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Walter Nicholson • Christopher Snyder

Intermediate Microeconomics and Its Application

13th Edition

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Intermediate Microeconomics and Its Application, 13e
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Dedication

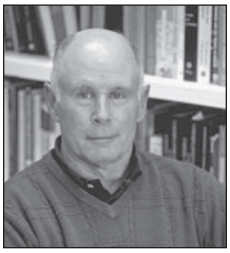
To my grandchildren: Elizabeth, Sarah, David, Sophia, Abigail, Nathaniel, Christopher, Ava, and Will

Walter Nicholson

To my daughters: Clare, Tess, and Meg

Christopher Snyder

About the Authors



Walter Nicholson is the Ward H. Patton Professor of Economics, *Emeritus,* at Amherst College and a Visiting Professor at Ave Maria University. He received a B.A. in mathematics from Williams College and a Ph.D. in economics from the Massachusetts Institute of Technology. Professor Nicholson's primary research interests are in the econometric analyses of labor market problems and of policies to address them including unemployment compensation, job training programs, welfare policies, and trade adjustment assistance. Professor Nicholson is also a Senior Fellow at Mathematica Policy Research and an adviser on labor market policies to the U.S. and Canadian governments. He and his wife Susan live in Naples, Florida, and Montague, Massachusetts.

Christopher Snyder is the Joel Z. and Susan Hyatt Professor of Economics at Dartmouth College, where he pursues research and teaching interests in microeconomic theory, industrial organization, and law and economics. He is a Research Associate in the National Bureau of Economic Research, serves on the board of the Industrial Organization Society, and is an Editor of the *Journal of Law and Economics.* Snyder received his B.A. in mathematics and economics from Fordham University and his Ph.D. in economics from the Massachusetts Institute of Technology. His recent research has appeared in leading journals in and outside of economics including the *Quarterly Journal of Economics* and *Science.* He lives in Hanover, New Hampshire, with his wife, Maura Doyle, who also teaches economics at Dartmouth, and three daughters.

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Preface

Welcome to the thirteenth edition of *Intermediate Microeconomics and Its Application*. We believe this edition achieves a new level of excellence for both the quality of the text itself and the pedagogical advantages offered by the entire "package" of text and electronic ancillaries. Instructors will find the new edition to be more clear, streamlined, and cogently organized than ever before. Students will find the updated electronic ancillaries to be powerful learning aids. The many new and updated applications demonstrate again and again that microeconomics is a vibrant, not dry, subject.

The most obvious new feature of this edition—apparent upon first opening the book—is adoption of **full color** for the text. This innovation has made the book more visually appealing and permitted some distinctive formatting to highlight the book's organization and special features. Use of full color means that the numerous figures now consist of **full-color graphs**. Besides being considerably more eye-catching, graphs can use distinct colors to better distinguish multiple curves and can maintain a consistent color palette (such as showing individual behavior always in shades of red, firm behavior in shades of blue), reinforcing the commonality among theoretical ideas that appear in different chapters. Colors and shades have been carefully calibrated to meet accessibility standards for visual impairment.

Another improvement—also obvious from its appearance right at the beginning of the book—is the expansion of the material on **Useful Mathematics** into a full chapter. This chapter now includes the same complete set of learning aids as the other chapters, therefore providing a more complete experience for students who find they need a mathematical review.

The authors have revisited every passage to make sure the **improved expositions** is as clear and concise as possible. The language (including pronouns and names) and examples have been updated to reflect current standards for **inclusiveness**.

Accompanying the text are an expanded set of **electronic ancillaries** including the following.

- A new test bank that includes more graphical-oriented questions.
- Improved videos demonstrating each step in the solution of the problems.
- A streamlined set of PowerPoint slides.
- A set of possible exam questions drawn from the authors' experiences.

The over 100 boxed applications in this text have always been one of its most attractive features. We believe these provide a great way to get students interested in economics and to help show that many of the concepts being introduced are in fact useful to them. In each new edition, therefore, we have spent considerable effort in updating the data in the applications, in retiring outdated applications, and in developing new and timely ones. For this edition, we have redoubled our efforts in this regard. Some of the following topics are covered by **new applications**.

- Several new applications analyze economic issues related to the COVID-19 pandemic. These range from the quite specific (effects of the pandemic on the market for eggs) to the very general (modeling the economic impact of the COVID lockdowns).

- A new application explores how "Big Tech" firms like Amazon, Google, and Facebook came to dominate their markets.
- Evolving technologies are also featured in other new applications such as "cord-cutting" of cable TV and patent-licensing issues that arise in gene editing.
- A new application examines the bargaining power of both private-sector and public-sector unions in labor markets.
- Several new applications provide economic analysis of current environmental policy ranging from "environmental justice" to adoption of the "Green New Deal."
- Just for fun, one application explains what game theory can tell us about the outcomes in chess, motivated by the award-winning recent Netflix miniseries, *The Queen's Gambit*.

To the Instructor

We have tried to organize this book in a way that most instructors will want to use it. We proceed in a very standard way through the topics of demand, supply, competitive equilibrium, and market structure before covering supplemental topics such as input markets, asymmetric information, or externalities. There are two important organizational decisions that instructors will need to make depending on their preferences. First is a decision about where to cover uncertainty and game theory. We have placed these topics near the front of the book (Chapters 5 and 6), right after the development of demand curves. The purpose of such an early placement is to provide students with some tools that they may find useful in subsequent chapters. But some users may find coverage of these topics so early in the course to be distracting and may therefore prefer to delay them until later. In any case, they should be covered before the material on imperfect competition (Chapter 13) because that chapter makes extensive use of game-theory concepts.

A second decision that must be made concerns our new chapter on behavioral economics (Chapter 18). We have placed this chapter at the end because it represents a departure from the paradigm used throughout the rest of the book. We realize that many instructors may not have the time or inclination to cover this additional topic. For those that do, one suggestion would be to cover it at the end of the term, providing students with an appreciation of the fact that economics is not cut-and-dried but is continually evolving as new ideas are proposed, tested, and refined. Another suggestion would be to sprinkle a few behavioral topics into the relevant places in the chapters on consumer choice, uncertainty, and game theory.

Some of the new digital content should be a big help for instructors who adopt MindTap for their classes. New videos have been provided offering step-by-step solutions to selected end of chapter problems. Some problems covered by the videos were hand picked to be those embodying the essence of the chapter material with a minimum of technical demands. These videos should help ensure no students are left behind in understanding chapter basics. Other videos cover the opposite case of the most technically demanding problems the sort that sometimes leads to a line in front of the instructor's door during office hours. These problem walkthrough videos should save the instructor time in office hours and lecture, time that can be used to carry on deeper discussions of applications or to more easily "flip" the classroom ensuring the students continue to master the basics.

Both of us have thoroughly enjoyed the correspondence we have had with users of our books over the years. If you have a chance, we hope you will let us know what you think of this edition and how it might be improved. Our goal is to provide a book that meshes well with each instructor's specific style. The feedback that we have received has really helped us develop this edition, and we hope this process will continue.

To the Student

We believe that the most important goal of any microeconomics course is to make this material interesting so that you will want to pursue economics further and begin to use its tools in your daily life. For this reason, we hope you will read most of our applications and think about how they might relate to you. But we also want you to realize that the study of economics is not all just interesting "stories." There is a clear body of theory in microeconomics that has been developed over more than two hundred years in an effort to understand the operations of markets. If you are to "think like an economist" you will need to learn this theoretical core. We hope that the attractive format of this book together with its many learning aids will help you in that process. As always, we would be happy to hear from any student who would care to comment on our presentation. We believe this book has been improved immeasurably over the years by replying to students' opinions and criticisms. We hope you will keep these coming. Words of praise would also be appreciated, of course.

Supplements to the Text

A wide and helpful array of supplements is available with this edition to both students and instructors.

- An Instructor's Manual, written by Walter Nicholson and Christopher Snyder, contains chapter summaries, lecture and discussion suggestions, chapter objectives, activities and assessment lists, a list of glossary terms, solutions to problems, and additional resources where applicable.
- The Instructor's Manual is available on the text website at http://www.cengage.com/ to instructors only.
- PowerPoint Slides, revised by Philip S. Heap, James Madison University, are available on the text website for use by instructors for enhancing their lectures. These fully accessible PowerPoint slides provide chapter-level presentations and highlight opportunities for increased peer-peer interactivity.
- A Test Bank, authored and revised for the thirteenth edition by Walter Nicholson and Christopher Snyder, is delivered via Cognero, an online assessment system that supports the computerized Test Bank. Cognero allows instructors to create and assign tests, deliver tests through a secure online test center, and have the complete reporting and data dissemination at their fingertips.

Acknowledgments

Chris Rader of Cengage piloted this edition throughout its development. He helped to outline the scope of the revision and assembled a "dream team" to work with us. Colleen Farmer guided the entire process, keeping us close to any semblance of a timeline for completion. How she kept track of all the files crossing her desk is a mystery. Kasie Jean, leveraging her exceptional understanding of the subject matter, helped develop many of the supplements to the text. She vastly improved the videos showing step-by-step solutions to quantitative problems and now serves as the mellifluous voice behind them, replacing the authors' grizzled voices and shaky handwriting. Kasie is also responsible for upgrading

the test bank, allowing it to be readily integrated in learning-management software, and advised us on ADA-compliant schemes for the full-color graphs. Sarah Keeling painstakingly reviewed every chapter, improving various aspects of our writing and ensuring it met current standards of inclusivity. Kumaresan Chandrakumar of Integra Software Services checked rights and permissions. Charu Verma of MPS Limited efficiently shepherded the copyediting, figure drafting, and page production. The book's extremely attractive look can be credited to Bethany Bourgeois, the internal and cover designer.

Simply put, this was the best publisher team we have ever worked with. We are deeply grateful for their talent and effort. A new edition is a daunting task under the best of circumstances, but the COVID-19 pandemic presented some of the greatest logistical challenges we have encountered over the many years we have been involved with this project. Social-distancing restrictions meant that the entire book and its related ancillaries had to be produced by team members working from home, with scheduled Zoom sessions serving as a poor substitute for in-person office collaboration. The team suffered the loss of beloved family members. Yet they persevered, and their dedication is evidenced is the quality of the edition you are now reading.

We certainly owe a debt of gratitude to our families for suffering through another edition of our books. For Walter Nicholson, most of the cost has been born by his wife of 54 years Susan (who should know better by now). Fortunately, his ever-expanding set of grandchildren has provided her with a well-deserved escape. The dedication of the book to them is intended both as gratitude for their being here and a not so subtle attempt to get them to be interested in this ever-fascinating subject.

Christopher Snyder is grateful to his wife Maura Doyle for accommodating the long hours needed for this revision and for providing economic insights from her teaching of the material. He is grateful to his daughters, to whom he has dedicated this edition, for expediting the writing process by behaving themselves despite being forced to return to the empty nest from their respective universities by COVID-19 pandemic. He also thanks his Dartmouth colleagues for their economic insights and patience.

Walter Nicholson	Christopher Snyder
Naples, Florida	Hanover, New Hampshire
May 2021	May 2021

PART 1

Introduction

"Economics is the study of mankind in the ordinary business of life."

—Alfred Marshall, Principles of Economics, 1890

Part 1 provides a general introduction for your study of microeconomics. There are two chapters in this part. Chapter 1 provides a brief review of two basic economic models you probably learned about in your course in introductory economics. First, we look at the "production possibility frontier," which shows the various options that are available to an economy based on the resources it has. Using this idea allows us to introduce a few important economic ideas about the trade-offs involved in making economic decisions. Second, we review the basic model of supply and demand. This shows how markets work to determine what is produced in an economy. Although some markets may not operate in the ways shown by this simple model, it will provide a good starting point for most of the topics we look at in this book.

Mathematical tools are widely used in economics. In this book we will make some use of these tools, but not beyond what is usually covered in a course on basic algebra. Chapter 2 reviews those concepts that you will encounter most frequently here. Not only will this material provide a useful reference for you as you proceed through the book, but it also offers a few important economic insights that are best explained using math.

