CHARLES I. JONES

Fifth Edition

Macroeconomics

MACROECONOMICS

Fifth Edition

Charles I. Jones

Stanford University, Graduate School of Business

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To Terry; for Audrey and Charlie

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BRIEF CONTENTS

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PART 4 APPLICATIONS AND MICROFOUNDATIONS

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PREFACE TO THE FIFTH EDITION

The macroeconomic events of the last twelve years are truly breathtaking—a once-in-a-lifetime (we hope) occurrence. While the basics of how economists understand the macroeconomy remain solid, the global financial crisis and the Great Recession took us into waters that, if not uncharted, at least had not been visited in more than half a century. The recovery of the U.S., European, and world economies from these shocks has been remarkably subdued. And, perhaps most troubling of all, the productivity growth that underlies long-run economic performance has been surprisingly slow for more than a decade.

It is a fascinating time to study macroeconomics, and I look forward to sharing facts about the macroeconomy with you and to discussing the Nobel-caliber ideas that help us understand them.

This new edition continues the tradition established in previous versions: providing up-to-date, modern analysis of both current events and classic issues in macroeconomics.

Key new additions in the fifth edition include

- A case study in Chapter 6, "On the Possibility of Progress," discussing the 2018 Nobel Prize to William Nordhaus and Paul Romer, which highlights a stunning decline in the real price of industrial commodities during the 20th century despite the enormous increase in demand, and the implications this has for growth in a world of finite resources;
- A case study in Chapter 6 on "Is Economic Growth Slowing Down," which highlights the new productivity slowdown that started around 2003, as well as a parallel case study at the end of Chapter 20 that notes the large declines in total factor productivity in several European countries over this same period, one of the fundamental problems facing the global economy;
- A section in Chapter 7 on "Economic Growth and Income Inequality" that discusses the Distributional National Accounts approach of Thomas Piketty, Emmanuel Saez, and Gabriel Zucman, showing one of their fascinating graphs of economic growth by income percentile for 1946–1980 and for 1980–2014;
- A worked example of a TFP shock in the AS/AD framework in Chapter 13, which helps to connect the long-run and short-run models and illustrates how it is possible for the economy to grow rapidly in the short-run without any inflationary pressures;
- A section in Chapter 14 on "How Large is the Output Gap" showing that the decline in the output gap since 2007 has occurred in large part because of a slowdown in potential GDP rather than because of a rapid recovery of the economy;
- A case study in Chapter 15 on "HANK Models" highlighting recent research on heterogeneous agent New Keynesian models that incorporates inequality into a frontier business cycle framework; and
- Updates to data, exercises, and cases. Exercises in every chapter ask students to obtain and analyze up-to-date data, typically from the Federal Reserve's FRED database.

This fifth edition also incorporates many new case studies and exercises, extensive updates to tables and figures to reflect the most current data, and improvements on nearly every page in the text.

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Innovations

(This section will make the most sense to instructors and those students with some familiarity with macroeconomics. Students new to the subject may skip to the Guided Tour.)

Most other books for teaching intermediate macroeconomics were first written more than twenty-five years ago. Our understanding of the macroeconomy has improved substantially since then. This book provides an accessible and yet modern treatment. Its order and structure will feel familiar to instructors, but the execution, examples, and pedagogy have been updated to incorporate the best that macroeconomics instruction has to offer.

What's special about this book? Innovations occur throughout, but the key ones are described below.

Two Chapters on the Great Recession

The global financial crisis and the Great Recession that followed are obviously the most important macroeconomic events in decades. While these events are discussed throughout in sections devoted to the short run, two chapters explicitly focus on recent events. Chapter 10 (The Great Recession: A First Look) immediately follows the first introductory chapter on the short run, exposing students to the facts of the last several years and to critical concepts like leverage, balance sheets, and securitization. Chapter 14 (The Great Recession and the Short-Run Model), the last chapter of the short-run section, provides a detailed application of the short-run model to recent events, explaining in the process the unconventional aspects of monetary and fiscal policy that featured prominently in the government's response to the crisis.

Rich Treatment of Economic Growth

Economic growth is the first major topic explored in the book. After an overview chapter that describes the facts and some tools, Chapter 4 presents a (static) model based on a Cobb-Douglas production function. Students learn what a model is with this simple structure and see it applied to understanding the 50-fold differences in the per capita GDP observed across countries. Chapter 5 presents the Solow model but with no technological change or population growth, which simplifies the presentation. Students learn Robert Solow's insight that capital accumulation cannot serve as the engine for long-run economic growth.

Chapter 6 offers something absent in most other intermediate macro books: a thorough exposition of the economics of ideas and Paul Romer's insight that the discovery of new ideas can drive long-run growth.

The approach taken in this book is to explain the macroeconomics of the long run before turning to the short run. It is much easier to understand fluctuations in macroeconomic aggregates when one understands how those aggregates behave in normal times.

Familiar Yet Updated Short-Run Model

The modern version of the short-run AS/AD model is the crowning achievement of the short-run section. By *modern,* I mean several things. First and foremost, the AS/AD graph is drawn with inflation on the vertical axis rather than the price level—perfect for teaching students about the threat of deflation that has reared its head following the Great Recession, the Volcker disinflation, and the Great Inflation of the 1970s. All the short-run analysis, including explicit dynamics, can be performed in this single graph.

Another innovation in getting to the AS/AD framework is a focus on interest rates and the absence of an LM curve. Chapter 12 explains how the central bank sets the interest rate. A primer in Chapter 12 helps students to bridge the gap between the old IS-LM model and the new IS-MP model, which is rapidly displacing the IS-LM framework as a guide to the short run. Chapter 13 introduces a simple version of John Taylor's monetary policy rule to get the AD curve.

A final innovation in the short-run model is that it features an open economy from the start: business cycles in the rest of the world are one source of shocks to the home economy. To keep things simple, however, the initial short-run model does not include exchange rates.

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DSGE Models: The Frontier of Business Cycle Research

A well-known tension exists between macroeconomics that is taught in most intermediate courses and one that is practiced by policymakers, central bankers, and researchers. Traditionally, it has been thought that the more difficult mathematics used by practitioners necessitated this divide. However, in Chapter 15, I've found a way to bridge some of this gap by giving students insights into the much richer DSGE models typically used to study macroeconomic fluctuations. Two innovations make this possible. First, I present the "impact effect" of shocks in a DSGE framework by studying the labor market. Second, I introduce impulse response functions graphically and then show estimates of these dynamic effects using state-of-the-art methods, in particular, the estimates of the famous Smets-Wouters model.

Interplay between Models and Data

A tight connection between models and data is a feature of modern macroeconomics, and this connection pervades the book. Many exercises ask students to work with real data, some of which are available in the book, some by using the online resources, and some from a data tool I've put together called Country Snapshots, a pdf file available at www.stanford.edu/~chadj/snapshots.html that contains a page of graphs for each country in the world. The data underlying the graphs can be obtained as a spreadsheet simply by clicking on a link at the top of each page. Finally, exercises in every chapter ask students to obtain and analyze up-to-date data, typically from the Federal Reserve's FRED database.

Worked Exercises at the End of Each Chapter

One of the most effective ways to learn is by working through problems. So a carefully chosen collection of exercises is included at the end of each chapter; from among these, one or two are selected and worked out in detail. Students are encouraged to attempt these exercises on their own before turning to the full solution.

More Emphasis on the World Economy

Relative to many intermediate macro books, this text features more emphasis on the world economy in three ways. First, the long-run growth chapters are a main emphasis in the book, and these inherently involve international comparisons. Second, the short-run model features an open economy (albeit without exchange rates) from the very beginning. Finally, the book includes two international chapters in Part 4: Chapter 20 is the standard international finance chapter and Chapter 19 is entirely devoted to international trade.

Better Applications and Microfoundations

Part 4 includes five chapters of applications and microfoundations. The basic structure of this part is traditional. There is a chapter for each component of the national income identity: consumption, investment, the government, and the international economy. However, the material inside is modern and novel. For example, the consumption chapter (Chapter 16) centers around the famous Euler equation that lies at the heart of today's macroeconomics. The investment chapter (Chapter 17) highlights the strong parallels between investment in physical capital and financial investments in the stock market using the "arbitrage equation" approach. The chapter on the government and the macroeconomy (Chapter 18) includes an application to what I call "The Fiscal Problem of the Twenty-First Century"—how to finance the growing expenditures on health care. And, as mentioned above, the international section features two chapters, one on international trade and one on international finance. These chapters are not essential and instructors may wish to skip one or both of them depending on time constraints.

A Guided Tour

The book consists of three main parts: the Long Run, the Short Run, and the Applications and Microfoundations. Surrounding these parts are an introductory section (Part 1: Preliminaries) and a concluding chapter (Chapter 21: Parting Thoughts).

This organization reflects an increasing appreciation of the importance of long-run macroeconomics in the profession. In addition, it makes sense from a pedagogical standpoint to put the long run first. This way students understand what it is that the economy fluctuates *around* when they get to the short-run chapters.

A brief overview of each part follows.

Part 1: Preliminaries

We begin with an overview of macroeconomics: what kind of questions macroeconomics addresses and how it goes about its business. A second chapter discusses the data of macroeconomics in more detail, with a focus on national income accounting.

Part 2: The Long Run

The second part of the book (Chapters 3 through 8) considers the macroeconomy in the long run. Chapter 3 presents an overview of the facts and tools economists use to study long-run macroeconomics, with special attention to economic growth. Chapter 4 introduces the Cobb-Douglas production function as a way to understand the enormous differences in standards of living seen across countries. The interplay between theory and data that is central to macroeconomics makes a starring appearance in this chapter.

Chapter 5 considers the Solow model of economic growth, one of the workhorse models of macroeconomics. Students study the extent to which the Solow model can help them understand (a) why some countries are rich while others are poor, and (b) why people in the advanced countries of the world are so much richer today than they were a hundred years ago. Surprisingly, they will see that the model does not do a good job of explaining long-run economic growth.

For this explanation, Chapter 6 turns to the Romer model, which emphasizes the role played by the discovery of new ideas. Thinking about the economics of ideas may lead to profound changes in the way students understand many areas of economics.

Chapter 7 studies the most important market in modern economies: the labor market. Students learn about the determination of the unemployment rate in the long run and discover that they are already, in some sense, millionaires.

Chapter 8 concludes the long-run portion of the book by considering inflation. The quantity theory of money provides a long-run theory of inflation, which, according to Milton Friedman, occurs because of "too much money chasing too few goods."

Part 3: The Short Run

Part 3 is devoted to the branch of macroeconomics that students are probably most familiar with: the study of booms, recessions, and the rise and fall of inflation in the short run. The five chapters in this part form a tight unit that develops the short-run model and applies it to current events.

Chapter 9 provides an overview of the macroeconomy in the short run, summarizing the key facts and providing an introduction to the short-run model that explains these facts. Chapter 10 provides a "first look" at the financial crisis and the Great Recession, carefully laying out the facts of how the crisis evolved and introducing the important concepts of "leverage" and "balance sheets."

The next three chapters then develop the short-run model. Chapter 11 introduces the IS curve, a key building block of the short-run model. The IS curve reveals that a fundamental determinant of output in the short run is the real interest rate. Chapter 12 shows how the central bank in an economy can move the interest rate to keep the economy close to full employment. The chapter also provides the link between the real economy and inflation, called the Phillips curve.

Chapter 13 looks at the short-run model in an aggregate supply/aggregate demand (AS/AD) framework. This framework allows the complete dynamics of the economy in the short run to be studied in a single graph. Using this framework, the chapter emphasizes the key roles played by expectations, credibility, and time consistency in modern macroeconomic policymaking.

Chapter 14 uses the short-run model to help students understand the financial crisis and the Great Recession and discusses the macroeconomic prospects going forward. Chapter 15 presents the DSGE models of macroeconomic fluctuations to take students closer to the frontier of advanced macroeconomics, as discussed earlier in the preface.

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Part 4: Applications and Microfoundations

Part 4 includes five chapters of applications and microfoundations. While it may be unapparent to students new to macroeconomics, the organization of these chapters follows the "national income identity," a concept discussed early in the book. These chapters include a number of important topics. Chapter 16 studies how individuals make their lifetime consumption plans. Chapter 17 considers the pricing of financial assets, such as stocks and houses, in the context of a broader chapter on investment.

Chapter 18 studies the role played by the government in the macroeconomy, including the role of budget deficits and the government's budget constraint. The chapter also considers a key problem that governments around the world will face in coming decades: how to finance the enormous increases in health spending that have occurred for the last fifty years and that seem likely to continue.

Both the long-run and the short-run parts of the book place the study of macroeconomics in an international context. The short-run model includes open economy forces from the very beginning, and the final two applications of the book go even farther in this direction.

Chapter 19 focuses on international trade. Why do countries trade? Are trade deficits good or bad? How have globalization and outsourcing affected the macroeconomy? Chapter 20 studies international finance, including the determination of the exchange rate and the Euro-area financial crisis.

Parting Thoughts

Chapter 21 concludes our study of macroeconomics. The chapter summarizes the important lessons learned in the book, and we offer a brief guide to the key questions that remain less than well understood.

Learning Aids

- *Overview:* The opening page of each chapter provides an overview of the main points that will be covered.
- *Boxes around key equations:* Key equations are boxed to highlight their importance.
- *Graphs and tables:* The main point of each figure is summarized in an accompanying marginal text box. Tables are used to summarize the key equations of a model.
- *Guide to notation:* The inside back cover contains a list of symbols, their meaning, and the chapter in which they first appear.
- *Case studies:* Case studies highlight items of interest in each chapter.
- *Chapter summaries:* The main points of each chapter are presented in list form for easy reference and review.
- *Key concepts:* Important economic concepts are set in boldface type where they first appear, and listed at the end of each chapter for review.
- *Review questions:* Review questions allow students to test their understanding of what they have learned.
- *Exercises:* Carefully chosen exercises reinforce the material from the chapter and are intended to be used for homework assignments. These exercises include many different kinds of problems. Some require graphical solutions while others use numbers. Some ask to look for economic data online and interpret it in a particular way. Others ask to write a position paper for a presidential candidate or to pretend to be advising the chair of the Federal Reserve.
- *Worked exercises:* From the exercises, one or two are selected and worked out in detail. These exercises are indicated by an asterisk (*) in the margin. Students will find these answers most helpful if they consult them only after having tried to work through each exercise on their own.
- *Glossary:* An extensive glossary at the end of the book defines terms and provides page numbers where more information can be found.

Country Snapshots

www.stanford.edu/~chadj/snapshots.html

To accompany the book, I have put together a resource containing data from more than 200 countries. Each page of the file snapshots.pdf corresponds to a country and provides graphs of that

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country's key macroeconomics statistics. Moreover, the data underlying the graphs can be obtained as a spreadsheet simply by selecting a link at the top of each page. Whenever students read about a particular country in the newspaper or in this book, detailed macroeconomics statistics are only a click away.

Available Formats for Students

The text is available in a number of student formats, including paperback and loose leaf, three-hole-punch versions at reduced costs. In addition, the Norton ebook provides students and instructors with an enhanced reading experience at a fraction of the cost of a print textbook.

Instructor Resources

Resources are available for download either from this book's catalog page at wwnorton.com or at digital.wwnorton.com/macro5.

Norton Coursepacks

Maria Apostolova-Mihaylova, *Centre College*

Available free to adopters and their students, the Norton Coursepack for the Fifth Edition can be downloaded, and it works directly in Blackboard, D2L, Moodle, and Canvas LMS systems. The coursepack includes easy to use materials, including:

- Flashcards
- Chapter Summaries
- Review Quizzes
- Review Discussion Questions
- Country Studies Snapshot Documents

Lecture PowerPoints

Aaron Meininger, *University of California, Santa Cruz*, with contributions from Emily C. Marshall, *Dickinson College*

The PowerPoint slides for this edition provide a lecture-ready resource for the instructor. Concise and visually rich, these slides help guide students through concepts in each chapter, especially those most misunderstood. Integrated teaching tips are designed to provide additional instructor support.

Instructor's Manual

Anthony Laramie, *Merrimack College*, with contributions from Pavel Kapinos, *Carleton College*, and Kenneth Kuttner, *Williams College*

This valuable instructor's resource includes an overview, a suggested approach to the chapter lecture, expanded case studies, additional case studies, and complete answers to the end-of-chapter problems for each chapter. New to the fifth edition, each Instructor's Manual chapter includes an additional international case.

Test Bank

Robert Sonora, *University of Montana*, with contributions from Todd Knoop, *Cornell College*, and Dietrich Vollrath, *University of Houston*

Available for download in rich-text and ExamView® formats, the updated test bank includes carefully constructed true/false, multiple-choice, and short answer/numerical questions.

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Photo credit: Theresa Tao

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MACROECONOMICS

Fifth Edition

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PART 1

PRELIMINARIES

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CHAPTER 1

INTRODUCTION TO MACROECONOMICS

OVERVIEW

In this chapter, we learn

- what macroeconomics is and consider some macroeconomic questions: What determines the wealth of nations? How do we understand the recent global financial crisis and the Great Recession that resulted? What caused the Great Inflation of the 1970s, and why has inflation been so much lower in recent decades?
- how macroeconomics uses models to answer such questions.
- the book's basic three-part structure: the long run, the short run, and issues for the future.

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> We shall not cease from exploration
> And the end of all our exploring
> Will be to arrive where we started
> And know the place for the first time.
>
> –T. S. ELIOT, *FOUR QUARTETS*

1.1 What Is Macroeconomics?

Macroeconomics is the study of collections of people and firms and how their interactions through markets determine the overall economic activity in a country or region. The other main area of economics, microeconomics, focuses on the study of individual people, firms, or markets. These two branches, however, are much closer than their standard separation into different courses would lead you to believe. Just as cosmologists who study black holes draw on concepts both large (general relativity) and small (quantum mechanics), macroeconomists look to individual behavior—which economists refer to as "microfoundations"—in creating their theories of aggregate economic activity. In this sense, macroeconomics is just one large black hole!

