during the growth of the crop. The residues from the previous crops remain largely undisturbed at the soil surface as mulch.

Adequate weed management is the key to successful application of the system. Weed control is performed using herbicides and also through the adoption of appropriate crop rotations including the use of adapted, aggressive species of cover crops. Some of the environment-relevant effects of no-tillage include erosion control, improvement of water quality, increased water infiltration which leads to reduced flood hazard, and climate-related consequences through carbon sequestration in the soil may appear after several years of continuous, uninterrupted application. Globally, the no-tillage technology is used on over 100 million hectares under a wide variety of climate and soil conditions.

Sources: CTIC (2011). Conservation Technology Information Center homepage. http://www.ctic.purdue.edu/media/pdf/TillageDefinitions.pdf
No-Tillage. http://www.rolf-derpsch.com/notill.htm

Another example of imperfect substitutes is from production agriculture in the United States. The federal government has taken millions of highly erodible acres out of agricultural production through the Conservation Reserve Program (CRP). However, when fewer acres are in production, producers substitute out of soil and into chemicals by applying higher levels of agrochemicals to the acres remaining in production.

5.5 Optimal input decisions

The preceding pages and examples beg the question ,"What is a systematic way to choose the optimal combination of inputs for use in a production process?" Cost minimization is related to profit maximization, since lowering costs results in increasing profits (π = TR – TC). Relative prices drive the decision regarding what inputs to use, and changes in relative prices result in shifts out of the relatively expensive input into the relatively inexpensive input.

Box 5.4 Conservation Reserve Program

The Conservation Reserve Program (CRP) is a voluntary program for agricultural landowners. Through CRP, a farmer can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible farmland. Participants enroll in CRP contracts for 10 to 15 years, and receive annual rental payments based on the agriculture rental value of the land. The program provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices.

CRP protects millions of acres of American topsoil from erosion and is designed to safeguard the nation's natural resources. By reducing water runoff and sedimentation, CRP protects groundwater and helps improve the condition of lakes, rivers, ponds, and streams. Acreage enrolled in the CRP is planted to resource-conserving vegetative covers, making the program a major contributor to increased wildlife populations in many parts of the country.

Source: USDA. Farm Service Agency. Conservation Programs. http://www.fsa.usda.gov/FSA/

The marginal rate of technical substitution

The slope of an isoquant defines the **Marginal Rate of Technical Substitution (MRTS)**. It reflects how well one input substitutes for another.

- ***Marginal Rate of Technical Substitution (MRTS)*** = the rate at which one input can be decreased as the use of another input increases to take its place. The slope of the isoquant. MRTS = $\Delta X_2/\Delta X_1$

A graph provides the best way to gain understanding of what the MRTS is all about.

The slope of the isoquant in Figure 5.10 shows the MRTS between inputs X_1 and X_2. In this graph, input X_2 is on the y-axis, and X_1 is on the x-axis, so the slope of the isoquant equals $\Delta Y/\Delta X = \Delta X_2/\Delta X_1$. In the case of imperfect substitutes, as in Figure 5.10, the slope becomes less steep as the combination of X and Y changes in response to substituting X_1 for X_2. The value of MRTS changes with moves along the isoquant. When moving from point A to point B, the firm keeps output constant by reducing X_2 by one unit (from 3 to 2 on the vertical scale), and increasing X_1 by one unit (from 1 to 2 on the horizontal scale). This results in a calculated MRTS of negative one:

$$\text{MRTS(AB)} = \Delta X_2/\Delta X_1 = (2-3)/(2-1) = -1. \quad (5.5)$$

The MRTS must always be a negative number, since isoquants based on two inputs that are imperfect substitutes must always be downward sloping for rational producers.

The move from A to B means that the firm can select a wide variety of input combinations that will yield the same level of output. In fact, any point on the isoquant will, by definition, result in the same level of output. So, the movement from A to B represents a shift out of input X_2 and into input X_1.

A move from point B to C will yield a smaller MRTS, because the slope of the isoquant becomes less steep with the move. This new MRTS (relating to the move from point B to point C) is calculated as:

$$\textbf{MRTS(BC)} = \text{slope of isoquant} = \Delta X_2/\Delta X_1 = (1-2)/(4-2) = -1/2 = -0.5. \quad (5.6)$$

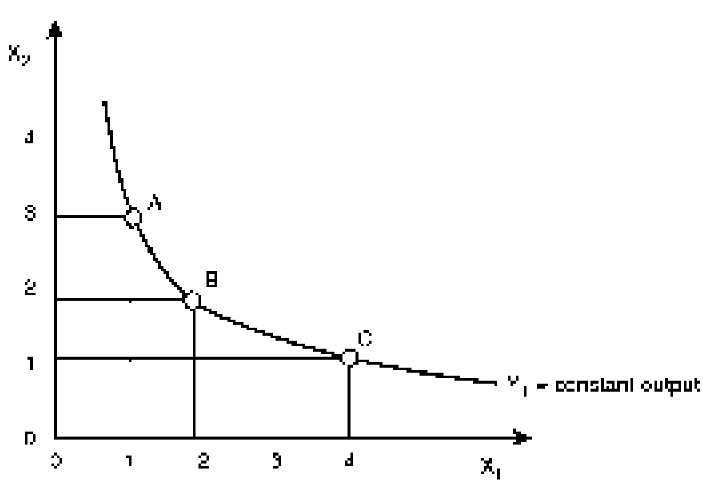

Figure 5.10 Marginal rate of technical substitution between two inputs.

The slope of the isoquant, or MRTS, is crucial to determining which combination of inputs a firm will choose. The isoquant describes input combinations that are technically feasible. Economic information (the prices of the two inputs) allows this technical information to determine the cost-minimizing levels of input use. In the next section, we will switch from the technical information relating to input productivity to relative prices of the inputs.

The Isocost Line

How will a profit-maximizing producer determine how many pounds of fertilizer, or what labor-intensive method, or capital-intensive technique is most profitable? The producer does so by combining the technical information contained in the isoquant with cost information summarized by the **Isocost Line**. The prefix "iso" means the "same, or equal" and the term "cost" refers to the value placed on inputs. Therefore, the term isocost means "equal costs," and an isocost line is a line on which every combination of inputs has the same value or costs.

- *Isocost Line* = a line indicating all combinations of two variable inputs that can be purchased for a given level of expenditure.

Consider an agricultural implement dealer facing a $10/hour price of labor, a $100/machine price of capital and total expenditures equal to $1000. This is enough information to use in developing an algebraic equation for an isocost line:

$$TC = P_1X_1 + P_2X_2. \quad (5.7)$$

Given "economic data" from the example, this becomes:

$$TC = (\$10/\text{hour})*X_1 + (\$100/\text{machine})*X_2 = 10L + 100K, \quad (5.8)$$

where X_1 is labor (L) and X_2 is capital (K). The terms in this equation rearrange to yield the equation of a line: $y = b + mx$, where b is the y-intercept and m is the slope. This is done to isolate the term on the vertical axis (K in this example) on the left-hand side of the equation. Total expenditures (TC) equal $1000, so:

$$TC = 10L + 100K, \text{ and} \quad (5.9)$$

$$1000 = 10L + 100K. \quad (5.10)$$

To isolate K on the left side of the equation, subtract 10L from both sides:

$$1000 - 10L = 100K. \quad (5.11)$$

Reverse sides to move K to the left-hand side:

$$100K = 1000 - 10L. \quad (5.12)$$

Finally, divide both sides by 100 to get:

$$K = 10 - 0.1L. \quad (5.13)$$

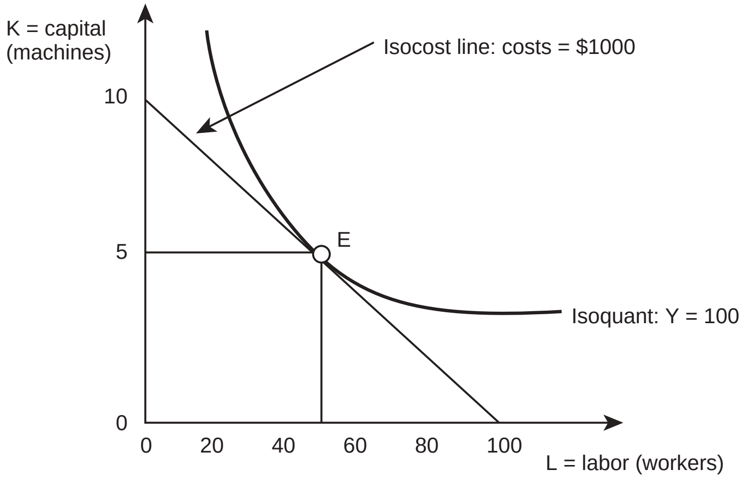

Figure 5.11 Equilibrium for input combination.

This is the equation for the isocost line. This line is graphically correct with Figure 5.11: the y-intercept is equal to 10 and the slope is equal to 0.1 (= 10/100). This simple algebra can be used for any two-variable isocost line. In summary:

$$TC = P_1X_1 + P_2X_2 \tag{5.14}$$

$$P_2X_2 = TC - P_1X_1 \tag{5.15}$$

$$X_2 = TC / P_2 + (-P_1 / P_2) * X_1. \tag{5.16}$$

The slope of the isocost line equals ($-P_1/P_2$), and the y-intercept equals (TC/P_2). This equation contains the information on relative prices, and helps locate the optimal, cost-minimizing combination of inputs for a business firm.

Equilibrium: the tangency of the isoquant and the isocost line

The “test” here is to help an agricultural implement dealer find the optimal combination of machines and workers for the firm to employ. This requires combining the isoquant and the isocost line in the same graph, as in Figure 5.11. To find the optimal combination of inputs, the firm will locate at the point of tangency of the isoquant and the isocost line (the only point where the two lines are barely touching). In Figure 5.11, this occurs at the point (50, 5), where the firm purchases 50 hours of labor and 5 machines.

Note that this point is exactly “in the middle” of the isocost line. This is due solely to the location of the hypothetical isoquant, and is not always the point where the firm will locate. The actual point depends on the technology (represented by the isoquant) and the relative prices (represented by the isocost line).

Plate 5.5 Modern tractor and plow.
Source: Dmitry Kalinovsky/Shutterstock.

The firm's objective is to minimize costs for a given level of output. It can meet this objective by finding an **Equilibrium** point at the tangency, where the slope of the isoquant is equal to the slope of the isocost line. Equilibrium is a point where the firm is doing as well as it possibly can, given the situation, and does not desire to change.

- ***Equilibrium*** = a point or situation from which there is no tendency to change.

Once the manager locates the equilibrium point, he or she has no forces pushing for change: the firm is "at rest." The equilibrium condition can be shown algebraically to be where the slope of the isoquant (= MRTS = $\Delta X_2/\Delta X_1$) is equal to the slope of the isocost line (= $-P_1/P_2$).

$$\Delta X_2 / \Delta X_1 = -P_1 / P_2. \tag{5.17}$$

We can rearrange this equation (by cross-multiplication) to find the equilibrium condition for optimal input use:

$$P_2\Delta X_2 = -P_1\Delta X_1. \tag{5.18}$$

This equation shows that in equilibrium, the changes in expenditures on each input are equal. The relationship states that a firm manager will continue to substitute inputs until the amount spent for the input added is just equal to the amount saved by reducing the amount spent on the other input. To make this idea clear, consider the case when the equality in the equilibrium condition above does not hold:

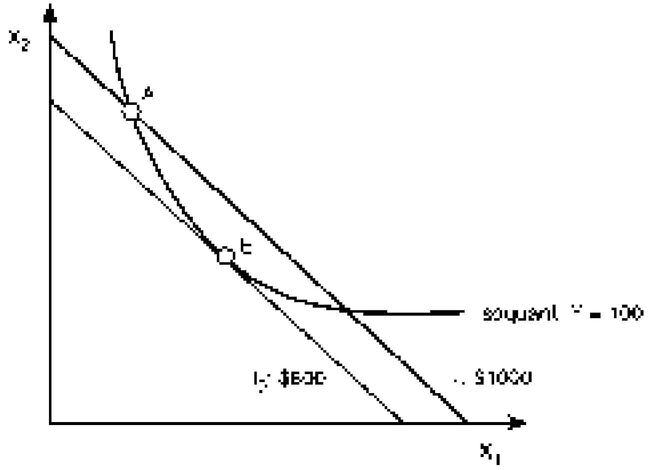

Figure 5.12 Disequilibrium example for input combination.

If $P_2\Delta X_2 > -P_1\Delta X_1$, then more X_1 should be used, because the cost of adding one more unit of X_2 is greater than the cost saved by decreasing the use of X_1.

If $P_2\Delta X_2 < -P_1\Delta X_1$, then more X_2 should be used, because the cost of adding one more unit of X_1 is greater than the cost saved by decreasing the use of X_2.

This equilibrium condition indicates that the optimal, cost-minimizing, combination of inputs occurs when the physical rate of substitution (MRTS) is equal to the economic rate of substitution (the price ratio). The equilibrium condition provides the least-cost solution for the firm.

At point A in Figure 5.12, the firm is not in equilibrium, since the slope of the isoquant (MRTS) is greater (steeper) than the price ratio

$$P_2\Delta X_2 > -P_1\Delta X_1. \quad (5.19)$$

This inequality signals to the manager to substitute out of the expensive input (X_2) and into the less expensive input (X_1). This substitution will continue until point E is reached, where $\Delta X_2/\Delta X_1 = -P_1/P_2$. At point E, the firm is in equilibrium.

Quick Quiz 5.7

What is the definition of equilibrium? Why is point E in Figure 5.12 an equilibrium point?

Figure 5.12 shows that through the process of input substitution, the firm reaches a lower isocost line (I_1) with a cost saving of $200 ($1000 − $800). The next step inquires about a corn producer's selection of inputs.

Example: corn producer near Newton, Iowa

The goal of a corn producer near Newton, Iowa, is to minimize costs. The producer's objective is to produce 100 bushels of corn at the lowest possible cost. The production of corn requires N inputs (X_1, X_2, X_3, …, X_N), and the two most expensive inputs are land (X_1) and fertilizer (X_2). Focusing on these two major inputs requires holding quantities of all other inputs constant. The corn producer's production function is:

$$Y = f(X_1, X_2 \mid X_3, \ldots X_N), \text{ where} \quad (5.20)$$

$$X_1 = \text{land (acres), and} \quad (5.21)$$

$$X_2 = \text{fertilizer (lbs).} \quad (5.22)$$

The objective is to find the optimal combination of land and fertilizer to use to produce 100 bushels of corn in Iowa. Figure 5.13 shows an isoquant that reflects all combinations of inputs (land and fertilizer) that produce the same level of output (corn).

The slope of the isoquant is the marginal rate of technical substitution = MRTS = $\Delta X_2/\Delta X_1$. Since land and fertilizer are substitutes, there are many combinations of the two inputs that will meet the objective and produce 100 bushels.

Quick Quiz 5.8

Explain why fertilizer and land are substitutes in the production of corn. Are they perfect or imperfect substitutes? Explain why.

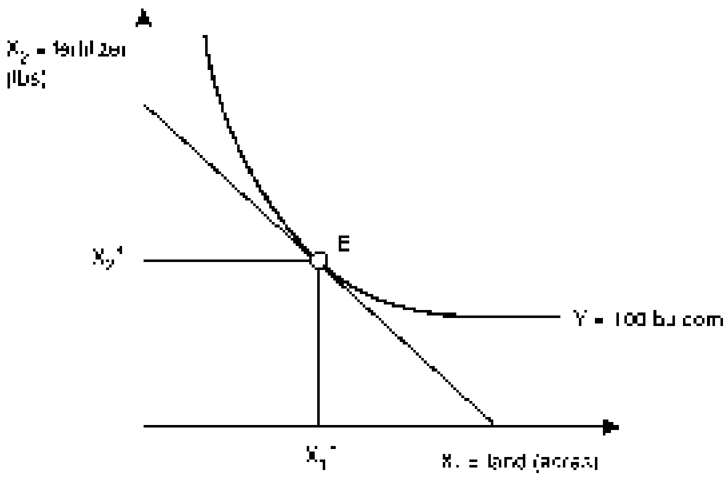

Figure 5.13 Equilibrium for input combination.

The producer will want to locate the cost-minimizing combination of inputs for the production of 100 bushels of corn. She or he can do this with the use of the isocost line. To minimize the costs of producing 100 bushels, the corn producer locates the tangency point of the isoquant and isocost lines: the point where the slope of the isoquant equals the slope of the isocost line (MRTS = price ratio).

$$\Delta X_2 / \Delta X_1 = -P_1 / P_2. \tag{5.23}$$

The equilibrium point in this hypothetical example is where the changes in expenditures from substituting land and fertilizer along the isoquant are equalized: the money released from the sale of land is equal to the cost of the fertilizer needed to make up for the lost land.

$$P_2 \Delta X_2 = P_1 \Delta X_1 \tag{5.24}$$

If the change in expenditure for one input were greater than the change in the other input, the producer could lower costs by moving toward the equilibrium point.

Interestingly, the equilibrium condition for selecting the optimal combination of inputs follows the same logic as the profit-maximizing condition of input use. Recall that the profit-maximizing rule for input use is to set the marginal revenue product ($MRP = MPP*P_Y$) equal to the marginal factor cost ($MFC = P_X$):

$$MRP = MFC \tag{5.25}$$

$$MPP * P_Y = P_X \tag{5.26}$$

$$(\Delta Y / \Delta X) * P_Y = P_X \tag{5.27}$$

$$\Delta Y * P_Y = \Delta X * P_X \tag{5.28}$$

Equation (5.28) shows that the profit-maximizing condition results in an equilibrium where the incremental increase in revenue ($\Delta Y*P_Y$) is equal to the incremental increase in input costs ($\Delta X*P_X$). The next section shows how producers (input users) react to changes in the price of inputs.

5.6 Optimal responses to price changes

Relative prices drive the economic decisions of producers in their quest to maximize profits and or minimize costs. Since prices are continuously changing, the question becomes, "How do producers respond to changes in prices?" Economic intuition says that when it is possible, shift out of expensive inputs and into less expensive inputs. A contemporary choice of this kind comes up with respect to finding the correct combination of agrochemicals and land to use in the production process.

The discussion of isoquants and isocost lines focused on setting the MRTS equal to the slope of the isocost line, or the price ratio (P_1/P_2). The equilibrium condition highlights the importance of relative prices in the economy: if the price of one input changes, it changes the price ratio, and results in a new equilibrium combination of inputs for producers.

Price change for the farm implement manufacturer

Consider the farm implement manufacturer (John Deere) to see how input price changes affect input selection. This firm uses labor (L = workers) and capital (K = machines) to produce implements. The price of labor is \$10/hour, the price of machines is \$100/hour, and total expenditures are \$1000, as can be seen in Figure 5.14.

Suppose the wage rate increases from \$10/hour to \$20/hour, shifting the isocost line from I_0 to I_1. Focus attention on the shift in isocost lines by recalling the algebraic equation ($y = b + mx$) of the isocost lines.

$$X_2 = TC/P_2 + (-P_1/P_2)X_1. \tag{5.29}$$

The y-intercept of the isocost line (TC/P_2) remains unchanged, because the total expenditures (TC) and the price of machines (P_2) have remained unaltered. The slope ($-P_1/P_2$), however, becomes steeper due to the increase in the price of labor (P_1). The slope of I_0 is equal to the price ratio prior to the price change, $-P_1/P_2 = -10/100 = -0.1$. After the wage increase, the price ratio increases to, $-P_1/P_2 = -20/100 = -0.2$. This change is shown in Figure 5.14. The addition of isoquants in Figure 5.15 provides information on the firm's need to change its input mix in response to the change in relative prices.

If the total expenditures of the firm remain constant at \$1000, the firm ends up on a lower isoquant, showing that production drops due to the increase in input price. This reflects the discussion in the previous chapter: if the price of an input increases, production costs increase, and the firm lowers its level of output. The price change also alters relative prices (the slope of the isocost line), and results in a substitution out of labor and into capital.

The corn producer's goal was to produce 100 bushels of corn at the lowest possible cost. If the price of land increases, the slope of the isocost will change, but this firm manager will desire to remain on the same isoquant, to remain at the production goal of 100 bushels. The price change will cause a shift in the cost-minimizing combination of inputs, shown in Figure 5.16.

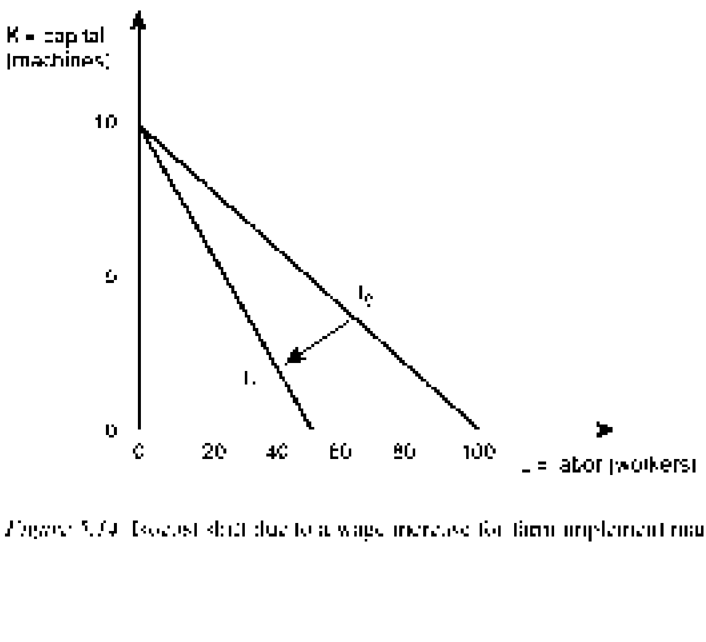

Figure 5.14 Isocost shift due to a wage increase for farm implement manufacturer.

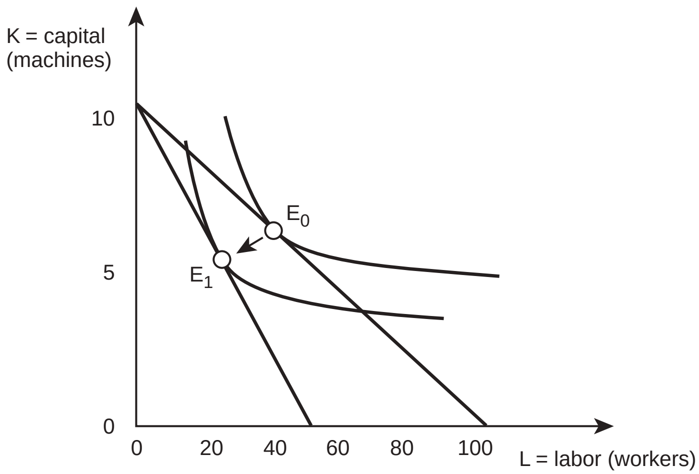

Figure 5.15 Equilibrium change due to a wage increase for implement manufacturer.

The increase in the price of land causes the slope of the isocost line to become steeper. To remain on the same isoquant, the producer will shift out of the more expensive input (land) and into the less expensive input (fertilizer) in order to reach a new equilibrium at (E_2). At the new equilibrium, fewer acres of land are employed, and more fertilizer.