1 Two Basic Economic Models

You have to deal with prices every day. When planning air travel, for example, you face a bewildering array of possible prices and travel-time restrictions. A given long distance flight can cost anywhere from $200 to $1,200, depending on where you look. How can that be? Surely the cost is the same for an airline to carry each passenger; so why do passengers pay such different prices?

Or, consider buying beer or wine to go with your meal at a restaurant. You will probably have to pay at least four or five times what you would have to pay for your beverage in a liquor store. How can that be? Why don't people balk at such extreme prices, and why don't restaurants offer a better deal?

Finally, think about prices of houses. During the years 2004–2007, house prices rose dramatically in the United States and in much of the rest of the world. Annual gains of 25 percent or more were common in areas of high demand, such as California and south Florida. But these increases were not sustainable. Starting in late 2007, housing demand stalled, partly in connection with much higher interest rates on mortgages. By mid-2012, house prices had fallen precipitously. Declines of more than 50 percent occurred in many locations. A decade later, prices had increased dramatically in some places, but in others houses sold for less than they did in 2007. How can you explain such wild gyrations? Are economic models capable of describing these rapid price moves, or would it be better to study these in a class on the psychology of crowds?

If these are the kinds of questions that interest you, microeconomics is the right course to take. As the quotation in the introduction to this part states, economics (especially microeconomics) is the study of "the ordinary business of life." That is, economists take such things as airfares, house prices, or restaurants' menus as interesting topics, worthy of detailed study. Why? Because understanding these everyday features of our world goes a long way toward understanding the welfare of the actual people who live here. The study of economics cuts through the garble of television sound bites and the hot air of politicians that often obscure rather than enlighten these issues. Our goal here is to help you to understand the market forces that affect all of our lives.

1-1 What Is Microeconomics?

As you probably learned in your introductory course, **economics** is formally defined as the "study of the allocation of scarce resources among alternative uses." This definition stresses that there simply are not

economics
The study of the allocation of scarce resources among alternative uses.

enough basic resources (such as land, labor, and capital equipment) in the world to produce everything that people want. Hence, every society must choose, either explicitly or implicitly, how its resources will be used. Of course, such "choices" are usually not made by an all-powerful dictator who specifies every citizen's life in minute detail. Instead, the way resources get allocated is determined by the actions of many people who engage in a bewildering variety of economic activities. Many of these activities involve participation in some sort of market transaction. Flying in airplanes, buying houses, and purchasing meals are just three of the practically infinite number of things that people do that have market consequences for them and for society as a whole. **Microeconomics** is the study of all of these choices and of how well the resulting market outcomes meet basic human needs.

microeconomics
The study of the economic choices individuals and firms make and of how these choices create markets and affect welfare.

1-1a The Need for Models in Economics

Obviously, any real-world economic system is far too complicated to be described in detail. Just think about how many items are available in the typical hardware store (not to mention in the typical Home Depot megastore). Surely it would be impossible to study in detail how each hammer or screwdriver was produced and how many were bought in each store. Not only would such a description take a very long time, but it also seems likely no one would care to know such trivia, especially if the information gathered could not be used elsewhere. For this reason, all economists build simple **models** of various activities that they wish to study. These models may not be especially realistic, at least in terms of their ability to capture the details of how a hammer is sold; but, just as scientists use models of the atom or architects use models of what they want to build, economists use simplified models to describe the basic features of markets. Of course, these models are "unrealistic." But maps are unrealistic too—they do not show every house or parking lot. Despite this lack of "realism," maps help you see the overall picture and get you where you want to go. That is precisely what a good economic model should do. The economic models that you will encounter in this book have a wide variety of uses, even though, at first, you may think that some of them are unrealistic. The applications scattered throughout the book are intended to illustrate such practical uses. But they can also suggest the many ways in which the study of microeconomics can help you understand the economic events that affect your life. We begin by looking at two very basic economic models that provide the foundations for much of this book.

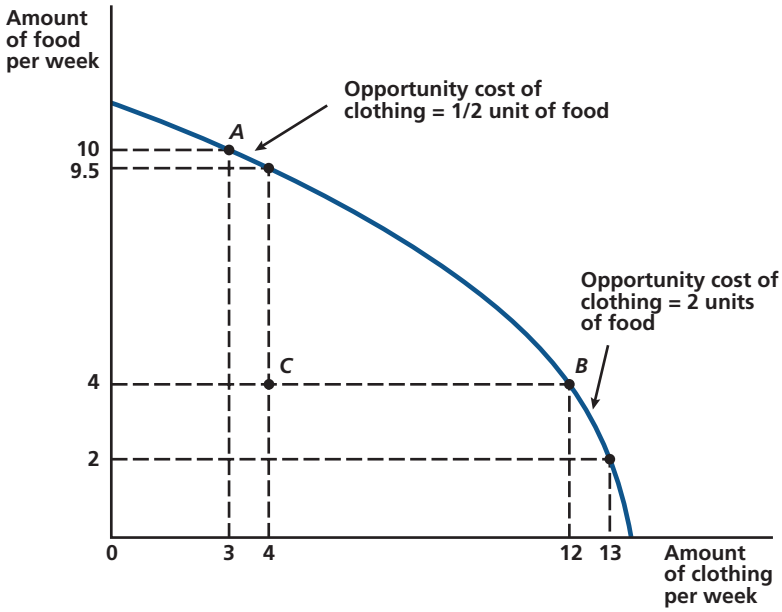
models
Simple theoretical descriptions that capture the essentials of how the economy works.

1-2 The Production Possibility Frontier: Six Basic Economic Principles

Much of microeconomics consists of simply applying a few basic principles to new situations. We can illustrate some of these by examining an economic model with which you already should be familiar—the **production possibility frontier.** This graph shows the various amounts of two goods that an economy can produce during some period (say, one year). **Figure 1.1**, for example, shows all the combinations of two goods (say, food and clothing) that can be produced with this economy's resources. For example, 10 units of food and 3 units of clothing can be made, or 4 units of food and 12 units of clothing. Many other combinations of food and clothing can also be produced, and Figure 1.1 shows all of them. Any combination on or inside the frontier can be produced, but combinations of food and clothing outside the frontier cannot be made because there are not enough resources to do so.

production possibility frontier
A graph showing all possible combinations of goods that can be produced with a fixed amount of resources.

Figure 1.1 Production Possibility Frontier



The production possibility frontier shows the different combinations of two goods that can be produced from a fixed amount of scarce resources. It also shows the opportunity cost of producing more of one good as the quantity of the other good that cannot then be produced. The opportunity cost at two different levels of production of a good can be seen by comparing points *A* and *B*. Inefficiency is shown by comparing points *B* and *C*.

This simple model of production illustrates six principles that are common to practically every situation studied in microeconomics:

- *Resources are scarce.* Some combinations of food and clothing (such as 10 units of food together with 12 units of clothing) are impossible to make given the resources available. We simply cannot have all of everything we might want.
- *Scarcity involves* ***opportunity costs.*** That is, producing more of one good necessarily involves producing less of something else. For example, if this economy produces 10 units of food and 3 units of clothing per year at point A, producing one more unit of clothing would "cost" one-half unit of food. In other words, to increase the output of clothing by 1 unit means the production of food would have to decrease by one-half unit.
- *Opportunity costs are increasing.* Expanding the output of one particular goodwill usually involves increasing opportunity costs as diminishing returns set in. Although the precise reasons for this will be explained later, Figure 1.1 shows this principle clearly. If clothing output were expanded to 12 units per year (point B), the opportunity cost of clothing would rise from one-half a unit of food to 2 units of food. Hence, the opportunity cost of an economic action is not constant but varies with the circumstances.

MICRO QUIZ 1.1

Consider the production possibility frontier shown in Figure 1.1:

1. Why is this curve called a "frontier"?
2. This curve has a "concave" shape. Would the opportunity cost of clothing production increase if the shape of the curve were convex instead?

opportunity cost
The cost of a good as measured by the alternative uses that are foregone by producing it.

- *Incentives matter.* When people make economic decisions, they will consider opportunity costs. Only when the extra (marginal) benefits from an action exceed the extra (marginal) opportunity costs will they take the action being considered. Suppose that the economy is operating at a place on its production possibility frontier where the opportunity cost of 1 unit of clothing is 1 unit of food. Then any person could judge whether they would prefer more clothing or more food and trade at this ratio. But if, say, there were a 100 percent tax on clothing, it would seem as if you could get only one-half a unit of clothing in exchange for giving up food—so you might choose to eat more and dress in last year's apparel. Or, suppose a rich uncle offers to pay one-half your clothing costs. Now it appears that additional clothing costs only one-half unit of food, so you might choose to dress much better, even though true opportunity costs (as shown on the production possibility frontier) are unchanged. Much of the material in this book looks at the problems that arise in situations like these, when people do not recognize the true opportunity costs of their actions and therefore take actions that are not the best from the perspective of the economy as a whole.
- *Inefficiency involves real costs.* An economy operating inside its production possibility frontier is said to be performing "inefficiently"—a term we will be making more precise later. Producing, say, 4 units of clothing and 4 units of food (at point *C* in Figure 1.1) would constitute an inefficient use of this economy's resources. Such production would involve the loss of, say, 8 units of clothing that could have been produced along with the 4 units of food. When we study why markets might produce such inefficiencies, it will be important to keep in mind that such losses are not purely conceptual, being of interest only to economic researchers. These are real losses. They involve real opportunity costs. Avoiding such costs will make people better off.
- *Whether markets work well is important.* Most economic transactions occur through markets. As we shall see, if markets work well, they can enhance everyone's well-being. But, when markets perform poorly, they can impose real costs on the real economy—that is, they can cause the economy to operate inside its production possibility frontier. Sorting out situations where markets work well from those where they don't is one of the key goals of the study of microeconomics.

In the next section, we show how applying these basic concepts helps in understanding some important economic issues. First, in **Application 1.1: Economics in the Natural World?** we show how the problem of scarcity and the opportunity costs it entails are universal. It appears that these basic principles can even help explain the choices made by wolves or hawks.

1-3 Uses of Microeconomics

Microeconomic principles have been applied to study practically every aspect of human behavior. The insights gained by applying a few basic ideas to new problems can be far-reaching. For example, in Chapter 12, we see how one economist's initial fascination with the way prices were set for the attractions at Disneyland opened the way for understanding pricing in such complex areas as air travel or the bundling and pricing of Internet connections. In Chapter 16, we look at another economist's attempt to understand the pricing of used cars. The resulting model of the pricing of "lemons" offers surprising insights about how the information available in markets can affect the pricing of such important products as health care and legal services. One must, therefore, be careful in trying to list the ways in which microeconomics is used because new uses are being discovered every day.

APPLICATION 1.1

Economics in the Natural World?

Scarcity is a dominant fact of nature. Indeed, the effect of scarcity is often easier to study in natural environments because they are less complex than modern human societies. In trying to understand the pressures that scarcity imposes on actions, economists and biologists have used models with many similarities. Charles Darwin, the founder of modern evolutionary biology, was well acquainted with the writings of the major eighteenth- and nineteenth-century economists. Their thinking helped to sharpen his insights in *The Origin of Species*. Here we look at the ways in which economic principles are illustrated in the natural world.

Foraging for Food

All animals must use time and energy in their daily search for food. In many ways, this poses an "economic" problem for them in deciding how to use these resources most effectively. Biologists have developed general theories of animal-foraging behavior that draw largely on economic notions of weighing the (marginal) benefits and costs associated with various ways of finding food.[1]

Two examples illustrate this "economic" approach to foraging. First, in the study of birds of prey (eagles, hawks, and so forth), biologists have found that the length of time a bird will hunt in a particular area is determined both by the prevalence of food in that area and by the flight time to another location. These hunters recognize a clear trade-off between spending time and energy looking in one area and using those same resources to go somewhere else. Factors such as the types of food available and the mechanics of the bird's flight can explain observed hunting behavior.