One good way to get a sense of macroeconomics is to consider the questions it deals with, some of the most important in all of economics:

- Why is the typical American today more than 10 times richer than the typical American a century ago?
- Why is the American of today 50 times richer than the typical Ethiopian? Some of the data that motivate these first two questions are shown in Figure 1.1, a graph of GDP per person since 1870 for six countries. (GDP stands for gross domestic product, an overall measure of income that we will study in more detail in Chapter 2.)
- How do we understand the global financial crisis, the Great Recession, and the European debt crisis of recent years? As shown in Figure 1.2, this latest recession has seen the largest sustained decline in employment in the United States in many decades. More generally, what causes recessions and booms in the overall economy?
- What determines the rate of inflation; that is, what determines how rapidly prices are increasing in an economy? Why was inflation so high in much of the world in the 1970s, and why has it fallen so dramatically in many of the richest countries since the early 1980s? These facts are shown in Figure 1.3. Why do some countries experience hyperinflation, where the price level can explode and rise by a thousandfold or more, essentially rendering the currency worthless?
- Why has the unemployment rate—the fraction of the labor force that would like to work but does not currently have a job—been nearly twice as high in Europe as in the United States the past two decades? Consider

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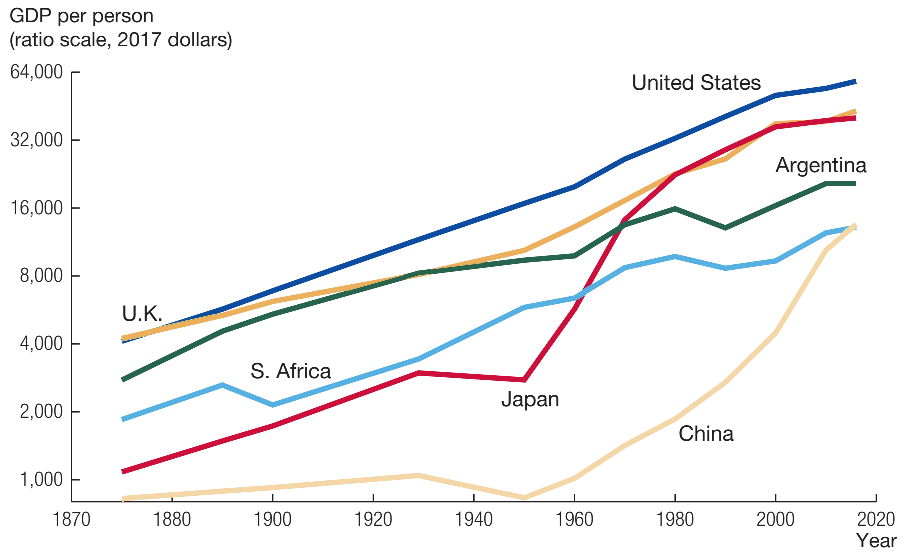
As we will see in Chapter 2, per capita GDP is a useful, though imperfect, measure of economic welfare. Notice both the large differences across countries as well as the increases in per capita GDP over time.

FIGURE 1.1

GDP per Person in Six Countries

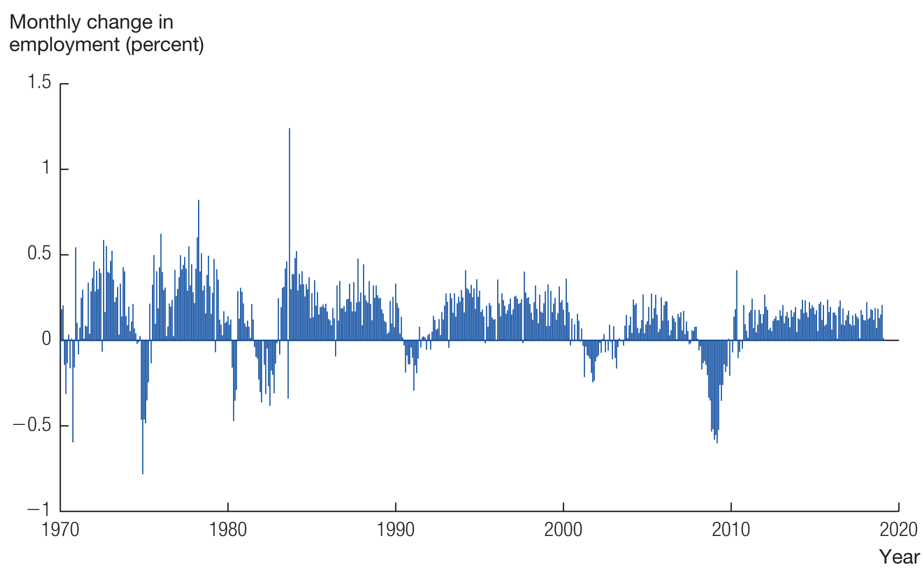


Source: The Maddison-Project, www.ggdc.net/maddison/.

Employment typically rises each month. But the 2007–2009 recession led to the largest sustained decline in employment in many decades.

FIGURE 1.2

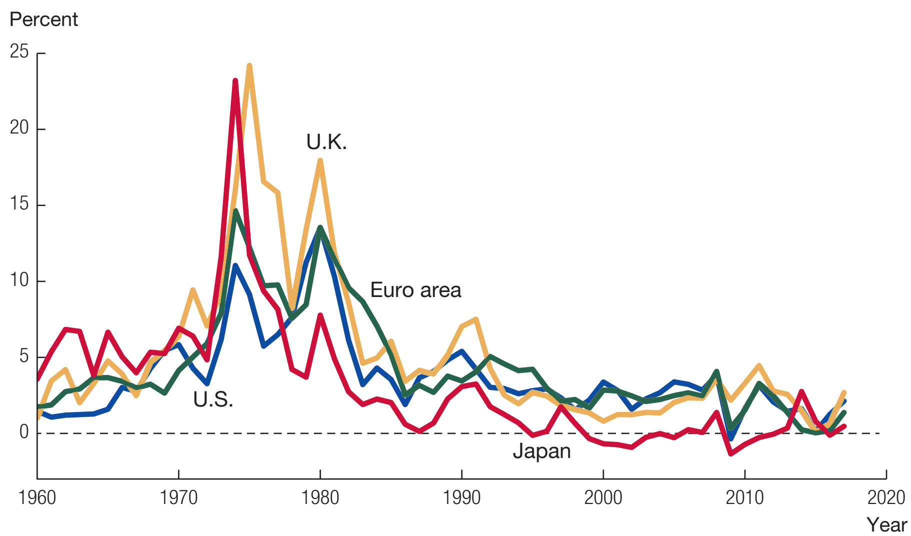
Changes in U.S. Employment



Source: Federal Reserve Economic Data (FRED), courtesy of the Federal Reserve Bank of St. Louis.

FIGURE 1.3

Inflation Rates in Certain Rich Countries



Source: FRED. The inflation rate measures the percentage change in consumer prices.

In many rich countries, inflation was high in the 1970s and has been low since the late 1980s. As we will see in Chapter 8, this fact generally holds across many countries in the world.

the evidence shown in Figure 1.4. This experience is particularly surprising in light of the fact that unemployment rates in Europe were much lower than in the United States up until about 1980. Why has unemployment in Japan been so low for most of this period?

- What role does the government, both the fiscal authority and the monetary authority, play in recessions and booms and in determining the rate of inflation?
- Budget deficits result when the government borrows money to finance its spending. Trade deficits result when one economy borrows from another. Why would an economy run a high budget deficit or a high trade deficit, or both? What are the consequences of these deficits? Figure 1.5 shows the evolution of both deficits in the United States since 1960. Are large deficits a problem?
- What prompted the currency crises in Mexico in the mid-1990s and in many Asian economies at the end of the 1990s? What are the consequences of the recent decision by China to let its currency, the renminbi, appreciate after it was fixed for many years relative to the dollar?
- What role do financial markets like the stock market play in an economy? What is a "bubble," and how can we tell if the stock market or the housing market is in one?

To study questions such as these, macroeconomists construct mathematical models, similar in spirit to the models used in microeconomics. Yet one of the most

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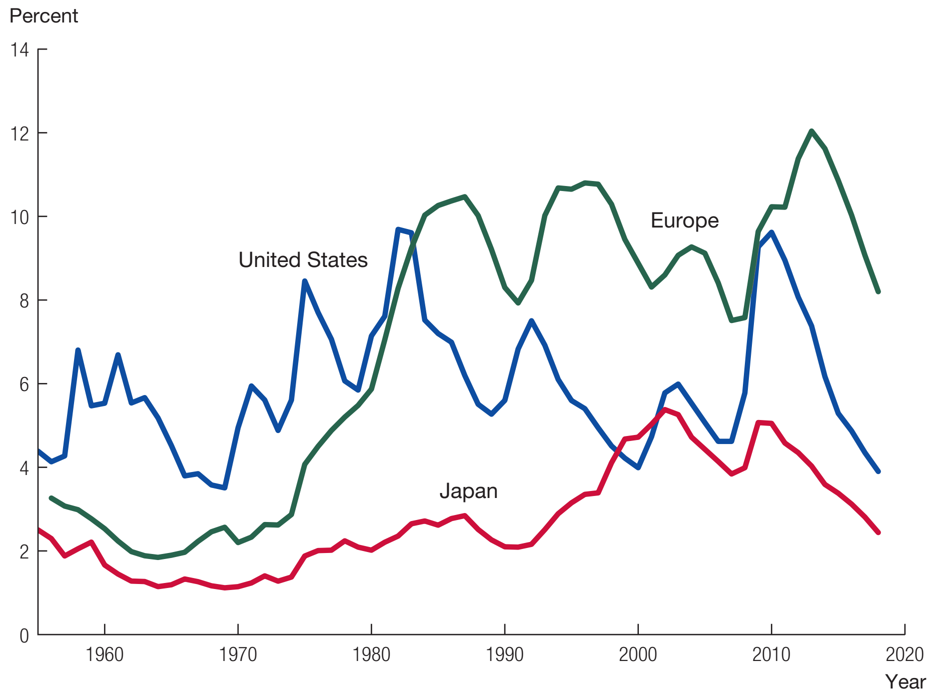
What explains the very different histories of the unemployment rate in the United States, Europe, and Japan?

FIGURE 1.4

The Unemployment Rate in the United States, Europe, Japan

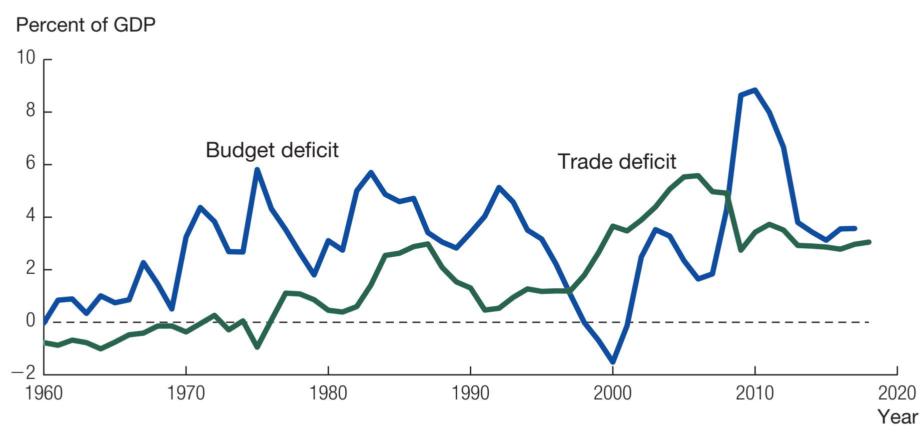


Sources: OECD Main Economic Indicators and the U.S. Bureau of Labor Statistics.

The U.S. budget and trade deficits have been relatively high in recent years.

FIGURE 1.5

Budget and Trade Deficits in the United States



Source: Department of Commerce, Bureau of Economic Analysis.

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exciting features of macroeconomics is the way it combines these models with real-world phenomena—history, politics, and economic policy. This interaction between theory and practice is a key reason students enjoy studying macroeconomics.

1.2 How Macroeconomics Studies Key Questions

The preceding questions all concern the economy taken as a whole. This is obvious in the case of economic growth, but it is true of the other questions as well. For example, we care about budget and trade deficits because they may affect standards of living for the economy in the future. We care about bubbles in financial markets because the collapse of a bubble may send the economy into a recession.

Macroeconomics is also unified in a different way: by the approach it takes to studying these questions. In general, this approach consists of four steps:

1. Document the facts.
2. Develop a model.
3. Compare the predictions of the model with the original facts.
4. Use the model to make other predictions that may eventually be tested.

1. First, we document the key facts related to the question we want to consider. For example, suppose we ask, "Why are people in Europe so much richer today than a century ago?" Our first step is to gather economic *data* to document how rich Europeans are today and how rich they were a hundred years ago. With such data we can make precise, quantitative statements.

2. Next, we develop a model. You are already familiar with one of the most important models in economics, that of supply and demand. Models are extremely useful because they allow us to abstract from the nearly infinite number of forces at play in the real world in order to focus on those that are most relevant. For example, in studying the effect of a minimum wage law, economists will use a supply-and-demand model of the labor market. We act as if there is a single labor market that pays a single wage in a world with no schooling decisions, on-the-job training, or geography. This abstract model is an unrealistic picture of the real world, but it nevertheless allows us to learn important lessons about the effect of introducing minimum wage legislation.

All models in economics share an important general structure, shown in Figure 1.6. Each takes as inputs a set of parameters and exogenous variables: the features of the economy that the model builder gets to pick in advance, features that are outside the model, or given. **Parameter** refers to an input that is generally fixed over time, except when the model builder decides to experiment by changing it. In our labor market model, the level of the minimum wage would be an example of a parameter. **Exogenous variable** ("exo-" means "outside") refers to an input that is allowed to change over time, but in a way that is completely determined ahead of time by the model builder. For example, we might assume the population in the economy grows over time at a constant, exogenous rate, regardless of

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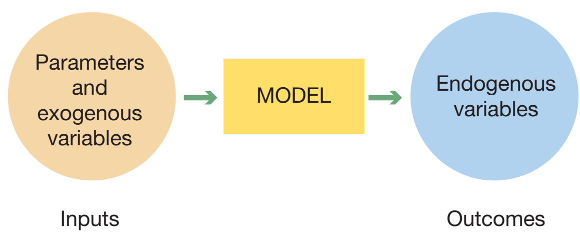
A model takes some inputs, called parameters and exogenous variables, and determines some outcomes, called endogenous variables. For example, a labor market model may take the level of the minimum wage and the number of people in the economy as parameters and determine the wage and the level of employment (the endogenous variables).

FIGURE 1.6

The Structure of Economic Models



what happens in the labor market. Population then would be an example of an exogenous variable.

A model operates on the exogenous variables and parameters in order to generate outcomes, called **endogenous variables** ("endo-" means "within": within, or explained by, the model). For example, in the labor market model, the level of the wage and the level of employment would be endogenous variables (outcomes) determined by supply and demand.

Unlike what you may have seen in an introductory economics class, the models we develop in this book will consist of a set of mathematical equations and a set of unknowns (the endogenous variables). Solving a model is in principle as simple as solving the equations for the values of the unknowns. For example, an equation describing labor supply and an equation describing labor demand constitute the mathematical version of the labor market model. Both equations involve our two endogenous variables, the wage and the level of employment. So we have two equations and two unknowns. Equilibrium in the labor market occurs when labor supply is equal to labor demand at the market wage, and the solution to these equations gives us the equilibrium levels of the wage and employment.

The end of each chapter contains one or two worked exercises to help you learn the material.

At the moment, this is all admittedly very abstract. A worked exercise at the end of this chapter will take you through the labor market example in more detail. Later, in Chapter 4, we will develop our first model in order to understand why some countries are so much richer than others. That example will go a long way toward helping you understand exactly what a model is and why models are useful. You can then build on that knowledge as you work with other models throughout the book.

3. The third step is to consider how well our model helps us understand the facts we began with. A successful model of why some countries are so much richer than others, for example, should predict that countries will have different levels of income. But that is not enough. To be truly successful, the model should also get the *quantitative* predictions right as well; that is, it should not only predict that the United States will be richer than Ethiopia but also give the 50-fold difference that we observe in practice.

4. The fourth and final step is related to the third: using the model to run "experiments." Once we have a model in hand, the model builder is free to change the underlying parameters in order to analyze how this change affects the endogenous

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variables. For example, we might change a tax rate and study the response of investment and standards of living. Or we might consider lowering a short-term nominal interest rate to study the evolution of inflation and unemployment over time. The advantage of having an explicit mathematical model is that it can make quantitative predictions. These predictions can then be compared with real evidence to judge the validity of the model and can be used to analyze particular policy changes.

An important issue that arises is that such "experiments" are very different from the controlled experiments that are the hallmark of much of science. Part of the reason there is often substantial debate over macroeconomic policies in practice is that we do not have access to a "parallel universe machine" in which to study the counterfactual of "what would have happened if we had pursued a different policy."[1]

For example, consider a recent question that has been the subject of much debate: How effective was the $800 billion fiscal stimulus program approved by the U.S. government during the global financial crisis in January 2008? The unemployment rate during the next 2 years rose by substantially more than macroeconomic forecasters had predicted. Was this because the fiscal stimulus implied higher future taxes that made businesses reluctant to hire? Or was it because the macroeconomic shocks of the period were more severe than forecasters realized? Ideally, economists would observe two parallel universes, one in which the fiscal stimulus plan is implemented and another that is identical except that the plan is not implemented. The frequent absence of this kind of evidence makes it remarkably difficult to answer many such policy questions with extreme confidence.

1.3 An Overview of the Book

Figure 1.7, a graph of per capita GDP for the United States, is one of the most famous and intriguing graphs of macroeconomics, and it serves as an organizing device for this book. There are three important features of the graph that parallel the three main sections of the text.