Example: the impact of gambling on input selection in Minnesota

The general principles outlined in the previous sections are useful in exploring any changes in relative prices, including unusual situations like the impact of gambling casinos on the

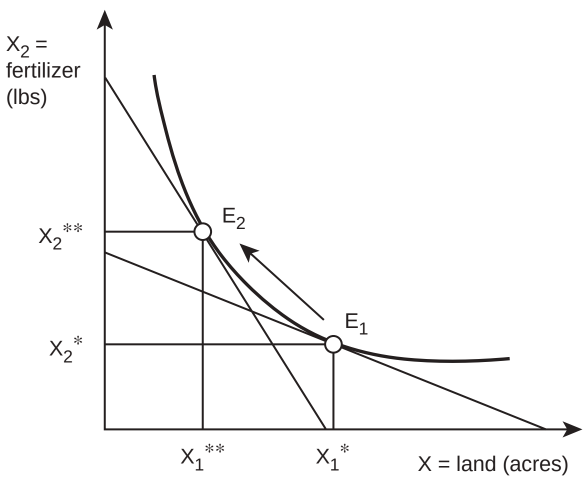

Figure 5.16 Equilibrium change due to a land price increase.

optimal selection of inputs to use in agriculture. Minnesota is the point of reference, but the issue could appear in any number of places.

Over the past few years, several large gambling casinos have located in the Midwest, including Minnesota. These casinos, often built on agricultural land, reduce the number of acres available for agricultural production in this area. The casinos employ several hundred persons. Many have moved to the area and purchased houses. The increase in visitors has also increased the demand for hotel rooms, restaurants, gasoline stations, and convenience stores. As a result, the business climate in these areas has improved dramatically. The casinos have also caused an increase in the price of land, due to their own needs for buildings and parking space and the increase in the population of the area. Graphical analysis helps understand how gambling has affected the use of land and agrochemicals in Minnesota agriculture (Figure 5.17).

If the price of land (P_1) increases, the price ratio increases, and the isocost line becomes steeper. To produce the same amount of agricultural output, or remain on the same isoquant, the producers in the area must use more chemicals to replace the land that has been lost.

Relative prices rule!

Relative prices determine the optimal level of output (Chapter 3), the optimal level of inputs to use (Chapter 4), and the cost-minimizing combination of inputs to use (Chapter 5).

Plate 5.6 Impact of gambling on land price near casino.

Source: Lipik/Shutterstock

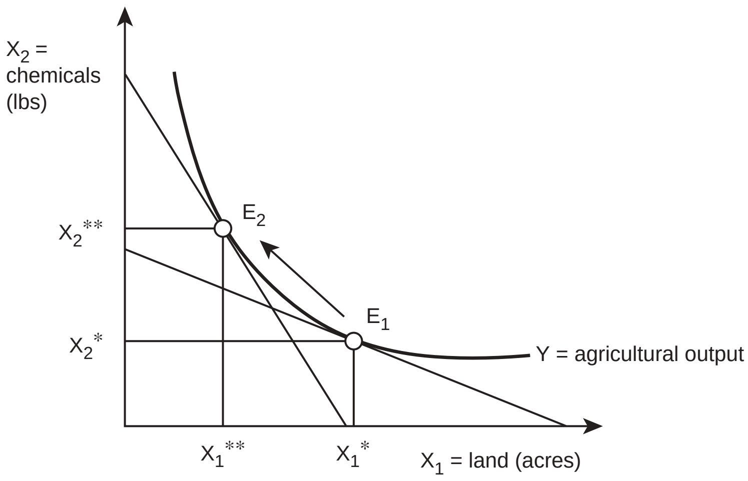

Figure 5.17 Impact of casinos on equilibrium use of land and chemicals.

Chapter 6 will show how relative prices also determine the most profitable combination of outputs to produce. Relative prices run the entire market-based economy, since the decisions of business firms are all determined by the relative prices of scarce resources.

5.7 Summary

1. A firm will select inputs based on relative prices.
2. There are many different combinations of inputs that can produce the same level of output.
3. An isoquant is a line that represents all combinations of two variable inputs that will produce a given level of output.
4. Different nations use drastically different production practices based on relative prices. When labor is cheap relative to capital, a labor-intensive production practice will be used.
5. Agribusiness firms will choose combinations of inputs that minimize their costs of production for a given level of output.
6. Perfect substitutes are inputs that can be interchanged completely. The isoquant for perfect substitutes is a straight line.
7. Perfect complements are inputs that must be used together in a fixed ratio. The isoquant for perfect complements has an "L" shape.
8. Imperfect substitutes are inputs that substitute for each other incompletely. The isoquant for imperfect substitutes is convex to the origin.
9. The Marginal Rate of Technical Substitution (MRTS) is the rate one input can be decreased as the use of another input increases. The MRTS is the slope of the isoquant.
10. The isocost line indicates all combinations of two variable inputs that can be purchased at the same level of expenditure.
11. To find the optimal combination of inputs, the firm will locate at the point where the isoquant is tangent to the isocost line. At this point, the marginal rate of technical substitution equals the relative price ratio.

12. An equilibrium is a point from which there is no tendency to change.
13. Changes in relative prices result in shifts in the isocost line, and changes in the equilibrium combination of inputs. Firms will substitute out of relatively expensive inputs and into relatively less expensive inputs.
14. Relative prices rule: relative prices determine the optimal level of output, the optimal level of inputs, and the cost-minimizing combination of inputs to use.

5.8 Glossary

Complements in Production. Goods that are produced together using the same collection of inputs.

Equilibrium. A point from which there is no tendency to change.

Imperfect Substitutes. Inputs that are incomplete substitutes for each other in the production process.

Isocost Line. A line indicating all combinations of two variable inputs that can be purchased for a given level of expenditure.

Isoquant. A line indicating all combinations of two variable inputs that will produce a given level of output.

Marginal Rate of Technical Substitution [MRTS]. The rate at which one input can be decreased as the use of another input increases to take its place. The slope of the isoquant. MRTS = $\Delta X_2/\Delta X_1$.

Perfect Complements. Goods that are produced together using the same collection of resources (beef and hides) or inputs that must be used together in a fixed ratio (one tractor and one plow).

Perfect Substitutes. Inputs that are completely substitutable in the production process.

Relative Price. The prices of goods relative to each others. (Example: The price of wheat increased relative to the price of corn).

Substitutes in Production. Goods that compete for the same resources in the production process (wheat and barley). Or inputs that can replace each other in the production process (land and fertilizer).

5.9 Review questions

1. To draw an isoquant, the graph must show:
   a. one input on each axis
   b. one input and one output
   c. one output on each axis
   d. cost of production on the vertical axis
2. Each point on the isoquant shows:
   a. the same level of output
   b. the same level of profit
   c. the same level of inputs
   d. the same level of expenditures
3. Relative prices are captured in the:
   a. equilibrium point
   b. isoquant
   c. isocost line
   d. vertical axis

4. The optimal combination of inputs depends on:
   a. land grant university recommendations
   b. tradition
   c. resource availability
   d. relative prices
5. In the wide open spaces of the American West, farms are likely to be:
   a. larger than in the Eastern US
   b. smaller than in the Eastern US
   c. the same size as in the Eastern US
   d. cannot determine from the information given
6. Sugar and High Fructose Corn Syrup (HFCS) are:
   a. perfect substitutes
   b. perfect complements
   c. imperfect complements
   d. imperfect substitutes
7. A pen and a pencil are:
   a. substitutes
   b. complements
   c. unrelated
   d. irreplaceable
8. Capital and labor are:
   a. perfect complements
   b. perfect substitutes
   c. imperfect substitutes
   d. unrelated
9. If the price of the input on the x-axis decreases, then the slope of the isocost line will:
   a. become steeper
   b. become less steep
   c. shift out parallel
   d. shift in parallel
10. Labor-intensive agricultural production practices are most likely to occur in:
    a. Florida
    b. Kansas
    c. Texas
    d. Sub-Saharan Africa

Plate 6.1 Optimal output selection.

Source: Jim Parkin/Shutterstock

6 Optimal output selection

Synopsis

This chapter covers the intuition of profit maximization, and how this intuition can be used to improve both personal and professional decision making. Emphasis is on economic decision making, or comparing costs against benefits in all choices. The concepts discussed here include how an agribusiness firm selects outputs under continuously changing prices. The production possibilities frontier is defined and explained, as is the marginal rate of product substitution, and the isorevenue lines used to find the optimal output combination. The chapter concludes with a brief review of profit-maximization rules for input use, outputs, and input combination.

6.0 Introduction

Agriculture and the agricultural economy are changing rapidly as new technologies such as no-till production, Global Positioning Systems (GPS), sophisticated machinery, and biotechnology have been introduced and adopted by agricultural producers. With constant change, producers spend great amounts of time searching for the commodities that are best for their available resources. Agricultural producers and agribusinesses must be prepared to deal with rapid and large changes in relative prices. In the Midwestern Corn Belt states, large increases in corn and soybean acres have followed the biofuel-driven increases in the prices of these two crops since 2008.

Agribusinesses are also changing. As mergers and consolidations take place, large agribusiness corporations shift into new product lines, and sometimes abandon old ones. On farms and in factories, the decisions about which products to produce are made using a combination of technical and economic information. This chapter is devoted to understanding how firms, farm and non-farm, make decisions about which outputs to produce and sell.

6.1 The Production Possibilities Frontier (PPF)

Most firms can produce more than one output. Farm managers worldwide often must choose between several competing crops: wheat, corn, milo, soybeans, and hay. Animals, primarily beef, hogs, and chickens, are also alternative sources of income on some farms. Packing plants have numerous outputs that could be produced, depending on the relative profitability of each output. They could grind all of their meat into hamburger, or slice it into steaks. Most business firms that are able to produce any of several outputs require some guidance when making final decisions regarding which products bring the most economic benefit to the firm.

Relative prices continue as important variables in economic decisions. Other important variables include diversification and risk minimization. Firms and businesses will often make production choices based on reducing their exposure to risk, or relying too heavily on a single product. These need to be mentioned even though the main focus continues to be relative prices.

A **Production Possibilities Frontier (PPF)** describes a firm's possible combinations of outputs.

- ***Production Possibilities Frontier (PPF)*** = a curve depicting all possible combinations of two outputs that can be produced using a constant level of inputs.

A farmer-stockman in the Northern Great Plains provides an example of how managers make decisions regarding the optimal combination of outputs. Suppose farmer-stockmen can allocate their resources to the production of two outputs: wheat (Y_1) or cattle (Y_2). The production function or the technical relationship between inputs (X) and outputs (Y) is adaptable to include multiple outputs:

$$Y_1, Y_2 = f(X_1, X_2, X_3, \ldots, X_n). \quad (6.1)$$

Here, all inputs are held fixed, and are used to produce two outputs, Y_1 (wheat) and Y_2 (cattle). The firm under consideration has fixed resources (K, L, A, and M). Variables listed to the right of the vertical line in equation 6.1 indicate that these variables are available in fixed quantities, "holding all else constant," or *ceteris paribus*.

Quick Quiz 6.1

What are the four inputs K, L, A, and M? Name the four items that comprise capital.

The firm assumed in Figure 6.1 allocates these resources between the two outputs: raising cattle (Y_2) or growing wheat (Y_1). If the decision maker allocates all of the resources to cattle, then the firm produces all cattle and no wheat. If all of the resources go to wheat, the firm produces all wheat and no cattle. The firm can also select an intermediate point where some resources are devoted to each of the two possible products. Figure 6.1 shows all of the possible combinations of outputs that can be produced with a fixed level of inputs. The units for cattle are measured in hundredweight (cwt is the abbreviation of hundredweight, or one hundred pounds), and the units for wheat are bushels (bu).

Point A represents complete specialization in beef, and point C shows output when all productive resources are committed to wheat. Point B represents a situation that divides resource use between cattle and wheat production. Point D is attainable by the firm, but such a combination of products is irrational, because it does not make use of all available resources. Points inside (below) the PPF are physically possible to achieve, but can be improved upon by selecting combinations of wheat and cattle located on the PPF. Point E is not physically attainable, given the fixed level of resource use, as it lies outside of the PPF.

The shape of the production possibilities frontier

The Law of Diminishing Marginal Returns causes the PPF to be concave to the origin (bowed out). The reason is that the first unit of input used for either beef or wheat is the most productive. Adding more units of inputs causes the productivity level to decrease.

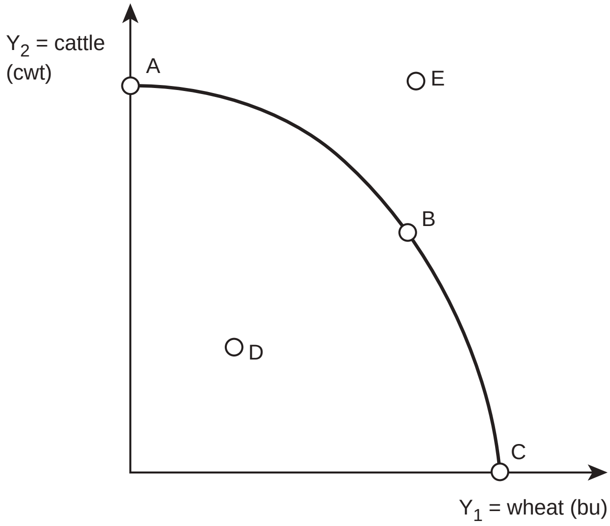

Figure 6.1 Production possibility frontier for a farmer-stockman.

Specialization of a firm's resources into what it does best allows the firm to use its best grazing acres to produce cattle and the best farmland to produce wheat. The PPF is concave to the origin because specialization allows the inputs to move to their most productive use. If the resources were not specialized, the PPF would be a straight line, since output could not be increased by specialization. Finding the profit-maximizing combination of output requires use of information contained in the PPF and information on the economic value of the two outputs (relative prices).

Quick Quiz 6.2

Explain why economists emphasize relative prices.

If the level of inputs changes or technological change occurs, the PPF will shift. For example, if the farmer-stockman increased the number of acres in the farm, then the PPF would shift out and to the right, as shown in Figure 6.2. Technological change may also result in an outward shift of the PPF, since it is a change in the relationship between inputs and outputs. Technological change results in more output produced with the same level of inputs.

Quick Quiz 6.3

What is another way of stating the impact of technological change?

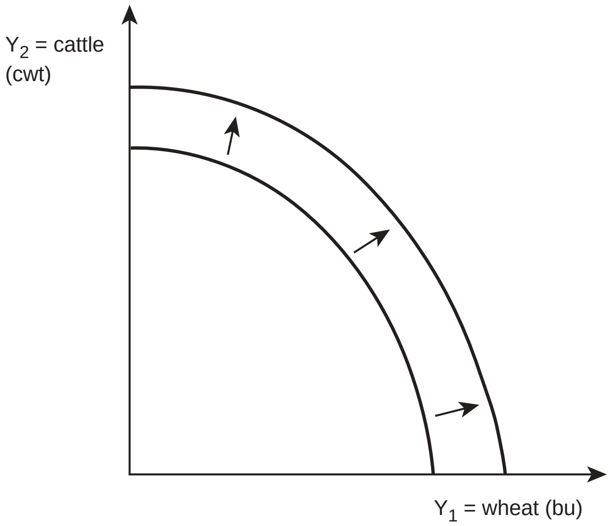

Figure 6.2 The impact of technological change on the production possibility frontier.

Technological change in both cattle production and wheat production results in an outward shift in the PPF (Figure 6.2).

A shift in the PPF will also occur if technological change affects only one output. If a new variety of wheat comes from university wheat breeding programs, the PPF will shift out for wheat, but remain in place for cattle, as shown in Figure 6.3.

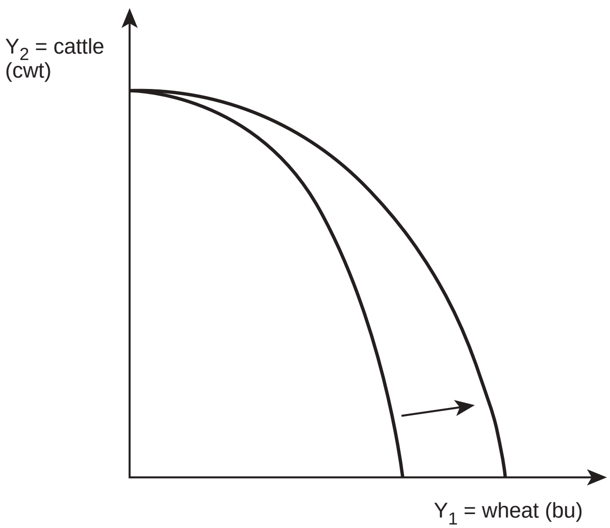

Figure 6.3 Technology change on one output of production possibility frontier.

With this type of technological change, the y-intercept remains the same, because if all of the firm's resources are devoted to the production of cattle, the total quantity produced will remain the same. If the resources are all devoted to wheat, however, more bushels of output will result from the same level of inputs. The technical change favored wheat and the PPF will shift to the right. The firm will be able to produce more of both outputs, since resources previously devoted to wheat will now become available for beef production. But how does the firm select the optimal, or profit-maximizing, combination of outputs? The rate of change in the PPF provides the key.

6.2 The Marginal Rate of Product Substitution (MRPS)

The slope of the PPF at any point reveals the rate of substitution between the two outputs at that point. This rate is the Marginal Rate of Product Substitution (MRPS). It represents the decrease in one output (Y_1) that must occur if the other output (Y_2) is to increase.

> **Quick Quiz 6.4**
>
> Why must one output decrease if the other increases?

- ***Marginal Rate of Product Substitution (MRPS)*** – the rate at which one output must decrease as production of another output is increased. The slope of the production possibilities frontier (PPF) defines the MRPS. MRPS = $\Delta Y_2/\Delta Y_1$.

In the present case, the slope of the production possibilities frontier is the "rise over the run," or the change in cattle production required by the desired change in wheat production: $\Delta Y_2/\Delta Y_1$. The MRPS represents the physical tradeoff that the farmer-stockman must make when determining the optimal allocation of inputs between the two products.

Figure 6.4 extends the study of the concave-shaped PPF by calculating the MRPS at different points along the PPF for cattle and wheat.

The rate of substitution between outputs (MRPS) changes with movement along the Production Possibilities Frontier (PPF). When the PPF is concave to the origin, the MRPS is increasing in magnitude from left to right. Start at point A, the point of complete specialization in cattle. At this point, the resources available for cattle production yield five hundredweight (cwt) of cattle but no wheat. If the firm takes enough resources from cattle production to reduce cattle output by one unit (from 5 to 4 cwt), cattle resources switch to wheat production. Figure 6.4 shows that the resources taken from cattle production will yield three bushels if used for wheat. The MRPS, or the slope of the PPF, measures this movement out of cattle and into wheat:

$$MRPS(AB) = \Delta Y_2 / \Delta Y_1 = (4 - 5)/(3 - 0) = -1/3. \qquad (6.2)$$

The first inputs used in wheat production are the most productive. As the firm adds more inputs, productivity per unit of resource declines. As cattle production is reduced one more unit from four bushels to three bushels, wheat production increases, but not as much as it did between points A and B. Using the MRPS as a measure, the move from B to C shows:

$$MRPS(BC) = \Delta Y_2 / \Delta Y_1 = (3 - 4)/(4 - 3) = -1. \qquad (6.3)$$

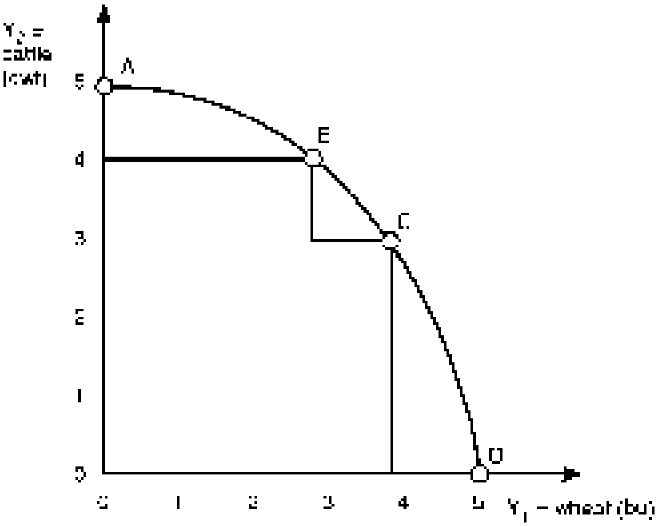

Figure 6.7 Production possibility frontier for a farmer-stockman

The absolute value of the MRPS has increased from one-third to one, reflecting decreasing returns. As the firm continues to switch resources from cattle to wheat, the productivity continues to decline:

$$\text{MRPS(CD)} = \Delta Y_2/\Delta Y_1 = (0 - 3)/(5 - 4) = -3. \quad (6.4)$$

The MRPS increases when the production functions are subject to decreasing returns. In all economic situations, inputs will be subject to decreasing returns, resulting in a PPF that is concave to the origin. Remember, though, that the PPF derives from the production functions of the two outputs. The shape of the PPF and its slope (MRPS) depend on the production function, or the physical relationship between inputs and outputs [$Y = f(X)$]. With the physical production possibilities in place and understood, attention turns to the economic relationships that determine the profit-maximizing combination of outputs.

6.3 The isorevenue line

To complete the firm's search for the profit-maximizing combination of outputs requires combining the physical production information in the PPF with the economic information in the relative prices. Market price information allows a firm to select the optimal combination of output. Relative prices provide the firm with information about the value of producing a good. In the farmer-stockman example, the firm is interested in allocating inputs between cattle and wheat: how many cattle to raise, and how much wheat to grow. The firm can determine this by looking at the revenue earned from the production and sale of beef and grain. An **Isorevenue Line** provides the revenue information in the same way that the isocost line helped with cost information in Chapter 5.

- ***Isorevenue Line*** – a line depicting all combinations of two outputs that will generate a constant level of total revenue.

An isorevenue line for the farmer-stockman can be graphed using assumptions about the price of wheat [(P_1) is \$100/bu], and the price of cattle [(P_2) is \$50/cwt]. Recall the definition of total revenue (TR).

$$\mathbf{TR} = P_1Y_1 + \mathbf{P}_2Y_2. \tag{6.5}$$

$$\mathbf{TR} = 100^*Y_1 + 50^*Y_2. \tag{6.6}$$

To illustrate a specific isorevenue line, let TR = \$500. Figure 6.5 shows an isorevenue line. As in the case of the isocost line, there are an infinite number of isorevenue lines, one for each dollar value of total revenue. The isorevenue line is shown using mathematics to find the profit-maximizing level of output. The algebraic equation ($y = b + mx$) for the isorevenue line derives from the definition of total revenue.

$$\mathbf{TR} = P_1Y_1 + \mathbf{P}_2Y_2. \tag{6.7}$$

$$P_2Y_2 = \mathbf{TR} - P_1Y_1. \tag{6.8}$$

$$Y_2 = \mathrm{TR}/P_2 + (-\mathbf{P}_1/P_2)^*Y_1. \tag{6.9}$$

Equation (6.9) shows that the y-intercept is equal to TR/P_2. The y-intercept of an isorevenue line is the situation where all of the revenue comes from the good on the y-axis (cattle in Figure 6.5). In this situation, no wheat is sold, so $Y_1 = 0$, and TR = P_2Y_2. Given this, it can be shown that the quantity of cattle sold is Y_2 = **TR**/**P_2**. The slope of the isorevenue line

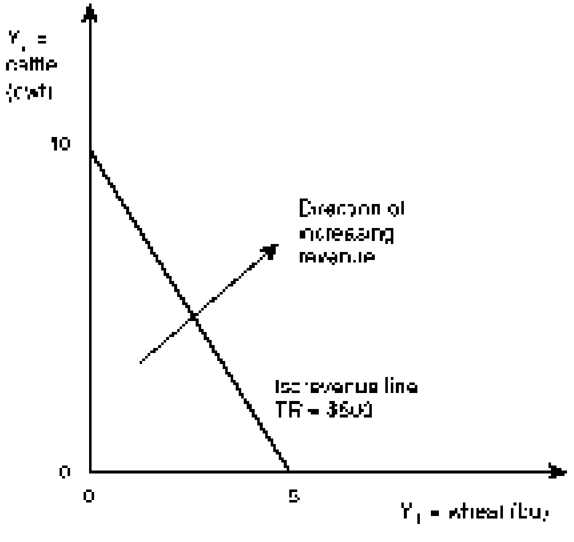

Figure 6.5 Isorevenue line for a farmer-stockman.

represents relative prices, and is equal to the price ratio ($-P_1/P_2$). The slope of the isorevenue line contains all of the economic information that the firm needs to choose the profit-maximizing combination of outputs.