A related observation about foraging behavior is the fact that no animal will stay in a given area until all of the food there is exhausted. For example, once a relatively large portion of the prey in a particular area has been caught, a hawk will go elsewhere. Similarly, studies of honeybees have found that they generally do not gather all of the nectar in a particular flower before moving on. To collect the last drop of nectar is not worth the time and energy the bee must expend to get it. Such weighing of marginal benefits and costs is precisely what an economist would predict.

Scarcity and Human Evolution

Charles Darwin's greatest discovery was the theory of evolution. Later research has tended to confirm his views that species evolve biologically over long periods of time in ways that adapt to their changing natural environments. In that process, scarcity plays a major role. For example, many of Darwin's conclusions were drawn from his study of finches on the Galápagos Islands. He discovered that these birds had evolved in ways that made it possible to thrive in that rather inhospitable locale. Specifically, they had developed strong jaws and beaks that made it possible for them to crack open nuts that are the only source of food during droughts.

It may even be the case that the evolution of economic-type activities led to the emergence of human beings. About 50,000 years ago *Homo sapiens* were engaged in active competition with Neanderthals. Although the fact that *Homo sapiens* eventually won out is usually attributed to their superior brainpower, some research suggests that this dominance may have derived instead from superior economic organization. Specifically, it appears that our forerunners were better at specialization in production and in trade than were Neanderthals. *Homo sapiens* made better use of the resources available than did Neanderthals.[2] Hence, Adam Smith's observation that humans have "the propensity to truck, barter, and trade one thing for another"[3] may indeed reflect an evolutionarily valuable aspect of human nature.

TO THINK ABOUT

1. Does it make sense to assume that animals consciously choose an optimal strategy for dealing with the scarcity of resources (see the discussion of Friedman's pool player later in this chapter)?
2. Why do some companies grow whereas others decline? Name one company for which the failure to adapt to a changing environment was catastrophic.

[1]See, for example, David W. Stephens and John R. Krebs, *Foraging Theory* (Princeton, NJ: Princeton University Press, 1986).
[2]See R. D. Horan, E. H. Bulte, and J. F. Shogren, "How Trade Saved Humanity from Biological Exclusion: An Economic Theory of Neanderthal Extinction," *Journal of Economic Behavior and* Organization (2005): 1–29.
[3]Adam Smith, *The Wealth of Nations* (New York: Random House, 1937), 13. Citations are to the Modern Library edition.

One way to categorize the uses of microeconomics is to look at the types of people who use it. At the most basic level, microeconomics has a variety of uses for people in their own lives. An understanding of how markets work can help you make decisions about future jobs, about the wisdom of major purchases (such as houses), or about important financial decisions (such as retirement). Of course, economists are not much better than anyone else in predicting the future. There are legendary examples of economists who in fact made disastrous decisions—perhaps best illustrated by the financial collapse of a "hedge fund" run by two Nobel Prize-winning economists. But the study of microeconomics can help you conceptualize the important economic decisions you must make in your life and that can often lead to better decision making. For example, **Application 1.2: Is It Worth Your Time to Be Here?** illustrates how notions of opportunity cost can clarify whether college attendance is really a good investment. Similarly, our discussion of home ownership in Chapter 8 should be of some help in deciding whether owning or renting is the better option.

Businesses also use the tools of microeconomics. Any firm must try to understand the nature of the demand for its product. A firm that stubbornly continues to produce a good or service that no one wants will soon find itself in bankruptcy. **Application 1.3: Coping with the Streaming Revolution** illustrates how firms must make major adaptations to changing circumstances. Those that do not adapt will rapidly disappear.

Firms must also be concerned with their costs; for this topic, too, microeconomics has found many applications. For example, in Chapter 8 we look at some of the research on airline company costs, focusing especially on why Southwest and Jet Blue have been able to make such extensive inroads into U.S. markets. As we show, although each airline has taken a somewhat different approach, both have been able to achieve efficiencies that allow them to undercut the pricing of the older airlines. Microeconomic tools can help to understand such efficiencies. They can also help explore the implications of introducing these efficiencies into such notoriously high-cost markets as those for air travel within Europe.

Microeconomics is also often used to evaluate broad questions of government policy. At the deepest level, these investigations focus on whether certain laws and regulations contribute to or detract from overall welfare. For example, the 2008 financial crisis caused a major rethinking of how financial markets work and whether new forms of government regulation may be needed. As we see in later chapters, economists have devised a number of imaginative ways of addressing questions like this by modeling how such regulations may affect consumers, workers, and firms. These models often play crucial roles in the political debate surrounding the adoption or repeal of major policies. Later in this book, we look at many examples. Of course, there are usually two sides to most policy questions, and economists are no more immune than anyone else from the temptation to bend their arguments to fit a particular point of view. Knowledge of microeconomics provides a basic framework—that is, a common language—in which many such discussions are conducted, and it should help you to sort out good arguments from self-serving ones. In many of our applications we include a "Policy Challenge" that we hope will provide a succinct summary of the key economic issues that must be considered in making government decisions.

1-4 The Basic Supply-Demand Model

supply-demand model
A model describing how a good's price is determined by the behavior of the individuals who buy the good and of the firms that sell it.

As the saying goes, "Even your pet parrot can learn economics—just teach it to say 'supply and demand' in answer to every question." Of course, there is often more to the story. But economists tend to insist that market behavior can usually be explained by the relationship between preferences for a good (demand) and the costs involved in producing that good (supply). The basic **supply-demand model** of price determination is a staple of all courses

APPLICATION 1.2

Is It Worth Your Time to Be Here?

Those of you who are studying microeconomics as part of your college education are probably paying quite a bit to be in school. It is reasonable to ask whether this spending is somehow worth it. Of course, many of the benefits of college (such as the better appreciation of culture or new friendships) do not have monetary value. In this application, we ask whether the cost is worth it purely in dollar terms.

Measuring Costs Correctly

The typical U.S. college student pays about $35,000 per year for in-state tuition, fees, and room and board charges. So one might conclude that the "cost" of four years of college is about $140,000. But this would be incorrect for at least three reasons—all of which derive from a simple application of the opportunity cost idea:

- Inclusion of room and board fees overstates the true cost of college because most of these costs would likely be incurred whether you were in college or not.
- Including only out-of-pocket costs omits important opportunity costs because you might be able to work more hours or earn higher wages if you were not in school.
- College costs are paid over time, so you cannot simply add four years of costs together to get the total.

The costs of college can be adjusted for these factors as follows. First, room and board costs amount to about $9,000 annually, so tuition and fees alone come to $26,000. To determine the opportunity cost of lost wages, we must make several assumptions, one of which is that you could earn about $35,000 if you were not in school versus about $10,000 that you can earn while in school. Hence, the opportunity cost associated with lost wages is about $25,000 per year, raising the total annual cost to $51,000. For reasons to be discussed in Chapter 15, we cannot simply multiply 4 · $51,000 but must allow for the fact that some of these dollar payments will be made in the future. In all, this adjustment would result in a total present cost figure of around $200,000.

The Earnings Gains to College

A number of recent studies have suggested that college graduates earn much more than those without such an education. A typical finding is that annual earnings for otherwise identical people are about 50 percent higher if one has attended college. If graduating from college would increase your earnings from $35,000 to $50,000, your $200,000 investment would have earned a real return of about 7.5 percent (= 15/200). This is a relatively attractive real return, exceeding that on long-term bonds (about 1 percent) and on stocks (about 5 percent). Hence, being here does seem worth your time.

Will the Payoffs Last?

These calculations are not especially surprising—most people know that college pays off. Indeed, college attendance in the United States has been expanding rapidly, presumably in response to such rosy statistics. What is surprising is that this large increase in college-educated people does not seem to have reduced the attractiveness of the investment, although results from the recession induced by the COVID-19 lockdowns are not yet clear. Overall, however, it seems to be the case that the demand for college-educated workers has managed to keep up with the supply. Possible reasons for this have been the subject of much investigation.[1] One likely explanation is that some jobs have become more complex over time. This process has been accelerated by the adoption of computer technology. Another explanation is that trade patterns in the United States may have benefited college-educated workers because they are employed disproportionately in export industries. Whatever the explanation, one effect of the increased demand for such workers has been a trend toward greater wage inequality in the United States and other countries (see Application 14.3: Why is Wage Inequality Increasing?).

POLICY CHALLENGE

The U.S. government offers loans and grants to many students so that they can attend college. Why are such loans necessary if college is such a good investment? Should the government provide larger loans to students who attend private schools where tuitions can be up to three times those charged for in-state students at public universities? From our calculations it seems that the return to attending a private college would be much smaller than from attending a public school because of these higher tuitions. Do you believe that actually is true? Should the promised rate of return determine how much the government will lend?

[1]For a discussion, see D. Acemoglu, "Technical Change, Inequality, and the Labor Market," *Journal of Economic Literature* (March 2002): 7–72.

APPLICATION 1.3

Coping with the Streaming Revolution

The widespread adoption of high speed Internet connections has revolutionized many industries. Perhaps the most visible such effect has been an explosion in the availability of home video entertainment. Not only has the Internet made it possible to obtain films and TV shows almost instantaneously, but it has also vastly increased the variety of such offerings available. Application of some basic economic principles can help to understand why some firms had problems in adapting to this new reality whereas others thrived, becoming some of the largest firms in the world.

Retail Outlets

Before the availability of streaming, consumers had only two choices to receive video entertainment in their homes. They could watch or record the small selection of offerings available through over-the-air or cable television, or they could seek a wider variety through video retail outlets. The advent of video streaming sharply reduced the transactions costs involved in the second of these options. To obtain the video they wanted, people no longer had to incur the opportunity costs involved in spending the time to go to retail outlets. Any firm that based its business on "brick-and-mortar" sales was in trouble. The most important such victim was the Blockbuster company, which filed for bankruptcy in 2010. Today video rentals through retail outlets are practically nonexistent.

Netflix and Amazon

Originally, Netflix provided competition to retail outlets by providing DVDs through the mail. This spared consumers the costs on going to the store, but still involved costs in mailing and in having to wait to receive what was ordered. Netflix early on recognized that their mailing operations were being made obsolete by the spread of the Internet. By 2007 it had started moving away from its DVD business and focusing on instant delivery over the Internet. It was soon joined by Amazon, which also had originally offered video entertainment primarily on DVD. Both Netflix and Amazon also soon began producing their own video content (*House of Cards* was the first Netflix original movie, released in 2013). This began the latest chapter in the streaming revolution, which continues to this day.

Video Channels and Cord-Cutting

People's preferences are incredibly diverse. Throughout this book we will see illustrations of how markets work to accommodate this diversity. For the case of video entertainment, diversity of preferences is especially pronounced. Some people only like crime dramas, others only watch home repair, and some prefer only science fiction and fantasy. The arrival of the Internet with its practically infinite ability to provide specialized content made it possible to match preferences much more closely than had been the case. Netflix and Amazon were rapidly joined in the streaming market by other general content providers such as Showtime. Networks that were more narrowly focused included ESPN, Motor Trend, and Disney+. Some networks such as Hulu or Sling began providing a mixture of existing shows together with some live TV offerings. The fact that getting into the video streaming business was relatively low cost made this explosion in diversity inevitable.

One potential casualty of the growth in streaming options were the cable and satellite TV providers such as Comcast and DIRECTV. These firms tended provided a fixed bundle of offerings to their subscribers. Even though these could often amount to hundreds of individual TV channels, they could not compete with the much wider variety being offered by the specialized streaming outlets. One result was the growth in "cord-cutting" where customers dropped their cable subscriptions in favor of creating their own bundles of streaming networks. Whether the traditional cable systems can survive in this new environment is an open question.[1]

TO THINK ABOUT

1. Joseph Schumpeter coined the term "creative destruction" to refer to the dynamic relationship between changing consumer demands and the responses of existing and new firms to meet them. This application shows that Schumpeter's ideas are perfectly illustrated by the case of video streaming. In general, do you think this is a good thing for society?
2. Over-the-air television is highly regulated in many countries, including the United States. The purported goal of such regulation is to provide better and more consistent services to consumers. Video streaming, on the other hand, is currently subject to very little regulation. Do you think that regulation of TV has been successful and should be applied to streaming? Or does the streaming revolution show that regulation is largely unnecessary?