The Long Run

The most impressive feature of the graph is the enormous increase in standards of living over the years. Income per person began at $3,600 in 1870 and rose by more than a factor of 15 to $61,600 in 2018. Why have living standards grown so dramatically in the United States? And why have some regions of the world, like Ethiopia (as we saw earlier), not experienced a similar revolutionary change? These are among the most important questions in macroeconomics. The first part of this book—Chapters 3 through 6—develops the answers that macroeconomics currently offers. More generally, this first section is concerned with economic growth and the determinants of the macroeconomy in **the long run**. Chapter 7 then turns to the labor market in the long run, and Chapter 8 considers the long-run causes of inflation. A solid understanding of the macroeconomics of the long run turns out to be essential to understanding everything else that follows.

[1] The wonderful phrase "parallel universe machine" was used in this context on an NPR *Planet Money* episode called "The Great Stimulus Experiment," August 10, 2010.

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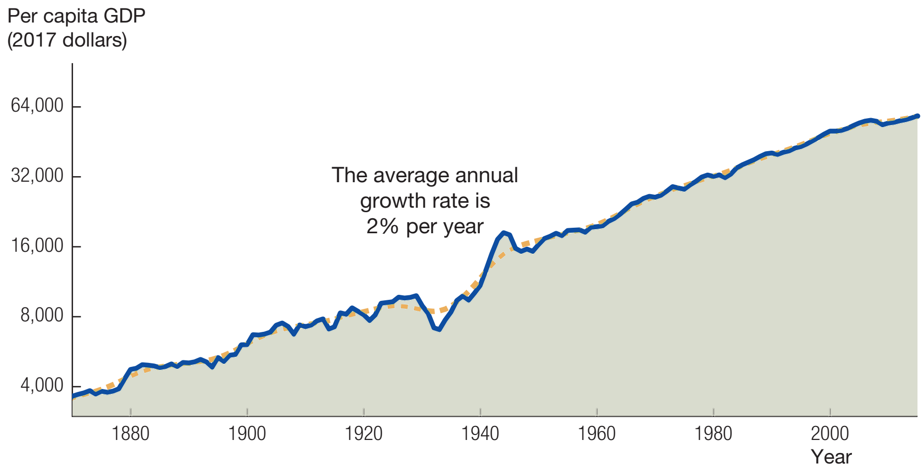
Three features of the graph stand out: (1) the overall upward trend due to economic growth, (2) the short-run fluctuations in economic activity, and (3) the suggested question of what the future holds. These features reflect the structure of the book.

FIGURE 1.7

Per Capita GDP in the United States



Sources: The Maddison-Project, www.ggdc.net/maddison/, and U.S. Department of Commerce, Bureau of Economic Analysis. The blue line shows actual per capita GDP in the United States. The orange line, which is hard to distinguish from the blue line, shows potential output. The difference between actual and potential output is a measure of short-run fluctuations in GDP.

The Short Run

Notice that in Figure 1.7 two lines are plotted: the blue line is actual per capita GDP, or output, while the orange line, a "smoothed" version of the solid line, is called **potential output**. Potential output measures the way per capita GDP would evolve if prices were completely flexible and resources were fully employed. The second important feature of the figure is that actual output deviates from potential output. Other than the Great Depression of the 1930s, these deviations are hard to see, but they are still economically important. For example, in 1982, the U.S. economy suffered one of the largest recessions of the post–World War II era, and actual output was about 5 percent less than potential output. In today's prices, this gap was roughly $1,500 per person, or $6,000 for a typical family of four, so this recession represented a large cost in terms of lost income.

The third part of this book, Chapters 9 through 15, examines the economics underlying these fluctuations in GDP. Actual GDP is sometimes below potential and sometimes above, and the rise and fall of these deviations is traditionally called the "business cycle." In modern macroeconomics, this term is often avoided because it suggests some regularity to the movements—that a boom period is naturally followed by a recessionary period. Instead, most economists today prefer the more neutral "economic fluctuations."

The deviations between actual and potential output usually last only a short time. The second part of this book thus focuses on what is called **the short run**. We seek to understand the forces that lead the economy to fluctuate over time, sometimes producing recessions like the one experienced throughout much of the world starting at the end of 2007.

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By almost any measure, the recent financial crisis and the ensuing economic downturn is exceptional. For example, this was clear at the start of this chapter in the graph of monthly employment changes (Figure 1.2). In recognition of this fact, this book devotes two unique chapters to the macroeconomics of the financial crisis, Chapters 10 and 14. These chapters explain the facts of the crisis, introduce several important concepts like balance sheets and leverage, and use the basic macroeconomics of the short run to shed light on the events surrounding the crisis.

A central topic of short-run macroeconomics that is not conveyed by our organizing graph is the role of inflation. As we will see, economic fluctuations and inflation are connected in an important way: one reason economic activity fluctuates is that the central bank leads the economy into a recession in order to bring down inflation. Chapters 9 through 15 develop a model of how inflation and GDP are jointly determined in the short run.

The fact that the fluctuations in GDP are somewhat difficult to see in Figure 1.7 is itself worthy of note. Even the worst crisis—the Great Depression of the 1930s—painful as it was, proved to be temporary, and the overwhelming fact of twentieth-century macroeconomics was one of sustained economic growth. Over the long term, economic growth swamps economic fluctuations.

Issues for the Future

Finally, the natural question raised by Figure 1.7 concerns the future. We can't help but look at the sustained rise in income and wonder if it will continue. Will the next century see another 10-fold increase in per capita GDP, so that our great-grandchildren will earn an average of $500,000 per year?

This theme of what the future holds—or of macroeconomics beyond economic growth and fluctuations—is one way of thinking about the last section of the book. Chapter 16 explores the microfoundations that underlie the modern understanding of consumption. What determines how much the economy consumes or saves in any given year? Chapter 17 studies investment. One very important type of investment, central to macroeconomics, is investment in physical capital—machine tools, computers, and buildings, for example. We explore how firms determine how much to invest in physical capital. Another key theme of this chapter, though, is that many kinds of investment can be understood in the same way. So this chapter also studies the determinants of financial investment and prices in the stock market.

Chapter 18 discusses the government budget constraint and the size of the current deficit and debt. A key point of this chapter is that major decisions about government spending and taxation, especially regarding health care, will have to be made in the coming decades. Virtually all economists agree that current policies cannot be sustained.

Chapters 19 and 20 explore another key theme related to the future of the macroeconomy: the rise of globalization. The United States is but one (albeit large and important) member of the world economy. Earlier chapters in the book explicitly recognize this fact and explore its implications. For example, the discovery of new ideas in a distant part of the world affects potential output in *every* country, and changes in the demand for U.S. exports can be a source of short-run fluctuations. Here, however, we make globalization a focus.

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Chapter 19 explores the theory of international trade: Why do economies trade with each other, and what are the consequences of this trade? Chapter 20 studies exchange rates and international finance. Both chapters help us think about the effects of globalization on the macroeconomy and the consequences of the high trade deficits seen in recent years in the United States. Finally, in Chapter 21 we look back at the ground we have covered and consider the important questions that remain.

Macroeconomics is a fascinating and intriguing subject. Understanding the answers to the questions it poses offers the possibility of enormous improvements in welfare throughout the world. If we understand the sources of economic growth, perhaps all countries can unleash its powerful engine. If we understand why hyperinflations or depressions occur, perhaps we can prevent them from recurring. Education is the first step to a better future.

CHAPTER REVIEW

SUMMARY

1. Macroeconomics is the study of collections of people and firms and how their interactions through markets determine the overall performance of the economy.
2. Many of the most important questions in economics require macroeconomic analysis: What determines the wealth of nations? How do we understand the recent global financial crisis and the Great Recession that resulted? What caused the Great Inflation of the 1970s, and why has inflation been so much lower for the past decade? What are the consequences of trade deficits and budget deficits?
3. Macroeconomics studies these questions in four steps: document the relevant facts, develop a model, compare the predictions of the model with the facts, use the model to make and test other predictions.
4. A model is a collection of mathematical equations that are used to study a particular economic issue. Models determine the value of endogenous variables, like the price and quantity of computers sold or the rate of economic growth.
5. This book is organized around a key graph, Figure 1.7. The first part focuses on macroeconomics in the long run, the second part deals with the short run, and the third part takes up a number of important topics that will concern us in the future.

KEY CONCEPTS

endogenous variables
exogenous variables
potential output
macroeconomics
parameters
the short run
the long run

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REVIEW QUESTIONS

1. Which questions in macroeconomics interest you the most? Why?
2. Given your current knowledge, what do you think are the answers to these questions?
3. How does macroeconomics study these questions?
4. What are the key ingredients of an economic model, and why are models useful?

EXERCISES

1. **Macroeconomic questions and answers:** Select one of the macroeconomic questions in this chapter. Describe what you think the answer is.
2. **The macroeconomics of your favorite country:** Pick a country that you find interesting, and learn some basic facts about its economy. Summarize these facts in a half-page essay. You may find the following resources to be helpful; feel free to explore others on your own.
   —The *CIA World Factbook:* www.cia.gov/cia/publications/factbook
   —Wikipedia: wikipedia.org
   —The "Country Snapshots" file, snapshots.pdf, which should be available on your course web page or from the web address in the next question.
3. **Country snapshots:** Download the file snapshots.pdf from web.stanford.edu/~chadj/snapshots.html and answer the following. (At the moment, the latest year in the data file is 2017. Over time, this year will advance, so please use the latest year available in the Country Snapshots file whenever the year 2017 appears in questions below.)
   (a) What was the ratio of per capita income in each of the following countries to that in the United States in the year 2017. Ethiopia, Mexico, India, and Japan?
   (b) Which country had the faster average annual growth rate of per capita GDP between 1960 and 2017, Botswana or China?
   (c) Rank these countries in order of population: Bangladesh, Brazil, Indonesia, Nigeria, Russia, the United States.
   (d) Which is larger as a share of GDP in most rich countries, investment or government purchases? What about in most poor countries?
   (e) Exchange rates are reported as units of domestic currency (like the Japanese yen or the British pound) per U.S. dollar. Look at the exchange rate for several countries. Do you detect any overall pattern? Why might that be?
4. **Making graphs (spreadsheet):** Use the snapshots.pdf file, together with its hyperlinks to the underlying spreadsheet data. Use a spreadsheet program of your choice to complete the following.
   (a) Make a plot of per capita GDP (in dollars) for the years 1950 to 2017 for a country of your choice. Label the x-axis "year" and the y-axis "per capita GDP."

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(b) Make a plot of per capita GDP relative to the United States (U.S. = 100) for the years 1950 to 2017 that includes the United States and three other countries of your choice, all on the same graph. Be sure to label the lines on the graph in some informative way so that each line can be associated with its country.

* 5. **The labor market model (I):** Suppose the following equations characterize supply and demand in the labor market model:

$$\begin{aligned} \text{labor supply:} \quad & L^s = 2 \times w + 30 \\ \text{labor demand:} \quad & L^d = 60 - w \end{aligned}$$

Equilibrium occurs at an employment level L^* and a wage w^*, so that the labor market clears. That is, supply is equal to demand: $L^s = L^d$.

(a) What are the endogenous variables in the labor market model?
(b) Solve for the equilibrium values of these endogenous variables.

6. **The labor market model (II):** Now we add some parameters to the labor market model:

$$\begin{aligned} \text{labor supply:} \quad & L^s = \bar{a} \times w + \bar{\ell} \\ \text{labor demand:} \quad & L^d = \bar{f} - w \end{aligned}$$

The parameters in this setup are $\bar{a}$, $\bar{\ell}$, and $\bar{f}$. (Notice that parameters are denoted with an overbar, a convention we will maintain throughout the book.) The parameter $\bar{\ell}$ 0 represents the number of hours workers would supply to the market even if the wage were zero; it therefore reflects the inherent amount of time people like to work. The parameter $\bar{f}$, in contrast, reflects the amount of labor the firm would like to hire if the wage were zero. It might be thought of as some inherent capacity of the firm (perhaps because the firm owns a given amount of land and capital that cannot be altered).

(a) What is the economic interpretation of $\bar{a}$?
(b) What are the endogenous variables in this model?
(c) Solve for the equilibrium of the labor market. That is, solve for the endogenous variables as a function of the parameters of the model.
(d) If $\bar{\ell}$ increases, what happens to the equilibrium wage and employment levels? Does this make sense? (*Hint:* Think about what happens in the supply-and-demand diagram for the labor market.)
(e) Answer the same questions in (d) for an increase in $\bar{f}$.

7. **Models:** Apply the supply-and-demand model to the following markets. In each case, state the key endogenous variables in the market as well as some important exogenous variables or parameters. Also, express each model as a system of mathematical equations. As an example, $Q = F(P, \bar{X})$ might be the demand curve in the computer market, where $\bar{X}$ captures some exogenous variables like the availability of the iPad or computer games. How many equations are there within each example? How many unknowns?

(a) The computer market.
(b) The market for your favorite music.
(c) The market for a particular currency, such as the dollar, the yen, or the euro. (*Hint:* This last example suggests an important point about "exogenous

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variables"): what is exogenous in one model, as in a narrow study of the supply and demand for dollars, may be endogenous in a richer model—like a study of the entire U.S. macroeconomy.)

WORKED EXERCISE

Here and in each following chapter, you will find the worked exercises most helpful if you try to work through them completely on your own before consulting the answers.

5. The labor market model (I):

(a) The endogenous variables are the price and quantity: the wage w and the quantity of labor L. Another way to think about this problem is that we have three equations and three unknowns, the unknowns being the wage, labor supply, and labor demand. However, since the "third" equation is that labor supply equals labor demand, this naturally reduces our model to two equations in w and L.

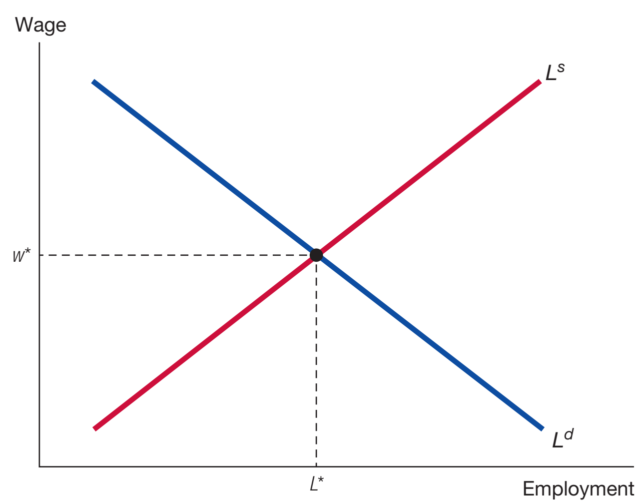
(b) The equilibrium of the labor market is shown in Figure 1.8. To solve for this equilibrium, we first find the wage rate that equates supply and demand. This wage solves

$$2w + 30 = 60 - w.$$

(The left side is labor supply and the right side is labor demand.) The solution to this equation is $w^* = 10$. Substituting this wage into either the labor supply equation or the labor demand equation, we find that the equilibrium quantity of labor is $L^* = 50$.

FIGURE 1.8

The Labor Market



CHAPTER 2

MEASURING THE MACROECONOMY

OVERVIEW

In this chapter, we learn

- the importance of gross domestic product (GDP), and how it is measured.
- the composition of GDP, and how it has changed over time.
- how to use GDP to measure the evolution of living standards over time.
- how to use GDP to measure differences in living standards across countries.

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> While the GDP and the rest of the national income accounts may seem to be arcane concepts, they are truly among the great inventions of the twentieth century.
>
> —PAUL A. SAMUELSON AND WILLIAM D. NORDHAUS

2.1 Introduction

Exactly how severe was the Great Depression? Perhaps surprisingly, it was difficult for policymakers in the early 1930s to know. Stock prices, railroad freight reports, and some limited measures of industrial production did signal problems. But no broad-based measure of economic activity was available to quantify the Depression or to indicate the effectiveness of steps designed to spur economic recovery. This ignorance in the face of such an important phenomenon led Simon Kuznets and his colleagues at the U.S. Department of Commerce to create the National Income and Product Accounts that same decade. The development of "national income accounting," together with improvements made subsequently, stands as one of the fundamental contributions of economics during the twentieth century.[1]

National income accounting provides a systematic method for aggregating the production of cars, computers, health care, and music into a single measure of overall economic activity. Moreover, it relates this measure of aggregate production to the total amount of income earned by every person in the economy and to all the spending that occurs. In one of the most beautiful accounting relations in economics, total production equals total income equals total spending; in this chapter, we will see how.

National accounting allows us to take a detailed snapshot of the state of the economy at a given point in time. But it also shows us how these snapshots can be linked together over time to provide a picture of economic growth. Further, pictures for different countries can be lined up to help us understand how economic performance varies throughout the world.

This chapter discusses the central elements of national accounting and how these pictures of economic performance are created. The accounting theory is presented with real-world examples, so that you simultaneously learn the economic concepts as well as important empirical facts about economic activity in the United States and other countries.

2.2 Measuring the State of the Economy

The key measure of the state of the economy is called **gross domestic product**, or **GDP** for short. Gross domestic product is defined as the market value of the final goods and services produced in an economy over a certain period. If you

Epigraph: "GDP: One of the Great Inventions of the 20th Century," *Survey of Current Business* (January 2000), pp. 6–14.

[1] This history is discussed in detail in the article cited in the epigraph.

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add together the value of all the cars, clothes, peanut butter, airline travel, musical performances, magazine articles, and everything else produced in a year, you will get GDP. In 2018, GDP in the United States was equal to $20.5 trillion, or about $62,000 per person.

Production = Expenditure = Income

Like nearly all other accounting systems, national income accounting involves a large number of detailed definitions and constructs. Its overall principles, however, are elegantly straightforward. We can see how they work by considering a simple example.

Suppose the economy consists of only a single family farm with a small fruit stand in the front yard. Our farmers, Homer and Marge, grow tangerines on the land, hire some workers to help them with the harvest, and then sell the tangerines at the fruit stand. GDP in this simple economy is the total number of tangerines Homer and Marge produce in a year. This is the *production* measure of GDP, and we could compute it by following the farmworkers through the orchard and counting the tangerines as they get picked.