> **Quick Quiz 6.5**
>
> The derivation of the equation of the isorevenue line is similar to the derivation for the isocost line. Derive the algebraic equation for the isocost line.

To complete the firm's search for the profit-maximizing combination of goods requires combining the physical production information in the PPF with the economic information in the relative prices.

6.4 The optimal output combination

To maximize profits, the firm will want to reach the highest isorevenue line possible, consistent with the technical information from the PPF and the relative price information summarized in the isorevenue line. Since higher levels of revenue appear on lines to the northeast, the profit-maximizing firm will locate on the isorevenue line that is tangent to the PPF, represented by point E in Figure 6.6.

This point of tangency shows where the slope of the PPF (the MRPS) is equal to the slope of the isorevenue line (the price ratio). Point E is an equilibrium point for the firm; the firm can do no better than point E given current prices and the current stage of technology.

> **Quick Quiz 6.6**
>
> Why is point E an equilibrium point for the firm?

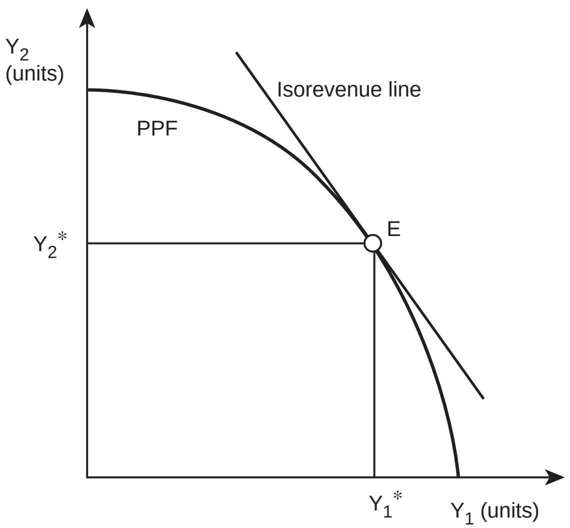

Figure 6.6 Optimal output combination.

The profit-maximizing rule for optimal output selection is to set the MRPS equal to the slope of the isorevenue line, or the output price ratio.

$$\text{MRPS} = \text{slope of isorevenue line.} \qquad (6.10)$$

$$\Delta Y_2 / \Delta Y_1 = -P_1 / P_2 \qquad (6.11)$$

$$\Delta Y_2 * P_2 = -\Delta Y_1 * P_1 \qquad (6.12)$$

This is a familiar result. The firm's manager should shift resources toward the output with the highest revenue. Intuition alone is sufficient to indicate that the firm loses its hold on equilibrium as soon as it moves away from this point. The strategy to maximize profits is to employ resources in the output that generates the highest returns.

> If $\Delta Y_2 * P_2 > -\Delta Y_1 * P_1$, then the firm should move out of Y_1 and into Y_2,
> and
> if $\Delta Y_2 * P_2 < -\Delta Y_1 * P_1$, then the firm should move out of Y_2 and into Y_1.

The graph in Figure 6.7 demonstrates this position. Point A is a feasible point of production, since it lies on the PPF. However, the point is not a profit-maximizing point for the firm, since higher revenue is available at point E. To see this, note that at point A, the slope of the isorevenue line is steeper than the slope of the PPF (the MRPS). The following relationship holds at point A:

$$\text{MRPS(A)} < \text{the price ratio.} \qquad (6.13)$$

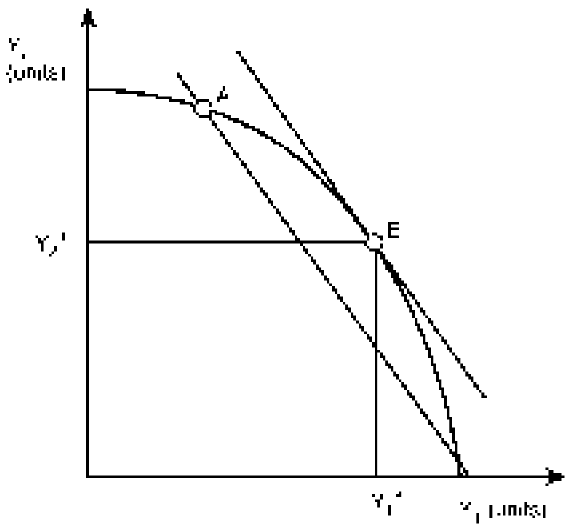

Figure 6.7 Locating the profit-maximizing point.

$$\Delta Y_2 / \Delta Y_1 < -P_1 / P_2, \tag{6.14}$$

$$\Delta Y_2 * P_2 < -\Delta Y_1 * P_1. \tag{6.15}$$

The profitable strategy for this firm is to reduce the inputs devoted to Y_2, and shift them to the production of Y_1. At point A, the revenue associated with good Y_1 is higher than the revenue earned from the production and sale of Y_2.

The firm will continue to shift resources out of Y_2 and into Y_1 until it reaches the equilibrium point E. At E, the firm cannot earn higher revenue from the production of the two goods: E is an optimal, profit-maximizing point. If the price of one output changes, the price ratio will shift, and the isorevenue lines will have a different slope. The firm will then shift resources between outputs until it reaches the new equilibrium.

6.5 Price changes and the optimal output combination

Relative prices allocate resources in a market economy.

Quick Quiz 6.7

What are the three types of economic organization? How does each allocate resources?

In the past several years, the price of corn has increased relative to the price of other grains. This has caused a major shift of agricultural land use in the United States. Land has moved out of wheat, soybeans, milo, and cotton production and into the production of corn. The production possibilities frontier in Figure 6.8 shows how grain producers have shifted resources from wheat to corn in response to the change in relative prices.

Plate 6.2 Corn and ethanol.
Source: Jim Barber/Shutterstock

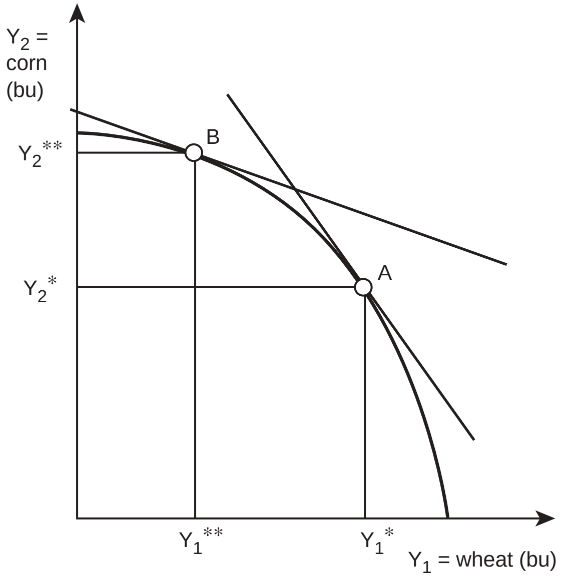

Figure 6.8 Locating the profit-maximizing point between wheat and corn.

At point A, grain farmers will produce Y_1* bushels of wheat and Y_2* bushels of corn. The initial prices of wheat (P_1) and corn (P_2) define the slope of the isorevenue line ($-P_1/P_2$). When the relative price of corn increases, the denominator of the price ratio increases, resulting in a decrease in the slope of the isorevenue line. Point A becomes less profitable after the price change.

Box 6.1 Biofuels

A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Biofuels have become increasingly popular in recent years, because of higher oil prices, the desire for energy independence, concern over greenhouse gas emissions from fossil fuels, and support from government subsidies.

Bioethanol is an alcohol made by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn or sugarcane. Cellulosic biomass, derived from non-food sources such as trees and grasses, is also being developed as a feedstock for ethanol production. In its pure form ethanol can be used as a fuel for vehicles, but it is usually used as a gasoline additive to increase octane and reduce the volume of harmful vehicle emissions. Bioethanol is widely used in the US and in Brazil.

Biodiesel is made from vegetable oils and animal fats. Biodiesel in its pure form can be used as a fuel for vehicles but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats and is the most common biofuel in Europe.

Source: Demirbas, A. (2009). "Political, Economic and Environmental Impacts of Biofuels: A Review." *Applied Energy* 86: S108–S117, doi: 10.1016/j.apenergy.2009.04.036.

Grain producers relocate to point B by shifting resources out of wheat and into corn. This is what has happened in the past few years due to biofuels. Corn and soybean acres are at an all-time high, and there has been a reduction in acres planted to wheat! Economic theory has done a good job of explaining this shift in the outputs in many grain-producing areas.

6.6 Review of profit-maximization rules

The first six chapters of this book have outlined profit-maximizing and cost-minimizing rules for the optimal use of inputs and the optimal combinations of outputs. There is a striking symmetry between the profit-maximizing and cost-minimizing rules developed for use by a business firm. This brief section reviews the profit-maximizing rules for:

1. The optimal level of input use (Chapter 4),
2. The optimal level of output (Chapter 4),
3. The optimal input combination (Chapter 5), and
4. The optimal output combination (Chapter 6).

Rule for optimal input use

To maximize profits by selecting the proper level of input use, set the marginal benefits (the marginal revenue product = MRP) equal to the marginal costs (the marginal factor cost = MFC). Recall the definitions: MRP = MPP*P_Y, and MPP = $\Delta Y/\Delta X$.

$$MRP = MFC \tag{6.16}$$

$$MPP * P_Y = P_X \tag{6.17}$$

$$(\Delta Y / \Delta X) * P_Y = P_X \tag{6.18}$$

$$\Delta Y * P_Y = \Delta X * P_X \tag{6.19}$$

The profit-maximizing rule states that the firm manager should continue to use an input until the additional benefits of using the input to produce and sell a good ($\Delta Y * P_Y$) are equal to the additional costs of employing the unit of input ($\Delta X * P_X$).

Rule for optimal output production

To maximize profits by selecting the level of output, set the marginal benefits (the marginal revenue = MR) equal to the marginal costs (= MC). Next, recall the definitions: MC = $\Delta TC/\Delta Y$, and MR = P_Y, assuming a competitive industry. Total costs are the input price times the quantity of input utilized (TC = P_X*X).

$$MR = MC \tag{6.20}$$

$$P_Y = \Delta TC / \Delta Y \tag{6.21}$$

$$P_Y = \Delta (P_X * X) / \Delta Y \tag{6.22}$$

$$\Delta Y * P_Y = \Delta X * P_X \tag{6.23}$$

The profit-maximizing rule states that the firm manager should increase output until the additional benefits of production ($\Delta Y * P_Y$) are equal to the additional costs of producing one more unit of output ($\Delta X * P_X$). Compare this result with that for the optimal level of input rule above.

Rule for optimal input combination

To minimize costs by selecting the optimal combination of inputs, the firm manager will set the slope of the isoquant (MRTS) equal to the slope of the isocost line (the price ratio). Recall the definition: MRTS = $\Delta X_2/\Delta X_1$.

$$MRTS = \text{slope of isocost line} \tag{6.24}$$

$$MRTS = -P_1 / P_2 \tag{6.25}$$

$$\Delta X_2 / \Delta X_1 = -P_1 / P_2 \tag{6.26}$$

$$-\Delta X_2 * P_2 = \Delta X_1 * P_1 \tag{6.27}$$

The cost-minimizing rule states that the firm manager should purchase inputs until the additional expenditures on each input are equal.

Rule for optimal output combination

To maximize profits by selecting the optimal combination of outputs, the firm manager will set the slope of the production possibility frontier (MRPS) equal to the slope of the isorevenue line (the price ratio). Next, recall the definition: MRPS = $\Delta X_2/\Delta X_1$.

$$MRPS = \text{slope of isorevenue line} \tag{6.28}$$

$$MRPS = -P_1 / P_2 \tag{6.29}$$

$$\Delta Y_2 / \Delta Y_1 = -P_1 / P_2 \tag{6.30}$$

$$-\Delta Y_2 * P_2 = \Delta Y_1 * P_1 \tag{6.31}$$

The profit-maximizing rule states that the firm manager should produce output until the additional revenues from each output are equal.

Thinking like an economist

Relative prices drive all economic decision making: firms determine what to produce, how to produce, and what quantity to produce based on relative prices. The main idea behind thinking like an economist is to weigh the benefits and costs of every activity. If the benefits outweigh the costs, then the activity should be undertaken. This holds true for all aspects of production, as shown in Chapters 2 through 6. The next chapter shifts the focus from producers to consumers. Consumers make economic choices in much the same way that producers do: a consumer will buy a good if the benefits outweigh the costs.

6.7 Summary

1. The Production Possibilities Frontier (PPF) is a curve that represents all combinations of two outputs that can be produced with a constant level of inputs.
2. The production possibilities frontier is concave to the origin due to the Law of Diminishing Marginal Returns.
3. Technological change results in an outward shift in the production possibilities frontier.
4. The Marginal Rate of Product Substitution (MRPS) is the rate of decrease required in one output in order for the output of another product to be increased. It is also the slope of the production possibilities frontier.
5. An isorevenue line depicts all combinations of the two outputs that generate a constant level of total revenue.
6. To find the revenue-maximizing combination of outputs, a firm will reach the highest isorevenue line possible by locating at the tangency between the production possibilities frontier and the isorevenue line.
7. Relative price changes result in shifts in the isorevenue line and a reallocation of resources.

6.8 Glossary

Isorevenue Line. A line showing all combinations of two outputs that will generate a constant level of total revenue.

Marginal Rate of Product Substitution [MRPS]. The rate at which one output must decrease as production of another output is increased. The slope of the production possibilities frontier (PPF) defines the MRPS. MRPS = $\Delta Y_2/\Delta Y_1$.

Production Possibilities Frontier [PPF]. A curve depicting all possible combinations of two outputs that can be produced using a constant level of inputs.

6.9 Review questions

1. The production possibilities frontier shows:
   a. all combinations of two inputs that can produce a constant level of output
   b. all combinations of two outputs that can be produced with a constant level of inputs
   c. all levels of one output that can be produced with varying levels of inputs
   d. an isoquant
2. A point located inside the PPF is:
   a. efficient and attainable
   b. efficient but not attainable

c. not efficient but attainable
d. neither efficient nor attainable

3. A point located outside of the PPF is:
a. efficient and attainable
b. efficient but not attainable
c. not efficient but attainable
d. neither efficient nor attainable
4. The Marginal Rate of Product Substitution refers to:
a. the physical tradeoff between inputs
b. the physical tradeoff between outputs
c. the economic tradeoff between inputs
d. the economic tradeoff between outputs
5. The MRPS is:
a. constant along the PPF
b. increasing in absolute value along the PPF
c. decreasing in absolute value along the PPF
d. increasing or decreasing, depending on if there is increasing or decreasing returns
6. The slope of the PPF is due to:
a. the isoquant
b. relative prices
c. the production functions of the two outputs
d. the cost of inputs
7. The isorevenue line is derived from:
a. the isoquant
b. relative prices
c. the production functions of the two outputs
d. the cost of inputs
8. The profit-maximizing combination of outputs can be found at the tangency of:
a. the PPF and the isorevenue line
b. the PPF and the isocost line
c. the isocost and isoquant lines
d. the isoquant and isorevenue lines

Plate 7.1 Consumer choices.
Source: Studio online/Shutterstock

7 Consumer choices

Synopsis

In a market economy, consumers are the driving force behind all production decisions, since successful business firms "give consumers what they want." This chapter enhances the understanding of how consumers decide what to purchase. Economists consider consumers to be rational, or purposeful and consistent. This assumption allows economists to predict and explain consumer choices. In particular, they are able to make strong predictions about how consumers respond to changes in income and relative prices. The Law of Diminishing Marginal Utility explains why consumers prefer variety. Real-world examples include meat consumption in the US and China, and the Diamond–Water Paradox.

7.0 Introduction

The circular flow diagram in Chapter 1 (Figure 1.1) summarized an economy composed of two groups: producers and consumers. The next several chapters of this book explained the profit-maximizing behavior of producers. Very little was said about consumers. That leaves the question, "What role do consumers play in a market economy?" Consumers spend their incomes on the goods and services produced by firms. In a market economy, consumers are the driving force behind all production decisions, since producers will give consumers what they want by responding to relative prices. This chapter explains the behavior of consumers, and the following chapters explain the interactions between producers and consumers in domestic and international markets. The lessons begin with a study of rational behavior: the consumers' counterpart of profit maximization.

7.1 Rational behavior

Economic logic assumes that all human behavior is purposeful and consistent. The term **Rational Behavior** in economics is different from the dictionary definition of the term. The dictionary definition states that an individual's rational behavior is "fully competent, or sane." In economics, rational means that individuals do the best they can, given the constraints they face. Rational behavior is purposeful and consistent.

- ***Rational Behavior*** = individuals do the best that they can, given the constraints they face. Rational behavior is purposeful and consistent.

Suppose that students seeking a good grade were to skip class in order to play a video game. Is this rational? It would be hard to claim this as, “rational,” using the dictionary definition of the word, since it is counter to the objective of the students to perform well. However, according to the economic definition, this behavior would be rational if the benefits of the activity outweighed the costs. Any behavior is considered to be rational, as long as its benefits outweigh its costs.

Another way to think about rational behavior is that individuals do the best that they can, given the constraints that they face. Consumers maximize their own happiness given a budget. For example, a college professor gets a paycheck twice a month, and uses the income to purchase food, clothes, housing, water, electricity, toothpaste, etc., as long as each purchase adds to her satisfaction. In this way, consumers maximize their satisfaction given a budget constraint. Notice the similarities with how economists describe producer behavior: producers maximize profits given input and output prices, and technology. Casting the consumers’ problems in the same terms, all individuals (consumers) do the best that they can by maximizing satisfaction, given the constraints that they face: income and prices.

The study of consumer behavior begins with consumers who have preferences for some goods over others. Examples are everywhere. Which is preferred:

- Pizza or cheeseburgers?
- Wranglers or Levis?
- McDonald’s or Burger King?
- Hamburgers or sushi?
- White bread or wheat bread?
- House in the country or high-rise apartment?
- Mercedes or Kia?
- Fur stole or wool coat?
- Small liberal arts college or large state university?

Box 7.1 Behavioral economics

Economics as a social science assumes that all economic decision making is “rational.” Behavioral Economics integrates irrational, emotional, and psychological aspects into models of decision making and market outcomes. This approach allows for human behavior to be subject to emotion, error, poor judgment, inconsistency, and lack of knowledge. Behavioral models of individual and institutional behavior typically include insights from psychology in economic models.

This tradition has a long history, including Adam Smith’s 1759 work, *The Theory of Moral Sentiments*, which included psychological explanations of individual behavior and the nature of morality and ethics. Behavioral economics highlights the use of heuristics, or simple rules of thumb, in decision making, rather than strict logic. The field also emphasizes how decision makers “frame” their choices based on past experience and emotion. The behavioral approach also emphasizes inefficiencies and anomalies that arise from non-rational behavior.

Behavioral economics has been controversial, since some behavioral economists focus on the divergence between the rationality assumption of standard economics and the non-rational assumptions of the behavioral approach. However, social scientists are in search of the truth, and the insights from the behavioral approach can advance our understanding of individual decision making and market outcomes. Simplifying assumptions in science are not meant to be factual, but rather a method of organizing our thoughts about the complex real world. The objective of science is to explain and predict. If a new model or new approach can make better, more useful, explanations and predictions, then it will be adopted and integrated into a field such as economics.

Source: "Behavioral Economics." The New Palgrave Dictionary of Economics Online (2008).

Consumer choices about what goods to buy depend on these preferences and the relative prices of goods and services. The benefits of consuming a good come from the satisfaction that comes from consuming it. The costs of consuming a good are the total monetary and non-monetary costs of obtaining the good: the price plus such things as the time costs associated with the purchase of the good (having to drive to Walmart, locate the good, and then stand in line to pay for it, etc.). A consumer will purchase a good if the benefits, or the gains in satisfaction, are greater than the costs of obtaining it.

This way of thinking provides simple information for firms that desire to maximize profits. Therefore, manufacturers and merchants rely on consumers so they must always:

- Pay attention to what consumers want, since consumer preferences determine what they buy, and
- Pay attention to prices, since consumer decisions stem from relative prices.

Therefore, successful, profitable firms are the ones that do the best job of providing consumers with what they want. The next section relates to the formation of consumer preferences.

7.2 Utility

The specialized language of economics makes broad use of the word "utility." It means much more than just usefulness. It takes on a meaning of satisfaction, or happiness, or fulfillment. If an object has utility in an economic sense, then it is bringing some kind of reward to its owner or the person who is using it. Food has utility because it keeps people alive. A football game has utility because it entertains the spectators. Social friends have utility because they are there to help or to be helped. In language that is more straightforward:

- ***Utility*** = satisfaction derived from consuming a good.

Utility is a concept applicable to all goods and services, whether or not they move through markets. Consumers increase their utility by purchasing new CDs, clothes, appendectomies, houses, vacations, or trucks. Utility can also come from nonmarket goods or experiences: babies, singing in a choir, love, gossiping with the neighbor, or watching the sunset. What is it that gives babies, singing, and gossiping the capacity to confer "utility?" The next section is devoted to answering that question.

Cardinal and ordinal utility

About 200 years ago, Jeremy Bentham (1748–1832) and a number of other economists struggled to find a way to measure utility. They tried to assign an actual numerical value to the amount of satisfaction that each good or service produced and conferred on its user. These economists developed a hypothetical unit, called a "util," to measure consumers' levels of happiness, or satisfaction.

- ***Utils*** = hypothetical units of satisfaction derived from consumption of goods or services.

Assigning quantitative measures to levels of satisfaction yields a measure called **Cardinal Utility**.

- ***Cardinal Utility*** = assigns specific, but hypothetical, numerical values to the level of satisfaction gained from the consumption of a good. The unit of measurement is the hypothetical util.

Recall that cardinal numbers are the simple numbers used for counting: 1, 2, 3,..., 10, 14, 19, etc. These early economists and other social scientists tried to develop the util as a measure of satisfaction assignable to each good. Their list might include:

- Apple = 20 utils
- Orange = 10 utils
- Hamburger = 50 utils
- Beethoven symphony download = 100 utils
- New clothes = 200 utils
- New automobile = 40,000 utils.

These early scientists and scholars soon found that assigning utils was impossible. People cannot assign a meaningful value to the level of satisfaction because the measures of satisfaction differ between individuals, and are not observable. Since science requires accurate and measurable observation, the early scholars concluded that they could not use cardinal utility measures to quantify an individual's feelings or level of satisfaction. Once economists and others realized that measuring utility was impossible, they turned attention to **Ordinal Utility**, or ranking goods in order of preference (A is preferred to B, B is preferred to C, C is preferred to D, etc.). Ordinal utility replaced the earlier concept of cardinal utility.

- ***Ordinal Utility*** = a way of considering consumer satisfaction in which goods are ranked in order of preference: first, second, third, etc.