[1]For an analysis of the motives for cord-cutting, see Jeffrey Prince and Shawn Greenstein, "Measuring Consumer Preferences for Video Content via Cord-cutting Behavior," *Journal of Economics and Business Strategy* (Summer 2017): 293–319.

in introductory economics—in fact, this model may be the first thing you studied in your introductory course. This is the second basic model we look at in this chapter. At the same time we add a bit of historical perspective on the current state of microeconomics.

1-4a Adam Smith and the Invisible Hand

The Scottish philosopher Adam Smith (1723–1790) is generally credited with being the first true economist. In *The Wealth of Nations* (published in 1776), Smith examined a large number of the pressing economic issues of his day and tried to develop economic tools for understanding them. Smith's most important insight was his recognition that the system of market-determined prices that he observed was not as chaotic and undisciplined as most other writers had assumed. Rather, Smith saw prices as providing a powerful "invisible hand" that directed resources into activities where they would be most valuable. Prices play the crucial role of telling both consumers and firms what goods are "worth" and thereby prompt these economic actors to make efficient choices about how to use them. To Smith, it was this ability to use resources efficiently that provided the ultimate explanation for a nation's "wealth."

Because Smith placed great importance on the role of prices in directing how a nation's resources are used, he needed to develop some theories about how those prices are determined. He offered a very simple and only partly correct explanation. Because in Smith's day (and, to some extent, even today), the primary costs of producing goods were costs associated with the labor that went into a good, it was only a short step for him to embrace a labor-based theory of prices. For example, to paraphrase an illustration from *The Wealth of Nations,* if it takes twice as long for a hunter to catch a deer as to catch a beaver, one deer should trade for two beavers. The relative price of a deer is high because of the extra labor costs involved in catching one.

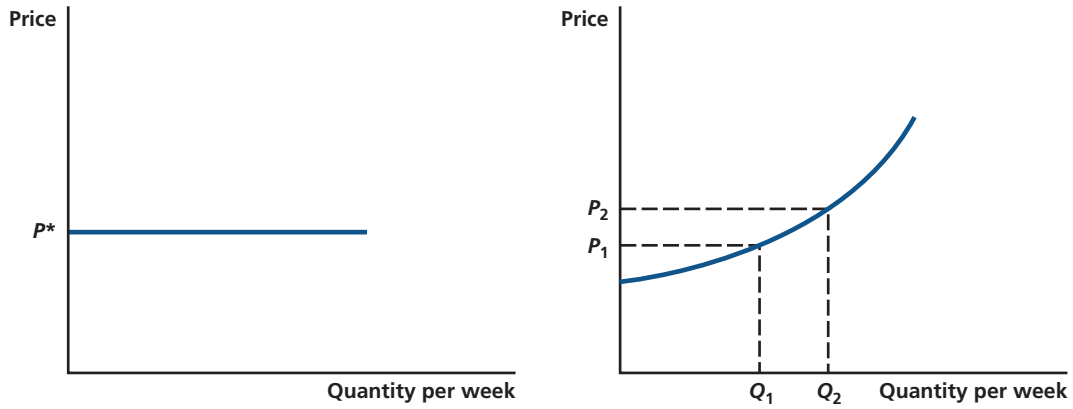
Smith's explanation for the price of a good is illustrated in **Figure 1.2**(a). The horizontal line at P^* shows that any number of deer can be produced without affecting the relative cost of doing so. That relative cost sets the price of deer (P^*), which might be measured in beavers (a deer costs two beavers), in dollars (a deer costs $200, whereas a beaver costs $100), or in any other units that this society uses to indicate exchange value. This value will change only when the technology for producing deer changes. If, for example, this society developed better running shoes (which would aid in catching deer but be of little use in capturing beavers), the relative labor costs associated with hunting deer would fall. Now a deer would trade for, say, 1.5 beavers, and the supply curve illustrated in the figure would shift downward. In the absence of such technical changes, however, the relative price of deer would remain constant, reflecting relative costs of production.

1-4b David Ricardo and Diminishing Returns

The early nineteenth century was a period of considerable controversy in economics, especially in England. The two most pressing issues of the day were whether international trade was having a negative effect on the economy and whether industrial growth was harming farmland and other natural resources. It is testimony to the timelessness of economic questions that these are some of the same issues that dominate political discussions in the United States (and elsewhere) today. One of the most influential contributors to the earlier debates was the British financier and pamphleteer David Ricardo (1772–1823).

Ricardo believed that labor and other costs would tend to rise as the level of production of a particular good expanded. He drew this insight primarily from looking at the way in which farmland was expanding in England at the time. As new and less-fertile land was brought into use, it would naturally take more labor (say, to pick out the rocks in addition

Figure 1.2 Early Views of Price Determination



(a) Smith's model (b) Ricardo's model

To Smith, the relative price of a good was determined by relative labor costs. As shown in the left-hand panel, relative price would be P^* unless something altered such costs. Ricardo added the concept of diminishing returns to this explanation. In the right-hand panel, relative price rises as quantity produced rises from Q_1 to Q_2.

diminishing returns Hypothesis that the cost associated with producing one more unit of a good rises as more of that good is produced.

to planting crops) to produce an extra bushel of grain. Hence, the relative price of grain would rise. Similarly, as deer hunters exhaust the stock of deer in a given area, they must spend more time locating their prey, so the relative price of deer would also rise. Ricardo believed that the phenomenon of increasing costs was quite general, and today we refer to his discovery as the law of **diminishing returns.** This generalization of Smith's notion of supply is reflected in Figure 1.2(b), in which the supply curve slopes upward as quantity produced expands.

The problem with Ricardo's explanation was that it really did not explain how relative prices are determined. Although the notion of diminishing returns improved Smith's model, it did so by showing that relative price was not determined by production technology alone. Instead, according to Ricardo, the relative price of a good can be practically anything, depending on how much of it is produced.

To complete his explanation, Ricardo relied on a subsistence argument. If, for example, the current population of a country needs Q_1 units of output to survive, Figure 1.2(b) shows that the relative price would be P_1. With a growing population, these subsistence needs might expand to Q_2, and the relative price of this necessity would rise to P_2. Ricardo's suggestion that the relative prices of goods necessary for survival would rise in response to diminishing returns provided the basis for much of the concern about population growth in England during the 1830s and 1840s. It was largely responsible for the application of the term "dismal science" to the study of economics.

1-4c Marginalism and Marshall's Model of Supply and Demand

Contrary to the fears of many worriers, relative prices of food and other necessities did not rise significantly during the nineteenth century. Instead, as methods of production improved, prices tended to fall and well-being improved dramatically. As a result, subsistence became

a less plausible explanation of the amounts of particular goods consumed, and economists found it necessary to develop a more general theory of demand. In the latter half of the nineteenth century, they adapted Ricardo's law of diminishing returns to this task. Just as diminishing returns mean that the cost of producing one more unit of a good rises as more is produced, so too, these economists argued, the willingness of people to pay for that last unit declines. Only if individuals are offered a lower price for a good will they be willing to consume more of it. By focusing on the value to buyers of the last, or *marginal,* unit purchased, these economists had at last developed a comprehensive theory of price determination.

The clearest statement of these ideas was provided by the English economist Alfred Marshall (1842–1924) in his *Principles of Economics,* first published in 1890. Marshall showed how the forces of demand and supply *simultaneously* determine price. Marshall's analysis is illustrated by the familiar cross diagram shown in **Figure 1.3**.

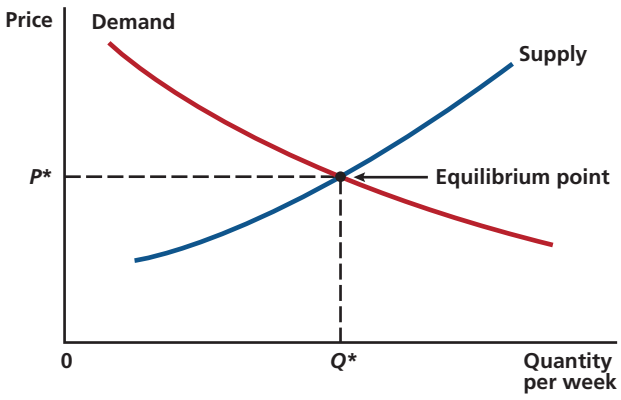
As before, the amount of a good purchased per period (say, each week) is shown on the horizontal axis and the price of the good appears on the vertical axis. The curve labeled "Demand" shows the amount of the good people want to buy at each price. The negative slope of this curve reflects the marginalist principle: Because people are willing to pay less and less for the last unit purchased, they will buy more only at a lower price. The curve labeled "Supply" shows the increasing cost of making one more unit of the good as the total amount produced increases. In other words, the upward slope of the supply curve reflects *increasing* marginal costs, just as the downward slope of the demand curve reflects *decreasing* marginal value.

1-4d Market Equilibrium

equilibrium price
The price at which the quantity demanded by buyers of a good is equal to the quantity supplied by sellers of the good.

In Figure 1.3, the demand and supply curves intersect at the point P^*, Q^*. At that point, P^* is the **equilibrium price.** That is, at this price, the quantity that people want to purchase (Q^*) is precisely equal to the quantity that suppliers are willing to produce. Because both demanders and suppliers are content with this outcome, no one has an incentive to alter his or her behavior. The equilibrium P^*, Q^* will tend to persist unless something happens to change things. This illustration is the first of many we encounter in this book about the way in which a

Figure 1.3 The Marshall Supply-Demand Cross



Marshall believed that demand and supply together determine the equilibrium price (P^*) and quantity (Q^*) of a good. The positive slope of the supply curve reflects diminishing returns (increasing marginal cost), whereas the negative slope of the demand curve reflects diminishing marginal usefulness. P^* is an equilibrium price. Any other price results in either a surplus or a shortage.

MICRO QUIZ 1.2

Another way to describe the equilibrium in Figure 1.3 is to say that at P^*, Q^* neither the supplier nor the demander has any incentive to change behavior. Use this notion of equilibrium to explain:

1. Why the fact that P^*, Q^* occurs where the supply and demand curves intersect implies that both parties to the transaction are content with this result?
2. Why no other P, Q point on the graph meets this definition of equilibrium?

balancing of forces results in a sustainable equilibrium outcome. To conceptualize the nature of this balancing of forces, Marshall used the analogy of a pair of scissors: Just as both blades of the scissors work together to do the cutting, so too the forces of demand and supply work together to establish equilibrium prices.

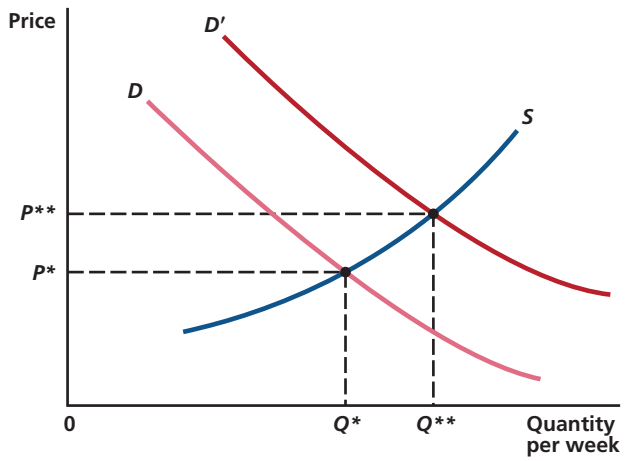
1-4e Nonequilibrium Outcomes

The smooth functioning of market forces envisioned by Marshall can, however, be thwarted in many ways. For example, a government decree that requires a price to be set in excess of P^* (perhaps because P^* was regarded as being the result of "unfair, ruinous competition") would prevent the establishment of equilibrium. With a price set above P^*, demanders would wish to buy less than Q^*, whereas suppliers would produce more than Q^*. This would lead to a surplus of production in the market—a situation that characterizes many agricultural markets. Similarly, a regulation that holds a price below P^* would result in a shortage. With such a price, demanders would want to buy more than Q^*, whereas suppliers would produce less than Q^*. In Chapter 10, we look at several such situations where this occurs.