An alternative way to measure this GDP is by focusing on sales at the fruit stand. Consumers visit the stand each day to buy tangerines, and the total purchases represent the *expenditure* approach to measuring GDP. As long as all the tangerines that are picked end up being sold, these two measures will be equal.[2]

Finally, the workers in this tangerine economy are paid a wage, and Homer and Marge also earn some income—the "profits" that are not paid out as wages to the workers. The *income* approach to measuring GDP adds up all the income earned in the economy. On the farm, all production gets paid out to someone as income—either to the workers as wages or to Homer and Marge as "profits"—so the production measure of GDP must also be equal to the income measure.

According to national income accounting, GDP in an economy equals production, expenditure, and income. We exploit this result repeatedly throughout the book.

This example illustrates a fundamental principle in national income accounting: *production equals expenditure equals income*. These terms reflect the three different ways to compute GDP in any economy, and all three are defined so that they will give identical values.

Why is "profits" in quotation marks above? The reason has to do with the distinction between the common use of the word—as in the profits Homer and Marge earn—and the "economic profits" referred to by economists. The profits earned by Homer and Marge are really just a normal, competitive return on their own labor, farm, and fruit stand. **Economic profits** are the above-normal returns associated with prices that exceed those that prevail under perfect competition. An important lesson from microeconomics is that unless there is some market power by which firms charge prices above marginal cost, economic profits are zero.

We now look at each approach to GDP in turn.

[2] In practice, you can imagine some firms producing goods—like dump trucks or airplanes—that are not sold during the same year in which they are produced. National accounting treats these goods as *inventories* and counts them as investment expenditures so that the production and expenditure measures of GDP are equal.

The Expenditure Approach to GDP

The national income accounts divide the goods and services that are purchased into several categories. This breakdown appears in one of the fundamental accounting equations, called the **national income identity**:

$$Y = C + I + G + NX \tag{2.1}$$

where

$$\begin{aligned} \boldsymbol{Y} &= \text{GDP (in dollars)}, \\ \boldsymbol{C} &= \text{consumption}, \\ \boldsymbol{I} &= \text{investment}, \\ \boldsymbol{G} &= \text{government purchases, and} \\ \boldsymbol{NX} &= \text{net exports} = \text{exports} - \text{imports}. \end{aligned}$$

This equation, representing the *expenditure approach* to GDP, illustrates how expenditures are divided according to their purpose. Goods and services can be consumed, invested by the private sector, bought by the government, or shipped abroad for foreigners to use.

Table 2.1 shows the actual breakdown of U.S. GDP in 2018. Consumption expenditures accounted for 68 percent of GDP. Examples include expenditures on motor vehicles, food, housing services, and medical care, with consumption of the last two categories each exceeding 10 percent of GDP. Investment expenditures

GDP is the sum of consumption, investment, government purchases, and net exports. Some examples of these expenditure categories are listed.

TABLE 2.1

The Expenditure Approach to U.S. GDP in 2018

	Total (billions of dollars)	Share of GDP (percent)	Per person (dollars)
Gross domestic product	20,500	100.0	62,600
Personal consumption expenditures	13,950	68.0	42,600
Motor vehicles and parts	510	2.5	1,550
Food	390	1.9	1,210
Housing	2,560	12.5	7,820
Medical care	2,380	11.6	7,250
Gross private domestic investment	3,650	17.8	11,150
Structures (nonresidential)	640	3.1	1,950
Equipment	1,240	6.0	3,780
Intellectual property products	930	4.5	2,830
Residential	800	3.9	2,430
Government purchases	3,520	17.2	10,760
National defense	780	3.8	2,380
Net exports of goods and services	−630	−3.1	−1,910
Exports	2,530	12.3	7,730
Imports	3,160	15.4	9,640

Source: U.S. Department of Commerce, Bureau of Economic Analysis, www.bea.gov.

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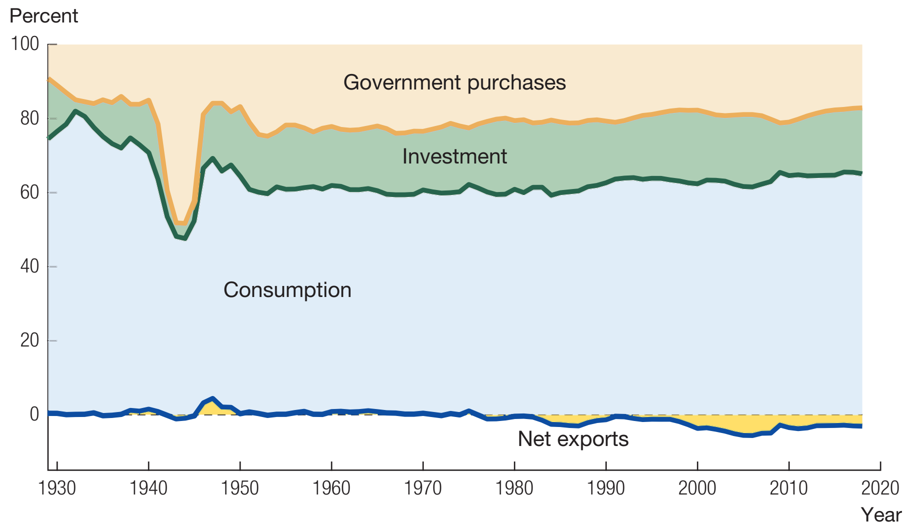
made up about 18 percent of GDP. This category includes purchases by businesses of structures like office buildings and equipment such as computers and machine tools. Starting in 2015, it also includes a new category of investment called **intellectual property products (IPP)**. This category includes R&D spending as well as expenditures on durable intangible goods like software, movies, books, and music. The construction of new homes ("Residential") is also counted as part of investment.

Government purchases, which totaled 17 percent of GDP, include expenditures on public schools, highways, government-funded research, and national defense. There is an important and sometimes confusing distinction between government purchases and government spending. Government spending includes purchases of goods and services, but also "transfer" payments (like Social Security and Medicare) and interest payments on any outstanding government debt. To see this distinction more clearly, suppose the government taxes businesses and pays out the proceeds to the unemployed in the form of unemployment insurance. Both taxes and government spending are then higher, but is a flow of GDP generated? No, there is simply a transfer of resources from one group to another. In 2018, government purchases accounted for just over 1/2 of government spending, with the remainder consisting of transfers and interest payments. It is only the purchases that directly involve new production and are properly recorded as GDP. Finally, 12.3 percent of the goods and services produced by U.S. businesses were shipped abroad and sold to foreigners; these sales are exports. At the same time, U.S. consumers and businesses imported goods and services from abroad equal in magnitude to 15.4 percent of GDP. Imports included cars, cell phones, machine tools, and financial services. On net, then, the United States imported more than it exported, so that "net exports"—exports minus imports—were equal to −3.1 percent of GDP. Another

This expenditure-side decomposition of GDP shows the general stability of the shares over much of the twentieth century.

FIGURE 2.1

Composition of U.S. GDP



Source: U.S. Department of Commerce, Bureau of Economic Analysis, www.bea.gov.

common name for net exports is the **trade balance**, and when the trade balance is negative, as in 2018, we say there is a trade deficit.

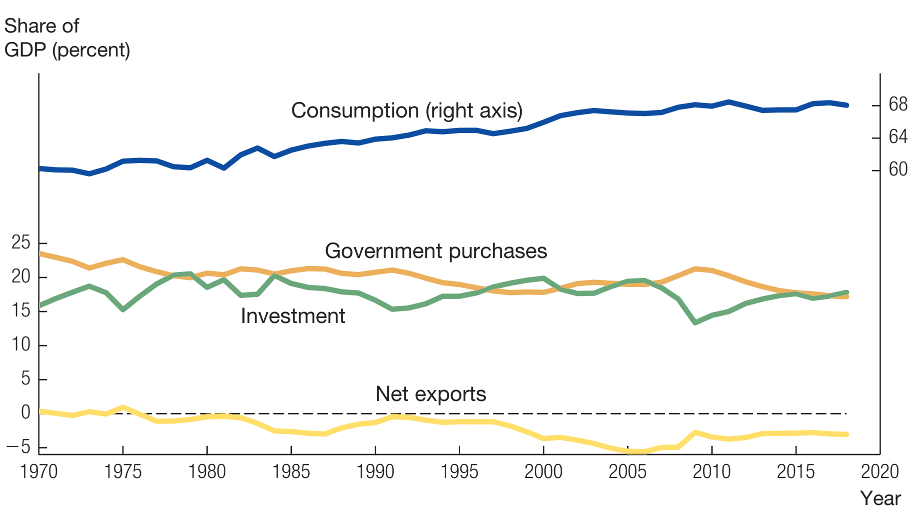
How have these percentages changed over time? The answer is shown in Figure 2.1. Broadly speaking, for the past 75 years or so, the composition of GDP has been relatively stable. The consumption share of GDP is roughly 65 percent, government purchases just under 20 percent, and investment about 15 to 20 percent. We can also see from the figure that a big change occurred during World War II (1939–1945), when government purchases for national defense expanded sharply and crowded out private investment and consumption. During the Great Depression of the 1930s, the consumption share was relatively high and the investment share relatively low. Finally, the trade deficits of the past three decades are a recent phenomenon, and the deficit reached nearly 6 percent of GDP in 2006 before declining during the Great Recession. Before 1980, the U.S. economy almost always had a trade balance that was zero or slightly positive. Why did it change? The next figure begins to address this question.

The broad stability of shares of GDP suggested by Figure 2.1 masks some of the more recent movements. Figure 2.2, which plots the shares since 1970, shows that the consumption share of GDP has actually been rising since about 1980: in 1970, it was just 60 percent, but by 2018, it had risen to 68 percent. At an accounting level, this rise is mirrored by a decline in the trade balance through 2018, from roughly 0 to −3.0 percent of GDP, and by a decline in government purchases from 24 percent to 17 percent. To some extent, then, the trade deficit is caused by the rise in consumption.

The economic explanation for these changes is not clear. On the one hand, if the government decides to reduce its share in the economy, more is left over for private consumption. On the other hand, the rising trade deficit should make us

FIGURE 2.2

Expenditure Shares of U.S. GDP



Source: U.S. Department of Commerce, Bureau of Economic Analysis, www.bea.gov.

The steady rise in the consumption share is associated with a slight decline in government purchases and the emergence of a large trade deficit (at least prior to the recent recession).

wary. A trade deficit is basically a way to borrow goods and services from another economy: the rest of the world sends more goods to the United States than we send in return. The only way they will agree to do this is if we promise to repay the "loan" in the future. This repayment will show up in the form of future trade surpluses, at which time there will be less GDP available for consumption, investment, and government purchases.

And the rise in consumption raises another question: What changes to the economy have U.S. consumers seen that lead them to want to increase their consumption share now at the expense of what will likely be a lower consumption share in the future? One possibility is a positive "technology shock" that will make the United States a richer country in the future (the AI revolution? biotech?). Another possibility, however, is that easy credit card access and easy methods of borrowing are leading people to consume too much and save too little. Exactly how much of the increased consumption share is due to each of these possibilities is unclear. This important issue will be explored in more detail in Chapter 18.

The Income Approach to GDP

An important lesson from national income accounting is that for every dollar of product sold there is a dollar of income earned. That is, as we saw with Homer and Marge, GDP is equal to the value of all goods and services produced in the economy, but it is also equal to the sum of all income earned in the economy.

Table 2.2 shows the income approach to U.S. GDP in 2018. A large part of income, just under 55 percent, came in the form of compensation to employees—wages and salaries as well as the (growing) category of benefits, including health and retirement benefits. The bulk of the remainder was the net operating surplus of businesses, a fancy name for the "profits" earned by Homer and Marge.

A much smaller category, depreciation of capital, constituted just over 15 percent of GDP. **Capital** refers to the inputs into production other than labor that are not completely used up in the production process. Examples include structures like a factory or office building and equipment like computers or copying machines. If this sounds like our description of investment (from Table 2.1), that is intentional: investment is the way a firm increases its stock of capital. For comparison, steel in

TABLE 2.2

The Income Approach to U.S. GDP in 2018

	Total (billions of dollars)	Share of GDP (percent)	Per person (dollars)
Gross domestic product	20,500	100.0	62,600
Compensation of employees	10,870	53.0	33,190
Wages and salaries	8,850	43.2	27,020
Benefits	2,020	9.9	6,170
Taxes less subsidies on businesses	1,360	6.6	4,160
Net operating surplus of businesses	5,900	28.8	18,000
Depreciation of fixed capital	3,270	16.0	10,000

Source: U.S. Department of Commerce, Bureau of Economic Analysis, www.bea.gov.

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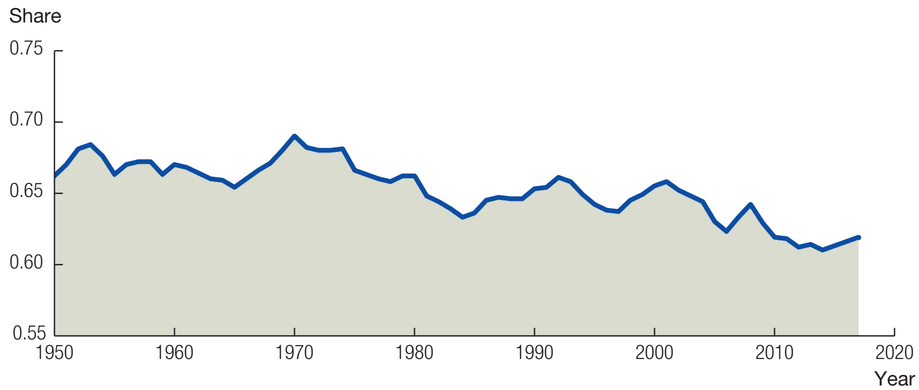
FIGURE 2.3

Labor's Share of GDP



Source: U.S. Department of Commerce and author's calculations.

Labor income as a share of GDP is about two-thirds.

an automotive factory is not capital, but an intermediate input that is used up in production: after the car is built, the factory remains but the steel is incorporated into the car.

When Homer and Marge run their fruit stand for a year, the shelving, light fixtures, and wooden structure all endure some wear and tear. These items are part of the farm's capital stock, and the wear and tear is called **depreciation**. Some of their income is implicitly a compensation for this wear and tear—that is, for the depreciation of the farm's capital. The presence of this depreciation accounts for the label "gross domestic product"; if we subtract out the depreciation, then the remainder is referred to as "net domestic product." Finally, indirect business taxes, the smallest component of income, include sales and property taxes paid by the business sector.

Another convenient way of presenting these income numbers is to assign all income to either labor or capital. If we do this, we discover two important things.[3] First, the fraction of GDP earned by labor is approximately two-thirds, or 67 percent; this leaves one-third as income to capital. Second, as we can see in Figure 2.3, the labor share fluctuates very little over time, lying between 60 and 70 percent of GDP.

One of the classic "stylized facts" of macroeconomics is that the labor share is relatively constant over time at around two-thirds. A close look at Figure 2.3, however, suggests that this stylized fact may be less true than it first appears. In particular, there is a notable downward trend in this measure of the labor share since around 1970. Recent research reveals that this negative trend is to some extent a product of recent changes in the way the National Income and Products Accounts treats "intellectual property products" like computer software and R&D

[3] The main difficulty in making this assignment is that the net operating surplus of business—such as the profits of Homer and Marge—includes both labor income (e.g., for Homer and Marge) and capital income (e.g., land rent).

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spending. Whether and how these new data should lead us to change our stylized fact of a constant labor share is an ongoing topic of research.[4]

The Production Approach to GDP

The stated definition of GDP—the value of the goods and services produced in an economy during a given period—is correct in a general way, but it misses one important qualifier. When GDP is computed as the value of goods and services produced in an economy, there is no double counting. For example, if a steel company produces $10 million worth of steel that is then used by an automobile company to make $100 million worth of trucks, the value of the steel is not counted twice. Rather, GDP goes up by $100 million.

We can view this in two ways. First, it is only the final sale of goods and services that counts toward GDP. Alternatively, and more accurately, each producer creates an amount of GDP equal to the amount of value that is added during production. This **value added**, as it is called, is computed by subtracting the value of intermediate products (like steel or electricity; $10 million in our example) from the revenue generated by each producer. In terms of value added, then, the steel producer generates $10 million of GDP, while the automobile producer generates $90 million ($100 million − $10 million), for a total increment once again of $100 million.

Another important implication of the production approach to GDP is that it is only new production that counts. For example, if a construction company builds a new house and sells it for $200,000, this amount counts toward GDP. But suppose a used-car dealer buys a 2012 minivan for $17,000 and then sells it the next day to a family for $20,000; by how much does GDP change? The full $20,000 does not count toward this year's GDP: the car already existed and does not represent new production. However, the "profit" of $3,000 earned by the dealer does count toward GDP: the product is the service of finding a match for minivan and family.

What Is Included in GDP and What's Not?

A key way to understand more thoroughly the usefulness of GDP is to examine some of its limitations. The first thing to note is that GDP includes only goods and services that transact in markets. If your family goes out to dinner at a nice restaurant, the entire amount you spend there is counted as GDP. However, if your parents pick up some ingredients at the local market and spend an hour preparing a gourmet meal, only the purchase of the ingredients contributes to GDP—not the value of the time they spend cooking. Similarly, if Aunt Zoe and Uncle Elmo put their kids in day care while they work, the day-care service gets counted as GDP, but if Uncle Bert stays home to care for his kids, no market transaction occurs and no contribution to GDP is recorded.[5]

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[4] For example, see Dongya Koh, Raul Santaeulalia-Llopis, and Yu Zheng, "Labor Share Decline and Intellectual Property Products Capital," working paper, Washington University of St. Louis, October 2018.

[5] A prominent exception to the market rule is the benefit associated with owner-occupied housing. If you rent your home, the rental income is captured in GDP. But if you own your home, there is no annual income like the rent. National accountants estimate a rental equivalent in this case and include it in GDP.