Ordinal preferences do not depend on specific numbers or values. Instead, the rankings of goods and services with respect to the satisfaction they provide relative to other goods allow economists to observe consumers and develop principles of human behavior to help understand consumer choices. Cardinal utility continues to provide examples of how consumer behavior works, as shown in the next section.

Positive and normative economics

Recall from Chapter 1 that economists do not make value judgments about the utility (satisfaction) that consumers derive from goods. Whatever it is that consumers desire, economists take as factual without bringing their own preferences or opinions to bear on the situation. Economists make no normative statements about what consumers desire to buy.

Quick Quiz 7.1

Define, explain, and compare positive and normative economics.

Quick Quiz 7.1a

You are an economist assigned to study the *price* of soybeans. Will you use positive methods or normative methods?

Quick Quiz 7.1b

You are an economist assigned to study *consumer preferences* for soybeans. Will you use positive methods or normative methods?

Utility, total utility, and marginal utility

Economists use the term **Utility** to refer to the amount of satisfaction that a consumer receives from the consumption of a good. In this use, the utility of a good stems from answers to questions such as, "How much satisfaction (utility) did you get from consuming those strawberries?" **Marginal Utility (MU)** is the additional amount of satisfaction gained from consuming one more unit of a good and **Total Utility (TU)** is the cumulative satisfaction received from the entire collection of the good or service, in this case strawberries.

- ***Marginal Utility [MU]*** = the change in the level of utility when consumption of a good is increased by one unit. $MU = \Delta TU/\Delta Y$.
- ***Total Utility [TU]*** = the total level of satisfaction derived from consuming a given bundle of goods and services.

Applying these concepts to a hypothetical example of consumer behavior enhances understanding. The example here is drinking bottles of cold water after a long, hot day of work. In this case, one major prediction regarding consumer behavior is that "first is best." The first unit of a good consumed yields the most satisfaction. The second unit is less satisfying. Additional satisfaction, or utility, comes from each unit consumed, but typically, the amount of satisfaction from each successive bottle of water diminishes.

To demonstrate this idea, consider the relationship between the quantity of a good consumed (Y) and the satisfaction derived from consuming it. Think of picking peaches in California's Sacramento Valley. Suppose that you have worked all day and are hot, tired, and thirsty (picking tree fruits is hard and dirty work most often done in the heat of the summer). The orchard owner brings the picking crew a large cooler filled with bottles of cold drinking water. Table 7.1 summarizes the satisfaction that you receive from drinking the water at the end of the hot day of hard work. Cardinal utility forms the basis for developing a numerical example of how consumers make decisions.

Quick Quiz 7.2

Define and explain the concepts of cardinal and ordinal utility.

Table 7.1 Total and marginal utility derived from drinking cold water on a hot day

Y = Quantity Consumed (bottles)	*TU = Total Utility (utils)*	*MU = Marginal Utility (utils/bottle)*
0	0	–
1	10	10
2	16	6
3	19	3
4	20	1
5	20	0
6	18	−2

Box 7.2 California agriculture

California agriculture is truly amazing. The state has a larger and more diverse farm sector than any of the other states. In 2010, California farms had cash receipts equal to USD 37.5 billion. The state accounted for 16 percent of national receipts for crops, and 7 percent of the US revenue for livestock and livestock products. Over 400 different commodities are grown in California, including olives, honey, pecans, pistachios, avocados, Christmas trees, wool, wheat, figs, artichokes, corn, and cotton. The state produces nearly half of US-grown fruits, nuts, and vegetables. Nine of the nation's top ten producing counties are in California. The top five California commodities are: (1) milk and cream, (2) grapes, (3) almonds, (4) nursery products, and (5) cattle and calves.

Johnston and McCalla, economists at the University of California at Davis, identified seven major forces driving California agriculture: (1) producers in California serve high-value and emerging markets, mostly distant and foreign, (2) California agriculture is highly dependent on land and water resources, (3) California agriculture is characterized by the absence of water in the right place, providing the incentive to irrigate, (4) California agriculture has always depended on a large supply of agricultural field labor from Asia and the Americas, (5) California agriculture has grown rapidly and almost continuously, although it has been periodically buffeted by natural catastrophes such as floods and droughts, and economic shocks such as the Great Depression, and various recessions, (6) California agriculture requires high levels of management skills—both technical and economic; it has always been dominated by large-scale operations that have grown in complexity and sophistication, and (7) agriculture in California has always been on the technological frontier in developing, modifying, or "borrowing" new technologies, such as large-scale mechanical technology, irrigation equipment, horticulture/plant varieties, pest control, food processing, and wine making.

Sources: USDA/NASS Statistics by State, California Ag Statistics, 2010.
US Census Bureau. Census of Agriculture. 2007.
Johnston, Warren E., and McCalla, Alex F. (2004). "Whither California Agriculture: Up, Down or Out? Some Thoughts about the Future." Giannini Foundation Special Report 04-1.

The first bottle of water brings great satisfaction: 10 utils. The second bottle brings additional satisfaction, since the total utility increased to 16 utils. However, the additional satisfaction gained from the second bottle is lower: the marginal utility is six additional utils gained from the consumption of the second bottle. This makes perfect sense: the first bottle is the most satisfying. In keeping with earlier notation, the variable Y denotes the total output of a firm and the output is now being consumed.

Looking at the rate of change in total utility ($MU = \Delta TU/\Delta Y$) allows calculation of the marginal utility. The move from no bottles to one bottle changes TU from zero to 10 utils ($\Delta TU = (10 - 0) = 10$), and the change in quantity consumed is equal to one util ($\Delta Y = (1 - 0) = 1$). Thus, the marginal utility at this level of consumption is equal to 10 utils/bottle: $MU = \Delta TU/\Delta Y = 10/1 = 10$.

As more bottles are consumed, total utility increases, but at a decreasing rate. This is due to the consumer's increasing level of satisfaction. The fifth bottle does not provide any additional satisfaction, so the consumer is fully satisfied and indifferent between drinking the bottle or not.

Quick Quiz 7.3

Have you ever had enough water so that when you are asked if you would like another bottle, you say, "I could take it or leave it?" Use economic terminology to describe this situation.

Something interesting occurs with consumption of the sixth drink. It moves the consumer past the point of indifference to one of dissatisfaction. Table 7.1 shows this where the marginal, or additional, satisfaction becomes negative. The sixth bottle makes the consumer feel worse than if he or she did not drink it at all. Remember that a rational consumer would never undertake any activity in which the costs outweigh the benefits, so the rational consumer in the example would not accept the sixth bottle of water.

Plate 7.2 Bottled water.
Source: Picsfive/Shutterstock

Quick Quiz 7.4

Would anyone ever be irrational enough to drink more than the utility-maximizing level of bottles of water, or any other beverage?

Graphs of the TU and MU functions look similar to, and have some of the same characteristics as some of the graphs used in earlier chapters. Since the MU represents the rate of change in TU, it also represents the slope of the TU function (recall that the slope of any function is “rise over run,” or $m = \Delta y/\Delta x$).

Quick Quiz 7.5

Explain why TU and MU are drawn on separate graphs.

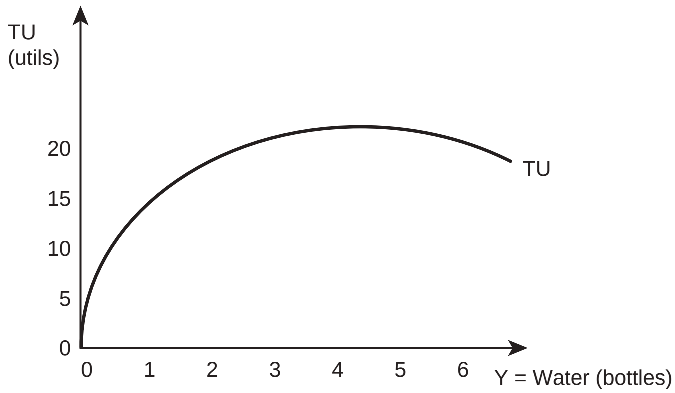

Figure 7.1 Total utility from consuming water on a hot day.

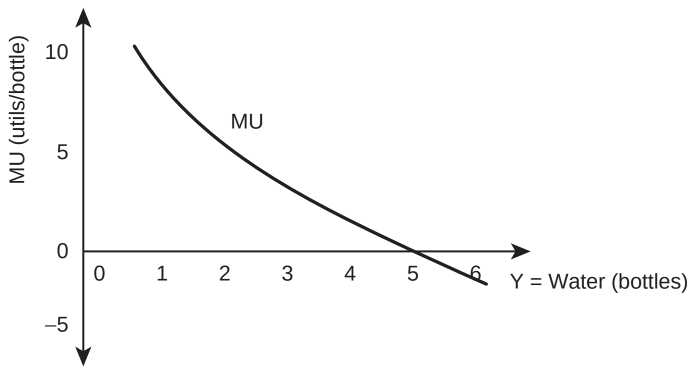

Figure 7.2 Marginal utility from consuming water on a hot day.

Figure 7.1 shows that as consumption of water increases, the level of utility (satisfaction) increases, but at a diminishing rate. In the example, the consumer becomes satiated at five bottles; any additional consumption of water will result in a decrease in total utility. The marginal utility graph in Figure 7.2 shows the additional utility gained from the consumption of one more bottle of water. Marginal utility decreases with additional consumption of the good. This decreasing rate of marginal utility is the topic of the next section.

7.3 The Law of Diminishing Marginal Utility

The previous section showed that as the consumption of water increases, marginal utility decreases. Each additional unit consumed gives the consumer less additional utility than the one before. This does not mean that total utility declines: four is preferred to three; more is better than less. However, more is better than less at a declining rate. At some point, the consumer can consume too much of a good: water becomes a noneconomic good at the point where its marginal utility becomes negative. This pattern of consumer utility is pervasive: so pervasive that economists have referred to it as a "law."

- ***Law of Diminishing Marginal Utility*** = marginal utility declines as more of a good or service is consumed during a given time period.

There is no actual proof of this: it is just intuition that appears to be so widespread that it is called a "law." This law is powerful enough to explain a great deal about the way consumers behave. The law of diminishing marginal utility implies that consumers will not spend all of their income on one good, because the marginal utility of continuing to buy the same good declines. Instead, consumers use their money to buy a variety of goods.

7.4 Indifference curves

Understanding consumer behavior requires considering the properties of consumer preferences. As in earlier cases, understanding consumer behavior requires several assumptions. The assumptions simplify the real world to provide greater understanding of consumer choices. The major assumptions associated with the study of consumer behavior include:

- **Assumption #1. Preferences for goods and services are complete.**

When given any two goods, a consumer can determine if he or she prefers A to B, B to A, or is indifferent between A and B. Let the symbol, "$\succ$" mean "is preferred to," and the symbol, "$\prec$" mean, "is less preferred to," and the symbol, "$\sim$" mean, "is indifferent to." Completeness of preferences requires that for any two goods, A and B, the consumer can tell if:

A $\succ$ B (A is preferred to B), (7.1a)

B $\succ$ A (B is preferred to A), or (7.1b)

A $\sim$ B (the consumer is indifferent between A and B) (7.1c)

Complete preferences allow economists to study all goods, since the consumer is able to rank how any good compares to all other goods in the generation of utility.

- **Assumption #2. Consumers are consistent.**

Using the same notation as above, consistency of preferences means that:

If A $\succ$ B and B $\succ$ C, then A $\succ$ C. (7.2)

"Transitive preferences," or simply "transitivity," means that consumers do not change their preferences haphazardly. Economists assume that consumer behavior is purposeful and consistent, so purchases must be consistent. This can be a difficult assumption in the real world since the transitivity among a few goods, or the entire universe of goods, applies only in one place, time, and context.

Consumer behavior is complicated, and known to be quite changeable. A quick look at selecting which political candidate to support helps make this point. One voter may choose the Democratic candidate until the Republican candidate makes a series of promises that are attractive to the voter. Two problems arise. First, if one candidate makes new promises, is the voter still comparing the same two goods? Second, the transitivity requirement must hold for only a brief moment. The result of these problems places boundaries around the notion of indifference. Nonetheless, it is an important attribute needed for the study of consumer preferences to move ahead.

- **Assumption #3. Nonsatiation: More is preferred to less.**

Consumers can never have enough! This assumption states that a consumer will always want more of a good. It states that a consumer will never consume "too much" of a good, and reach the point where marginal utility becomes negative.

These three assumptions are basic to models about consumer preferences. The objective of developing such models is to explain and then to predict consumer behavior. Relative prices drive a market economy. This simple notion received much attention in earlier chapters. It should not be surprising that consumer behavior must respond to the same rigorous questions: "What happens when prices change?"

Consumer responses to relative price changes

Suppose that freezing weather in Florida kills a significant fraction of the nation's citrus fruit crop. The frost results in reduced supplies of citrus fruit and the prices of oranges, grapefruit, lemons, and limes increase accordingly. How will consumers respond to the increase in the price of citrus fruit?

Plate 7.3 Florida oranges.
Source: Devi/Shutterstock

Box 7.3 Florida oranges

Florida is a major agricultural state, and ranks first in the United States in the value of production of oranges, grapefruit, tangerines, sugarcane for sugar and seed, squash, watermelons, sweet corn, fresh-market snap beans, fresh-market tomatoes, and fresh-market cucumbers. In 2007–08 Florida, with its 65 million orange trees, accounted for 70 percent of total US citrus production. California produced 27 percent of US citrus, and Texas and Arizona produced the remaining 3 percent. In 2007, Florida had over 5500 commercial orange farms, utilizing approximately 560,000 acres. In the United States, 90 percent of the orange juice consumed is from Florida oranges.

Globally, orange production is greatest in Brazil, the US, and Mexico, while China produces mandarins and India grows lemons and limes. The first citrus seeds planted and cultivated in the New World were under the supervision of Christopher Columbus in what is now Haiti in 1493. Oranges with their high level of Vitamin C helped prevent scurvy in sailors during long sea voyages.

Sources: USDA/NASS Statistics by State, Florida Ag Statistics, 2010.
US Census Bureau. Census of Agriculture. 2007.

Economists assume that consumers maximize their own utility, subject to a budget constraint. This is a serious assumption, since consumers of all ages and stations in life are constantly buffeted by forces explicitly designed to change the choices they make as consumers or citizens. Advertising aims explicitly at changing consumer preferences. Political rhetoric works the same way, and ever-present peer pressure causes consumers to make frequent changes in the pattern of their purchases.

The question here narrows in the hope that lessons from economics can help sort out what happens when the relative prices of consumer goods (food, clothing, books, vacuum cleaners, entertainment, etc.) change. When this occurs, consumers shift their purchases into the less expensive goods and away from the more expensive goods. **Indifference Curves** help show this movement between goods.

Indifference curves

The word, "indifferent" means that an individual, a consumer in this case, does not have a preference between two outcomes; it doesn't matter one way or the other. An indifference curve is a graphed function that shows all combinations of two goods that provide exactly the same degree of satisfaction to a consumer. Since each point provides the same satisfaction, the consumer is indifferent between any two points on the curve. If a friend asks, "What would you like to do tonight?" and you respond, "I don't care," then you are indifferent. Similarly, when you cannot decide between a new yellow shirt and a new blue shirt, you are indifferent.

An indifference curve shows a consumer's willingness to trade one good for another. If a consumer has a case of Pepsi, how many bottles is he willing to trade to get one hamburger? Similarly, if a Texas cattle producer raises cattle and has a freezer full of meat, how many pounds of beef would she trade for two pounds of fruit and vegetables? The indifference curve shows exactly how a consumer is willing to trade one good against another. The formal definition of an **Indifference Curve** is:

- ***Indifference Curve*** = a line showing all possible combinations of two goods that provide the same level of utility (satisfaction).

Indifference curve example: pizza and Coke

Pizza and Coke make a highly regarded snack or even a simple dinner, but the proportions between the two may change depending on the purpose: snack or dinner. A given consumer may be indifferent between several combinations of these popular foods. The indifference curve I_0 in Figure 7.3 shows a group of points, each representing the same degree of satisfaction. A consumer is indifferent between any pair of points on the curve. The indifference curve represents consumer preferences for only two goods: slices of pizza and bottles of Coke. The shape of the indifference curve comes from the fact that the supply of each of the goods is limited. Put another way, the curve takes its shape from the scarcity associated with the two goods.

> **Quick Quiz 7.6**
>
> Define the concept of scarcity, and explain why it is the foundation of economics.

Coke is scarce at point B. At this point, the consumer has a more-than-adequate amount of pizza and very little Coke. Therefore, he is willing to give up several slices of pizza in exchange for one Coke. The opposite is true at point A. Where Coke is plentiful and pizza is scarce, the consumer is willing to give up several Cokes to obtain one slice of pizza.

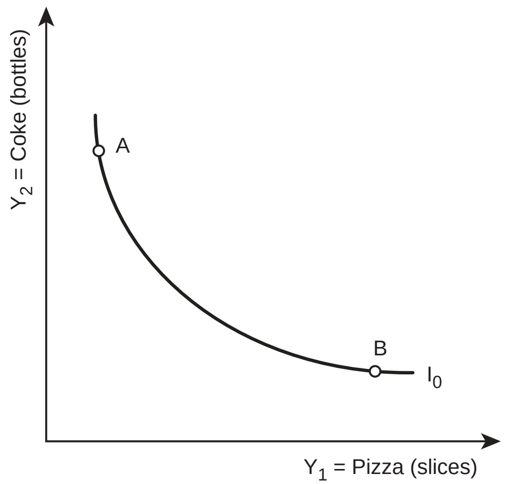

Figure 7.3 An indifference curve for pizza and Coke.

These tradeoffs make the indifference curve convex to the origin, reflecting the Law of Diminishing Marginal Utility: the first unit of consumption of a good is the most highly valued. There are four properties of all indifference curves, as explained below.

Four properties of indifference curves

Downward Sloping, (7.3a)

Everywhere Dense, (7.3b)

Cannot Intersect, and (7.3c)

Convex to Origin. (7.3d)

Explanations for these four properties follow.

1. **Downward Sloping**. By assumption, more is preferred to less. Figure 7.4 shows that this must be true. If an indifference curve were upward sloping, then a point such as B, with more of both goods than point A, would, by definition, produce the same level of utility (I_0) as point A, which has lower amounts of both goods.
   An indifference curve that slopes upward (Figure 7.4) violates the definition of "indifference." Point B shows more of both goods than point A, but since it lies on the same indifference curve as point A, it seemingly produces the same level of utility. This cannot be true. This reasoning applies to all combinations of two goods, and it follows that all real-world indifference curves are downward sloping. Put another way, the property of nonsatiation (more is preferred to less) insures that indifference curves must be downward sloping. A consumer must give up some of one good in order to get the

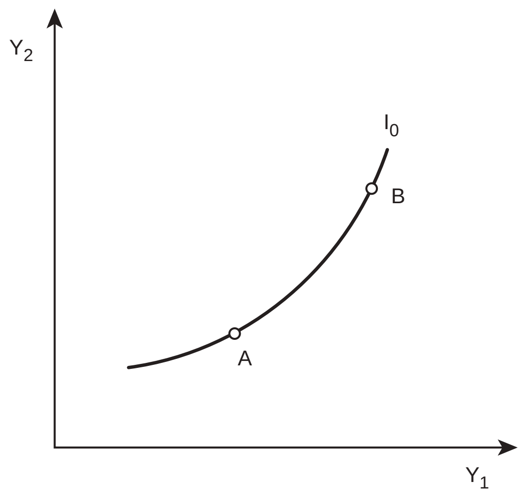

Figure 7.4 Proof that an indifference curve cannot be upward-sloping.

other good. The slope of the indifference curve represents the consumer's willingness to trade, or sacrifice, one good for another.

2. **Everywhere Dense**. This property means that there is an indifference curve through every single point in the positive quadrant. Every combination of the two goods produces some level of satisfaction. The term, "everywhere dense" means that there are an infinite number of isoquants in the plane.

> **Quick Quiz 7.7**
>
> Why do we only draw some of the indifference curves in the graphs?

3. **Cannot Intersect**. Indifference curves cannot intersect, since that would mean that two different levels of utility were equal to each other at the point of intersection. To untangle this problem, assume that two indifference curves intersect, as in Figure 7.5.

   First, notice that points A and B are on the same indifference curve (I_1). Each point provides the same level of utility. Next, notice that points B and C are on the same indifference curve (I_2), so they each represent the same level of utility. If A and B have equal levels of utility, and B and C have equal levels of utility, then it follows that A and C must have equal levels of utility (A = B and B = C, so A = C). However, Figure 7.5 shows that combination A produces a higher level of utility than combination C, since A has more of each good than C.

   Therefore, indifference curves cannot intersect. A contradiction follows if they do. The equations, $A \sim C$ and $A \succ C$ cannot both be true at the same time. Therefore, indifference curves must not touch, since each curve represents a different level of utility.

4. **Convex to Origin**. This property states that the indifference curves must bend toward the origin (be convex to the origin). This is due to the Law of Diminishing Marginal Utility: the first unit of a good is the most satisfying! The graph in Figure 7.6 shows this.

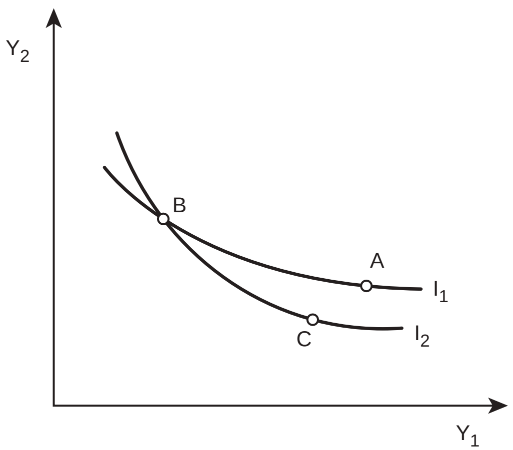

Figure 7.5 Proof of why indifference curves cannot intersect.

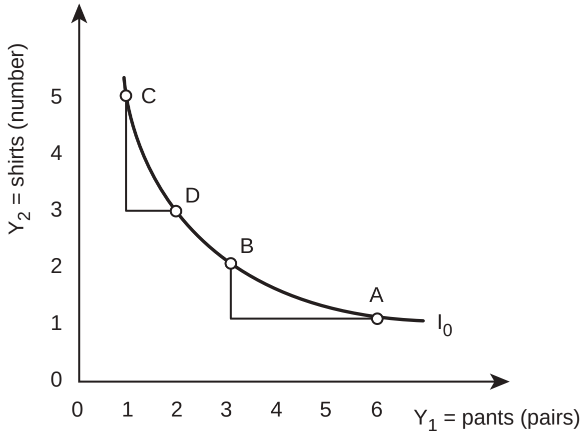

Figure 7.6 The Law of Diminishing Marginal Utility.

The Law of Diminishing Marginal Utility is used to show that if a consumer has many pairs of pants (point A: 6 pairs of pants, 1 shirt), she is willing to trade 3 pairs of pants for one additional shirt (point B: 3 pairs of pants, 2 shirts). On the other hand, if the consumer had 5 shirts and only one pair of pants (point C), she would be willing to give up two shirts for the second pair of pants (point D: 2 pairs of pants and 3 shirts). A consumer's willingness to trade one good for another depends on how much of each good he or she has. The first unit provides the higher level of satisfaction, and consumption of subsequent units provide less additional utility, as shown in Figure 7.6.

Indifference curves for substitutes and complements

Consider the case of two goods that are **Perfect Substitutes**, meaning that the consumer is indifferent between the consumption of either good. Suppose a consumer is purchasing shirts that are identical in every aspect other than color. If the consumer is indifferent between blue shirts and green shirts, then these two goods are perfect substitutes in consumption, as shown in Figure 7.7.