1-4f Change in Market Equilibrium

The equilibrium pictured in Figure 1.3 can persist as long as nothing happens to alter demand or supply relationships. If one of the curves were to shift, however, the equilibrium would change. In **Figure 1.4**, people's demand for the good increases. In this case, the demand curve moves outward (from curve D to curve D'). At each price, people now want to buy more of the good. The equilibrium price increases (from P^* to P^{**}). This higher price both tells firms to supply more goods and restrains individuals' demand for

Figure 1.4 An Increase in Demand Alters Equilibrium Price



If the demand curve shifts outward to D' because there is more desire for the product, P^*, Q^* will no longer be at equilibrium. Instead, equilibrium occurs at P^{**}, Q^{**}, where D' and S intersect.

the good. At the new equilibrium price of P^{**}, supply and demand again balance—at this higher price, the amount of goods demanded is exactly equal to the amount supplied.

A shift in the supply curve also affects market equilibrium. In **Figure 1.5**, the effects of an increase in supplier costs (for example, an increase in wages paid to workers) are illustrated. For any level of output, marginal costs associated with the supply curve S exceed those associated with S. This shift in supply causes the price of this product to rise (from P^* to P^{**}), and consumers respond to this price rise by reducing quantity demanded (from Q^* to Q^{**}) along the demand curve, D. As for the case of a shift in demand, the ultimate result of the shift in supply depicted in Figure 1.5 depends on the shape of both the demand curve and the supply curve.

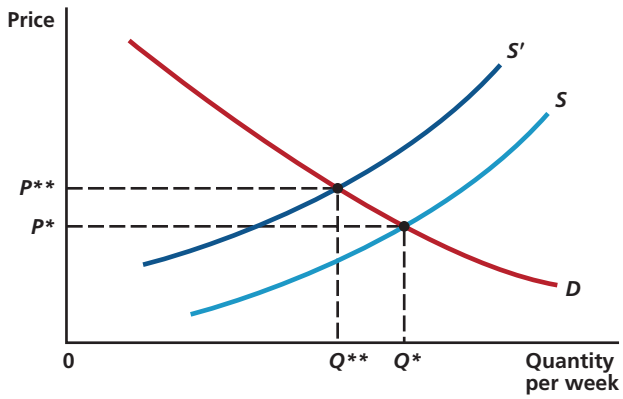
Marshall's model of supply and demand should be quite familiar to you, since it provides the principal focus of most courses in introductory economics. Indeed, the concepts of marginal cost, marginal value, and market equilibrium encountered in this model provide the starting place for most of the economic models you will learn about in this book. **Application 1.4: COVID-19 and the Price of Eggs** shows how the logic of supply and demand can often go a long way in explaining current events.

MICRO QUIZ 1.3

Supply and demand curves show the relationship between the price of a good and the quantity supplied or demanded when other factors are held constant. Explain:

1. What factors might shift the demand or supply curve for, say, personal computers?
2. Why would a change in the price of personal computers shift neither curve? Indeed, would this price ever change if all of the factors identified previously did not change?

Figure 1.5 A Shift in Supply Alters Equilibrium Price and Quality



A rise in costs would shift the supply curve upward to S'. This would cause an increase in equilibrium price from P^* to P^{**} and a decline in quantity from Q^* to Q^{**}.

1-5 How Economists Verify Theoretical Models

Not all models are as useful as Marshall's model of supply and demand. An important purpose of studying economics is to sort out bad models from good ones. Two methods are used to provide such a test of economic models. **Testing assumptions** looks at the assumptions upon which a model is based; **testing predictions**, on the other hand, uses the model to see if it can correctly predict real-world events. This book uses both approaches to try to illustrate the validity of the models that are presented. We now look briefly at the differences between the approaches.

testing assumptions Verifying economic models by examining the validity of the assumptions on which they are based.

testing predictions Verifying economic models by asking if they can accurately predict real-world events.

APPLICATION 1.4

COVID-19 and the Price of Eggs

The spread of COVID-19 in late 2019 and early 2020 had a huge impact on economies throughout the world. Applications throughout this book will touch on various ways that economists have tried to understand this impact. Here we take a simple (and perhaps trivial) example to show how economic tools might be used for this purpose.

The Demand for Eggs

People eat a huge number of eggs each year. They are consumed directly and as ingredients in many products. When COVID-19 and the related lockdowns of restaurants hit, individuals had to alter their eating habits, primarily by doing more cooking at home. Because of the flexibility that eggs provided for at-home recipes, the demand for eggs increased dramatically. This is shown in **Figure 1** by a shift outward in the demand curve from D to D′. One important fact about the egg market is that the supply curve is very steep ("inelastic" in the terms we will develop later). Price increases just do not tempt laying hens to produce many more eggs on short notice. Consequently, the large increase in demand led to a steep increase in egg prices (from P_0 to P_1). At the end of 2019, the wholesale price of large eggs in the New York area was about $.93 per dozen. By the end of March 2020, this price had risen to about $3.00. Rising consumer complaints about such "price-gouging" led attorneys general in several states to file lawsuits[1] against large egg producers saying they were "exploiting consumers."

A Supply Response

Although there is very little egg producers can do to expand egg production in the short run, that inflexibility does not last. It was a simple matter for such producers to let more of their eggs hatch. In about 6 to 8 weeks this can vastly increase the number of laying hens. This is precisely what happened in response to the price run-up in the spring of 2020. By May, the effect of this response began to be observed in the market. That is, the egg supply curve shown in Figure 1 shifted out from S to S′. Because egg demand is also not very responsive to price, this caused a large decline in price (from P_1 to P_2). As more dining options became available, the demand for eggs probably shifted back a bit from prior levels, further enhancing the price decline. By October 2020 the wholesale price of a dozen large eggs in New York had fallen to about $1.17, close to its pre-COVID level.

Figure 1 **Effects of COVID-19 on the Market for Eggs**

COVID-19 and its related lockdowns increased the demand from eggs from D to D′. In the short run this increased price from P_0 to P_1. The price rise caused egg producers to raise more hens, shifting supply from S to S′. This caused price to fall back from P_1 to P_2.

TO THINK ABOUT

1. Sharp price increases often occur when natural disasters strike. Prices of flashlights, bottled water, or electric generators can easily double or triple. Should the government pass laws that prevent such "price gouging"?
2. The price figures quoted in this application refer to wholesale prices—that is the prices paid by grocery stores for eggs. Do you think grocery stores were also able to take advantage of the increase in egg demand by raising their retail mark-up on eggs? What might have prevented them from doing so?

[1]See "New York's AG Lays a Rotten Egg," *The Wall Street Journal* (August 30, 2020).

1-5a Testing Assumptions

One approach to testing the assumptions of an economic model might begin with intuition. Do the model's assumptions seem reasonable? Unfortunately, this question is fraught with problems, since what appears reasonable to one person may seem preposterous to someone else (try arguing with a noneconomics student about how markets work, for example).

Assumptions can also be tested with empirical evidence. For example, economists usually assume that firms are in business to maximize profits—in fact, much of our discussion in this book is based on that assumption. Using the direct approach to test this assumption with real-world data, you might send questionnaires to managers asking them how they make decisions and whether they really do try to maximize profits. This approach has been used many times, but the results, like those from many opinion polls, are often difficult to interpret.

1-5b Testing Predictions

Some economists, such as Milton Friedman, do not believe that a theory can be tested by looking only at its assumptions. They argue that all theories are based on unrealistic assumptions—the very nature of theorizing demands that we make unrealistic assumptions.[1] Such economists believe that, in order to decide if a theory is valid, we must see if it is capable of explaining and predicting real-world events. The ultimate test of any economic model is whether it is consistent with events in the economy itself.

Friedman gives a good example of this idea by asking what theory explains the shots an expert pool player will make. He argues that the laws of velocity, momentum, and angles from physics make a suitable theoretical model because the pool player certainly shoots *as if* they followed these laws. If we asked the players whether they could state these physical principles, they would undoubtedly answer that they could not. That does not matter, Friedman argues, because the physical laws give very accurate predictions of the shots made and are therefore useful as theoretical models.

Going back to the question of whether firms try to maximize profits, the indirect approach would try to predict the firms' behavior by assuming that they do act *as if* they were maximizing profits. If we find that we can predict firms' behavior, then we can believe the profit-maximization hypothesis. Even if these firms said on questionnaires that they don't really try to maximize profits, the theory will still be valid, much as the pool players' disclaiming knowledge of the laws of physics does not make these laws untrue. The ultimate test in both cases is the theory's ability to predict real-world events.

1-5c The Positive-Normative Distinction

Related to the question of how the validity of economic models should be tested is the issue of how such models should be used. To some economists, the only proper analysis is "positive" in nature. As in the physical sciences, they argue, the correct role for theory is to explain the real world as it is. In this view, developing "normative" theories about how the world *should be* is an exercise for which economists have no more special skills than anyone else. For other economists, this **positive-normative distinction** is not so clear-cut. They argue that economic models invariably have normative consequences that should be recognized. **Application 1.5: Do Economists Ever Agree on Anything?** shows that, contrary to common perceptions, there is considerable agreement among economists about issues

positive-normative distinction
Distinction between theories that seek to explain the world as it is and theories that postulate the way the world should be.

[1]Milton Friedman, *Essays in Positive Economics* (Chicago: University of Chicago Press, 1953), Chapter 1. Another view stressing the importance of realistic assumptions can be found in H. A. Simon, "Rational Decision Making in Business Organizations," *American Economic Review* (September 1979): 493–513.

APPLICATION 1.5

Do Economists Ever Agree on Anything?

To the general public, economists seem to be completely confused. In many conversations, they bear the brunt of pointed jokes. Some of our favorites are:

1. If all economists in the world were laid end-to-end, they would never reach a decision.
2. How many economists does it take to change a light-bulb? Two—one to turn the bulb and one to say repeatedly, "Turn it the other way."

Positive Versus Normative Economics

These jokes convey the perception that economists never agree on anything. But that perception arises in part from an inability to differentiate between the positive and normative arguments that economists make. Economists (like everyone else) often disagree over political questions. They may, therefore, find themselves on opposite sides of controversial policy questions. Economists may also differ on empirical matters. For instance, they may disagree about whether a particular effect is large or small. But on basic theoretical questions, there is far less disagreement. Because most economists use the same tools, they tend to "speak the same language" and disagreements on positive questions are far less frequent.

Survey Results

This conclusion is supported by surveys of economists, a sample of which is described in **Table 1**. The table shows a high degree of agreement among U.S., Swiss, and German economists about positive questions such as the effects of tariffs or of rent controls.[1] There is considerably less agreement about broad normative questions, such as whether the government should redistribute income or act as the employer of last resort. For these types of policy questions, economists' opinions are affected by the same sort of political forces as are those of other citizens.[2]

TO THINK ABOUT

1. The 2020 presidential election featured much discussion about tax policy. Especially prominent were discussions of raising the maximum tax rate on capital income (that is, dividends and capital gains). Economists differed significantly among themselves about the wisdom of such an increase. List some statements regarding this increase about which you might expect most economists to agree. Then list some statements about which you might expect considerable disagreement. Can you find any evidence to support your conclusions?
2. As Table 1 shows, a significant majority of economists believe that tariffs reduce economic welfare. Yet President Donald Trump used increased tariffs in 2019 to try to get China to agree to restrictions on their use of U.S. intellectual property. Under what circumstances would this use of tariffs make sense?

Table 1 Percentage of Economists Agreeing with Various Propositions in Three Nations

PROPOSITION	UNITED STATES	SWITZERLAND	GERMANY
Tariffs reduce economic welfare	95	87	94
Flexible exchange rates are effective for international transactions	94	91	92
Rent controls reduce the quality of housing	96	79	94
Government should redistribute income	68	51	55
Government should hire the jobless	51	52	35

Source: B. S. Frey, W. W. Pommerehue, F. Schnieder, and G. Gilbert, "Consensus and Dissension Among Economists: An Empirical Inquiry," *American Economic Review* (December 1984): 986–994. Percentages represent the fraction that "Generally Agree" or "Agree with Provisions."