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Another important omission from GDP is the health of a nation's people. Over the past century, life expectancy has risen in virtually every country in the world. This increase is quantitatively very significant. In fact, William Nordhaus calculates that the rise in U.S. life expectancy in the twentieth century had roughly the same impact on the country's economic welfare as the entire gain in per capita consumption over that century.[6] To judge the validity of this calculation, ask yourself the following: Would you rather have the per capita income of the United States from 1900 together with the medical technology of 2000 or the per capita income from 2000 with the medical technology of 1900? Conventional measures of GDP do not incorporate this change in health. To take another example, the specter of the AIDS epidemic in Africa threatens to kill millions of people in the coming decades and has reduced life expectancy significantly in many sub-Saharan countries. The effect of this tragedy on measured GDP, however, will likely be relatively small.[7]

A third potentially significant limitation of GDP is that it doesn't include changes in environmental resources. For example, air and water pollution generated by factories as by-products of their manufacturing do not reduce GDP. Similarly, when nonrenewable natural resources like oil and natural gas are extracted, GDP goes up because of the productive effort spent turning the reserves into products, but there is no deduction from GDP associated with the reduction of oil and natural gas reserves. Interestingly, Martin Weitzman has calculated that the economic value of this depletion may be smaller than one might have expected: the price data used to measure the scarcity of these resources suggest that the overall cost of the finite nature of our nonrenewable resources is less than 1 percent of annual consumption.[8]

CASE STUDY

Beyond GDP

Many economists have sought to augment GDP to create broader measures of economic welfare. Here, we report on one recent attempt.

Charles I. Jones and Peter J. Klenow of Stanford University begin by looking at consumption per person as their basis for welfare. This is motivated by the fact that consumption is the key measure that enters the utility functions that economists often use to study welfare. They then use common specifications of the utility function to incorporate life expectancy, leisure, and consumption inequality into the analysis. Results for a sample of countries in the year 2007 are shown in Table 2.3.

[6] William Nordhaus, "The Health of Nations: The Contribution of Improved Health to Living Standards," in *Measuring the Gains from Medical Research: An Economic Approach*, Kevin M. Murphy and Robert Topel, eds. (Chicago: University of Chicago Press, 2003).

[7] See, for example, Alwyn Young, "The Gift of the Dying: The Tragedy of AIDS and the Welfare of Future African Generations," *Quarterly Journal of Economics,* vol. 120 (May 2005), pp. 423–66.

[8] Martin L. Weitzman, "Pricing the Limits to Growth from Minerals Depletion," *Quarterly Journal of Economics,* vol. 114 (May 1999), pp. 691–706.

Relative to the United States, the rich countries of Western Europe are better off than their GDPs indicate because of higher life expectancy, higher leisure, and lower inequality. The poor countries are typically even poorer because of lower life expectancy, less leisure, and more inequality.

TABLE 2.3

GDP and Welfare across Countries

			Decomposition			
Country	Per capita GDP	Welfare	Life expectancy	*C*/*Y*	Leisure	Inequality
United States	100.0	100.0	0.000	0.000	0.000	0.000
			77.8	0.845	836	0.658
Sweden	79.4	91.2	0.181	−0.186	0.010	0.135
			80.9	0.701	807	0.404
France	70.3	91.1	0.176	−0.085	0.063	0.106
			80.8	0.776	629	0.471
Japan	71.3	82.6	0.265	−0.154	−0.028	0.063
			82.5	0.724	912	0.554
Norway	112.8	81.0	0.148	−0.598	0.019	0.100
			80.4	0.464	780	0.483
Germany	74.4	77.4	0.098	−0.195	0.047	0.089
			79.5	0.695	687	0.506
Ireland	96.4	69.6	0.069	−0.454	−0.022	0.082
			79.0	0.536	896	0.519
Hong Kong	83.4	59.0	0.239	−0.433	−0.151	−0.000
			82.4	0.548	1194	0.658
Singapore	117.1	56.7	0.139	−0.685	−0.180	−0.000
			80.4	0.426	1251	0.658
South Korea	58.3	45.3	0.078	−0.290	−0.116	0.076
			79.3	0.632	1120	0.531
Argentina	26.2	21.8	−0.121	−0.108	0.048	−0.000
			75.1	0.759	684	0.658
Chile	30.9	19.7	0.029	−0.254	−0.026	−0.199
			78.5	0.655	908	0.912
Thailand	18.1	10.9	−0.158	−0.207	−0.043	−0.099
			73.5	0.687	951	0.794
South Africa	17.4	4.5	−0.931	−0.053	0.061	−0.427
			51.0	0.801	636	1.135
Botswana	25.1	4.3	−0.852	−0.574	−0.008	−0.333
			52.1	0.476	859	1.048
Vietnam	5.9	4.0	−0.082	−0.269	−0.020	−0.006
			74.2	0.645	893	0.668
Zimbabwe	8.3	3.1	−0.983	0.155	−0.050	−0.094
			45.8	0.986	969	0.789
Kenya	2.8	1.9	−0.394	0.104	0.059	−0.157
			54.4	0.938	644	0.865

Source: C. Jones and P. Klenow, "Beyond GDP? Welfare across Countries and Time," *American Economic Review*, vol. 106, no. 9 (September 2016): 2426–57. The second line for each country displays the raw data on life expectancy, the consumption share of GDP, leisure per adult, and the standard deviation of log consumption. All data are for the year 2007.

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To read this table, first consider the United States. Both per capita GDP and the consumption-equivalent welfare measure are normalized to the value of 100 for the United States. The green numbers in the second line for each country report the actual values of the underlying data. For example, in 2007, average life expectancy in the United States was 77.8 years, the consumption share of GDP (including government consumption) was 84.5 percent, annual hours worked per person was 836, and the standard deviation of consumption was about 65.8 percent of its mean.

Now consider the next few lines in the table. In general, per capita GDP in Western European countries is surprisingly modest, around 75 percent of the U.S. value. According to the welfare measure, however, Western Europe essentially closes the gap with the United States. Consider France as an example. In 2007, French life expectancy was 3 years longer than that in the United States, and this boosted their welfare by 17.6 percent. The French worked less than Americans, and the extra leisure boosted their welfare by 6.3 percent. Finally, inequality was lower in France, and this added 10.6 percent to welfare. Taking all these factors into account, French welfare was 91.1 percent of the U.S. value, much closer than the large difference in GDP would suggest. A similar pattern holds for Japan and many other advanced economies.

Unfortunately, the results move in the opposite direction when we look at poor countries. For example, consider Thailand. In 2007, Thailand's per capita GDP was 18.1 percent of that in the United States. However, Thailand's life expectancy was lower, their consumption share of GDP was lower, leisure was lower, and inequality was higher. Each of these factors reduced welfare, and according to the table, welfare in Thailand was just 10.9 percent of the U.S. value. This pattern is typical of poor countries.

Other interesting examples are reported in the table. For example, the dire effect of AIDS in Botswana and South Africa dramatically reduced their welfare, leading to a life expectancy of just over 50 years in these countries and making them much poorer than their GDPs indicate.

Jones and Klenow find important differences between their welfare measure and per capita GDP, as we've just seen. However, they also find that across more than 100 countries, welfare and GDP are very highly correlated. So while GDP is far from perfect and can certainly be improved, it remains an informative measure of living standards across countries.

2.3 Measuring Changes over Time

Measuring GDP in any given year is primarily a matter of careful counting. Measuring how GDP changes over time or comparing GDP between two countries is substantially harder. Each process involves separating out changes in prices and quantities.

Economists use the word "nominal" to refer to a measure like GDP when prices and quantities have not been separated out and use "real" to refer only to

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the actual quantity of goods and services. **Nominal** and **real GDP** are related by a simple equation:

$$\text{nominal GDP} = \text{price level} \times \text{real GDP} \tag{2.2}$$

If an economy produces 37 cell phones and nothing else, and if the price of each is \$100, then nominal GDP would equal \$3,700, while real GDP would equal 37 cell phones.

Nominal GDP can go up either because the price level has gone up or because real GDP has gone up. For example, nominal GDP in 2018 in the United States was \$20.5 trillion and in 1995 only \$7.4 trillion. How many more goods and services—that is, how much more real GDP—were produced in 2018 than in 1995?

What makes this question difficult is that prices have changed over the past two decades. It is possible, for example, that all the increase in GDP is accounted for by higher prices, and real GDP has not changed. Alternatively, it is equally possible that prices haven't changed at all, and all the increase is explained by an increase in the quantity of real GDP. The truth lies somewhere in between, and the challenge is to figure out exactly where.

A Simple Example: Where Real GDP Doesn't Change

Imagine a simple economy in which there are two goods, apples and computers. Nominal GDP in this economy is the sum of the values of apples and computers that are produced:

$$\begin{aligned}\text{nominal GDP} = &\ (\text{price of apples} \times \text{quantity of apples})\\ &+ (\text{price of computers} \times \text{quantity of computers}).\end{aligned}$$

Suppose that in 2025, an apple costs \$1, a computer costs \$900, and the economy produces 500 apples and 5 computers. Then nominal GDP in this economy is

$$\frac{\$1}{\text{apple}} \times 500 \text{ apples} + \frac{\$900}{\text{computer}} \times 5 \text{ computers} = \$5{,}000.$$

These numbers are shown in Table 2.4.

Now suppose that in 2026, the economy still produces 500 apples and 5 computers, but an apple now costs \$2 while a computer costs \$1,000. Nominal GDP in 2026 is then

$$\frac{\$2}{\text{apple}} \times 500 \text{ apples} + \frac{\$1{,}000}{\text{computer}} \times 5 \text{ computers} = \$6{,}000.$$

Nominal GDP is higher by \$1,000 in 2026, but we know that nothing "real" has changed: the economy is producing the same number of apples and computers. Here, all the change in nominal GDP occurs because of changes in prices.

What about real GDP in this economy? In our example of 37 cell phones, real GDP was easy to measure: it was just the number of cell phones produced. Here,

TABLE 2.4

Real and Nominal GDP in a Simple Economy, 2025–2027

	2025	2026	2027	Percentage change 2026–2027
Quantity of apples	500	500	550	10.0
Quantity of computers	5	5	6	20.0
Price of apples (dollars)	1	2	3	50.0
Price of computers (dollars)	900	1,000	1,000	0.0
Nominal GDP	5,000	6,000	7,650	27.5
Real GDP in 2025 prices	5,000	5,000	?	?
Real GDP in 2026 prices	6,000	6,000	7,100	18.3
Real GDP in 2027 prices	?	6,500	7,650	17.7
Real GDP in chained prices, benchmarked to 2027	?	6,483	7,650	18.0

The table shows the calculation of real and nominal GDP for our apple and computer example. The question marks are entries that you will fill in yourself in an exercise at the end of the chapter.

though, things are more complicated because we have two goods. How can we construct a summary statistic that adds these two goods together but controls for the change in prices that occurred from 2025 to 2026? The answer is that we use the *same* set of prices to compute real GDP in each of the two years—either the 2025 prices or the 2026 prices. If we use the 2026 prices, we will measure real GDP to be \$6,000 in both years. If we use the 2025 prices, we will measure real GDP to be \$5,000 in both years. Both approaches yield the right answer that real GDP is unchanged. (The calculations are exactly the same as the ones we carried out at the beginning of this section.)

Notice that, perhaps confusingly, real GDP is measured in dollars, just like nominal GDP. This is because there is more than one good in the economy, so we can't just count the number of cell phones produced. To distinguish nominal from real variables, we measure nominal variables in "current dollars" and real variables in, say, "2026 prices" or "2026 dollars."

A Second Example: Where Real GDP Changes

Now consider an example where real GDP does change. Suppose that in 2027 the economy looks like this: an apple costs \$3, a computer still costs \$1,000, and the economy produces 550 apples and 6 computers. If you calculate nominal GDP for this economy, you will find that the answer is \$7,650 (\$6,000 + \$1,650).

But what about real GDP? Relative to 2026, the economy is producing 50 more apples and 1 more computer, so real GDP should be higher, but by how much? If we use the 2026 prices, we find that real GDP in 2027 is

$$\frac{\$2}{\text{apple}} \times 550 \text{ apples} + \frac{\$1{,}000}{\text{computer}} \times 6 \text{ computers} = \$7{,}100.$$

Measured in 2026 prices, real GDP in 2026 is equal to nominal GDP, which was \$6,000. So according to this calculation, real GDP in 2027 is higher by \$1,100 (\$7,100 − \$6,000), or by 1,100/6,000 = 18.3 percent (see Table 2.4).

Alternatively, suppose we compute real GDP using the 2027 prices. Real GDP in 2027 is then equal to nominal GDP in 2027, or \$7,650. Real GDP in 2026 is

$$\frac{\$3}{\text{apple}} \times 500 \text{ apples} + \frac{\$1{,}000}{\text{computer}} \times 5 \text{ computers} = \$6{,}500 \text{ (in 2027 prices)}.$$

So using 2027 prices, we find that real GDP is higher in 2027 by \$1,150 (\$7,650 − \$6,500), or by 1,150/6,500 = 17.7 percent.

This second example, then, reveals that the change in real GDP differs, although only slightly, depending on whether we use the initial 2026 prices or the final 2027 prices.

Quantity Indexes: Laspeyres, Paasche, and Chain Weighting

The method of computing the change in real GDP with the initial prices is called the **Laspeyres index**, while the method that uses the final prices is called the **Paasche index**. (To keep these straight, you might remember that the alphabetical order of Laspeyres and Paasche corresponds to the initial versus final order.) In general, these approaches give different answers, and the size of the difference depends on the extent to which relative prices have changed. If we are comparing two consecutive years in an economy, then the differences usually aren't great. But if we are comparing real GDP across a long period such as a decade or if we are looking at any economy with high inflation, the differences can be substantial.

A third, preferred, approach to computing real GDP is called the *Fisher index*, or **chain weighting**. To compute the chain-weighted index of real GDP, first compute the Laspeyres and Paasche indexes, then calculate the average of the two growth rates. In our Table 2.4 example, this approach gives a growth rate of $1/2 \times (18.3\% + 17.7\%) = 18.0\%$. The chain-weighted index therefore says that real GDP is 18 percent higher in 2027 than in 2026.[9] The level of real chain-weighted GDP in 2026 is then computed by finding the level x such that if it were to grow at 18 percent, it would equal the 2027 level of GDP. That is,

$$x \times (1 + 0.180) = 7{,}650 \Rightarrow x \times 7{,}650/1.180 = 6{,}483.$$

National income accountants would say that real chain-weighted GDP in 2026 is therefore equal to \$6,483. These calculations are reported in the last line of Table 2.4.

Modern national income statisticians generally prefer to use chain weighting when comparing real GDP over time, particularly when the time period is a long one. Why? Suppose we are comparing real GDP in 1960 with real GDP in 2020. The Laspeyres index would make the comparison using 1960 prices. In 1960, computers were extremely expensive relative to apples, so they would get a very high weight in this comparison. A Paasche index would make the comparison using 2020 prices, when computers were relatively cheap. Because computer output has grown so rapidly, the Laspeyres index (1960 weights) would produce

[9] To be more precise, the Fisher index actually involves taking the geometric average of the "gross" percentage changes (i.e., $\sqrt{1.183 \times 1.177} = 1.180$) to get the 18.0 percent growth rate. As long as relative prices are not changing too rapidly, the arithmetic average used in the text will give a similar answer.

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very fast growth for real GDP, while the Paasche index (2020 weights) would produce much slower growth. Chain weighting gives us an average of these two extremes and in general provides a more accurate view of how standards of living change over time.[10]

More generally, real chain-weighted GDP is computed by applying the Fisher index on a year-by-year basis. To construct the chain index over the period 1960 to 2020, we compute real GDP in *each* year: real GDP in 2020 is computed using both the 2019 and the 2020 prices, real GDP in 2019 is computed using both the 2018 and 2019 prices, and so on. In other words, the 1960 level of real GDP is based on prices that were applicable in 1960, while 2020 real GDP is computed using prices that were applicable around 2020. Chain weighting therefore produces a more accurate portrayal of how real GDP changes over time.

Price Indexes and Inflation

For each quantity index—Laspeyres, Paasche, and chain weighting—there is a corresponding price index. Recall the basic formula for nominal GDP:

$$\text{nominal GDP} = \text{price level} \times \text{real GDP}. \tag{2.3}$$

In the national accounts, the price level that satisfies this equation is called the **GDP deflator**. This name captures the fact that real GDP can be computed by "deflating" nominal GDP; that is, by dividing by the price level. Similar deflators exist for the various components of GDP, such as consumption and investment.

We *could* compute the percentage change in the price level by applying the formula in equation (2.3) in two different years. But there's a simple mathematical trick that makes this even easier; in fact, this trick is just one of the basic rules for computing growth rates that we will learn in Chapter 3. The percentage change in a mathematical product is approximately equal to the sum of the percentage changes of the components. Applying this formula to equation (2.3) means that

$$\begin{array}{c} \text{percentage} \\ \text{change in} \\ \text{nominal GDP} \end{array} \approx \begin{array}{c} \text{percentage} \\ \text{change in} \\ \text{price level} \end{array} + \begin{array}{c} \text{percentage} \\ \text{change in} \\ \text{real GDP.} \end{array}$$

We saw above in our simple example that the chain-weighted index of real GDP grew at a rate of 18.0 percent between 2026 and 2027. If we compute the change in nominal GDP, we discover a change of 27.5 percent. This means that the change in the price level between these two periods was 27.5 − 18.0 = 9.5 percent. Another name for the percentage change in the price level is the **inflation rate**.

Using Chain-Weighted Data

The U.S. Department of Commerce introduced chain weighting into the national accounts in the late 1990s. One of the main motivations was the fact that relative prices for goods that involve semiconductors were falling rapidly. For example, the

[10] See Jack E. Triplett, "Economic Theory and BEA's Alternative Quantity and Price Indexes," *Survey of Current Business* (April 1992), pp. 49–52.

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price of computers relative to the price of other nondurable consumer goods has fallen at a rate of more than 15 percent per year when you adjust for the improvements in the quality of computers, like the speed of the processor and the storage capacity. In calculating real GDP growth over a period of 5 or 10 years, these changes in relative prices are large enough to cause large errors in Laspeyres or Paasche indexes. (This is especially true since an increasing fraction of our GDP benefits from "Moore's law," the assertion by the former CEO of Intel, Gordon Moore, that the number of transistors on a computer chip is doubling about every 18 months.) Chain weighting eliminates these errors.