- ***Perfect Substitutes*** = goods that are completely substitutable, so that the consumer is indifferent between the two goods (see **Substitutes**).

The indifference curve for perfect substitutes is a straight line with a constant slope. In Figure 7.7, the consumer is indifferent between any combination of blue and green shirts that adds up to three shirts. This indifference curve is a special case, since it is not convex to the origin. The consumer is willing to trade one good for the other at a constant rate, so the goods are, in a way, the same good—"shirts." The opposite case of perfect substitutes is **Perfect Complements**.

- ***Perfect Complements*** = Goods that must be purchased together in a fixed ratio (see **Complements**).

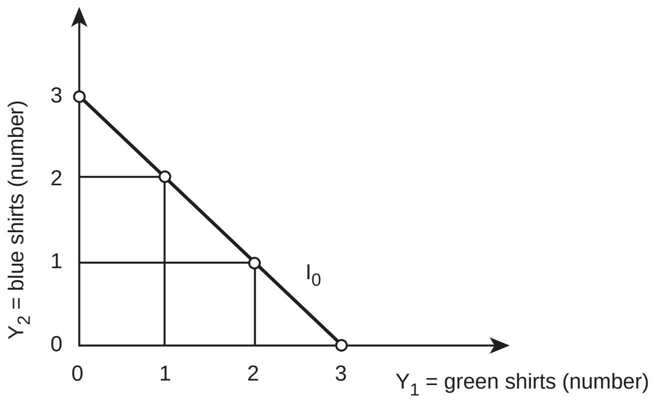

Figure 7.7 Perfect substitutes in consumption.

Here, consuming one of the two goods requires consuming some of the other good at the same time. For example, except in rare cases, consuming a left shoe commits a person to consume a right shoe (Figure 7.8). The level of utility along indifference curve I_0 does not increase when the consumer buys additional right shoes to go with one left shoe. Left and right shoes must be consumed together in order to produce satisfaction for the consumer. Similarly, as left shoes accumulate without the right shoes that match them, the utility level stays constant. Utility increases only with the purchase of one of each good: a right shoe and a left shoe. This is also a special case of an indifference curve, since the curve is not convex to the origin. Almost all goods are "imperfect substitutes," meaning that they can be substituted with each other, but not perfectly. Convex indifference curves characterize these goods.

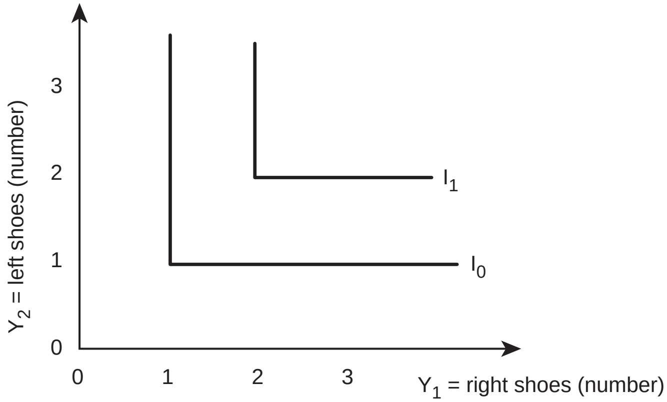

Figure 7.8 Perfect complements in consumption.

7.5 The marginal rate of substitution

The slope of the indifference curve reflects the rate of change between goods and is called the **Marginal Rate of Substitution (MRS)**.

- ***Marginal Rate of Substitution [MRS]*** = the rate of exchange of one good for another that leaves utility unchanged. The MRS defines the slope of an indifference curve. MRS = $\Delta Y_2/\Delta Y_1$.

The term, "marginal" refers to a small change. The term, "substitution" refers to the tradeoff between the goods. Thus, the MRS is the number of units of good Y_2 that must be given up per unit of good $Y_{1,}$ if the consumer is to remain indifferent, or retain the same level of satisfaction.

The Diamond–Water Paradox

The literature of economics includes many examples of unusual relationships existing between goods. Among these is a paradox simply called the Diamond–Water Paradox. The issue is very simple: why is water, an absolute necessity to life, so inexpensive (often free), while diamonds, stones used as romantic baubles and egoistic ornamentation, but which have only a few industrial uses, are expensive?

Quick Quiz 7.8

Can you use simple economic reasoning to explain the Diamond–Water Paradox?

Plate 7.4 Diamond-water paradox.

Source: Sebastian Duda/Shutterstock

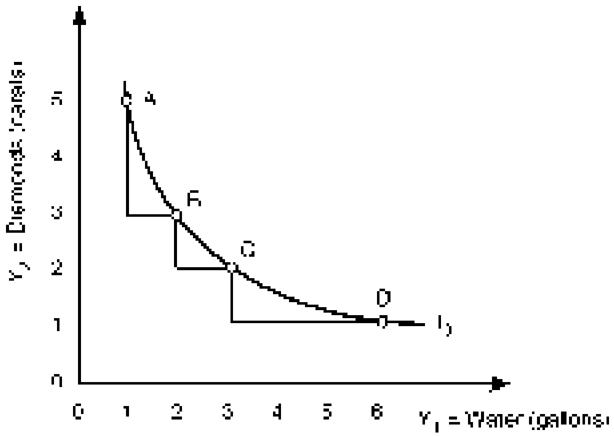

Figure 7.9 The "Diamond–Water Paradox"

The economic answer to the paradox centers on scarcity. Diamonds are valuable because they are scarce, whereas water is inexpensive because it is relatively plentiful. Would people ever give up diamonds for water? It sounds unlikely, but the transaction would take place if you had only diamonds and no water. Would anyone give up water for diamonds? Certainly, if they had enough water to meet their needs. The graph in Figure 7.9 shows this.

The slope of the indifference curve in Figure 7.9 is easily interpreted to be the marginal rate of substitution (MRS) between the two goods. The MRS between points A and B shows the willingness of a consumer to trade diamonds for water.

$$MRS(AB) = \Delta Y_2 / \Delta Y_1 = (3-5)/(2-1) = -2. \quad (7.4)$$

At point A, diamonds are relatively plentiful, so the consumer is willing to give up two diamonds for one more gallon of water. But what happens to the Marginal Rate of Substitution when the consumer trades for one more unit of water?

$$MRS(BC) = \Delta Y_2 / \Delta Y_1 = (2-3)/(3-2) = -1. \quad (7.5)$$

The absolute value of the rate of substitution has declined, as shown in Figure 7.9, where the slope of the indifference curve has decreased. This reflects the fact that as water becomes more plentiful (less scarce) the consumer is willing to give up fewer diamonds to acquire more water. The calculation of the MRS for the next gallon of water is:

$$MRS(CD) = \Delta Y_2 / \Delta Y_1 = (1-2)/(6-3) = -1/3. \quad (7.6)$$

The MRS continues to fall in absolute value with the consumption of more units of water. Previous sections of this chapter established the connection between the Law of Diminishing Marginal Utility and the convexity of the indifference curve.

Another example of the tradeoffs that occur between goods is the time allocation of a college student. Suppose that there are two ways for a college student to spend time: (1) studying, and (2) relaxing. The possibilities are depicted in Figure 7.10. If a student has

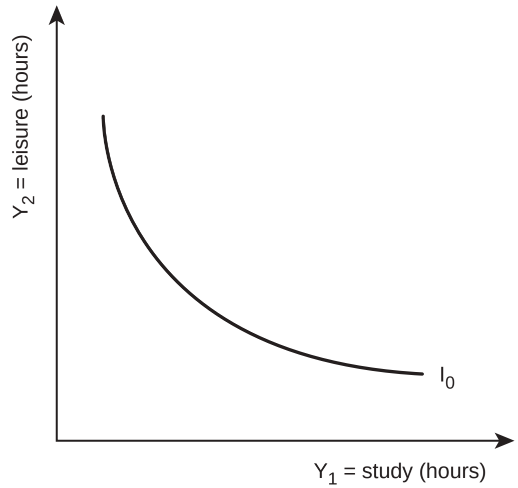

Figure 7.10 Time allocation for a college student.

been working all of the time, he may be willing to give up several hours of work to get the first hour of play. As a student increases the amount of play, extra hours of play become less valuable, as shown in Figure 7.10.

The indifference curve in Figure 7.10 shows that it is possible that some students may eventually settle at a position somewhere near the middle of the graph. The notion of "balance" suggests that a student will want to consume some of each good. An indifference curve reflects consumer preferences. However, consumers must spend within their limits, or, in language that is more technical, they must comply with a budget constraint, the theme of the following section. After studying the budget constraint, it will be combined with indifference curves to find a utility-maximizing (most satisfying) equilibrium point that combines what consumers want with what they can afford.

Quick Quiz 7.9

What is an equilibrium?

7.6 The budget constraint

Indifference curves are everywhere present in a graph drawn with the satisfaction provided by one good shown on each axis. This collection of indifference curves (as in Figure 7.11) is called an indifference curves map.

The indifference curves shown in Figure 7.11 each include a group of points that represent combinations of the two goods. In addition, each point (combination) on a single curve yields the same amount of satisfaction. Given the assumption that more is preferred to

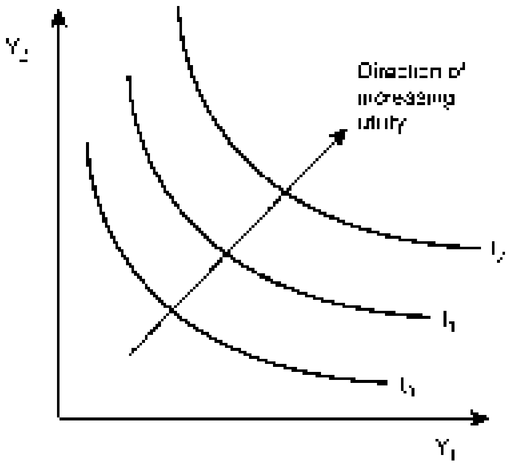

Figure 7.11 An indifference curve map.

less, the level of utility increases as one moves to the northeast from curve I_0 to curve I_1 to curve I_2. The consumer's budget limits him to considering only those combinations on the highest indifference curve. The consumer is constrained by a budget. Utility, or consumer preference, is represented by the indifference curves, and the budget constraint represents the amount that the consumer has to spend on the goods.

- *Budget Constraint* – a limit on consumption determined by the size of the consumer's budget and the prices of goods

A line added to the indifference curve map shows the consumer's budget constraint. Assume that a consumer spends all of his income on only the two goods (food and clothes) in Figure 7.12. Define the variables of a budget constraint as:

M = income ($) (7.9a)

Y_1 = food (calories) (7.9b)

P_1 = price of food ($/calorie) (7.9c)

Y_2 = clothes (outfits) (7.9d)

P_2 = price of clothes ($/outfit) (7.9e)

The budget line stems from the assumption that the consumer spends all of his income on food and clothes. The equation for the line states that income must be greater or equal to the combined expenditures on food (Y_1) and clothing (Y_2).

$$M \geq P_1Y_1 + P_2Y_2 \quad (7.10)$$

If all income is spent on food and clothing, then the inequality in Equation 7.10 becomes an equality.

$$M = P_1Y_1 + P_2Y_2. \tag{7.11}$$

This equality (the budget constraint) shows that the amount of money available (M) is exactly equal to the amount spent on food and clothing. Some specific numbers illustrate a budget constraint.

$$M = \$100/\text{month}; P_1 = \$1/\text{calorie}; P_2 = \$20/\text{outfit}. \tag{7.12}$$

This information defines a line on the graph in Figure 7.12, showing combinations of food and clothing affordable with the given budget.

The y-intercept shows the affordable quantity of clothing if all of M goes for clothing. The x-intercept shows the maximum amount of food that M can purchase. The x-intercept is found by calculating how many calories of food could be purchased at an income level of \$100/month, and a price of food equal to \$1/calorie (M/P_1 = \$100/(\$1/calorie) = 100 calories).

The y-intercept is found by calculating how many outfits of clothing could be purchased if all of the income were spent on clothing (M/P_2 = \$100/(\$20/outfit) = 5 outfits). Finding these two intercepts and connecting them with a straight line, provides a "picture" of the budget constraint. The slope of this **Budget Line** is the "rise over the run," or $\Delta y/\Delta x = \Delta Y_2/\Delta Y_1 = -5/100 = -0.05$.

- ***Budget Line*** = a line indicating all possible combinations of two goods that can be purchased using the consumer's entire budget.

The equation of a line is given by: y = b + mx, where b is the y-intercept and m is the slope. The equation of a budget constraint leads to derivation of the equation for the budget line. This derivation should look familiar: it is similar to the derivation of the isocost and isorevenue lines used to study the behavior of producers (Chapter 5).

$$M = P_1Y_1 + P_2Y_2 \tag{7.13a}$$

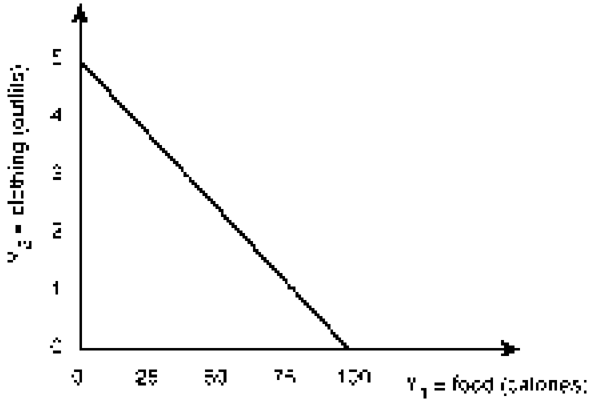

Figure 7.12 The budget constraint

$$P_2Y_2 = M - P_1Y_1 \quad (7.13b)$$

$$Y_2 = (M/P_2) + (-P_1/P_2)\ Y_1. \quad (7.13c)$$

The y-intercept (b) is equal to M/P_2, equal to \$100/(\$20/outfit) = 5 outfits (this confirms the above calculation). The calculation of the slope of the budget line, is confirmed by $m = \Delta y/\Delta x = -P_1/P_2$ = relative prices. The slope of the budget constraint represents the relative prices of the two goods. The **Opportunity Set** is the triangle formed by the budget line, as in Figure 7.13.

- ***Opportunity Set*** = the collection of all combinations of goods within the budget constraint of the consumer.

The triangle formed by the axes and the budget line is called the opportunity set, because any combination of goods in the set is within the given budget and affordable. Points such as “A” that are outside of the opportunity set are not feasible: the consumer does not have enough money to afford them.

A consumer will desire to maximize utility, subject to the budget constraint as shown in Figure 7.13. The consumer will desire to locate as far to the northeast as possible while staying within the opportunity set. The next section shows how a consumer will select the utility-maximizing point by combining the preference information from the indifference curves with budget information in the budget line.

7.7 Consumer equilibrium

The term “equilibrium” describes a situation where there is no tendency to change. When an economy is in equilibrium, producers and consumers are doing the best that they can, given the constraints that they face. In equilibrium, producers are maximizing profits subject to technology and prices, and consumers are maximizing utility, subject to a budget constraint and prices. Equilibrium is an “optimal” point.

A “map” of indifference curves summarizes consumer preferences. The curves represent the tradeoffs between food (Y_1) and clothes (Y_2). The slope of an indifference

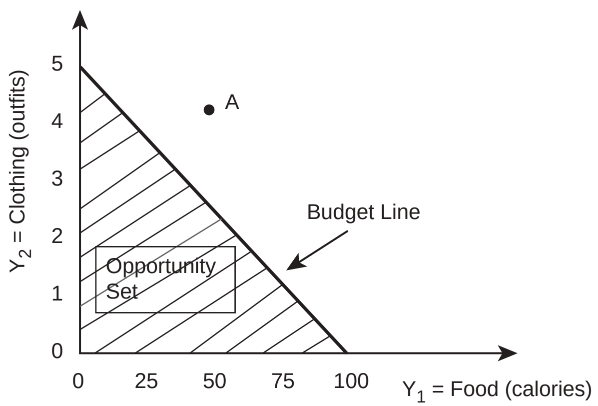

Figure 7.13 The opportunity set.

curve is the Marginal Rate of Substitution (MRS), which represents a consumer's relative preferences for the two goods, Y_1 and Y_2. It answers the question, "How many units of Y_1 am I willing to give up to receive an additional unit of good Y_2?" This depends on the consumer's preferences for each good. The MRS reflects the Marginal Utility for each good, and defines how much additional satisfaction a consumer can receive from each unit of the good.

$$MRS = \Delta Y_2 / \Delta Y_1 = MU_1 / MU_2. \tag{7.14}$$

A consumer will want to reach the highest possible level of satisfaction. This optimal, or highest, level of utility will be the highest indifference curve that is still within the opportunity set, or the indifference curve that is tangent to the budget line.

Point E in Figure 7.14 represents the consumer's optimum, or equilibrium point. In this example, the equilibrium combination includes 50 calories of food and 2.5 outfits. This equilibrium point is arbitrarily set at the "half-way" mark on the budget constraint between the vertical (food) and horizontal (clothing) axes. However, there are numerous possible equilibria, each depending on the location of the consumer's indifference curve. Regardless of how many indifference curves come under consideration, the optimal, or equilibrium point, from which there is no tendency to change, always appears at the point where the indifference curve is tangent to the budget line.

The slope of the budget line represents relative prices, as it is equal to the price ratio $(-P_1/P_2)$. The budget line represents what the consumer can buy. The slope of the indifference curve defines the consumer's preferences. This graphical analysis is a story about a shopping trip taken in order to match two things:

1. What the shopper can afford (the budget constraint), and
2. What the shopper prefers to consume (the indifference curve).

The mathematical equation for the equilibrium reflects this story:

$$\text{Slope of the indifference curve} = \text{slope of the budget line} \tag{7.15a}$$

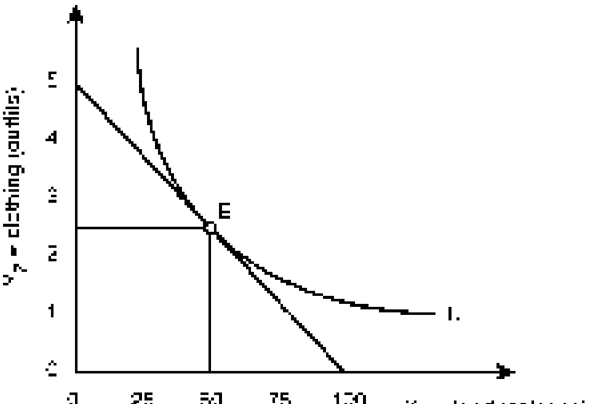

Figure 7.14 Consumer equilibrium.

$$MRS = \text{price ratio} \tag{7.15b}$$

$$\Delta Y_2 / \Delta Y_1 = P_1 / P_2 \tag{7.15c}$$

$$MU_1 / MU_2 = P_1 / P_2 \tag{7.15d}$$

$$MU_1 / P_1 = MU_2 / P_2. \tag{7.15e}$$

This equilibrium condition states that a consumer should equalize the additional utility gained from the consumption of a good (MU) per price of the good for all goods. If a consumer can gain more satisfaction from one unit of cost from one good than from another good, then the consumer should shift consumption into the higher utility good and out of other, lower utility goods. This allows the consumer to reach the highest indifference curve possible, while remaining within the budget constraint.

7.8 The demand for meat in Phoenix, Arizona

Learning about consumer behavior helps observers understand real-world issues in the agricultural economy. Currently, there is an important issue in the red meat industry: the per-capita consumption of beef in the US has declined rather steadily (the US population consumed an average of 59.7 pounds of beef per capita in 2010: the lowest rate of beef consumption per capita in at least 55 years). Economists argue about whether this decrease stems from price changes (beef is expensive relative to meats such as pork and chicken) or health issues (some consumers perceive red meat to be unhealthy).

Plate 7.5 Demand for meat in Phoenix, Arizona.

Source: Gresei/Shutterstock

Consumer equilibrium for the Phoenix consumer

A simple model of consumer behavior helps analyze this issue. Assume that the budget for weekly expenditures on meat is 20 dollars (M = \$20), the price of beef is four dollars per pound (P_1 = \$4/lb), and the price of chicken is two dollars per pound (P_2 = \$2/lb). Figure 7.15 shows the budget line for the Phoenix consumer.

> **Quick Quiz 7.10**
>
> Locate the opportunity set in Figure 7.15.

The opportunity set for meat tells how much beef and chicken the consumer could purchase if all of the consumer's income were spent on one good. If the entire budget was spent on beef, the consumer could purchase five pounds of meat (x-intercept, M/P_1 = \$20/\$4/lb = 5 lbs).

If, alternatively, the consumer spent all of the income on chicken, 10 pounds of chicken could be purchased (y-intercept, M/P_2 = \$20/\$2/lb = 10 lbs). The opportunity set reflects what is possible for the consumer to purchase.

The indifference curves represent the consumer's preferences. The slope of the indifference curve is the marginal rate of substitution ($MRS = MU_1/MU_2$). The slope of the budget line reflects relative prices, and is equal to $-P_1/P_2$. The equilibrium for purchases of meat occurs where the MRS is equal to the relative price ratio, as shown in Figure 7.15. At the equilibrium point (E), the Phoenix meat eater consumes 2.5 pounds of beef and 5 pounds of chicken.

An increase in income for the Phoenix consumer

If the local Phoenix economy expands, wages and salaries paid to the workers in the area will rise. This, in turn, allows these consumers to spend more money on meat. Suppose that total meat expenditures rise from M_0 = \$20/week to M_1 = \$40/week.

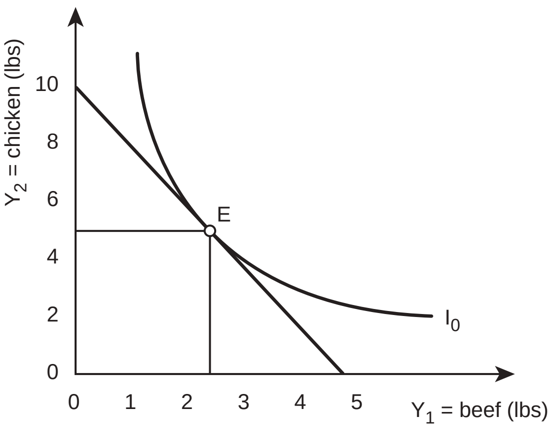

Figure 7.15 Phoenix consumer equilibrium.

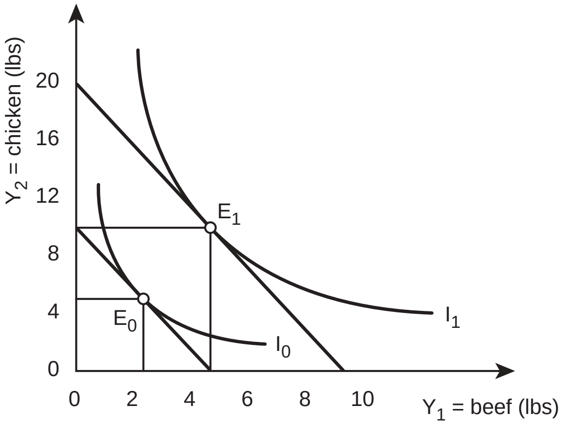

Figure 7.16 Effect of an increase in income on Phoenix consumer equilibrium.

This increase in income is good for consumers; it is good for the beef industry, and good for beef producers in the US and other beef-producing nations. Figure 7.16 shows the impact of the increase in income on the consumer's meat purchases.

The original consumer equilibrium for the beef eater in Phoenix (E_0) is 2.5 pounds of beef and 5 pounds of chicken. After the income increase, the equilibrium shifts to 5 pounds of beef and 10 pounds of chicken (E_1).