[1]Surveys also tend to show considerable agreement over the likely size of many economic effects. For a summary, see Victor R. Fuchs, Alan B. Krueger, and James M. Poterba, "Economists' Views about Parameters, Values, and Policy," *Journal of Economic Literature* (September 1998): 1387–1425.
[2]See Daniel B. Klein and Charlotta Stern, "Economists' Policy Views and Voting," *Public Choice* (2006): 331–342.

that are suitable for positive scientific analysis. There is far less agreement about normative questions related to what should be done. In this book, we take primarily a positive approach by using economic models to explain real-world events. The book's applications pursue some of these explanations in greater detail. You should feel free to adapt these models to whatever normative goals you believe are worth pursuing.

SUMMARY

This chapter reminds you about two basic economic models that will help you get started on your study of microeconomics. Undoubtedly this material will be familiar to you from your introductory economics course, but that should come as no surprise. In many respects, the study of economics repeatedly investigates the same questions with an increasingly sophisticated set of tools. This course gives you some more of these tools. In establishing the basis for that investigation, this chapter reminds you of several important ideas:

- Economics is the study of allocating scarce resources among possible uses. Because resources are scarce, choices have to be made on how they will be used. Economists develop theoretical models to explain these choices.
- The production possibility frontier provides a simple illustration of the various output options that can be supplied in an economy. The curve clearly shows the limits imposed on the economy because resources are scarce. Producing more of one good means that less of something else must be produced. This reduction in output elsewhere measures the opportunity cost involved in such additional production.
- The most commonly used model of the allocation of resources is the model of supply and demand first fully described by Alfred Marshall in the latter part of the nineteenth century. The model shows how prices are determined by creating an equilibrium between the amount people want to buy and the amount firms are willing to produce. If supply and demand curves shift, new prices are established to restore equilibrium to the market.
- Proving the validity of economic models is difficult and sometimes controversial. Occasionally, the validity of a model can be determined by whether it is based on reasonable assumptions. More often, however, models are judged by how well they explain actual economic events.

KEY TERMS

economics
microeconomics
models
production possibility frontier
opportunity cost
supply-demand model
diminishing returns
equilibrium price
testing assumptions
testing predictions
positive-normative distinction

REVIEW QUESTIONS

A Note for Students: The chapters in this book conclude with "Review Questions" and "Problems." Generally, the Review Questions stress a qualitative understanding of the topics covered in the chapter whereas the Problems stress the calculation of numerical answers. Chapter 1, however, has only Review Questions that focus qualitatively on the two models discussed in the chapter. Later, the Problems in Chapter 2 take a numerical approach to looking at these same models. First, however, you should work through the mathematical material in Chapter 2 itself. This will help you solve the Problems in Chapter 2 and in all the remaining chapters of this book.

1. "To an economist, a resource is 'scarce' only if it has a positive price. Resources with zero prices are, by definition, not scarce." Do you agree? Or does the term *scarce* convey some other meaning?
2. The Production Possibility Frontier (PPF), shown in Figure 1.1, has a "concave" shape (you can remember that this shape is called "concave" because it resembles part of the entrance to a cave). Explain in words why this shape is consistent with the concept of diminishing returns to increasing clothing production—that is, describe why the opportunity cost of producing more units of clothing increases as more is produced. How would the PPF look if there were no diminishing returns to clothing production? How might the PPF look if clothing production experienced "increasing returns" because bigger weaving machines could be used as clothing production expands?
3. Why do honeybees find it in their interest to leave some nectar in each flower they visit? Can you think of any human activities that yield a similar result?

4. Classical economists struggled with the "Water-Diamond Paradox," which seeks an explanation for why water (which is very useful) has a low price, whereas diamonds (which are not particularly important to life) have a high price. How would Smith explain the relative prices of water and diamonds? Would Ricardo's concept of diminishing returns pose some problem for this explanation? Can you resolve matters by using Marshall's model of supply and demand? If water is "very useful" to the demanders in Marshall's model, how would you know?

5. Marshall's model pictures price *and* quantity as being determined simultaneously by the interaction of supply and demand. Using this insight, explain the fallacies in the following paragraph:

   A rise in the price of oranges reduces the number of oranges people want to buy. This reduction by itself reduces growers' costs by allowing them to use only their best trees. Price, therefore, declines along with costs, and the initial price rise cannot be sustained.

6. "Gasoline sells for $4.00 per gallon this year, and it sold for $3.00 per gallon last year. But consumers bought more gasoline this year than they did last year. This is clear proof that the economic theory that people buy less when the price rises is incorrect." Do you agree? Explain.

7. "A shift outward in the demand curve always results in an increase in total spending (price times quantity) on a good. On the other hand, a shift outward in the supply curve may increase or decrease total spending." Explain.

8. Housing advocates often claim that "the demand for affordable housing vastly exceeds the supply." Use a supply-demand diagram to show whether you can make any sense out of this statement. In particular, show how a proper interpretation may depend on precisely how the word *affordable* is to be defined.

9. A key concept in the development of positive economic theories is the notion of "refutability"—a "theory" is not a "theory" unless there is some evidence that, if true, could prove it wrong. Use this notion to discuss whether one can conceive of evidence with which the following theories might be refuted:
   - Friedman's claim that pool players play as if they were using the rules of physics
   - The theory that firms operate so as to maximize profits
   - The theory that demand curves slope downward
   - The theory that adoption of capitalism makes people who are poor more miserable

10. The following conversation was heard among four economists discussing whether the minimum wage should be increased:

    Economist A. "Increasing the minimum wage would reduce employment of minority teenagers."

    Economist B. "Increasing the minimum wage would represent an unwarranted interference with private relations between workers and their employers."
    Economist C. "Increasing the minimum wage would raise the incomes of some unskilled workers."

    Economist D. "Increasing the minimum wage would benefit higher-wage workers and would probably be supported by organized labor."

    Which of these economists are using positive analysis and which are using normative analysis in arriving at their conclusions? Which of these predictions might be tested with empirical data? How might such tests be conducted?

2 Some Useful Math

Mathematics began to be widely used in economics near the end of the nineteenth century. For example, Marshall's *Principles of Economics,* published in 1890, included a lengthy mathematical appendix that developed his arguments more systematically than the book itself. Today, mathematics is indispensable for economists. They use it to move logically from the basic assumptions of a model to deriving the results of those assumptions. Without mathematics, this process would be both more cumbersome and less accurate.

This chapter reviews some of the basic concepts of algebra and discusses a few issues that arise in applying those concepts to the study of economics. We will use the tools introduced here throughout the rest of the book.

2-1 Functions of One Variable

The basic elements of algebra are called **variables**. These can be labeled X and Y and may be given any numerical value. Sometimes the values of one variable (Y) may be related to those of another variable (X) according to a specific functional relationship. This relationship is denoted by the **functional notation**

$$Y = f(X). \tag{2.1}$$

This is read, "Y is a function of X," meaning that the value of Y depends on the value given to X. For example, if we make X calories eaten per day and Y body weight, then Equation 2.1 shows the relationship between the amount of food intake and an individual's weight. The form of this equation also shows causality. X is an **independent variable** and may be given any value. On the other hand, the value of Y is completely determined by X; Y is a **dependent variable**. This functional notation conveys the idea that "X causes Y."

The exact functional relationship between X and Y may take on a wide variety of forms. Two possibilities are:

1. Y is a *linear function* of X. In this case

$$Y = a + bX, \tag{2.2}$$

where a and b are constants that may be given any numerical value. For example, if $a = 3$ and $b = 2$, this equation would be written as

$$Y = 3 + 2X. \tag{2.3}$$

variables
The basic elements of algebra, usually called *X, Y,* and so on, that may be given any numerical value in an equation.

functional notation
A way of denoting the fact that the value taken on by one variable (*Y*) depends on the value taken on by some other variable (*X*) or set of variables.

independent variable
In an algebraic equation, a variable that is unaffected by the action of another variable and may be assigned any value.

dependent variable
In algebra, a variable whose value is determined by another variable or set of variables.

Table 2.1 Values of X and Y for Linear and Quadratic Functions

LINEAR FUNCTION		QUADRATIC FUNCTION	
X	$Y = f(X) = 3 + 2X$	X	$Y = f(X) = -X^2 + 15X$
−3	−3	−3	−54
−2	−1	−2	−34
−1	1	−1	−16
0	3	0	0
1	5	1	14
2	7	2	26
3	9	3	36
4	11	4	44
5	13	5	50
6	15	6	54

We could give this equation an economic interpretation. For example, if we make Y the labor costs of a firm and X the number of labor hours hired, then the equation could record the relationship between costs and workers hired. In this case, there is a fixed cost of \$3 (when $X = 0$, $Y = \$3$), and the wage rate is \$2 per hour. A firm that hired 6 labor hours, for example, would incur total labor costs of \$15[$= 3 + 2(6) = 3 + 12$]. **Table 2.1** illustrates some other values for this function for various values of X.

2. Y is a *nonlinear function* of X. This case covers a number of possibilities, including quadratic functions (containing X^2), higher-order polynomials (containing X^3, X^4, and so forth), and those based on special functions such as logarithms. All of these have the property that a given change in X can have different effects on Y depending on the value of X. This contrasts with linear functions for which any unit change in X always changes Y by the same amount no matter what X is.

   To see this, consider the quadratic equation

$$Y = -X^2 + 15X. \tag{2.4}$$

   Y values for this equation for values of X between −3 and +6 are shown in Table 2.1. Notice that as X increases by 1 unit, the values of Y go up rapidly at first but then slow down. When X increases from 0 to 1, for example, Y increases from 0 to 14. But when X increases from 5 to 6, Y increases only from 50 to 54. This looks like Ricardo's notion of diminishing returns—as X increases, its ability to increase Y diminishes.[1]

2-2 Graphing Functions of One Variable

When we write down the functional relationship between X and Y, we are summarizing all there is to know about that relationship. In principle, this book, or any book that uses mathematics, could be written using only these equations. Graphs of some of these

[1]Of course, for other nonlinear functions, unit increases in X may result in increasing amounts of Y (consider, for example, $X^2 + 15X$).

functions, however, are very helpful. Graphs not only make it easier for us to understand certain arguments; but they also can take the place of a lot of the mathematical notation that must be developed. For these reasons, this book relies heavily on graphs to develop its basic economic models. Here we look at a few graphic techniques.

A graph is simply one way to show the relationship between two variables. Usually, the values of the dependent variable (Y) are shown on the vertical axis and the values of the independent variable (X) are shown on the horizontal axis.[2] **Figure 2.1** uses this form to graph Equation 2.3. Although we use heavy dots to show only the points of this function that are listed in the table, the graph represents the function for every possible value of X. The graph of Equation 2.3 is a straight line, which is why this is called a **linear function**. In Figure 2.1, X and Y can take on both positive and negative values. The variables used in economics generally take on only positive values, and therefore we only have to use the upper-right-hand (positive) quadrant of the axes.

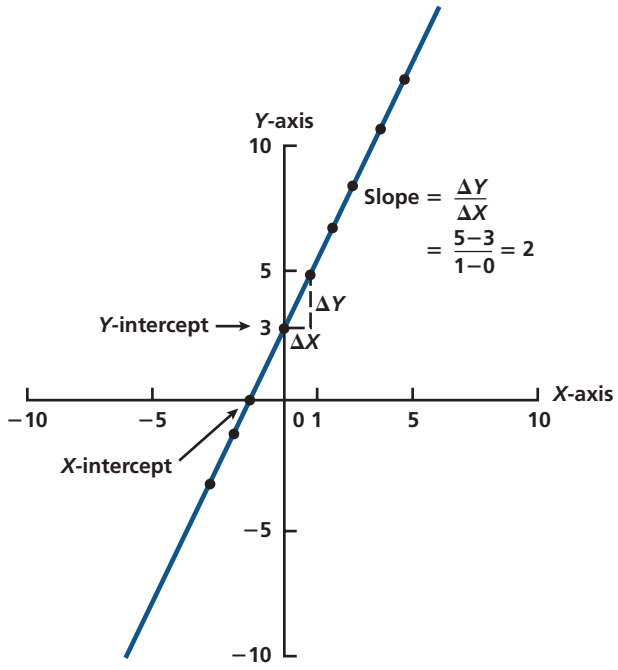
linear function
An equation that is represented by a straight-line graph.

intercept
The value of Y when X equals zero.