The main downside to chain weighting in national accounts is that we must be careful when adding together the components of real GDP. Recall that the sum of nominal consumption, investment, government purchases, and net exports is equal to nominal GDP. Unfortunately, this is not true for the chain-weighted numbers: the sum of *real* chain-weighted consumption, investment, government purchases, and net exports does not generally equal real chain-weighted GDP. (The reason is that different prices are used in constructing the different components.) The important lesson to remember is this: *If you are interested in particular shares, like the share of investment in GDP, then you want to look at the ratio of nominal variables, since the nominal shares will add up. If you are interested in real rates of economic growth, then you want to use the chain-weighted real measures.*

CASE STUDY

The FRED Database

The Federal Reserve Economic Data database—often called the "FRED" data—is a wonderful public resource for economic data. It is very user friendly and can be used to answer many factual questions easily and quickly.

For example, suppose you wish to find data on the GDP deflator as a measure of inflation. A quick web search of "FRED data" will take you to the FRED database, hosted by the Federal Reserve Bank of St. Louis. And typing "GDP deflator" into the main search box on that page will give you a list of data series, the first of which is the "Gross Domestic Product: Implicit Price Deflator." Click on that link, and you will see a time series graph of this variable that should look something like Figure 2.4.

FRED makes it easy to create an inflation rate from this series. Under the "Edit Graph" button, click on the "Units" box and select "Percent Change from a Year Ago." You should immediately see something like Figure 2.5. Congratulations!

FRED has many other useful features—have fun playing around with it. You might try searching for the latest data on GDP or the unemployment rate. You can download the data yourself to explore in a spreadsheet. FRED also has many other useful tools—for example, it is possible to combine different series on a single graph, say, if you wanted to see what investment as a share of GDP looks like over time in the United States.

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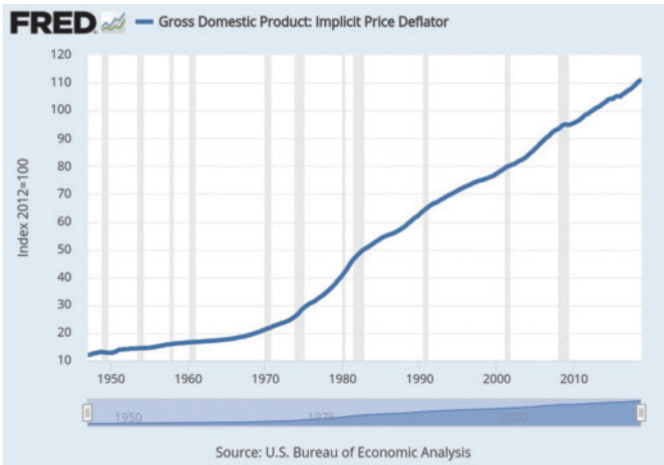
FIGURE 2.4

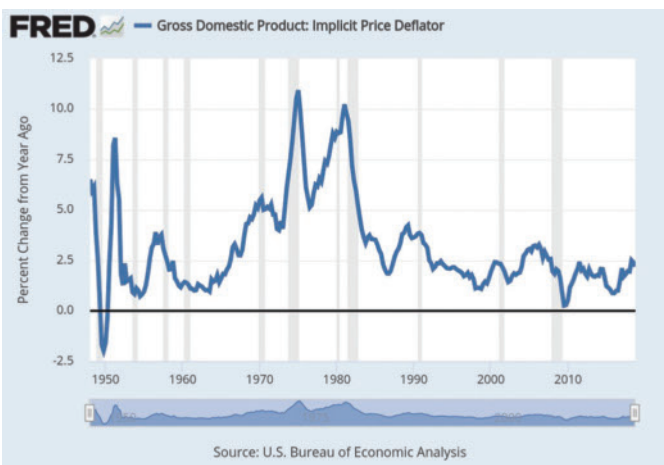
The Level of the GDP Deflator



Source: U.S. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPDEF, September 23, 2019.

FIGURE 2.5

The Annual Inflation Rate Using the GDP Deflator



Source: U.S. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPDEF, September 9, 2019.

Many economists, financial analysts, and consultants use the FRED data on a daily basis. You'll get additional practice as we use the FRED data in various exercises throughout the rest of the textbook.

For more help, visit http://fred.stlouisfed.org and select the "Get Help!" tab, where Tutorials and FAQs are available.

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2.4 Comparing Economic Performance across Countries

With the help of local statistical agencies, the United Nations assembles national income accounts data for nearly every country in the world. With these data, economists can make comparisons of GDP across countries and over time. Such comparisons are important in helping us answer basic questions like "How large is the gap between incomes in the richest and poorest countries?" and "How has this gap changed over time?" We will explore these questions in detail in the next few chapters.

When we try to compare GDP across countries, we will need to separate quantities and prices as we did with comparisons of GDP over time. Say, for example, we want to determine how large China's economy is in comparison with the U.S. economy. The national accounts for the two countries show that U.S. GDP was \$17.7 trillion in 2017, while China's GDP was 75.2 trillion yuan (in this case, both measured in 2011 prices). The first problem we are confronted with, then, is that the countries use different currencies.

As almost anyone who has traveled internationally knows, there are markets that allow you to exchange dollars for yuan, pesos for euros, or rubles for pounds. The price at which one of these exchanges occurs is called the **exchange rate**. For example, the exchange rate between the Chinese yuan and the U.S. dollar in 2017 was about 6.76 yuan per dollar: at the airport in Shanghai, you could receive 6.76 yuan for every dollar traded (or probably a little bit less, as the company doing the exchange takes a commission, and commissions at airports are notoriously high), and in San Francisco, you would have to give up 6.76 yuan for every dollar you wanted to buy.

If we use the 2017 exchange rate to convert China's GDP of 75.2 trillion yuan into dollars, we get

$$75.2 \text{ trillion yuan} \times \frac{\$1}{6.76 \text{ yuan}} = \$11.1 \text{ trillion.}$$

And since U.S. GDP in 2017 was \$17.7 trillion, we conclude that China's economy was about 63% of the size of the U.S. economy that year $(11.1/17.7 = 0.63)$.

Is that the final answer? Well, not really. We saw in Section 2.3 that the problem comparing GDP over time is that prices might change. If we want a fair comparison, we need to make sure we are applying the same prices in the two periods. Otherwise, the quantities of all the goods produced might be the same, and any difference we see in GDP might just be due to the different prices.

Exactly the same problem exists in comparing GDP across different countries. To see this more clearly, consider an extreme example in which only a single good, rice, is produced in China and the United States. Now suppose that for some reason rice is less expensive in China than in the United States: at current exchange rates, a bag of rice costs \$1 in Shanghai but \$2 in New York. Even if China and the United States produce identical quantities of rice (so that their real GDPs are the same), we will find differences in GDP if we use the local prices to compute it. The right way to correct for this, as we did over time, is to use a common set of prices to calculate real GDP in each country.

Recall the equation relating nominal and real GDP:

$$\text{nominal GDP} = \text{price level} \times \text{real GDP}. \tag{2.4}$$

Say we'd like to compute China's GDP using U.S. prices rather than Chinese prices. (We could alternatively compute U.S. GDP using Chinese prices; these are the spatial equivalents of the Laspeyres and Paasche quantity indexes. In reality, we will use international prices, representing the average of world prices.) Here's how we do this:

$$\text{real GDP}^{\text{U.S. prices}}_{\text{China}} = \text{price level}_{\text{U.S.}} \times \text{real GDP}_{\text{China}}. \tag{2.5}$$

For this example, you may find it helpful to think of real $\text{GDP}_{\text{China}}$ as being measured in kilograms of rice.

Next, since equation (2.4) tells us that real GDP in China is also equal to nominal GDP divided by the price level, we can substitute this result into equation (2.5) to get

$$\begin{aligned} \text{real GDP}^{\text{U.S. prices}}_{\text{China}} &= \text{price level}_{\text{U.S.}} \times \frac{\text{nominal GDP}^{\text{dollars}}_{\text{China}}}{\text{price level}_{\text{China}}} \\ &= \frac{\text{price level}_{\text{U.S.}}}{\text{price level}_{\text{China}}} \times \text{nominal GDP}^{\text{dollars}}_{\text{China}}. \end{aligned} \tag{2.6}$$

That is, to measure China's GDP in U.S. prices, we need to adjust for the relative price level of goods in the United States versus China.

The United Nations International Comparisons Program collects price data from different countries in order to facilitate this comparison. And the Penn World Tables data set incorporates these prices to construct measures of real GDP that are comparable across countries. These data will be used here and in the remainder of the book.[11]

According to these data, the rice example is not far from the truth. Goods in China, on average, cost about 62.5 percent of goods in the United States. That is, price $\text{level}_{\text{U.S.}}/\text{price level}_{\text{China}}$ is roughly equal to 1/0.625. Therefore, the formula above says that real GDP in China is about \$17.8 trillion (11.1/0.625). In other words, at common prices, the Chinese economy is much larger than it first appeared: about 1 percent larger than the U.S. economy instead of 40 percent smaller! Indeed, as of 2017, China had the largest economy in the world, as measured by aggregate GDP at common prices. This makes sense when you think about it: on a per person basis, China is about 4 times poorer than the United States, but it also has about 4 times as many people, so the United States and China have roughly the same total GDP.

In general, rich countries tend to have higher price levels than poor countries. The main reason is that the low wage rate in poor countries translates into lower prices for goods like haircuts or other services that are difficult to trade or for products that involve a retail or distribution channel that uses labor extensively, like restaurant meals or clothing. In practice, this means that, as we saw in the China–U.S. example, comparisons of GDP based on exchange rates tend to yield larger differences across countries than comparisons based on common prices. We will explore comparisons like these in much more detail in the coming chapters.

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[11] Robert C. Feenstra, Robert Inklaar, and Marcel P. Timmer, "The Next Generation of the Penn World Table," *American Economic Review*, vol. 105, no. 10 (October 2015), pp. 3150–82, Version 9.1 available for download at www.ggdc.net/pwt.

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CHAPTER REVIEW

SUMMARY

1. National income accounting provides systematic measures of aggregate economic activity. Gross domestic product (GDP) is the key overall measure of economic activity in an economy. It can be viewed as total expenditure, total income, or total production in an economy.
2. The expenditure approach to GDP makes use of a fundamental *national income identity*, $Y = C + I + G + NX$, which says that total spending is the sum of spending on consumption, investment, government purchases, and net exports.
3. A key lesson of the income approach is that labor's share of GDP is relatively stable over time at about two-thirds.
4. In the production approach, it is only the value of final production that counts. Equivalently, GDP is the sum of *value added* at each stage of production.
5. Nominal GDP refers to the value of GDP measured in current prices in a given year. Real GDP involves computing GDP in two different years using the *same* set of prices. Changes in real GDP therefore reflect changes in actual production rather than changes in prices.
6. Chain weighting allows us to compare real GDP in 1950, for example, with real GDP in 2020 by gradually updating the prices: 1950 and 1951 prices are used to compare 1950 and 1951 real GDPs, 1951 and 1952 prices are then used to compare 1951 and 1952 real GDPs, and so on. By linking the chain of comparisons in this way, we construct a more accurate measure of real GDP. (If we used 2020 prices to value production in 1950, we'd get a distorted picture: telephone service that was extremely valuable and expensive in 1950, for example, would be valued according to the cheap modern prices.)
7. International comparisons of GDP involve two conversions. First, we need exchange rates to convert the measures into a common currency. Second, just as we need to use common prices to measure real GDP over time, we also need to use common prices to compare real GDP across countries.

KEY CONCEPTS

capital
chain weighting
depreciation
economic profits
exchange rate
expenditure
GDP deflator
gross domestic product (GDP)
income
inflation
inflation rate
intellectual property products (IPP)
labor's share of GDP
Laspeyres index
national income identity
nominal versus real GDP
Paasche index
production
trade balance
value added

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REVIEW QUESTIONS

1. What is GDP, and why is it a useful measure? What are the most important components of GDP in the U.S. economy today?
2. What are net exports, and how is this concept related to the trade deficit?
3. What are some problems with using GDP as a measure of overall economic welfare?
4. What is the difference between real and nominal GDP? How do you compare GDPs over time within an economy? How do you compare GDPs across different economies?

EXERCISES

1. **Real versus nominal GDP (a FRED question):** Using the FRED database, locate the data on real and nominal GDP for the U.S. economy. You may notice that there are both annual and quarterly data (i.e., measures of production every 3 months) available. For the purpose of this question, let's stick with the annual data. The easy way to find this is to type "annual nominal GDP" and "annual real GDP" into the FRED search box. (For an introduction to FRED, see the case study "The FRED Database" earlier in this chaper on page 34.)
   (a) What is the value of real GDP and nominal GDP for the most recent year available? Explain why these numbers are different.
   (b) What was the value of real GDP and nominal GDP in 1970?
   (c) By what factor (e.g., a number like 2.0 if it doubled) did real GDP increase between 1970 and the most recent year? What about nominal GDP?
   (d) What explains the difference between the two numbers in part (c)?

* 2. **What counts as GDP (I)?** By how much does GDP rise in each of the following scenarios? Explain.
   (a) You spend $5,000 on college tuition this semester.
   (b) You buy a used car from a friend for $2,500.
   (c) The government spends $100 million to build a dam.
   (d) Foreign graduate students work as teaching assistants at the local university and earn $5,000 each.

3. **What counts as GDP (II)?** By how much does GDP rise in each of the following scenarios? Explain.
   (a) A computer company buys parts from a local distributor for $1 million, assembles the parts, and sells the resulting computers for $2 million.
   (b) A real estate agent sells a house for $200,000 that the previous owners had bought 10 years earlier for $100,000. The agent earns a commission of $6,000.
   (c) During a recession, the government raises unemployment benefits by $100 million.
   (d) A new U.S. airline purchases and imports $50 million worth of airplanes from the European company Airbus.

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(e) A new European airline purchases \$50 million worth of airplanes from the American company Boeing.
(f) A store buys \$100,000 of chocolate from Belgium and sells it to consumers in the United States for \$125,000.

4. **National accounting over time (I):** Look back at Table 2.4. Some missing entries are labeled with question marks. Compute the values that belong in these positions.

5. **National accounting over time (II):** Consider an economy that produces oranges and boomerangs. The prices and quantities of these goods in two different years are reported in the table below. Fill in the missing entries.

	2020	2021	Percentage change 2020–2021
Quantity of oranges	100	105	?
Quantity of boomerangs	20	22	?
Price of oranges (dollars)	1	1.10	?
Price of boomerangs (dollars)	3	3.10	?
Nominal GDP	?	?	?
Real GDP in 2020 prices	?	?	?
Real GDP in 2021 prices	?	?	?
Real GDP in chained prices, benchmarked to 2021	?	?	?

6. **Inflation in the orange and boomerang economy:** Consider the economy from exercise 5. Calculate the inflation rate for the 2025–2027 period using the GDP deflator based on the Laspeyres, Paasche, and chain-weighted indexes of GDP.

7. **How large is the economy of India?** Indian GDP in 2017 was 152 trillion rupees, while U.S. GDP was \$17.7 trillion. The exchange rate in 2017 was 65.1 rupees per dollar. India turns out to have lower prices than the United States (this is true more generally for poor countries): the price level in India (converted to dollars) divided by the price level in the United States was 0.277 in 2017.
   (a) What is the ratio of Indian GDP to U.S. GDP if we don't take into account the differences in relative prices and simply use the exchange rate to make the conversion?
   (b) What is the ratio of real GDP in India to real GDP in the United States in common prices?
   (c) Why are these two numbers different?

8. **How large is the economy of Sweden?** Swedish GDP in 2017 was 440 billion kronor (U.S. GDP was \$17.7 trillion). The exchange rate in 2017 was 8.5 kronor per dollar. Contrary to China and India, however, Sweden had higher prices than the United States: the price level in Sweden (converted to dollars) divided by the price level in the United States was 1.11 in 2017.
   (a) What is the ratio of Swedish GDP to U.S. GDP if we don't take into account the differences in relative prices and simply use the exchange rate to make the conversion?

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(b) What is the ratio of GDP in Sweden to real GDP in the United States in common prices?
(c) Why are these two numbers different?

9. **Earthquakes and GDP:** Suppose the rural part of a country is hit by a major earthquake that destroys 10 percent of the country's housing stock. The government and private sector respond with a major construction effort to help rebuild houses. Discuss how this episode is likely to affect (a) the economic well-being of the people in the country and (b) the economy's measured GDP.

WORKED EXERCISE

2. **What counts as GDP (I)?**

(a) GDP rises by the $5,000 amount of your tuition payment. This is the purchase of a service (education) that is produced this semester.
(b) The purchase of used goods does not involve new production. This example is just the transfer of an existing good, so GDP is unchanged. If you bought the used car from a used-car dealer, the service of selling the car would represent new production—so something like $200 of the $2,500 might be included in GDP.
(c) The new dam is new production, and the government spending of $100 million is counted as GDP. Notice that if the spending were spread over several years, then the flow of new production (and GDP) would also be spread over time.
(d) Foreign graduate students working in the United States contribute to production that occurs within the United States, and this is included in GDP. So GDP goes up by $5,000 for each student.

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PART 2

THE LONG RUN

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CHAPTER 3

AN OVERVIEW OF LONG-RUN ECONOMIC GROWTH

OVERVIEW

In this chapter, we learn

- some facts related to economic growth that later chapters will seek to explain.
- how economic growth has dramatically improved welfare around the world.
- that this growth is actually a relatively recent phenomenon.
- some tools used to study economic growth, including how to calculate growth rates and why a “ratio scale” makes plots of per capita GDP easier to understand.

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> The first step in making things better is to understand why things are the way they are.
>
> —ANONYMOUS

3.1 Introduction

Let's play a game. I'll describe some economic characteristics of a country, and you tell me which country I am describing. In this country, life expectancy at birth is under 50 years, and 1 out of every 10 infants dies before reaching a first birthday. More than 90 percent of households have no electricity, refrigerator, telephone, or car. Fewer than 10 percent of young adults have graduated from high school. Is it Ethiopia, or Haiti, or perhaps North Korea? All good guesses, but in fact the country is the United States, not today but at the end of the nineteenth century.