Quick Quiz 7.11

What defines the location of the equilibrium point on the budget line?

An increase in income will have an impact on the beef industry. When income levels increase, consumers typically spend more money on "luxury" goods such as beef. Changes in income have a large impact on consumption.

Box 7.4 Meat consumption in China

Many agricultural economists believe that economic growth in China will result in a huge increase in the demand for both meat products and grain products imported from the US. Chapter 1 of this book notes that meat consumption in Japan grew rapidly in the years following World War II due in large part to increases in the level of living. If China follows the same pattern, it is likely that meat consumption will increase enormously. This would increase the consumption of meat and grain products, since conventional meat production requires seven pounds of grain to produce one pound of meat. Thus, beef producers in the US are very interested in the economic development of China.

Source: FAOSTAT. United Nations Food and Agriculture Organization.

Quick Quiz 7.12

Can you think of any goods that would have a decrease in consumption when income levels increase?

The impact of general inflation on the Phoenix consumer

A simultaneous and continued increase in all prices in an economy is referred to as a general inflation. Chapter 1 includes a short discussion indicating that inflation would not affect the economy at all, since the price of labor (wages and salaries) would increase at the same rate as the prices of all other goods and services. If all prices in the economy double, for example, including wages and salaries, then the consumption and production of goods and services would remain unchanged. In the real world, inflation does not increase all prices in a uniform and simultaneous fashion.

The simple model of consumer behavior sheds light on this issue by investigating the logic behind it. The price and income data below reflect a general inflation where all prices double. The subscripts refer to the good (1 = beef; 2 = chicken) and the superscripts refer to time periods zero and one.

Before:	After:
$M^0 = \$20$/week	$M^1 = \$40$/week
$P_1^0 = \$4$/lb	$P_1^1 = \$8$/lb
$P_2^0 = \$2$/lb	$P_2^1 = \$4$/lb

The budget line ($M = P_1Y_1 + P_2Y_2$) will be identical before and after the inflation.

Before:	After:
$20 = 4Y_1 + 2Y_2$	$40 = 8Y_1 + 4Y_2$
$2Y_2 = 20 - 4Y_1$	$4Y_2 = 40 - 8Y_1$
$Y_2 = 10 - 2Y_1$	$Y_2 = 10 - 2Y_1$

Since the budget line remains unchanged, the equilibrium does not change. The general inflation has no effect on the economy. Relative prices have not changed, so nothing happens.

The impact of a change in beef prices on the Phoenix consumer

The situation is different for changes in relative prices. Suppose that the cost of production for beef deceases due to technological changes in packing plants. Prior to the change, P_1^0 = \$4/lb and after the change, P_1^1 = \$2/lb. The price and income data are as follows, where the subscript refers to the good (1 = beef; 2 = chicken) and the superscript refers to time periods zero and one.

$M^0 = \$20$/week	$P_1^0 = \$4$/lb	$P_2^0 = \$2$/lb
$M^1 = \$20$/week	$P_1^1 = \$2$/lb	$P_2^1 = \$2$/lb

The budget constraint changes, since the relative prices of beef and chicken change. The slope of the budget line is the relative price ratio.

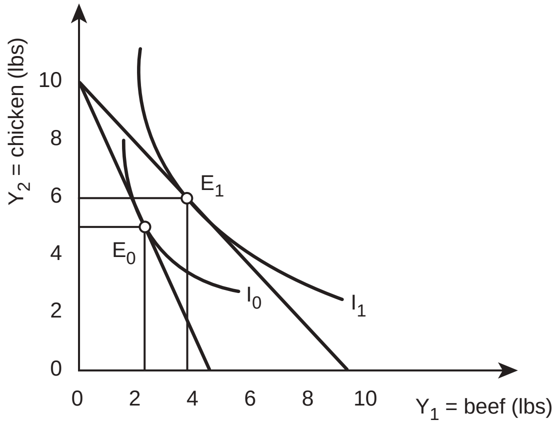

Figure 7.17 Decrease in beef price effect on Phoenix consumer equilibrium.

Before:	After:
$20 = 4Y_1 + 2Y$	$20 = 2Y_1 + 2Y_2$
$Y_2 = 10 - 2Y_1$	$Y_2 = 10 - Y_1$

In Figure 7.17, the consumer equilibrium before the price change is (E_0), 2.5 pounds of beef, and 5 pounds of chicken. After the price change, the budget line shifts to reflect an increase in purchasing power, since the price of beef is lower. The y-intercept remains at 10, since both income (M) and the price of chicken (P_2) have remained unchanged. The x-intercept shifts from 5 pounds ($M^0/P_1{}^0$= \$20/\$4/lb = 5 lbs) to 10 pounds ($M^1/P_1{}^1$ = \$20/\$2/lb = 10 lbs).

The consumer equilibrium after the technological change (E_1) moves to four pounds of beef and six pounds of chicken, as shown by the tangency of the indifference curve and the budget line (MRS = the price ratio). The consumer can expand the consumption of both goods, although the price of chicken remains constant. This is because of the increase in the consumer's purchasing power associated with the price decrease. The price of beef has a strong effect on consumer purchases of both beef and chicken.

The technological change increased the amount of beef sold in Phoenix. Any circumstance that causes a relative price decrease will result in more of the good being sold. Cattle producers are better off, since consumers purchase more beef (note that the price of cattle does not decrease, just the price of meat in the grocery store). Conversely, any factor that increases the relative price of beef in the grocery store will have an adverse effect on the cattle producers.

The impact of a change in chicken prices on the Phoenix consumer

Does a change in the price of chicken affect the beef market? Definitely, yes. Just as the beef price decline caused an increase in the consumption of both beef and chicken, a change in the price of chicken will affect both the beef and the chicken markets since

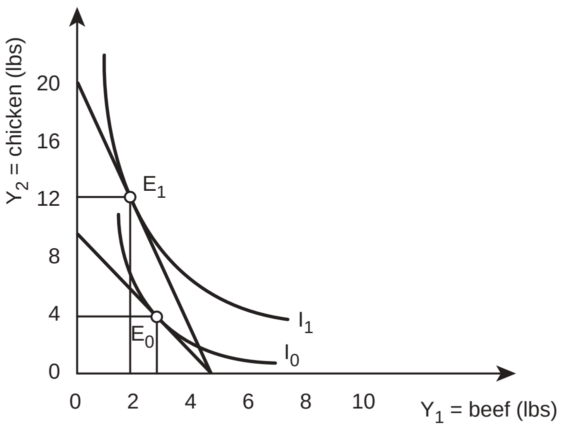

Figure 7.18 Decrease in chicken price effect on Phoenix consumer equilibrium.

they are substitutes. Suppose that there is a decrease in the relative price of chicken from \$2/lb to \$1/lb:

M^0 = \$20/week	P_1^0 = \$4/lb	P_2^0 = \$2/lb
M^1 = \$20/week	P_1^1 = \$4/lb	P_2^1 = \$1/lb

The budget line shifts due to the price change.

Before:	After:
$20 = 4Y_1 + 2Y_2$	$20 = 4Y_1 + Y_2$
$Y_2 = 10 - 2Y_1$	$Y_2 = 20 - 4Y_1$

Figure 7.18 shows that the x-intercept does not change, but the budget line pivots upward and outward; the original equilibrium (E_0: 2.5 lbs beef; 5 lbs chicken) and the equilibrium after the price change (E_1: 2 lbs beef; 12 lbs chicken). With the price decrease of chicken, the consumer substitutes out of the more expensive product (beef) and into the less expensive product (chicken). Beef and chicken are substitutes: consumers will shift their purchases toward the less expensive product.

Relative prices rule. Any change in the relative price of beef will affect the quantity of beef purchased, whether the real change as opposed to the relative change is a change in the price of beef or a change in the price of chicken.

Quick Quiz 7.13

Are beef and chicken substitutes or complements in consumption? Why? Are beef and chicken perfect substitutes or imperfect substitutes in consumption? Why?

Conclusions for the beef industry based on consumer theory

Given the above example, what conclusion stems from the demand for beef in Phoenix, Arizona? Let the quantity of beef purchased by consumers be the demand for beef, Q^d_{beef}. The demand for beef is a function of income as are the prices of beef and chicken: $Q^d_{beef} = f(M, P_1, P_2)$. A summary of this analysis appears below.

1. $P_1\downarrow$: The price of beef decreases:
   $P_1\downarrow$: Q^d_{beef} increases
2. $P_2\downarrow$: The price of chicken decreases:
   $P_2\downarrow$: Q^d_{beef} decreases
3. $M\uparrow$: Income increases:
   $M\uparrow$: Q^d_{beef} increases.

Armed with knowledge of the demand for beef, an economist can provide advice to the beef industry:

- Lower production costs in every way possible. Lower P_1 to sell more beef.
- Pay attention to consumer preferences: especially to the prices of competing products such as chicken (P_2).
- Look to consumer groups with growing incomes (M) for new markets: low-income nations.

These three statements apply to any good, with the basic message for producers to pay careful attention to their consumers. This chapter has identified the optimal, utility-maximizing point for the consumer. The model of consumer behavior yielded the major determinants of consumer demand: relative prices and income. The next chapter explains how markets work. Supply and demand curves show the interaction of sellers and buyers. Chapter 8 is a study of markets.

7.9 Summary

1. In economics, we assume that individuals are rational. Rational behavior indicates that individuals do the best that they can, given the constraints that they face. Rational behavior is purposeful and consistent.
2. Utility is the satisfaction derived from consuming a good.
3. Cardinal utility assigns specific values to the level of satisfaction gained from the consumption of a good.
4. Ordinal utility ranks consumer satisfaction from the consumption of a good.
5. Total utility is the level of satisfaction derived from consuming a given bundle of goods and services. Marginal utility is the change in the level of utility as consumption of a good is increased by one unit.
6. The Law of Diminishing Marginal Utility states that MU declines as more of a good is consumed.
7. Three assumptions about consumer behavior are: (1) preferences are complete, (2) consumers are consistent, and (3) more is preferred to less (nonsatiation).
8. An indifference curve is a line showing all of the combinations of two goods that provide the same level of utility.
9. Indifference curves have four properties: (1) downward-sloping, (2) everywhere dense, (3) can't intersect, and (4) convex to the origin.

10. Perfect substitutes are goods that a consumer is indifferent between. Perfect complements are goods that must be purchased together in a fixed ratio. Most goods are imperfect substitutes, meaning that they can be substituted for each other, but not perfectly.
11. The Marginal Rate of Substitution (MRS) is the rate of exchange of one good for another that leaves utility unaffected and the slope of the indifference curve. The slope of the indifference curve is equal to the marginal valuation of the two goods.
12. The budget constraint is the limit imposed on consumption by the size of the budget and the prices of the two goods.
13. A consumer maximizes utility by locating at the tangency of the indifference curve and the budget line.
14. The opportunity set includes all combinations of goods within the budget constraint of the consumer.

7.10 Glossary

Budget Constraint. A limit on consumption determined by the size of the budget and the prices of goods.

Budget Line. A line indicating all possible combinations of two goods that can be purchased using the consumer's entire budget.

Cardinal Utility. Assigns specific, but hypothetical, numerical values to the level of satisfaction gained from the consumption of a good. The unit of measurement is the hypothetical util (see **Ordinal Utility**).

Complements in Consumption. Goods that are consumed together (e.g. peanut butter and jelly, see **Substitutes in Consumption**).

Complements in Production. Goods that are produced together (e.g. beef and leather, see **Substitutes in Production**).

Indifference Curve. A line showing all possible combinations of two goods that provide the same level of utility (satisfaction).

Law of Diminishing Marginal Utility. Marginal utility declines as more of a good or service is consumed during a given time period.

Marginal Rate of Substitution [MRS]. The rate of exchange of one good for another that leaves utility unchanged. The slope of an indifference curve. $MRS = \Delta Y_2/\Delta Y_1$.

Marginal Utility [MU]. The change in the level of utility when consumption of a good is increased by one unit. $MU = \Delta TU/\Delta Y$.

Opportunity Set. The collection of all combinations of goods within the budget constraint of the consumer.

Ordinal Utility. A way of considering consumer satisfaction in which goods are ranked in order of preference: first, second, third, etc. (see **Cardinal Utility**).

Perfect Complements. Goods that must be purchased together in a fixed ratio (see **Complements**).

Perfect Substitutes. Goods that are completely substitutable, so that the consumer is indifferent between the two goods (see **Substitutes**).

Rational Behavior. Individuals do the best that they can, given the constraints they face. Rational behavior is purposeful and consistent.

Substitutes in Consumption. Goods that are consumed either/or (e.g. wheat bread and white bread, see **Complements in Consumption**).

Substitutes in Production. Goods that compete for the same resources in production (e.g. wheat and barley, see **Complements in Production**).

Total Utility [TU]. The total level of satisfaction derived from consuming a given bundle of goods and services.

Utility. Satisfaction derived from consuming a good.

Utils. Hypothetical units of satisfaction derived from consumption of goods or services.

7.11 Review questions

1. An individual who stays up so late that he feels sick the next day is:
   a. rational
   b. irrational
   c. not an economic individual
   d. cannot tell from the information given
2. Placing a numerical value on the consumption of a piece of apple pie is an example of:
   a. normative economics
   b. cardinal utility
   c. ordinal utility
   d. positive economics
3. Modern economics uses which type of consumer theory?
   a. cardinal utility
   b. ordinal utility
   c. total utility
   d. public utility
4. Marginal utility refers to:
   a. the extra level of electricity from a public utility
   b. the level of satisfaction from consuming a good
   c. utility derived from consuming a good
   d. a change in utility when consumption is increased by one unit
5. When a consumer is indifferent between consuming an additional unit of a good:
   a. TU is negative
   b. MU is equal to zero
   c. TU is equal to zero
   d. MU is negative
6. All of the following are assumptions about consumer behavior except:
   a. complete preferences
   b. consistent consumers
   c. nonsatiation
   d. relativity
7. Indifference curves are convex to the origin due to:
   a. the Law of Diminishing Marginal Utility
   b. the Law of Diminishing Returns
   c. relative prices
   d. the Law of Demand
8. A tractor and a plow are:
   a. substitutes
   b. complements
   c. perfect substitutes
   d. not enough information to answer

9. Peanut butter and jelly are:
   a. substitutes
   b. complements
   c. perfect substitutes
   d. not enough information to answer
10. The indifference curve represents:
   a. consumer income
   b. consumer preferences
   c. what consumers can afford
   d. what consumers actually purchase
11. An increase in the price of chicken will affect:
   a. the amount of chicken purchased
   b. the amount of beef purchased
   c. the relative price of beef and chicken
   d. all of the other three answers
12. A general inflation will lead to:
   a. a decrease in the consumption of beef
   b. an increase in the consumption of beef
   c. no change in the consumption of beef
   d. unemployment
13. If income decreases then the consumption of beef will:
   a. increase
   b. decrease
   c. not change
   d. not enough information to answer

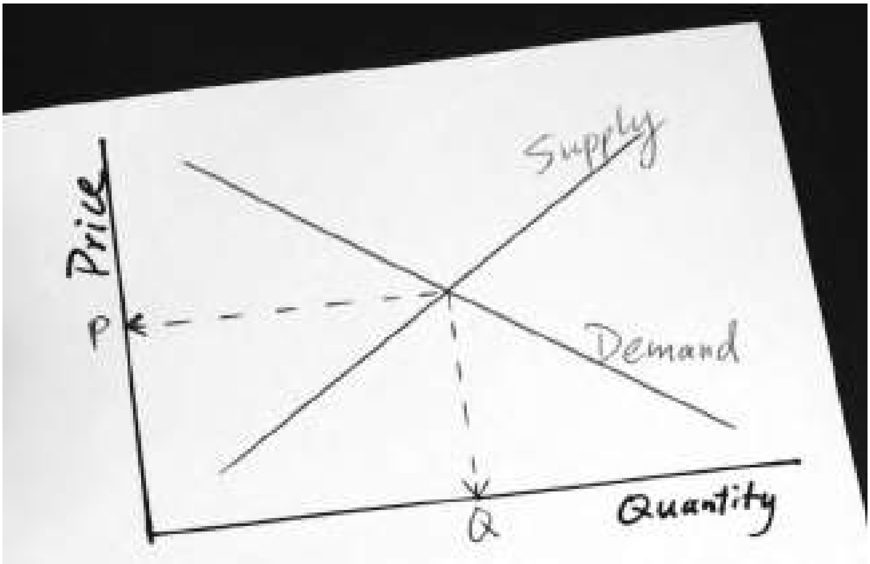

Plate 8.1 Supply and demand.

Source: JohnKwan/Shutterstock

8 Supply and demand

Synopsis

This chapter explains the two most famous building blocks of economics, supply and demand. These tools are crucial to understanding markets and how they function to allocate goods and resources. The supply curve is derived. We then explore what causes firms to produce goods, what resources to use in production, and how the firms respond to changes in prices of either inputs or outputs. Attention then turns to demand. The Law of Demand is a major feature of economics. Consumer responses to changes in relative prices, income, and other variables are carefully explained and explored.

8.0 Introduction

Chapters 1 through 7 describe and explain the behavior of individual economic units. These economic actors use specific methods to locate the optimal point in their economic decisions. Producers select the profit-maximizing combinations of inputs and outputs, and consumers purchase combinations of goods to maximize their own utility or satisfaction. Consumers determine what to purchase based on maximizing satisfaction, given income and relative prices. This chapter shows the explicit connection between individuals and markets by deriving market, or aggregate, supply and demand curves. The chapter also explains the determinants of market supply and demand, and introduces the concept of elasticity, or responsiveness, of producers and consumers to changes in prices and other economic conditions. Chapter 9 shows how supply and demand curves interact to determine the prices and quantities of goods.

8.1 Supply

A supply function shows the relationship between the quantity of a good and its price. Points on a supply function represent the quantity that will be placed on the market at each price.

- ***Supply*** = the relationship between the price of a good and the amount of a good available at a given location and at a given time.

In more formal terms, supply refers to a direct functional relationship between the price and quantity of a good:

$$Q^s = f(P), \tag{8.1}$$

where Q^s is the quantity supplied of a good, and P is the price of the good. When the price of a good increases, the quantity supplied of a good also increases.

The individual firm's supply curve

In the next several chapters, the notation Q^s denotes the market, or aggregate (total) level of quantity supplied, and q^s denotes a single firm's contribution to Q^s. This allows a distinction between graphs for single firms and graphs for an entire market supply. As we will see below, market supply is the aggregated supply of all individual firms that produce and sell the same product.

Understanding supply and demand at the aggregate, or market, level, requires understanding the component parts of an individual firm's supply curve. Specifically, deriving the supply curve for an entire market begins with a study of the costs incurred by an individual firm, as shown in Figure 8.1.

An individual profit-maximizing producer will continue to produce a good until MR = MC. The situation shown in Figure 8.1 relates to a firm in a competitive industry. The firm has no control over price. The price is fixed, constant, and equal to the MR line associated with each price: P_0, P_1, and P_2.

> **Quick Quiz 8.1**
>
> Why does the assumption of competition result in a fixed price? Why is the price equal to the MR?

For example, at a given point in time, price P_2 is fixed and given, and the firm cannot change the price. At the market price of P_2 in Figure 8.1, this single firm will maximize profits by setting MR = MC, or P = MC at q_2 units of output. If the firm were to produce one more unit of output ($q_2 + 1$), the additional (marginal) costs would increase to a level above the marginal revenue line, and profits would decrease. At one less unit of output ($q_2 - 1$), profits would fall, since marginal revenue would be higher than the marginal costs.

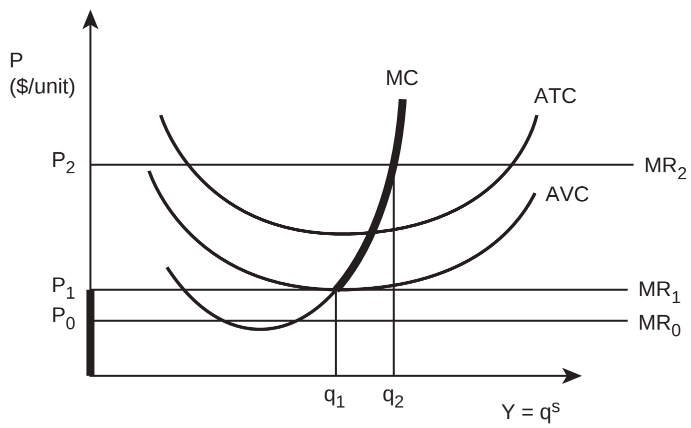

Figure 8.1 Individual firm short run supply curve.

The individual firm will always set price equal to MC, so the MC curve defines the relationship between the price of a good and the quantity supplied by the individual firm. Since supply refers to a direct, functional relationship between the price and the quantity supplied of a good, the marginal cost curve represents the supply curve of the individual firm. This is true for all prices, as long as the price is above the shutdown point.

Quick Quiz 8.2

Define the shutdown point for a firm in the short run and the long run (see Chapter 3).

In the short run, the firm will continue to produce as long as the price is greater or equal to the average variable cost (P ≥ AVC). At prices below AVC, the firm will shut down because costs are higher than revenue. The price P_1 in Figure 8.1 defines the shutdown price. For all prices above P_1, the individual firm's supply curve is equal to the MC curve, and for all prices below P_1, the supply curve is equal to zero (the heavy line on the vertical axis below P_1 in Figure 8.1).

- ***Supply Curve for an Individual Firm*** = the firm's marginal cost curve above the minimum point on the average variable cost curve.

Notice that there are two segments to the individual firm's supply curve: (1) above the shutdown point, supply is equal to the marginal cost curve, and (2) below the shutdown point, the supply curve is equal to zero. In the long run, the shutdown point is the ATC curve, since ATC = AVC in the long run, as in Figure 8.2.

Quick Quiz 8.3

Why does ATC = AVC in the long run? Draw an individual firm's long run supply curve.

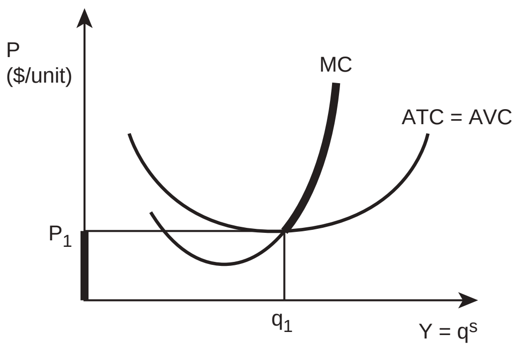

Figure 8.2 Individual firm long run supply curve.

The market supply curve

Aggregating all the supply curves of the individual firms in the market yields the market supply curve (sometimes called the industry, or aggregate, supply curve). Figure 8.3 provides the derivation of such a supply curve.

The term, "horizontal summation" refers to the aggregation of the quantity supplied by each firm into the market supply curve. Figure 8.3 shows the aggregation procedure for three firms, taken as representative of all firms in an entire market. The ellipsis (…) represents the numerous other firms that are in the same market, but are not included in the diagram due to lack of space.

Adding together the MC curve of each of the firms in the industry yields the market supply curve shown in the far right graph. Each of the three graphs to the left refers to an individual firm, represented by the symbol, "q." The "Q" represents the market supply curve, to indicate that the units scale (measurement on the horizontal axis) for the total market is much larger than the units scale for the individual firms.