2-2a Linear Functions: Intercepts and Slopes

Two important features of the graph in Figure 2.1 are its slope and its **intercept** on the Y-axis. The Y-intercept is the value of Y when X is equal to 0. For example, as shown in

Figure 2.1 Graph of the Linear Function $Y = 3 + 2X$



The Y-intercept is 3; when $X = 0$, $Y = 3$. The slope of the line is 2; an increase in X by 1 will increase Y by 2.

[2]In economics, this convention is not always followed. Sometimes a dependent variable is shown on the horizontal axis as, for example, in the case of demand and supply curves. In that case, the independent variable (price) is shown on the vertical axis and the dependent variable (quantity) on the horizontal axis. See the discussion of "Marshall's Trap" later in this section.

Figure 2.1, when $X = 0$, $Y = 3$; this means that 3 is the Y-intercept.[3] In the general linear form of Equation 2.2,

$$Y = a + bX,$$

the Y-intercept will be $Y = a$, because this is the value of Y when $X = 0$.

slope
The direction of a line on a graph; shows the change in Y that results from a unit change in X.

We define the **slope** of any straight line to be the ratio of the change in Y to the change in X for a movement along the line. The slope can be defined mathematically as

$$\text{Slope} = \frac{\text{Change in } Y}{\text{Change in } X} = \frac{\Delta Y}{\Delta X}, \tag{2.5}$$

where the Δ ("delta") notation simply means "change in." For the particular function shown in Figure 2.1, the slope is equal to 2. You can clearly see from the dashed lines, representing changes in X and Y, that a given change in X is met by a change of twice that amount in Y. Table 2.1 shows the same result—as X increases from 0 to 1, Y increases from 3 to 5. Consequently

$$\text{Slope} = \frac{\Delta Y}{\Delta X} = \frac{5 - 3}{1 - 0} = 2. \tag{2.6}$$

It should be obvious that this is true for all the other points in the table. Everywhere along the straight line, the slope is the same. Generally, for any linear function, the slope is given by b in Equation 2.2. The slope of a straight line may be positive (as shown in Figure 2.1), or it may be negative, in which case the line would run from upper left to lower right.

A straight line may also have a slope of 0, which is a horizontal line. In this case, the value of Y is constant; changes in X will not affect Y. The function would be $Y = a + 0X$, or $Y = a$. This equation is represented by a horizontal line (parallel to the X-axis) through point a on the Y-axis.

2-2b Interpreting Slopes

The slope of the relationship between a cause (X) and an effect (Y) is one of the most important things that economists try to measure. Because the slope (or the related concept of elasticity) shows, in quantitative terms, how a small (marginal) change in one variable affects some other variable, this is a valuable piece of information for building most every economic model. For example, a researcher discovered that the quantity of oranges (Q) a typical family eats during any week can be represented by the equation:

$$Q = 12 - 0.2P, \tag{2.7}$$

where P is the price of a single orange, in cents. Hence, if an orange costs 20 cents, this family would consume eight oranges per week. If the price rose to 50 cents, orange consumption would fall to only two per week.[4] On the other hand, if oranges were given away ($P = 0$), the family would eat 12 each week. With this sort of information, it would be possible for an agricultural economist to assess how families might react to factors such as winter freezes or increased imports of oranges that might affect their price.

[3]One can also speak of the X-intercept of a function, which is defined as that value of X for which $Y = 0$. For Equation 2.3, it is easy to see that $Y = 0$ when $X = -3/2$, which is then the X-intercept. The X-intercept for the general linear function in Equation 2.2 is given by $X = -a/b$, as may be seen by substituting that value into the equation.
[4]Notice that this equation only makes sense for $P \leqq 60$ because it is impossible to eat negative numbers of oranges.

2-2c Slopes and Units of Measurement

When introducing Equation 2.7, we were careful to state precisely how the variables Q and P were measured. In the usual algebra course, this issue does not arise because Y and X have no specific physical meaning. But in economics, this issue is crucial—the slope of a relationship will depend on how variables are measured. For example, if orange prices were measured in dollars, the same behavior described in Equation 2.7 would be represented by

$$Q = 12 - 20P. \qquad (2.8)$$

Notice that at a price of \$0.20, the family still eats eight oranges per week. With a price of \$0.50, they eat only two. The slope here is 100 times the slope in Equation 2.7, however, because of the change in the way P is measured.

Changing the way that Q is measured will also change the relationship. If orange consumption is now measured in boxes of 10 oranges each, and P represents the price for such a box in cents, Equation 2.7 would become:

$$Q = 1.2 - 0.002P. \qquad (2.9)$$

This equation still says that the family will consume eight oranges (that is, 0.8 of a box) each week if each box of oranges costs 200 cents and two oranges (0.2 of a box) if each box costs 500 cents. Notice that, in this case, changing the units in which Q is measured changes both the intercept and the slope of this equation.

Because slopes of economic relationships depend on the units of measurement used, they are not a very convenient concept for economists to use to summarize behavior. Instead, they usually use elasticities, which are unit-free. This concept is introduced in Chapter 4 and then used throughout the remainder of the book.

MICRO QUIZ 2.1

Suppose that the quantity of flounder caught each week off New Jersey is given by $Q = 100 + 5P$ (where Q is the quantity of flounder measured in thousands of pounds and P is the price per pound in dollars). Explain:

1. What are the units of the intercept and the slope in this equation?
2. How would this equation change if flounder catch were measured in pounds and price measured in cents per pound?

2-2d Marshall's Trap

In Chapter 1, we described how the nineteenth century English economist Alfred Marshall introduced endless difficulties for economics students by choosing to graph supply and demand curves by putting the independent variable (price) on the vertical axis. As we shall see, Marshall had good reasons for doing this, and his method of graphing has been used ever since his time. When interpreting the "slope" of a relationship, however, it is especially important to keep this change in mind.

As an example, consider the demand equation shown in Equation 2.7 ($Q = 12 - 0.2P$). This equation is written, as it should be, with quantity demanded (the dependent variable) as a function of price (the independent variable). Again, this stresses that prices are quoted by the marketplace to people and they choose how much to consume at each price. Unfortunately, when Marshall came to graph this relationship, he put the dependent variable (Q) on the horizontal axis and the independent variable (P) on the vertical axis. The "slope" of this equation (as we usually think about such things) is not 0.2. Rather, to get the correct slope we must put this equation into the form we usually employ by solving for the variable we wish to put on the vertical axis (P). This is quite easy to do using simple algebra:

$$\begin{aligned} Q &= 12 - 0.2P \text{ or} \\ 0.2P &= 12 - Q \text{ or} \\ P &= 60 - 5Q \end{aligned} \qquad (2.10)$$

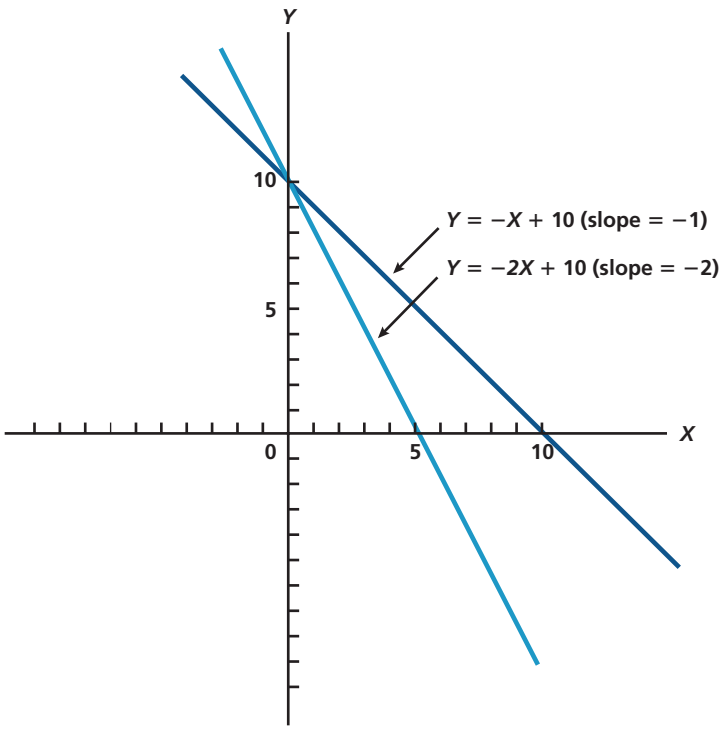
This equation says precisely the same thing as out original one did. For example, if $Q = 8$, $P = 20$, just as before. The equation also has an economic meaning. It says that if people consume eight oranges per week, they value the last orange consumed at \$0.20. But this is not the way we usually think about demand—instead, we usually prefer to have market price being the cause of quantity consumed. There is no problem in thinking about demand in this way (as we should), but the concept of "slope" is now rather confusing. Clearly the slope in Equation 2.10 is -5 if we graph this equation in the normal way. This is the reciprocal of the original effect of price on quantity (which was -0.2 in Equation 2.7). You must be careful therefore when discussing the "slope" of a demand curve since that slope as usually drawn does not reflect the effect of price on quantity. That is, it does not represent what we are usually interested in, which is whether price affects quantity demanded by a lot or a little. Similarly, notions of what it means for a curve to be "steep" or "flat" must be adapted to take this into account. In our presentation we will generally avoid the word "slope" when referring to demand or supply equations. Instead we will use terminology such as "the effect of price on quantity demanded" or "the effect of price on quantity supplied" and will often include an equation to make clear what we are talking about.

2-2e Changes in Slope

Quite often in this text we are interested in changing the parameters (that is, a and b) of a linear function. We can do this in two ways: We can change the *Y*-intercept, or we can change the slope. **Figure 2.2** shows the graph of the function

$$Y = -X + 10 \qquad (2.11)$$

Figure 2.2 Changes in the Slope of a Linear Function



When the slope of a linear function is changed but the *Y*-intercept remains fixed, the graph of the function rotates about the *Y*-intercept.

This linear function has a slope of -1 and a Y-intercept of $Y = 10$. Figure 2.2 also shows the function

$$Y = -2X + 10. \tag{2.12}$$

We have doubled the slope of the previous equation from -1 to -2 and kept the Y-intercept at $Y = 10$. This causes the graph of the function to become steeper and to rotate about the Y-intercept. In general, a change in the slope of a function will cause this kind of rotation without changing the value of its Y-intercept. Since a linear function takes on the value of its Y-intercept when $X = 0$, changing the slope will not change the value of the function at this point.