Such is the power of economic growth: in just over a century, the United States has been completely transformed. Almost all households have electricity, refrigerators, telephones, and cars. The overwhelming majority of young adults have graduated from high school, with many going on to college. But this only hints at the scale of the transformation. Think of the new goods that were nearly unimaginable a hundred years ago: air-conditioning, dishwashers, skyscrapers, jet airplanes, satellites, television, movie theaters, computers and the Internet, iPhones, and the multitude of other goods available in supermarkets, restaurants, and superstores.

The tremendous gains in health are equally impressive. Life expectancy at birth in the United States is 50 percent higher than a century ago, at more than 78 years. The great European financier Nathan Rothschild, the richest man in the world in the early 1800s, died from an infection that $10 of antibiotics could cure today.

Not all countries in the world have experienced this rapid growth. The fact that the United States of a century ago could be mistaken for Ethiopia or Haiti today is testimony to an enormous lost opportunity.

This chapter provides an overview of the basic facts of economic growth. We use statistics on GDP per person to quantify the large differences in economic performance between the present and the past and between the rich and poor countries of the world today. In the process, we develop a number of mathematical tools that are extremely useful in studying macroeconomics. Subsequent chapters in the long-run portion of this book will draw on these tools to provide economic theories that help us understand the facts of economic growth.

3.2 Growth over the Very Long Run

One of the most important facts of economic growth is that sustained increases in standards of living are a remarkably recent phenomenon. Figure 3.1 makes this point by showing estimates of per capita GDP over the past 2,000 years for six

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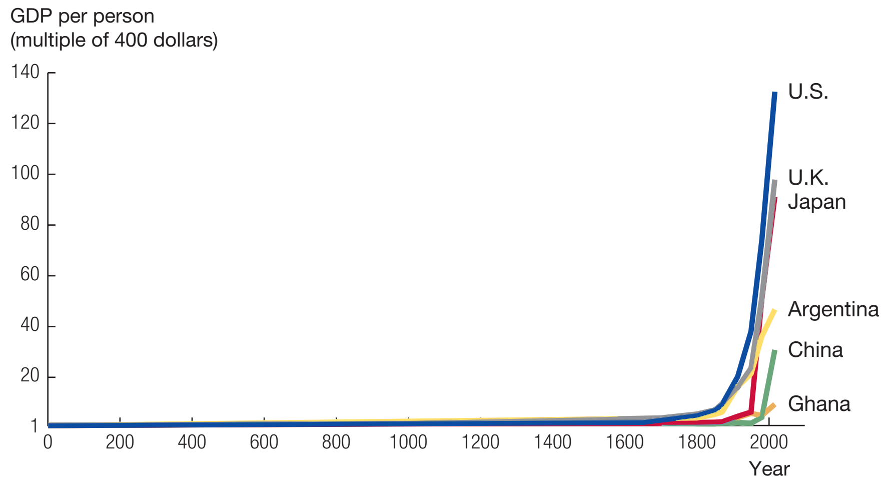
On a long timescale, economic growth is so recent that a plot of per capita GDP looks like a hockey stick, and the lines for different countries are hard to distinguish.

FIGURE 3.1

Economic Growth over the Very Long Run in Six Countries



Source: The Maddison-Project, www.ggdc.net/maddison/.

countries. For most of history, standards of living were extremely low, not much different from that in the poorest countries of the world today. The figure shows this going back for 2,000 years, but it is surely true going back even further. Up until about 12,000 years ago, humans were hunters and gatherers, living a nomadic existence. Then around 10,000 B.C. came an agricultural revolution, which led to the emergence of settlements and eventually cities. Yet even the sporadic peaks of economic achievement that followed were characterized by low average standards of living. Evidence suggests, for example, that wages in ancient Greece and Rome were approximately equal to wages in Britain in the fifteenth century or France in the seventeenth, periods distinctly prior to the emergence of modern economic growth.[1]

It is only in the most recent two or three centuries that modern economic growth emerges, but when it appears, the results are stunning. In the words of seventeenth-century English philosopher Thomas Hobbes, life was "nasty, brutish, and short" for hundreds of thousands of years. Since 1700, however, living standards in the richest countries have risen sharply. Incomes have exploded by a factor of 90 during a period that is but a flash in the pan of human history. If the 130,000-year period since modern humans made their first appearance were compressed into a single day, the era of modern growth would have begun only in the past 3 minutes.

Another point to be gleaned from Figure 3.1 is that sustained growth emerges in different places at different times. Growth first starts to appear in the United Kingdom and then in the United States. Standards of living in Argentina and

[1] For more on this evidence, see Robert E. Lucas Jr., *Lectures on Economic Growth* (Cambridge, Mass.: Harvard University Press, 2004); and Charles I. Jones, "Was an Industrial Revolution Inevitable? Economic Growth over the Very Long Run," *Advances in Macroeconomics* (2001).

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Japan begin to rise mainly in the past century or so, and in China, only during the past several decades. Finally, standards of living in Ghana today are perhaps less than ten times as high as they were over most of history, and sustained growth is not especially evident.

An important result of these differences in timing is that living standards around the world today vary dramatically. Per capita GDP in Japan and the United Kingdom is about 3/4 that in the United States; for Argentina and China, the ratio is around 1/3; and for Ghana, only 1/15. These differences are especially stunning when we consider that living standards around the world probably differed by no more than a factor of 2 or 3 before the year 1700. In the past three centuries, standards of living have diverged dramatically, a phenomenon that has been called **the Great Divergence**.[2]

3.3 Modern Economic Growth

On a scale of thousands of years like that shown in Figure 3.1, the era of modern economic growth is so compressed that incomes almost appear to rise as a vertical line. But if we stretch out the timescale and focus on the past 150 years or so, we get a fuller picture of what has been occurring. Figure 3.2 does this for the United States.

Measured in year 2017 prices, per capita GDP in the United States was about \$3,600 in 1870 and rose to \$61,000 by 2018, a more than 15-fold increase. A more mundane way to appreciate this rate of change is to compare GDP in the year you were born with GDP in the year your parents were born. In 2000, for example, per capita income was around \$50,000. Thirty years earlier it was just half this amount. Assuming this economic growth continues, the typical American college student today will earn a lifetime income about twice that of his or her parents.

The Definition of Economic Growth

Up to this point, the phrase "economic growth" has been used generically to refer to increases in living standards. However, "growth" also has a more precise meaning, related to the exact rate of change of per capita GDP.

Notice that the slope of the income series shown in Figure 3.2 has been rising over time: our incomes are rising by an ever-increasing amount each year. In fact, these income changes are roughly proportional to the level of per capita income at any particular time.

Some algebra may help us see what this statement means. Let y stand for per capita income. Then, at least as an approximation,

$$y_{2022} - y_{2021} = \bar{g} \times y_{2021},$$

[2] See Lant Pritchett, "Divergence, Big Time," *Journal of Economic Perspectives*, vol. 11 (Summer 1997), pp. 3–17, as well as Robert E. Lucas Jr., "Some Macroeconomics for the 21st Century," *Journal of Economic Perspectives*, vol. 14 (Winter 2000), pp. 159–68. The term "Great Divergence" is borrowed from Kenneth Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, N.J.: Princeton University Press, 2000).

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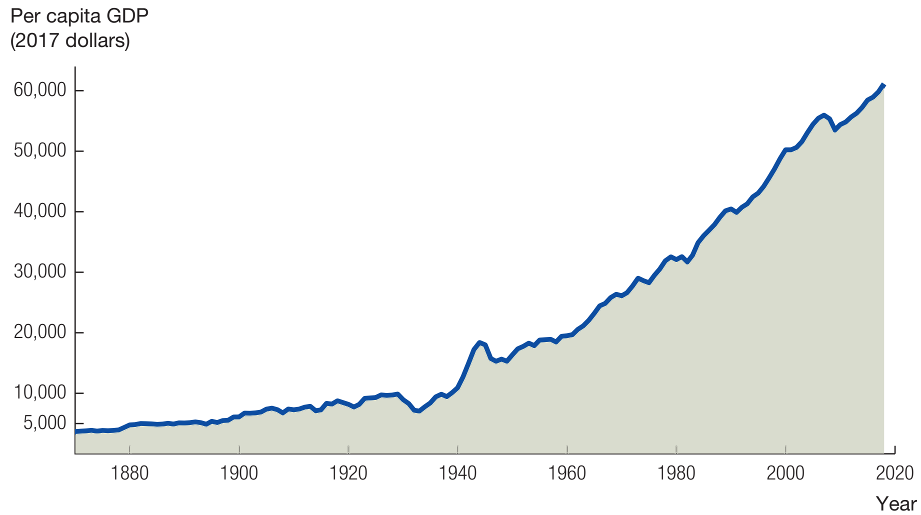
Per capita GDP in the United States has risen by more than a factor of 15 since 1870.

FIGURE 3.2

Per Capita GDP in the United States



Source: Data from 1870 to 1928 from Barro- Ursua Macroeconomic Data, 2010. Data from 1929 to 2018 from U.S. Department of Commerce, Bureau of Economic Analysis.

where, as we will see, the numerical value for $\bar{g}$ turns out to be about 0.02. That is, the change in per capita income between 2021 and 2022 is roughly proportional to the level of per capita income in 2021, where the factor of proportionality is 2 percent.

Dividing both sides of this equation by income in 2021, we discover another way of expressing this relationship:

$$\frac{y_{2022} - y_{2021}}{y_{2021}} = \bar{g}.$$

The left-hand side of this equation is the *percentage change* in per capita income. This expression says that the percentage change in per capita income is the constant $\bar{g}$, and it is this percentage change that we call a growth rate.

We can look at the growth rate between any two consecutive years. Suppose y_t is income in some period. Then we could study the growth rate between 2020 and 2021, or 1950 and 1951, or more generally between year t and year $t + 1$. This leads us to the following general definition: a **growth rate** in some variable y is the percentage change in that variable. The growth rate between period t and $t + 1$ is

$$\frac{y_{t+1} - y_t}{y_t}.$$

From this definition of a growth rate as a percentage change, we can derive a number of useful insights. For example, if the growth rate of per capita income happens to equal some number $\bar{g}$, then we can express the level of per capita income as

$$y_{t+1} = y_t(1 + \bar{g}). \tag{3.1}$$

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This equation is useful because it allows us to determine the value of per capita income tomorrow if we know the value today and the growth rate.

A Population Growth Example

To see equation (3.1) in action, consider the following example. Suppose the population of the world is given by L_0; we might suppose L_0 is equal to 6 billion, to reflect the number of people in the world in the year 2000. Now consider the possibility that population growth will be constant over the next century at a rate given by $\bar{n}$. For example, $\bar{n}$ might equal 0.02, implying that the world's population will grow at 2 percent per year. Under these assumptions, what will the level of the population be 100 years from now?

Inserting our population notation into equation (3.1), we have

$$L_{t+1} = L_t(1 + \bar{n}). \tag{3.2}$$

The population next year is equal to the population this year multiplied by (1 plus the growth rate). Why? Well, the 1 simply reflects the fact that we carry over the people who were already alive. In addition, for every person at the start, $\bar{n}$ new people are added, so we must add $\bar{n}L_t$ people to the original population L_t.

Let's apply this equation to our example. We begin at year 0 with L_0 people. Then at year 1 we have

$$L_1 = L_0(1 + \bar{n}). \tag{3.3}$$

Similarly, we can calculate the population in year 2 as

$$L_2 = L_1(1 + \bar{n}).$$

But we already know the value of L_1 from equation (3.3). Substituting from this equation, we have

$$L_2 = L_0(1 + \bar{n})(1 + \bar{n}) = L_0(1 + \bar{n})^2. \tag{3.4}$$

What about the population in year 3? Again, we take our basic growth equation, $L_3 = L_2(1 + \bar{n})$, and substitute the expression for L_2 from equation (3.4), which gives

$$L_3 = [L_0(1 + \bar{n})^2](1 + \bar{n}) = L_0(1 + \bar{n})^3. \tag{3.5}$$

At this point, you should start to see a pattern. In particular, this process suggests that the population in any arbitrary year t is

$$L_t = L_0(1 + \bar{n})^t. \tag{3.6}$$

This is the key expression that we need to answer our original question: Given values for L_0 and $\bar{n}$, what will the world population be 100 years from now? Evaluating equation (3.6) at $t = 100$, we get

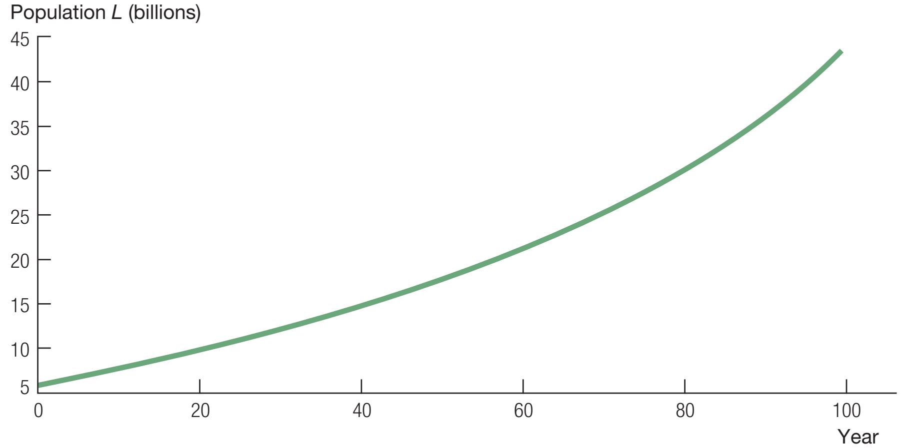
$$L_{100} = L_0(1 + \bar{n})^{100}.$$

With $L_0 = 6$ billion and $\bar{n} = 0.02$, we thus find that the population 100 years from now would equal 43.5 billion. By the way, this example is helpful for understanding growth, but the numbers are not realistic at all. Most demographers expect population growth rates to fall to zero or even turn negative during the coming century.

This graph shows the level of the population computed according to $L_t = L_0(1 + \bar{n})^t$ for $L_0 = 6$ and $\bar{n} = 0.02$.

FIGURE 3.3

Population over Time



More generally, this example illustrates the following important result, known as the **constant growth rule**: if a variable starts at some initial value y_0 at time 0 and grows at a constant rate $\bar{g}$, then the value of the variable at some future time t is given by

$$y_t = y_0(1 + \bar{g})^t \tag{3.7}$$

There is one more lesson to be learned from our simple population example. Equation (3.6) provides us with the size of the population at any time t, not just $t = 100$. In principle, we can use it to produce a plot of the population at each point in time. What do you think such a plot would look like? Try making one on your own, with a calculator and a judicious choice of a few years, or even with a computer spreadsheet program. You should end up with a plot that looks like Figure 3.3. Where have you seen a graph that looked something like this before? While the numbers are different, the signature growth curve here looks a lot like the pattern of per capita GDP in the United States, shown in Figure 3.2. It is this similarity that we explore next.

The Rule of 70 and the Ratio Scale

A major shortcoming of an illustration like Figure 3.2 or Figure 3.3 is that it's difficult to "see" the rate of growth in the figure. For example, is it possible to tell from Figure 3.3 that the rate of growth of the world population is constant over the 100 years? Not really. In Figure 3.2, is the average growth rate increasing, decreasing, or constant? Again, it's nearly impossible to tell.

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Fortunately, there is an alternative way of plotting these figures, called a "ratio scale," that makes it much easier to see what is happening to the growth rate. Suppose a country called Utopia has a per capita income that exhibits a constant growth rate $\bar{g}$. How many years does it take before income doubles? If income starts at y_0, we are asking how many years it takes until $y_t = 2 \times y_0$. We know from the constant growth rule in equation (3.7) that $y_t = y_0(1 + \bar{g})^t$. So per capita income will double when

$$\begin{aligned} y_t = 2y_0 &= y_0(1 + \bar{g})^t \\ \Rightarrow 2 &= (1 + \bar{g})^t. \end{aligned} \tag{3.8}$$

That is, if income is growing at rate $\bar{g}$, then the number of years it takes until income doubles is the value of t such that $2 = (1 + \bar{g})^t$. Solving this equation for t requires you to take the logarithm of both sides of the equation. Here, it is sufficient for us simply to note the bottom line, which is important enough to have its own name, the **Rule of 70**: if y_t grows at a rate of g percent per year, then the number of years it takes y_t to double is approximately equal to $70/g$. For example, if y_t grows at 2 percent per year, then it doubles about every $70/2 = 35$ years.[3]

There are two points to note about the Rule of 70. First, it is very informative in its own right. If a country's income grows at 1 percent per year, then it takes about 70 years for income to double. However, if growth is slightly faster at 5 percent per year, then income doubles every 14 (70/5) years. Seemingly small differences in growth rates lead to quite different outcomes when compounded over time. This is a point we will return to often throughout the next several chapters.

The second implication of the Rule of 70 is that the time it takes for income to double depends only on the growth rate, not on the current level of income. If a country's income grows at 2 percent per year, then it doubles every 35 years, regardless of whether the initial income is \$500 or \$25,000.

How does this observation help us? First, let's go back to our population example, reproduced in a slightly different way in Figure 3.4. In part (a), because population is growing at a constant rate of 2 percent per year, it will double every 35 years; the points when the population hits 6 billion (today), 12 billion, 24 billion, and 48 billion are highlighted.