At an initial price of P_1 dollars per unit, firm A sets MR = MC, and produces two units of output. Firm B follows the same behavioral rule, and produces four units of output. Similar logic causes firm C to produce five units of output. Adding together all of the individual firm supply curves (including those that are not in the graph) yields the point on the market supply curve for price P_1:

$$Q_1 = q_A + q_B + \ldots + q_C \qquad (8.2)$$

Following this horizontal summation procedure for different price levels produces a market supply curve (Q*). Keep in mind that only three of the numerous firms appear in the example. The definition of the **Market Supply Curve** is:

- *Market Supply Curve* = the relationship between the price and quantity supplied of a good, *ceteris paribus*, derived by the horizontal summation of all individual supply curves for all individual producers in the market.

Summarizing data on how each individual firm in a market will adjust production levels to changes in price produces a hypothetical market supply schedule, as shown in Table 8.1. Real-world supply schedules would look very much the same, with real data substituted for hypothetical prices and quantities.

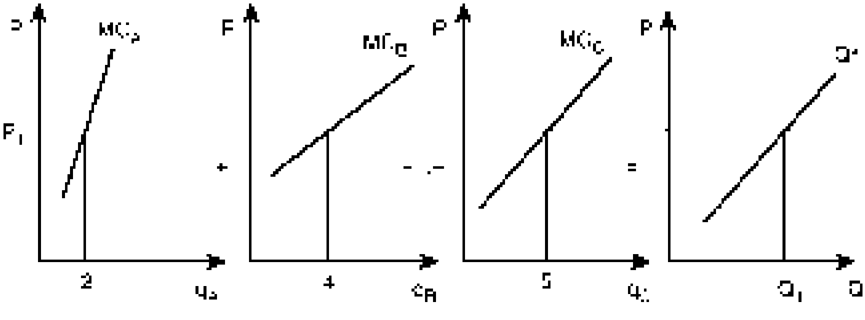

Figure 8.3 Derivation of a market supply curve.

Table 8.1 The hypothetical market supply of bread in New York City

Price (P) ($/loaf)	*Quantity Supplied (Q^s) (1000 loaves)*
1	10
2	20
3	30
4	40
5	50

The definition of the supply schedule is straightforward:

- ***Supply Schedule*** = a schedule showing the relationship between the price of a good and the quantity of a good supplied.

The information from the supply schedule leads to a graph of a market supply curve that summarizes the relationship between the price and quantity supplied of a good.

The Law of Supply

The key information provided in a supply schedule is that when the price of a good increases, the quantity supplied increases, due to the profit-maximizing behavior of individual firms. This positive, or direct, relationship between price and quantity supplied is so pervasive in market economies that economists are comfortable calling it a "law":

- ***Law of Supply*** = the quantity of goods offered to a market varies directly with the price of the good, *ceteris paribus*.

Plate 8.2 Bread supply.

Source: Senk/Shutterstock

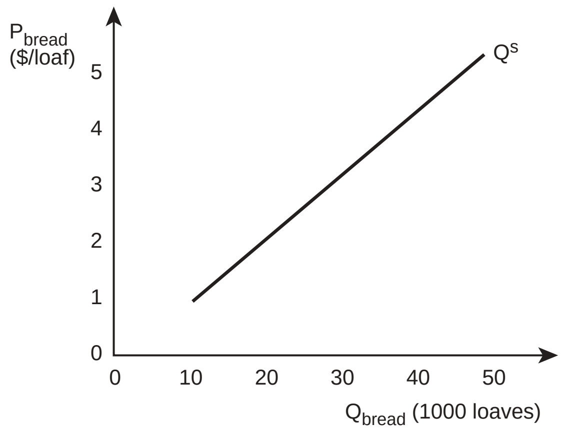

Figure 8.4 Market supply curve for bread in New York City.

The information contained in the supply schedule is the basis for a market supply curve, as shown in Figure 8.4.

There is an unusual but universal feature of this market supply graph. Economists study supply (the behavior of producers) and demand (the behavior of consumers). When they graph a supply curve, they are graphing the relationship between the price and quantity supplied of a good. Price is the independent variable, since it causes (determines) the quantity of a good sold. Price causes quantity supplied.

$$P \Rightarrow Q^s \left(P \text{ causes } Q^s\right), \tag{8.3a}$$

$$P = \text{independent variable}, \tag{8.3b}$$

$$Q^s = \text{dependent variable, and} \tag{8.3c}$$

$$Q^s = f\left(P\right). \tag{8.3d}$$

The study of competitive industries in Chapter 4 showed that producers in such industries take prices as given, and respond by deciding how much to sell. Individual firms are too small relative to the entire market to have any effect on the price of a good. Therefore, price causes quantity supplied.

Mathematicians locate the independent variable on the horizontal (x) axis and the dependent variable on the vertical (y) axis. For example, Figure 8.5 shows the physical relationship between precipitation and the yield of wheat.

$$x \Rightarrow y \left(x \text{ causes } y\right), \tag{8.4a}$$

$$y = f\left(x\right), \tag{8.4b}$$

$$x = \text{fixed} = \text{independent variable, and} \tag{8.4c}$$

$$y = \text{dependent variable.} \tag{8.4d}$$

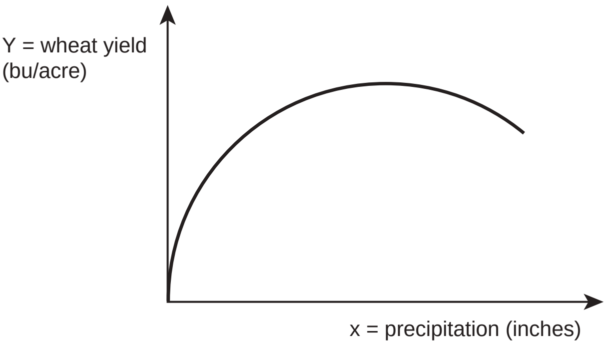

Figure 8.5 Wheat yield as a function of precipitation.

Economists draw supply and demand curves "backward" because Alfred Marshall, the first economist to draw supply and demand curves, drew them that way. Marshall lived in England, and in 1890 was among the first economists to study the relationship between price and quantity using graphical analysis. Economists have not changed. Analysts and students have continued to use these graphs and labels since Marshall's time, even though it breaks with the mathematicians' tradition of placing the independent variable on the horizontal axis and the dependent variable on the vertical axis.

In Figure 8.4, price is the independent variable, but it is on the vertical axis. Quantity supplied is the dependent variable, on the horizontal axis. Be aware when working with graphs of supply and demand that the graphs are "backward," since price is the independent variable.

In summary, a market supply curve shows the positive relationship between the price and quantity supplied of a good. The Law of Supply states that when the price of a good increases, the quantity supplied will also increase, holding all else constant.

To maximize profits, individual firms will produce greater levels of output when prices are high. A graph of market supply (Figure 8.4) isolates the relationship between price and quantity supplied by holding everything in the economy constant (*ceteris paribus*). Only the price and quantity supplied of a good can vary. The market supply curve provides an abundance of information about how a market economy functions. The next section expands and explains that information.

8.2 The elasticity of supply

The profit-maximizing behavior of business firms leads to a positive (upward sloping) relationship between the price and quantity supplied of a good. The rate of change in one variable in response to a change in the other variable is of critical importance. It comes down to the question, "How much will quantity supplied increase (decrease) for a given increase (decrease) in the price?" The term, "elasticity" describes this relationship, and understanding the relationship is important to understanding how a market economy functions.

Elasticity defined

Elasticity is a measure of the responsiveness of one variable to a small change in another variable.

- ***Elasticity*** = the percentage change in one economic variable resulting from a percentage change in another economic variable.

The elasticity of supply measures how quantity supplied changes when the price of a good increases 1 percent:

- ***Elasticity of Supply*** = the percentage change in the quantity supplied in response to a percentage increase in price.

Mathematically, the elasticity of supply (E^S) is given by:

$$E^S = (\%\text{ change in } Q^S)/(\%\text{ change in } P) = \%\Delta Q^S/\%\Delta P. \qquad (8.5)$$

Elasticity classifications

The formula, $E^S = \%\Delta Q^S/\%\Delta P$, shows that the price elasticity of supply is the responsiveness (measured by the percentage change) in quantity supplied, given a 1 percent change in the good's own price.

The price elasticity of supply measures the movements along a supply curve. A hypothetical example of the supply curve for bread in New York City appears in Figure 8.4. The degrees of responsiveness of producers to price changes fall into three categories: (1) **Inelastic Supply**, (2) **Elastic Supply**, and (3) **Unitary Elastic Supply**.

An **Inelastic** supply curve is one that shows relatively small changes in quantity supplied in response to changes in price: a 1 percent change in price results in a less than 1 percent change in quantity supplied. Mathematically, this is equivalent to $\%\Delta Q^S < \%\Delta P$, or $E^S < 1$.

- ***Inelastic Supply*** = a change in price brings about a relatively smaller change in quantity supplied.

An **Elastic** supply curve is one that shows a relatively large change in quantity supplied in response to changes in price: a 1 percent change in price results in a larger than 1 percent change in quantity supplied. Mathematically, this is equivalent to $\%\Delta Q^S > \%\Delta P$, or $E^S > 1$.

- ***Elastic Supply*** = a change in price brings about a relatively larger change in quantity supplied.

The third category of elasticity is **Unitary Elastic**, which takes its name from an elasticity of supply equal to one. This means that the percentage change in quantity supplied is equal to the percentage change in the price of a good ($\%\Delta Q^S = \%\Delta P$, or $E^S = 1$).

- ***Unitary Elastic Supply*** = the percentage change in price brings about an equal percentage change in quantity supplied.

The percentage change of a variable is the change in the variable (Δx), divided by the level of the variable ($\Delta x/x$). If a student's test scores improve from 80 points to 90 points, the percentage change in tests scores would be: $(\Delta x/x) = (90 - 80)/80 = 10/80 = 0.125$. Similarly, the percentage change in quantity supplied is equal to $\Delta Q^S/Q^S$, and the percentage change in price is equal to $\Delta P/P$.

$$E^S = (\Delta Q^S/Q^S)/(\Delta P/P) = (\Delta Q^S/\Delta P)*(P/Q^S). \quad (8.6)$$

The degree of price-responsiveness of a firm depends on the flexibility of the firm's production processes as it responds to a change in price. In the immediate run, the firm has very little flexibility, so supply is very inelastic. Over a longer time period, the firm has more opportunities to make production choices and changes, so supply becomes more elastic.

Suppose that due to an increase in the cost of flour, the price of bread in New York City suddenly increases from \$1/loaf to \$2/loaf. What is the elasticity of supply? Start with the mathematical expression for the supply elasticity.

$$E^S = (\Delta Q^S/Q^S)/(\Delta P/P) = (\Delta Q^S/\Delta P)*(P/Q^S). \quad (8.7)$$

Data in Table 8.1 show that if bread costs \$1/loaf, 10,000 loaves are supplied to the market. When the price rises to \$2/loaf, 20,000 loaves are produced. So, $\Delta Q^S = 20{,}000 - 10{,}000 = 10{,}000$, and $\Delta P = \$2/\text{loaf} - \$1/\text{loaf} = \$1/\text{loaf}$. These numbers substitute directly into the elasticity formula, but what numbers for "Q^S" and "P" are the correct ones to use? The initial values of price and quantity (\$1/loaf and 10,000) yield a different number for the supply elasticity than ending values (\$2/loaf and 20,000 loaves). Therefore, it is common practice to use the average values of prices and quantities to calculate the elasticity of supply over relatively small changes in price. This practice leads to the calculation of what is called the "arc elasticity."

- ***Arc Elasticity*** = a formula that measures responsiveness along a specific section (arc) of a supply or demand curve, and measures the "average" price elasticity between two points on the curve.

To calculate the arc elasticity, use the average value of price and quantity in the formula for price elasticity. Let Q^{S*} and P^* be the average values of price and quantity.

$$Q^{S*} = (Q^S_1 + Q^S_0)/2, \text{ and} \quad (8.8a)$$

$$P^* = (P_1 + P_0)/2. \quad (8.8b)$$

Substitution of these terms into the elasticity equation results in:

$$E^S = (\Delta Q^S/\Delta P)*(P^*/Q^{S*}) = (\Delta Q^S/\Delta P)*\left[(P_1 + P_0)/(Q^S_1 + Q^S_0)\right]. \quad (8.9)$$

The twos in the denominators drop out, since there is a two in both the numerator and the denominator. This formula yields the elasticity of supply of bread for a price increase from \$1/loaf to \$2/loaf, where "lf" is the abbreviation for "loaf."

$$\begin{aligned} E^S &= (\Delta Q^S/\Delta P)*\left[(P_1 + P_0)/(Q^S_1 + Q^S_0)\right] \\ &= \left[(20{,}000\text{ lf} - 10{,}000\text{ lf})/(\$2/\text{lf} - \$1/\text{lf})\right]* \\ &\quad \left[(\$2/\text{lf} + \$1/\text{lf})/(20{,}000\text{ lf} + 10{,}000\text{ lf})\right] \quad (8.10) \\ &= \left[10{,}000\text{ lf}/\$1/\text{lf}\right]*\left[\$3/\text{lf}/30{,}000\text{ lf}\right] \\ &= (10{,}000/30{,}000)*(3/1) = 1. \end{aligned}$$

The supply elasticity of bread in New York City is unitary elastic.

> ### Quick Quiz 8.4
>
> Define and explain the terms elastic, inelastic, and unitary elastic.

Interestingly, there are no units for elasticity. All of the loaves and dollars cancel each other out, since they appear in both the numerator and the denominator:

> **ELASTICITIES HAVE NO UNITS!**

This feature of elasticities is highly desirable, since it allows analysts to compare responsiveness to economic change across all goods and services in a uniform fashion. Comparing the change in the quantity available of two different goods such as apples and hamburgers to a change in price of a good is impossible, since different goods have different units. Calculating elasticities enables an observer to compare the responsiveness of any goods, since the units are identical: they are unitless.

Own-price and cross-price supply elasticities

It is possible to calculate elasticities of supply for changes in price, and for changes in any other economic variable. The most commonly used elasticity is the **Own-Price Elasticity of Supply**.

- ***Own-Price Elasticity of Supply*** = measures the responsiveness of the quantity supplied of a good to changes in the price of that good.

Another common elasticity is the **Cross-Price Elasticity of Supply**, which measures the responsiveness of quantity supplied of one good to a change in the price of a related good. A related good is any good that has an impact on the production of the good under consideration. Slaughtering cattle yields two major products: beef and hides (leather). If the price of hides increases, this will affect not only the quantity of hides supplied, but also the quantity of beef supplied.

- ***Cross-Price Elasticity of Supply*** = a measure of the responsiveness of the quantity supplied of a good to changes in the price of a related good.

The relationship between elasticity and slope

To get a better idea about how to calculate supply elasticities, assume that there are only two firms in the soft drink industry: Coke and Pepsi. Hypothetical price and quantity supplied information are presented in Table 8.2.

The arc elasticity of supply for Coke is:

$$E^S_{coke} = \{\Delta Q^S/\Delta P\} * \left[(P_1 + P_0)/(Q^S_1 - Q^S_0)\right]$$
$$E^S_{coke} = \left[(50 - 25)/(0.75 - 0.50)\right] * \left[(0.75 + 0.50)/(50 + 25)\right] \quad (8.11)$$
$$E^S_{coke} = \left[25/0.25\right] * \left[1.25/75\right] = 100 * 0.0167 = 1.67.$$

Table 8.2 Price and quantity supplied data for Coke and Pepsi

Soda Price ($/can)	*Coke (Q^s million cans)*	*Pepsi (Q^s million cans)*	*Soda Market (million cans)*
0.50	25	20	45
0.75	50	25	75

The supply of Coke is **elastic**, meaning that a 1 percent increase in the price of Coke results in a 1.67 percent increase in the quantity of Coke supplied. This means that Coke has a relatively flexible production function, and is able to respond to changes in price. Using the data in Table 8.2, the arc elasticity of supply for Pepsi is calculated:

$$
\begin{aligned}
E^s_{pepsi} &= (\Delta Q^s / \Delta P) * [(P_1 + P_0)/(Q^s_1 + Q^s_0)] \\
E^s_{pepsi} &= [(25 - 20)/(0.75 - 0.50)] * [(0.75 + 0.50)/(25 + 20)] \qquad (8.12) \\
E^s_{pepsi} &= [5/0.25] * [1.25/45] = 20 * 0.0278 = 0.55.
\end{aligned}
$$

The elasticity of supply of Pepsi is relatively **inelastic**. A 1 percent increase in the price of Pepsi results in only a 0.55 percent increase in the quantity of Pepsi supplied. Compared to Coke, Pepsi's production process is less flexible, and therefore, the company is less able to respond to changes in price. Calculation of the market elasticity of supply follows the same steps as calculation of the individual firm's supply elasticities. The market elasticity of supply lies between the two individual firm elasticities, since the market is comprised of only the two firms.

$$
\begin{aligned}
E^s_{market} &= (\Delta Q^s / \Delta P) * [(P_1 + P_0)/(Q^s_1 + Q^s_0)] \\
&= [(75 - 45)/(0.75 - 0.50)] * [(0.75 + 0.50)/(75 + 45)] \qquad (8.13) \\
E^s_{market} &= [30/0.25] * [1.25/120] = 120 * 0.0104 = 1.25
\end{aligned}
$$

As expected, the soda market supply elasticity is between the individual firm elasticities: 0.55 < 1.25 < 1.67.

Quick Quiz 8.5

Is the market supply for soda elastic or inelastic? Explain.

Quick Quiz 8.6

What is arc elasticity? Hint: see "Elasticity classifications" above.

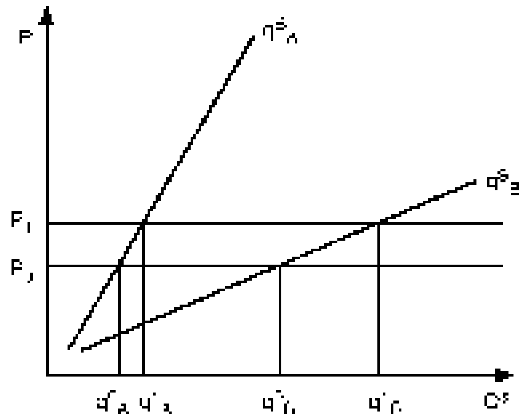

Figure 8.6 Elasticities of supply for two firms.

Figure 8.6 shows two supply curves with different elasticities. The elasticity of supply reflects how responsive a firm is to a change in price. The slope of the supply function reflects this.

In Figure 8.6, the firm with the more elastic supply (q^S_B) has a flatter slope than the firm with the more inelastic supply (q^S_A). Firm A is less responsive to the price increase from P_0 to P_1, and increases output from q^0_A to q^1_A. Firm B is more responsive to the change in price, and increases output from q^0_B to q^1_B. The own-price elasticity of a firm, or the responsiveness of a firm to a change in price, depends on the ability of the firm to adjust inputs and outputs in response to a change in price.

Although the price elasticity of supply relates to the slope of the supply curve, it is not equal to the slope:

$$\text{Slope} = \Delta y/\Delta x = \Delta P/\Delta Q, \qquad \text{Elasticity} = (\Delta Q/\Delta P)*(P/Q). \qquad (8.14)$$

When two supply curves share the same graph, an observer can easily determine which curve is more elastic by looking at the relative slope of the two curves. However, this is not an accurate test for curves on different graphs, because the slope depends on the scale of the graph. A steeply sloped curve may be elastic: it depends on the scale used for the graph.

8.3 Change in supply: change in quantity supplied

This section introduces terminology useful when working with supply curves. The terms supply and quantity supplied actually refer to two different things. This is a common source of confusion to newcomers to the world of elasticities. With a little practice, however, the terms become less intimidating, and very useful in determining the impact of economic variables on the quantity of a good placed on the market. A change in the price of a good causes a movement along a supply curve. This movement is referred to as a **Change in Quantity Supplied**:

- *Change in Quantity Supplied* = a change in the quantity of a good placed on the market due to a change in the price of the good. A movement along the supply curve.

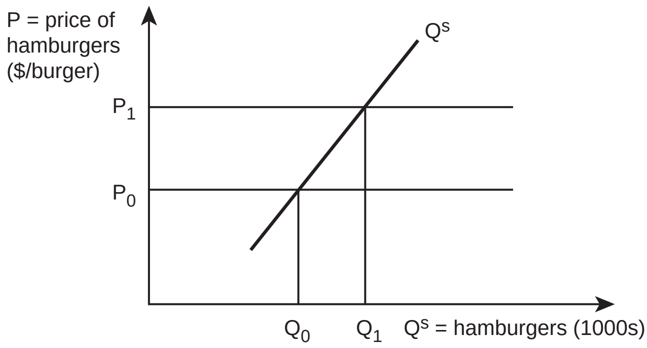

Figure 8.7 Market supply of hamburgers in Elko, Nevada.

The changes in the market supply of hamburgers in Elko, Nevada shown in Figure 8.7 make this clear.

The supply curve shows the increase in the number of hamburgers supplied to the market in Elko after a rise in price. In Figure 8.7, the price of hamburgers increases from P_0 to P_1. This causes a movement from Q_0 to Q_1 along the given supply curve. The movement reflects a change in the quantity supplied. This change in price and quantity does not reflect changes in any of the variables (production techniques, extent of market, labor prices, manufacturing

Plate 8.3 Hamburger demand.

Source: Robertlamphoto/Shutterstock

technology, and the like) used in the "manufacture" of a hamburger. It reflects the response to an increase in price: that is all. Because the change takes into consideration only the starting and ending prices and the starting and ending quantities, the existing supply curve records all known information related to the change. The curve showing the supplier's capabilities stays in place. This does not represent a change in supply.

The graph of the market supply curve for hamburgers holds everything constant other than the price and quantity supplied. Therefore, if anything other than the price of hamburgers changes, it causes a shift in the entire supply curve, or a **Change in Supply**:

- ***Change in Supply*** – a change in the quantity of a good produced due to a change in one or more economic variables other than the price of the good. A shift in the supply curve.

Figure 8.8 shows a change in supply.

A rightward shift in the supply curve represents an increase in supply, since more hamburgers will reach the market at each price. Similarly, a shift in the supply curve to the left would show a decrease in supply (fewer hamburgers at each price). The increase in supply in Figure 8.8 could result from an increase in the technology available to the firm, or a decrease in production costs. Shifts in the entire supply function represent a change in non-price determinants of supply. These supply determinants are explained in the next section.

8.4 Determinants of supply

The supply of a good results from the interaction of many economic variables. The list of supply determinants generally considered to be most important includes such things as (1) input prices, (2) production technology, (3) prices of related goods, and (4) the number of sellers. Therefore, a formula for a supply curve for a good includes own price (P), input prices (P_i), technology (T), prices of other, related goods (P_r), the number of sellers (N), and a category "Other," representing all other determinants of supply:

$$Q^s = f(P, P_i, T, P_r, N, Other) \quad (8.15)$$

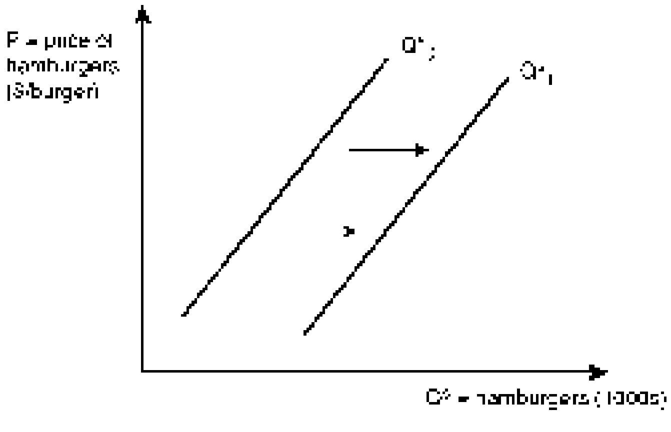

Figure 8.8 An increase in the supply of hamburgers in Elko, Nevada.