Changes in Intercept **Figure 2.3** also shows a graph of the function $Y = -X + 10$. It shows the effect of changes in the constant term, that is, the Y-intercept only, while the slope stays at -1. The figure also shows the graphs of

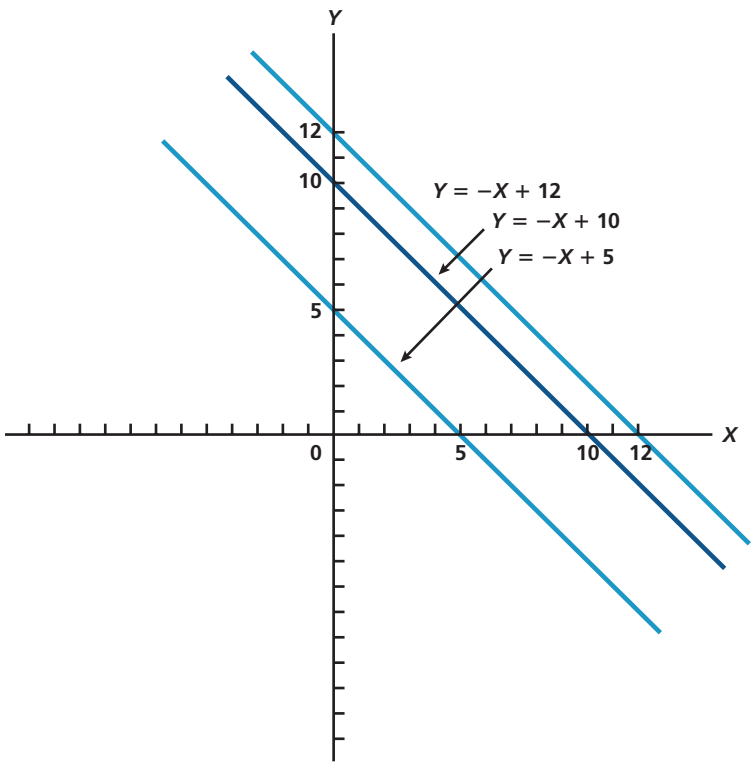
$$Y = -X + 12 \tag{2.13}$$

and

$$Y = -X + 5. \tag{2.14}$$

All three lines are parallel; they have the same slope. Changing the Y-intercept only makes the line shift up and down. Its slope does not change. Of course, changes in the Y-intercepts also cause the X-intercepts to change, and you can see these new intercepts.

Figure 2.3 Changes in the *Y*-Intercept of a Linear Function



When the Y-intercept of a function is changed, the graph of the function shifts up or down and is parallel to the other graphs.

MICRO QUIZ 2.2

In Figure 2.2, the *X*-intercept changes from 10 to 5 as the slope of the graph changes from −1 to −2. Explain:

1. What would happen to the *X*-intercept in the figure if the slope changed to −5/6?
2. What do you learn by comparing the graphs in Figure 2.2 to those in Figure 2.3?

In many places in this book, we show how economic changes can be represented by changes in slopes or in intercepts. Although the economic context varies, the mathematical form of these changes is of the general type shown here. **Application 2.1: How Does Zillow.com Do It?** employs these concepts to illustrate one way in which linear functions can be used to value houses.

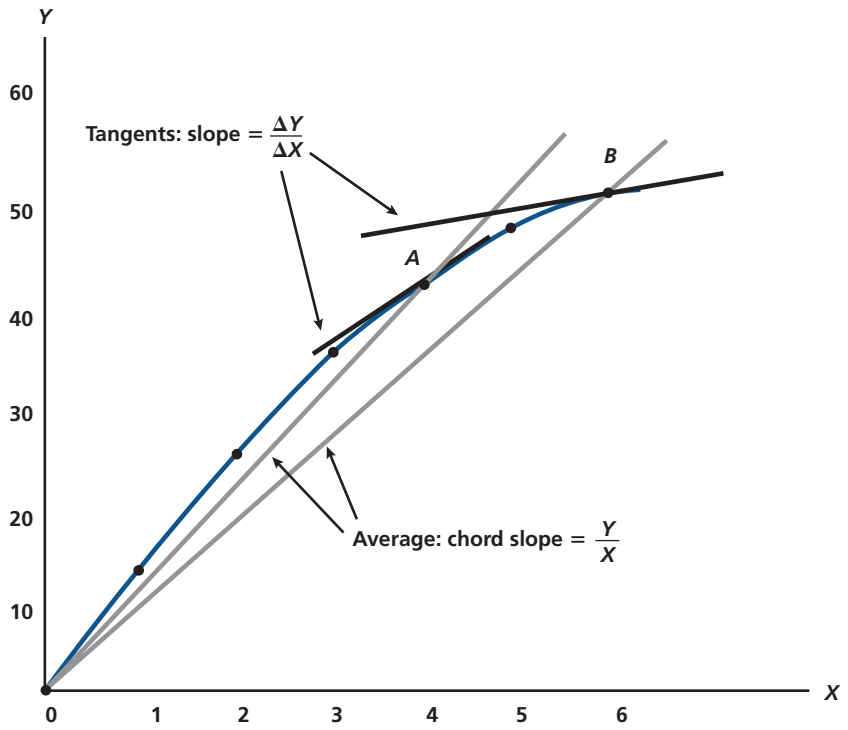
2-2f Nonlinear Functions

Graphing nonlinear functions is also straightforward. **Figure 2.4** shows a graph of

$$Y = -X^2 + 15X, \tag{2.15}$$

for relatively small, positive values of X. Heavy dots are used to indicate the specific values identified in Table 2.1, though, again, the function is defined for all values of *X*. The general concave shape of the graph in the figure reflects the nonlinear nature of this function.

Figure 2.4 Graph of the Quadratic Function $Y = -X^2 + 15X$



The quadratic equation $Y = -X^2 + 15X$ has a concave graph—the slopes of the tangents to the curve diminish as *X* increases. This shape reflects the economic principle of diminishing marginal returns. The slope of a chord from the function to the origin shows the ratio *Y*/*X*.

APPLICATION 2.1

How Does Zillow.com Do It?

The website Zillow.com (founded in 2006) provides estimated prices for practically every residential home in the United States. Because this amounts to more than 70 million homes, there is no way that the company can study the details of each house as a traditional real estate appraiser might. Instead, the company uses public data on homes that recently sold together with statistical techniques to estimate a relationship between the price of a house (P) and those characteristics of a house that can be obtained from public sources (such as the number of square feet, X).

A Simple Example

For example, Zillow might determine that houses in a particular area obey the relationship:

$$P = \$50{,}000 + \$150X. \quad (1)$$

This equation says that a house in this location costs $50,000 (for the lot, say) plus $150 for each square foot. So, a 2,000 square foot house would be worth $350,000, and a 3,000 square foot house would be worth $500,000. **Figure 1** shows this linear relationship. Using this relationship, Zillow can predict a value for every house in its database.

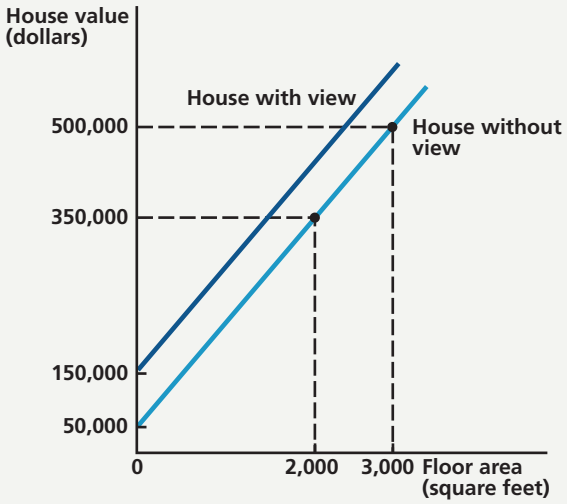
Location, Location, Location

One factor that Zillow must pay close attention to is the location of the houses it is pricing. As any real estate agent will tell you, location is often all that matters in a home price. Hence, it would not be appropriate to use a relationship such as Equation 1 for the entire United States or even for a fairly large city. Instead, the firm must narrow its focus on localities where the square foot value of a house might reasonably be expected to be constant. In especially desirable locations, houses might sell for $500 to $1,000 per square foot or more, and lots would cost much more than $50,000.

What Zillow Can't See

A second problem with the Zillow estimates is that actual house prices may depend on factors about which Zillow has no information. For example, real estate databases may have no information about whether a house has a nice view or not. If having a view would raise a typical lot price by $100,000, for example, the relationship for houses with views should be the one shown by the upper line in Figure 1. Zillow would systematically underestimate the values of such houses.

Figure 1 **Relationship between the Floor Area of a House and Its Market Value**



Using data on recent house sales, Zillow.com can calculate a relationship between floor area (X, measured in square feet) and market value (P). The entire relationship shifts upward by $100,000 if a house has a nice view.

How Good Are Zillow Estimates?

Zillow itself conducts regular analysis to determine whether their estimates are close to prices actually realized in the market. The company finds that their estimates are reasonably close, though their accuracy varies by city. Other independent researchers reach similar conclusions. There is also some evidence that Zillow estimates may affect the prices at which houses sell.[1]

TO THINK ABOUT

1. Figure 1 has the same slope for houses with and without a view. Can you think of any reason why the slopes of these two lines might be different?
2. Zillow's methods are also applied to making house price estimates on which to base real estate taxes. How might taxpayers react to using such methods to determine their taxes?

[1]See Yung Suk Lee and Yuya Saski, "Information in the Technology Market," *Information Economics and Policy* (September 2018): 1–7.

2-2g The Slope of a Nonlinear Function

Because the graph of a nonlinear function is, by definition, not a straight line, it does not have the same slope at every point. Instead, the slope of a nonlinear function at *a particular point* is defined to be the slope of the straight line that is tangent to the function at that point. For example, the slope of the function shown in Figure 2.4 at point *B* is the slope of the tangent line illustrated at that point. As is clear from the figure, in this particular case, the slope of this function gets smaller as *X* increases. This graphical interpretation of "diminishing returns" to increasing *X* is simply a visual illustration of the fact already pointed out in our previous discussion.

2-2h Marginal and Average Effects

marginal effect
The change in *Y* brought about by a one unit change in *X* at a particular value of *X*. (Also the slope of the function.)

average effect
The ratio of *Y* to *X* at a particular value of *X*. (Also the slope of the ray from the origin to the function.)

Economists are often interested in the size of the effect that *X* has on *Y*. There are two different ways of making this concept precise. The most usual is to look at the **marginal effect**—that is, how does a small change in *X* change *Y*? For this type of effect, the focus is on $\Delta Y/\Delta X$, the slope of the function. For the linear equations this effect is constant—in economic terms, the marginal effect of *X* on *Y* is constant for all values of *X*. For the nonlinear equation graphed in Figure 2.4, this marginal effect diminishes as *X* gets larger. Diminishing returns and diminishing marginal effects amount to the same thing. Of course, if a nonlinear function were convex, slopes and the marginal effect of *X* would increase as *X* increased.

Sometimes economists speak of the **average effect** of *X* on *Y*. By this, they simply mean the ratio *Y*/*X*. For example, as shown in Chapter 7, the average productivity of labor in, say, automobile production is measured as the ratio of total auto production (say, 10 million cars per year) to total labor employed (say, 250,000 workers). Hence, average productivity is 40 (= 10,000,000 ÷ 250,000) cars per year per worker.

Showing average values on a graph is more complex than showing marginal values (slopes). To do so, we take the point on the graph that is of interest (say, point *A* in Figure 2.4 whose coordinates are $X = 4$, $Y = 44$) and draw the chord *OA*. The slope of *OA* is then $Y/X = 44/4 = 11$—the average effect we seek to measure. By comparing the slope of *OA* to that of *OB* ($= 54/6 = 9$), it is easy to see that the average effect of *X* on *Y* also declines as *X* increases. This is another reflection of the diminishing returns in this function. In later chapters, we show the relationship between marginal and average effects in many different contexts. **Application 2.2: Can a "Flat" Tax Be Progressive?** shows how the concepts arise in disputes about revising the U.S. personal income tax.

MICRO QUIZ 2.3

Suppose that the relationship between grapes harvested per hour (*G*, measured in pounds) and the number of workers hired (*L*, measured in worker hours) is given by $G = 100 + 20L$:

1. How many additional grapes are harvested by the 10th worker? The 20th worker? The 50th worker?
2. What is the average productivity when 10 workers are hired? When 20 workers are hired? When 50 workers are hired?

2-2i Calculus and Marginalism

Although this book does not require that you know calculus, it should be clear that many of the concepts that we cover were originally discovered using that branch of mathematics. Specifically, many economic concepts are based on looking at the effect of a small (marginal) change in a variable *X* on some other variable *Y*. You should be familiar with some of these concepts (such as marginal cost, marginal revenue, or marginal productivity) from your introductory economics course. Calculus provides a way of making the definitions for these ideas more precise.