A graph of a supply curve condenses all of the determinants into the relationship between the quantity supplied of a good (Q^s) and the own price of the good (P), while all other variables are held constant (the *ceteris paribus* assumption).

Quick Quiz 8.7

Why are all variables other than the price held constant?

The nonprice determinants of supply are often called "supply shifters," because a change in any one of them results in a shift in the entire supply curve (a change in supply). However, if only the price of a good changes, the result is a movement along the supply curve, or a change in quantity supplied.

Input prices

The prices that firms pay to purchase inputs have a direct effect on the cost of production (Chapter 3). These prices multiplied by the quantities of inputs purchased represent the costs paid by the producing firm. Since the individual firm's supply curve is the marginal cost curve on any level of output above the shutdown point, any increase in the price of an input will increase the cost of production and hence shift the supply curve upward and to the left.

Quick Quiz 8.8

How is the shutdown point defined? How is the break-even point defined?

Figures 8.9 and 8.10 show how an increase in input prices shifts the supply curve. The comparison allows thinking of the decrease in supply in two ways. First, Figure 8.9 shows that if the price of ground beef increases, the supply of hamburgers shifts upward and to the left, since the marginal cost of a hamburger increases. This results in a decrease in supply.

Quick Quiz 8.9

Explain why this is not a decrease in quantity supplied.

At a given price of hamburgers (P_0), the firm will decrease its output of hamburgers from Q_0 to Q_1 in response to the increase in the price of ground beef. An increase in the price of an input causes an increase in the cost of production which results in a decrease in supply, or a shift of the supply curve to the left.

Figure 8.10 shows the same shift in the supply curve of hamburgers due to the increase in the price of ground beef, but the interpretation differs. In this case, the firm raises the price of hamburgers from P_0 to P_1 to cover the cost of production at the given level of output, Q_0.

Technology

In brief terms, technological change allows the production of more output with the same level of inputs, or the same level of output produced with fewer inputs (Chapter 2). Either way,

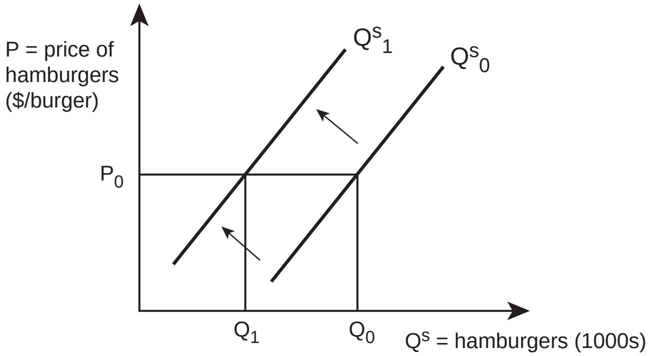

Figure 8.9 A decrease in the supply of hamburgers in Elko, Nevada, at constant price.

improved technology will lower the cost of production for every level of output. The entire supply curve shifts to the right.

> **Quick Quiz 8.10**
>
> Does a shift in the supply curve indicate a change in supply or change in quantity supplied?

Figure 8.11 shows technological change that allows the firm to produce a greater quantity at the same cost.

A rightward shift in supply is an increase in supply. More output produced at the same price, or the same level of output produced at a lower price.

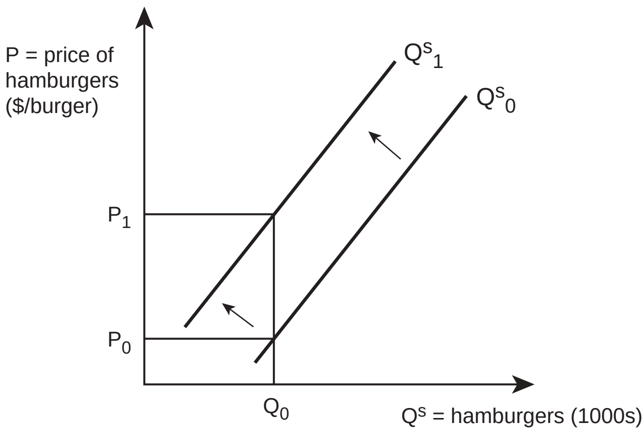

Figure 8.10 A decrease in the supply of hamburgers in Elko, Nevada, at constant quantity.

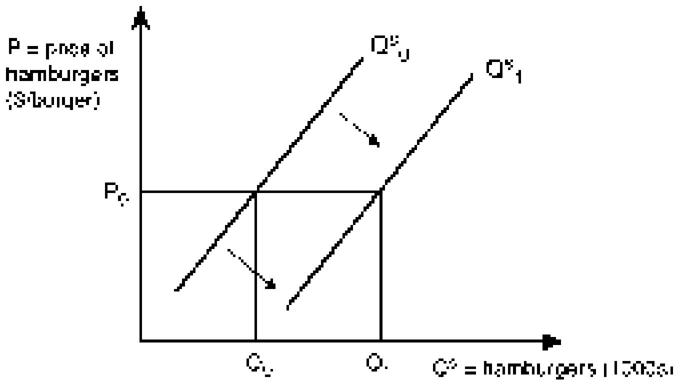

Figure 8.17 The impact of technological change on the supply of hamburgers.

Prices of related goods

In the real world, many firms produce more than one good. Multi-product firms will choose which good or goods to produce based on relative prices.

> **Quick Quiz 8.11**
>
> Graph the firm's optimal output selection.

Changes in relative prices affect goods that are related in the production process. A meat processing plant produces both beef and leather. If the price of leather increases, it will affect (1) the quantity supplied of leather, and (2) the supply of beef. Test your knowledge of the difference between a change in supply and a change in quantity supplied by explaining why an increase in the price of beef affects (1) the quantity supplied of beef, and (2) the supply of leather.

Complements in Production are defined as follows:

- ***Complements in Production*** = goods that are produced together (e.g., beef and leather).

The **Cross-Price Elasticity of Supply** ($E^S_{X,PY}$) for complements in production is positive: if the price of one of the complements increases, it results in an increase in the supply of the complementary good:

$$E^S_{XPY} = (\Delta Q^S_X / \Delta P_Y) * [(P_Y^0 + P_Y^1)/(Q^S_X{}^0 + Q^S_X{}^1)] > 0 \qquad (8.16)$$

Substitutes in Production are the opposite of complements in production. Two goods competing for the same resources are substitutes in the production process:

- ***Substitutes in Production*** = Goods that compete for the same resources in the process production (wheat and barley). Or inputs that can replace each other in the production process (land and fertilizer).

The cross-price elasticity of demand for substitutes in production is negative:

$$E^{s}_{Y1,Y2} = (\Delta Q^{s}_{Y1} / \Delta P_{Y2}) * \left[(P_{Y2}^{0} + P_{Y2}^{1}) / (Q^{s}_{Y1}{}^{0} + Q^{s}_{Y1}{}^{1}) \right] < 0. \quad (8.17)$$

An increase in the price of a substitute (e.g., barley) causes a decrease in the supply of its substitute good (e.g., wheat). The price change causes farm managers to shift resources into the good with the now relatively higher price, and out of the good with the now relatively lower price. Restated, the increase in the price of a substitute good results in a decrease in the supply of its substitute good.

Number of sellers

The impact of the number of sellers is direct: more sellers result in a larger supply of a good when they bring new resources into the production of a good. If this is the case, the supply curve will shift to the right, reflecting an increase in supply. If firms exit the industry and take productive resources with them, the supply curve shifts to the left, resulting in a decrease in supply.

There are many other determinants of supply, or "supply shifters." In agriculture, the weather is an important determinant of supply. When weather conditions are favorable, agricultural output increases, resulting in a shift in supply. Government programs can also shift the supply curves of agricultural goods. Government subsidies result in a shift in supply to the right, and increased taxes shift supply curves to the left.

8.5 Demand

While supply curves stem from the marginal cost curves of individual producers, demand curves derive from decisions made by consumers when they decide which goods and services to buy. Demand reflects the purchases that consumers make as they strive to maximize utility, given prices and income. Demand is a technical term that describes consumer purchases:

- *Demand* = consumer willingness and ability to pay for a good.

The good's price is the most important determinant of demand. A **Demand Curve** is a graphic representation of the relationship between the price of a good and the quantity demanded of that good. These curves are the common way to demonstrate consumer demand.

- *Demand Curve* = a function connecting all combinations of prices and quantities consumed for a good, *ceteris paribus*.

This section shows the derivation of an individual consumer's demand curve, then finds the market demand curve by adding together all the individual curves.

The individual consumer's demand curve for macaroni and cheese in Pittsburgh, Pennsylvania

The goal here is to derive an individual consumer's demand curve. Begin by assuming that a college student in Pittsburgh has $40/week to spend on food. The student purchases two

Plate 8.4 Macaroni and cheese.
Source: Matt Antonino/Shutterstock.

types of food: macaroni and cheese (Y_1), which initially costs \$2/box (P_{Y1} = \$2/box), and pizza (Y_2), which costs \$5/pizza (P_{Y2} = \$5/pizza). Suppose that the grocery store lowers the price of macaroni and cheese from the initial price of \$2/box to \$1/box, and later, to \$0.50/box. These data can be used to derive the relationship between the price of macaroni and cheese and the quantity demanded (Q^d). The data help answer the question, "How do changes in price affect the quantity demanded of a good?"

The student's budget for food is \$40/week so income (M) equals \$40/week. In this case, "income" refers to the amount of money allocated to food purchases in a given time period. The following facts allow an observer to graph the consumer's equilibrium as shown in Figure 8.12. The small circles indicate the consumer's equilibrium points at each price level:

$$Y_1 = \text{mac-n-cheese} \quad P_{Y1} = \$2 / \text{box}, \tag{8.18a}$$

$$Y_2 = \text{pizza} \quad P_{Y2} = \$5 / \text{pizza}. \tag{8.18b}$$

The graph shows the budget line for the student:

$$M = P_{Y1}Y_1 + P_{Y2}Y_2 \tag{8.19a}$$

$$Y_2 = (M / P_{Y2}) + (-P_{Y1} / P_{Y2}) * Y_1 \tag{8.19b}$$

$$Y_2 = (40 / 5) + (-2 / 5) * Y_1 = 8 - 0.4 * Y_1. \tag{8.19c}$$

The y-intercept (M/P_{Y2}) is equal to eight, and the slope is negative 0.4, as shown in Figure 8.12. Consumer equilibrium is located where the Marginal Rate of Substitution (MRS),

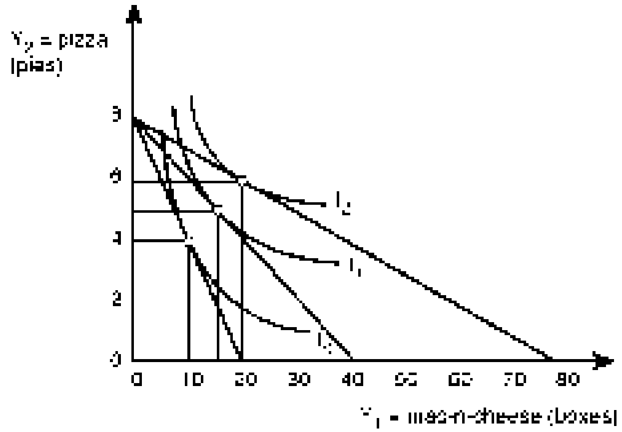

Figure 8.12 Derivation of a demand curve for macaroni and cheese

or the slope of the indifference curve, is equal to the price ratio, or the slope of the budget line. In Figure 8.12, this initial equilibrium is at the point (10, 4), or 10 boxes of macaroni and cheese, and 4 pizzas.

As the price of macaroni and cheese falls, the consumer's opportunity set increases. Figure 8.12 shows that the consumer can purchase more of both goods when the price of macaroni and cheese falls, since the consumer's purchasing power increases. By lowering the price of a good and observing how the quantity purchased of a good changes, the grocer can derive the relationship between price and quantity demanded, or a demand curve.

Quick Quiz 8.12

What is the opportunity set in Figure 8.12?

Table 8.3 is a compilation of data needed to derive a **Demand Schedule** for the Pittsburgh student.

- *Demand Schedule* = information on prices and quantities purchased.

A demand curve is the relationship between the price and quantity of a good purchased, or:

$$Q^d_{macncheese} = f(P_{Y1}, P_{Y2}, M). \tag{8.20}$$

The consumer's equilibrium points identified in Figure 8.12 and Table 8.3 lead to the derivation of the demand curve for the student, if everything other than the price of macaroni and cheese is held constant. Figure 8.13 shows the resulting demand curve.

The demand curve in Figure 8.13 includes the same information that appears in the consumer equilibrium graph in Figure 8.12. The variable on the y-axis is now the price of macaroni and cheese (P_{Y1}) rather than the quantity of pizza (Y_2), as in Figure 8.12.

Table 8.3 Price and quantity data for student consumption choices

Price of Mac-n-Cheese (P_1, $/box)	*Quantity of Mac-n-Cheese* (Y_1, boxes)	*Quantity of Pizza* (Y_2, pizzas)
2	10	4
1	15	5
0.5	20	6

The demand curve depicted in Figure 8.13 displays the relationship between the price of macaroni and cheese, and the quantity purchased of the good, *ceteris paribus*. The mathematical expression for this is:

$$Q^d_{mac-cheese} = f(P_1 \mid P_2, M) \quad (8.21)$$

A similar process allows derivation of demand curves for all pairs of goods and services.

The market demand curve

Deriving a market demand curve requires summing all of the individual demand curves in the market. As in the case with supply curves, this summation (or aggregation) requires specific steps to complete. The individual consumer demands (q) are summed horizontally to obtain the market demand curve (Q^d) as shown in Figure 8.14.

The market demand curve for any product is the horizontal summation of all of the individual demand curves, in this case, consumers A, B, and C. Note that there are many consumers whose demand curves do not appear in Figure 8.14: the ellipsis (. . .) represents all of the remaining consumers in the market. To add demand curves horizontally, take a given price such as P_1 and sum the quantities demanded by each consumer at that price.

Following Figure 8.14, consumer A buys 3 loaves, B purchases 6 loaves, and C buys 7 loaves. Adding all of these quantities together yields the total quantity of bread purchased (Q^d = 3 + 6 + . . . = 7). Next, select a different price and repeat the horizontal summation

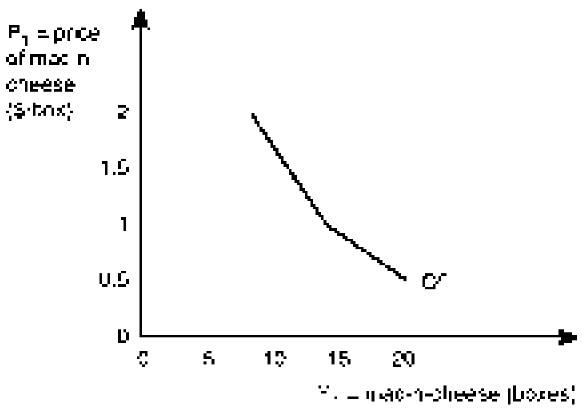

Figure 8.13 Demand curve for macaroni and cheese.

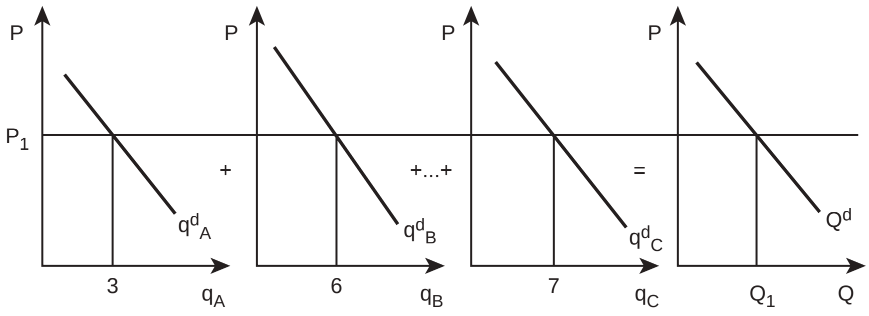

Figure 8.14 Derivation of a market demand curve.

process. The **Market Demand Curve** is the outcome of this procedure. It appears on the right-hand side of Figure 8.14.

- ***Market Demand Curve*** = the relationship between the price and quantity demanded of a good, *ceteris paribus*, derived by the horizontal summation of all individual consumer demand curves for all individuals in the market.

The Law of Demand

An increase in the price of a good results in a lower quantity of the good purchased. This regularity of consumer behavior is the **Law of Demand**:

- ***Law of Demand*** = the quantity of a good demanded varies inversely with the price of the good, *ceteris paribus*.

Restated, the Law of Demand says that, "Demand Curves Slope Down." This is true for all individual consumers, as well as all market demand curves. There can be exceptions to this Law, but these occur only in rare and extreme circumstances.

Figure 8.15 shows a demand curve for steak dinners in Philadelphia. A move from right to left along the curve indicates that as the good becomes increasingly scarce, it increases in value. This is consistent with the Law of Diminishing Marginal Utility: the first steak dinner is the best (provides the most utility). As consumers eat more steak dinners, the satisfaction derived from each successive steak dinner decreases.

Supply (a concept dealing with producer behavior) and demand (derived from consumer behavior) are of critical interest and importance in economics. Graphing a supply curve or a demand curve demonstrates the relationship between price and quantity. As has been noted, these graphs are conventionally drawn with price (the independent variable) on the vertical axis, and quantity demanded (the dependent variable) on the horizontal axis.

Quick Quiz 8.13

Why do economists draw supply and demand curves "backward?"

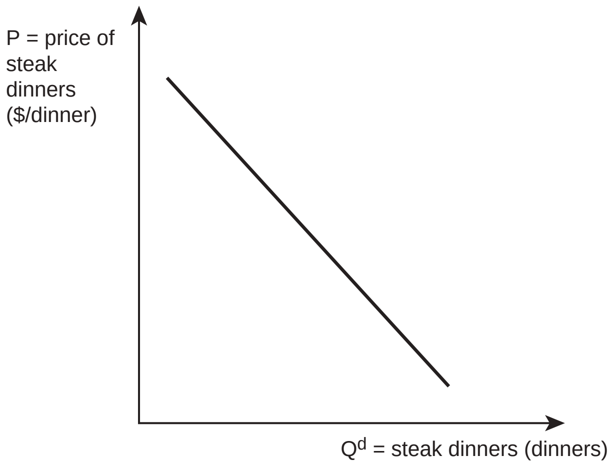

Figure 8.15 The demand for steak dinners in Philadelphia.

Plate 8.5 Steak dinner.

Source: Kasai Bialasiewicz/Shutterstock

Price causes quantity demanded:

$$P \rightarrow Q^d \qquad P = \text{independent variable.} \tag{8.22a}$$

$$Q^d = f(P) \qquad Q^d = \text{dependent variable.} \tag{8.22b}$$

Consumers of commonly purchased goods take prices as given and decide how much to buy. Assuming a competitive economy, each individual consumer is so small relative to the market that it cannot affect the price of a good. Therefore, price causes quantity demanded.

Quick Quiz 8.14

Why does the assumption of competition result in constant prices faced by an individual buyer?

To summarize, the demand curve captures the relationship between the price of a good (P), and the quantity demanded (Q^d), *ceteris paribus*. The Law of Demand states that if the price of a good increases, then the quantity demanded will decrease, *ceteris paribus*. The next section deals with elasticity of demand, a concept used to indicate how responsive consumers are to changes in prices and other economic variables.

8.6 The elasticity of demand

"Elasticity," introduced earlier in this chapter, measures the changes in one variable that come in response to changes in another variable. The price elasticity of demand tells how responsive the quantity demanded is to a change in price. The price elasticity of demand answers the question, "How much does quantity demanded change when price changes?" Figure 8.16 makes this clear.

When the price of steak dinners falls from P_0 to P_1, the Law of Demand states that consumers in Philadelphia (and most other places!) will purchase more steak dinners. The price elasticity of demand tells how many more steak dinners consumers purchase after a drop in price. The price elasticity of demand relates to the slope of the demand curve. The major determinant of the elasticity of demand is the availability of substitutes.

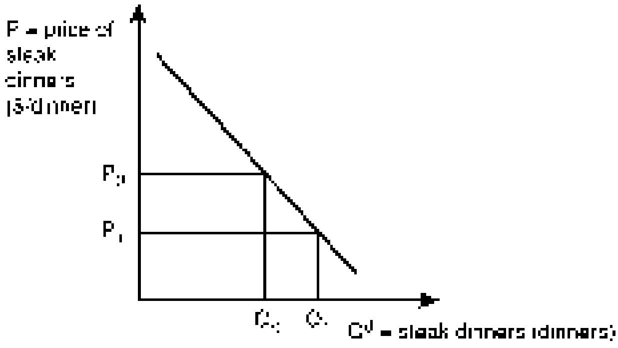

Figure 8.16 A price change for the demand for steak dinners in Philadelphia.

Box 8.1 Tobacco in North Carolina

Tobacco production and processing are among the most historically important industries in North Carolina. However, as globalization has increased and barriers to free trade in agricultural products have been reduced or eliminated, overseas production of tobacco has resulted in challenges for tobacco producers in North Carolina and the Southeast United States.

Settlers brought tobacco from Virginia to North Carolina as early as 1663. Tobacco became one of the most important crops in North Carolina agriculture, and tobacco remains an important part of the economy, representing 15 percent of the total value of all crops grown in North Carolina. Processing is also an important industry in North Carolina. The state ranks first in tobacco production.

Philip-Morris produces approximately one-half of all cigarettes and has a cigarette factory in North Carolina. RJ Reynolds is currently North Carolina's second-largest tobacco company. The livelihood of US tobacco farms is threatened by foreign tobacco production and decreased demand for tobacco products. In October 2004, Congress eliminated tobacco quotas, reducing profitability for smaller tobacco producers, as imported tobacco has increased from 690 million USD in 2004 to 752 million USD in 2011, shifting the tobacco supply curve to the right and causing the price to fall.

Sources: US Census Bureau: Foreign Trade Division, USA Trade Online.
US Import and Export Merchandise trade statistics.

THE AVAILABILITY OF SUBSTITUTES DETERMINES THE ELASTICITY OF DEMAND.

If there are very few substitutes for a good, then consumers will find it difficult to "substitute out" of goods that are more expensive and into less expensive goods. However, if there are substitutes available, then the consumer's reaction to a price change will be responsive, or elastic, to the change in price. Think of cigarettes. The many brands available make it easy to respond by switching to another brand when the price of a common brand increases.

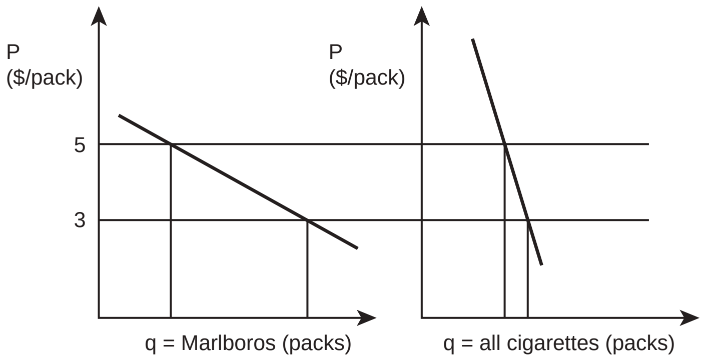

Figure 8.17 Price elasticity of demand for Marlboros and all cigarettes.