Now consider what happens if we "squish" the vertical axis of the population plot so that the key doubling points—the 6-, 12-, 24-, and 48-billion points—are equally far apart. That is, rather than labeling the vertical axis in the usual "1, 2, 3, 4" fashion, we label it as "1, 2, 4, 8" so that each interval represents a doubling; this is shown in part (b). Something remarkable happens: what was previously an ever-steepening curve has turned into a straight line. If the population is growing

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[3] Logarithms help you see how this rule is derived. Taking natural logs of both sides of equation (3.8) gives

$$\ln 2 = t \times \ln(1 + \bar{g}).$$

Next, note that $\ln 2 \approx 0.7$ and $\ln(1 + \bar{g}) \approx \bar{g}$, so this equation can be written as

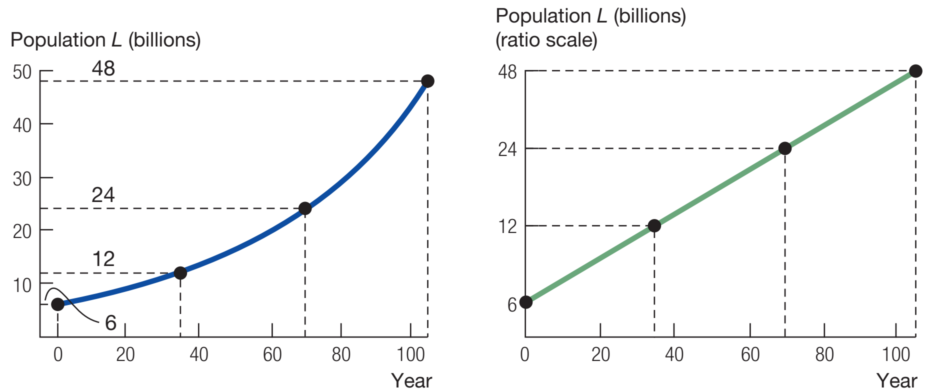
$$t = \frac{0.7}{\bar{g}}.$$

To get our rule, we multiply the top and bottom of this fraction by 100 so that the growth rate is expressed as a percent.

These graphs show the level of the population computed according to $L_t = L_0(1 + \bar{n})^t$ for $L_0 = 6$ and $\bar{n} = 0.02$. The vertical scale in part (b) is a *ratio scale*, so that equally spaced intervals are associated with a doubling of population.

FIGURE 3.4

Population over Time, Revisited



(a) On a standard scale... (b) and a ratio scale.

at a constant rate, we should hit our equally spaced markers every 35 years, and this is exactly what happens.

Squishing the vertical axis this way creates a **ratio scale**:[4] a plot where equally spaced tick marks on the vertical axis are labeled consecutively with numbers that exhibit a constant ratio, like "1, 2, 4, 8, . . ." (a constant ratio of 2) or "10, 100, 1,000, 10,000, . . ." (a constant ratio of 10). Plotted on a ratio scale, a variable growing at a constant rate appears as a straight line.

U.S. GDP on a Ratio Scale

The ratio scale is a tool that allows us to quickly read growth rates from a graph. For example, consider what we can learn by plotting U.S. per capita GDP on a ratio scale. If income grows at a constant rate, then the data points should lie on a straight line. Alternatively, if growth rates are rising, we would expect the slope between consecutive data points to be increasing.

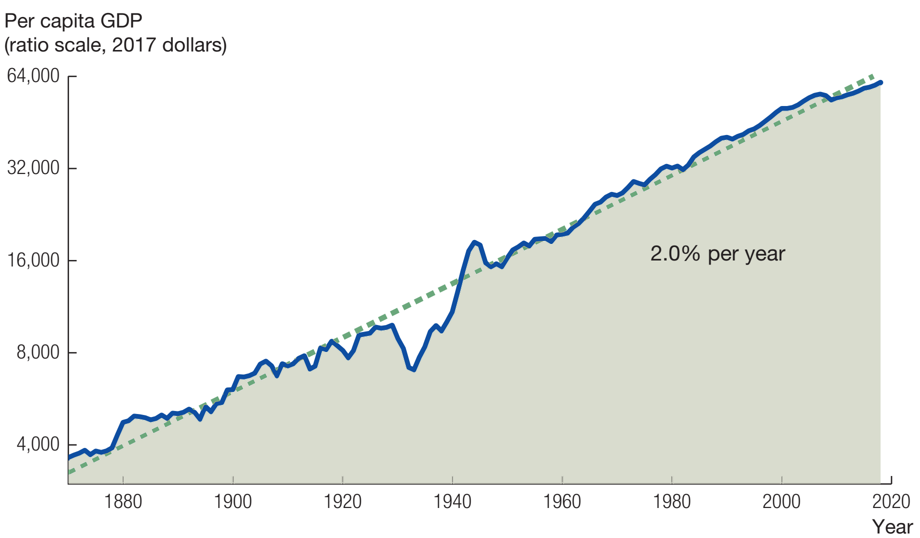
Figure 3.5 shows the same data as Figure 3.2, per capita GDP in the United States, but now on a ratio scale. Notice that the vertical axis here is labeled "2, 4, 8, 16"—doubling over equally spaced intervals. Quite remarkably, the data series lies close to a line that exhibits a constant slope of 2.0 percent per year. This means that to a first approximation, per capita GDP in the United States has been growing at a relatively constant annual rate of 2.0 percent over the past 150 years.

A closer look at the figure reveals that the growth rate in the first half of the sample was slightly lower than this. For example, the slope between 1870 and 1929 is slightly lower than that of the 2.0 percent line, while the slope between 1950 and 2015 is slightly higher. These are points that we can easily see on a ratio scale, as opposed to the standard linear scale in Figure 3.2.

[4] In computer spreadsheet programs, a ratio scale is sometimes called a "logarithmic" scale.

FIGURE 3.5

Per Capita GDP in the United States, Ratio Scale



This is the same data shown in Figure 3.2, but plotted using a *ratio scale*. Notice that the ratios of the equally spaced labels on the vertical axis are all the same, in this case equal to 2. The dashed line exhibits constant growth at a rate of 2.0 percent per year.

Calculating Growth Rates

Figure 3.5 raises a couple of interesting questions. How can we tell that the growth rate associated with the straight line is 2 percent instead of 5 percent or 1 percent? More generally, given some data on income or population, how do we compute a growth rate?

First, the fact that the graph is a straight line on a ratio scale tells us that the growth rate is constant. To get the actual rate of 2 percent, there are two approaches. For a quick estimate, we can use the Rule of 70. If you look closely at Figure 3.5, you will see that the straight line is doubling about every 35 years. For example, between 1880 and 1915, the line rises from about \$4,000 to about \$8,000; between 1915 and 1950, it doubles again to about \$16,000. From our Rule of 70, we know that a process that doubles every 35 years is growing at 2 percent per year $(70/35 = 2)$.

To get a more precise measure of the growth rate, we need the raw data. If the data for every year are available, we could compute the percentage change across each annual period, and this would be a fine way to measure growth. But what if instead we are given data only for the start and end of this series? For example, suppose we know that U.S. per capita GDP was \$3,600 in 1870 and \$61,000 in 2018. What is the average annual growth rate over these 148 years?

The answer can be found by applying the constant growth rule in equation (3.7); that is, for a quantity growing at a constant rate, the level in year t is given by $y_t = y_0(1 + \bar{g})^t$. When we encountered this rule earlier, we assumed we knew y_0 and $\bar{g}$ and wanted to solve for the value of y at some future date t. Now, though, we are given values of y_t and y_0 and asked to solve for $\bar{g}$. The way to do this is to

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rearrange the equation and then take the tth root of the ratio of the two incomes, as explained in the **rule for computing growth rates**: the average annual growth rate between year 0 and year t is given by

$$\bar{g} = \left(\frac{y_t}{y_0}\right)^{1/t} - 1 \tag{3.9}$$

Note that *if there were constant growth between year 0 and year t*, the growth rate we compute would lead income to grow from y_0 to y_t. We can, however, apply this formula even to a data series that does not exhibit constant growth, like U.S. per capita GDP. In this case, we are calculating an average annual growth rate. In the special case where $t = 1$, this rule yields our familiar percentage change calculation for the growth rate, here $(y_1 - y_0)/y_0$.

If we apply equation (3.9) to the U.S. per capita GDP numbers, the average annual growth rate is

$$\left(\frac{61{,}000}{3{,}600}\right)^{1/148} - 1 = 0.0193,$$

which justifies the rate of 2.0 percent reported in Figure 3.5.

3.4 Modern Growth around the World

Figure 3.6 uses the ratio scale to examine the behavior of per capita GDP in six countries over the past century. In the late nineteenth century, the United Kingdom was the richest country in the world, but it slipped from this position because it grew substantially slower than the United States. Notice how flat the per capita income line is for the United Kingdom relative to the United States. Since 1950, the United States and the United Kingdom have grown at more or less the same rate (indicated by the parallel lines), with income in the United Kingdom staying at about 3/4 the U.S. level.

Germany (not shown) and Japan are examples of countries whose incomes lagged substantially behind those of the United Kingdom and the United States over most of the past 150 years. After World War II, however, growth in both countries accelerated sharply, with growth in Japan averaging nearly 6 percent per year between 1950 and 1990. The rapid growth gradually slowed in both, and incomes have stabilized at something like 3/4 the U.S. level for the past two decades, similar to the income level in the United Kingdom. This catch-up behavior is related to an important concept in the study of economic growth known as **convergence**. You might say that income levels in Germany and Japan have converged to the level in the United Kingdom during the postwar period.

Economic growth in Argentina shows a different pattern, one that, to make a vast and somewhat unfair generalization, is more typical of growth in Latin America. Between 1900 and 1980, the country exhibited substantial economic

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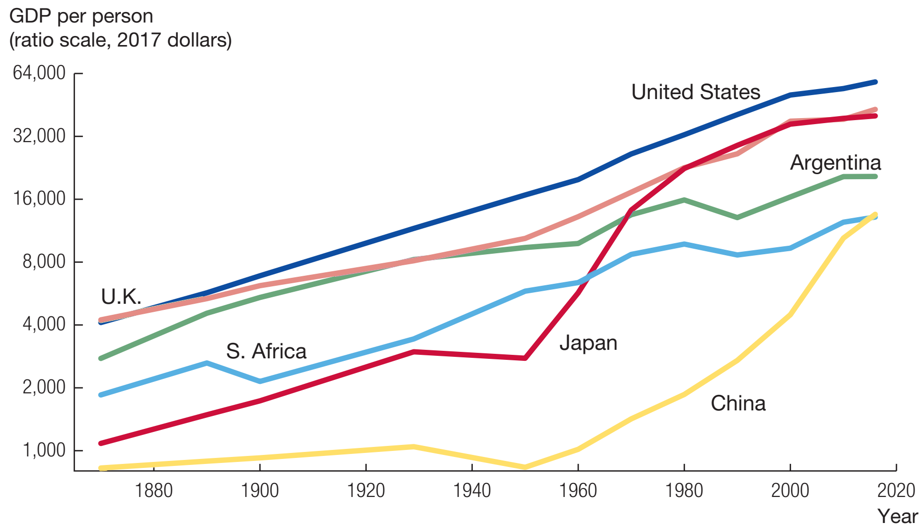
FIGURE 3.6

Per Capita GDP since 1870



Source: The Maddison-Project, www.ggdc.net/maddison/. Observations are presented every decade after 1950 and less frequently before that as a way of smoothing the series.

The ratio scale applied to incomes in several countries . . .

growth. Since 1980, however, growth has slowed considerably, so that by the end of the period income relative to the United States was just over 1/3.

China shows something of the opposite pattern, with growth really picking up after 1978 and reaching rates of more than 8 percent per year in recent decades. A country often grouped with China in such discussions is India, in part because the two countries together account for around 35 percent of the world's population. India's per capita GDP (not shown in the graph) looks somewhat similar to China's, especially before 1980. But since then, its growth has been rapid, averaging 5.9 percent per year between 1990 and 2017. By 2017, China's per capita income was about 1/4 the U.S. level, while India's was 1/8.

These last numbers may come as a surprise if you take only a casual glance at Figure 3.6; at first it appears that China's recent income was more than half the U.S. level. But remember that the graph is plotted on a ratio scale: look at the corresponding numbers on the vertical axis.

A Broad Sample of Countries

Figure 3.7 shows income levels and growth rates for a much larger sample of countries. The horizontal axis represents per capita GDP in the year 2017 relative to the United States. Ireland, Norway, Singapore, and the United States were among the countries with the highest per capita GDP in the world that year.

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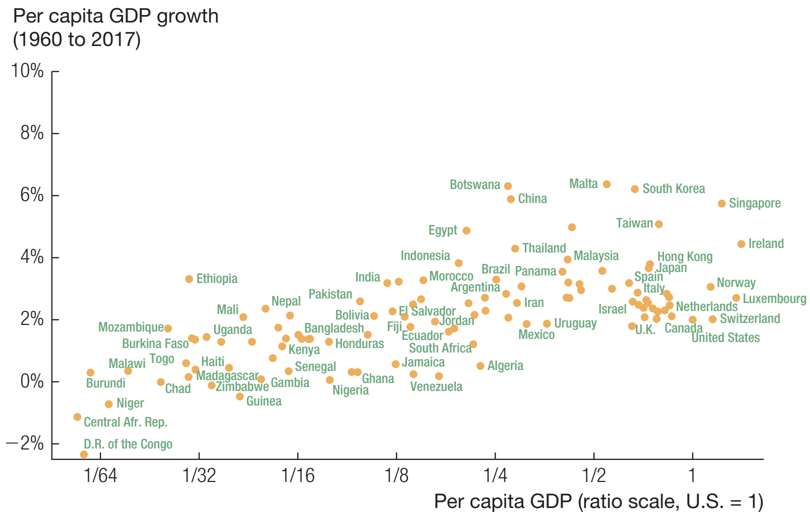
Growth rates between 1960 and 2017 range from −2% to +7% per year. Per capita GDP in 2017 varies by more than a factor of 64 across countries.

FIGURE 3.7

Levels and Growth Rates of Per Capita GDP



Source: Penn World Tables, Version 9.1. See the “Country Snapshots” file, snapshots.pdf, available from the author’s web page for these data. The level of per capita GDP is taken from the year 2017 and is normalized so that the U.S. value equals 1.

Other rich countries include Israel, Japan, South Korea, and Spain, with incomes greater than 1/2 the U.S. level. Middle-income countries like Iran, Mexico, and Argentina had incomes about 1/3 the U.S. level. China, India, and Indonesia are examples of countries with relative incomes between 1/10 and 1/4. Finally, Burundi, Niger, and Malawi, among the poorest countries of the world in 2017, had incomes around 1/64 the U.S. level.

The vertical axis illustrates the wide range of growth rates that countries have experienced since 1960. The fastest-growing countries over this period include South Korea, Egypt, Thailand, China, Botswana, and Japan, all with average growth rates between 4 and 7 percent per year. At the other end of the spectrum are the Central African Republic, the Democratic Republic of the Congo, Niger, and Guinea, each of which exhibited *negative* average growth over this half century. The bulk of the countries lie between these two extremes. For example, growth rates in Sweden, Colombia, Turkey, Mexico, and the United Kingdom all hover around 2 percent. A number of poor countries saw growth rates above this average, including Brazil, Egypt, India, Indonesia, and Mauritius.

The importance of these differences in growth rates is hard to overestimate. In Singapore, for example, which is growing at 6 percent per year, incomes will double every 12 years (remember the Rule of 70). Over the course of a half century—about two generations—incomes will increase by a factor of $2^4 = 16$. In a country like Singapore, young adults are 16 times richer than their grandparents. But in countries like Nicaragua and Madagascar, standards of living have been stagnant across these same two generations.

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CASE STUDY

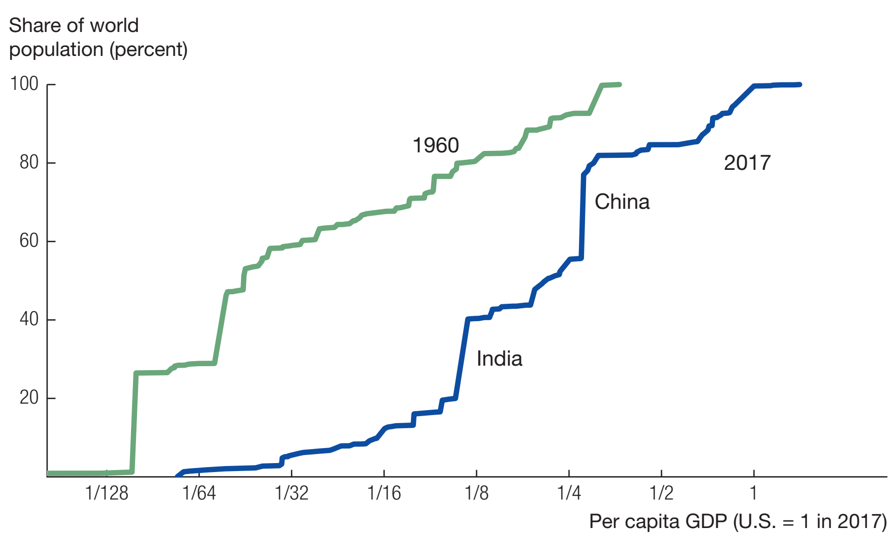
People versus Countries

Figure 3.8 takes a different perspective on economic growth and treats the *person* rather than the *country* as the unit of observation. Rather than letting China count as 1 observation out of 109 countries, for example, we count the 1.4 billion people in China as about one-fifth of the world's population. The figure, in other words, plots the distribution of the world's population according to per capita GDP. It shows the fraction of people living in countries that have a per capita GDP below the number on the horizontal axis. Importantly, this per capita GDP is measured as a fraction of U.S. per capita GDP in the year 2017.

A couple of interesting facts are revealed by the figure. First, the general growth rate of per capita GDP throughout the world is evident in the way the distribution shifts out over time. The bulk of the world's population is substantially richer today than it was in 1960. Second, the fraction of people living in poverty has fallen dramatically in the past half century. In 1960, 2 out of 3 people in the world lived in countries with a per capita GDP less than 5 percent of the 2017 U.S. level. In other words, in today's prices, these people made about $7 per day. By 2017, the fraction living in this kind of poverty had

FIGURE 3.8

The Distribution of World Population by Per Capita GDP, 1960 and 2017



The graph shows, for 1960 and 2017, the percentage of the world's population living in countries with a per capita GDP less than or equal to the number on the horizontal axis. This per capita GDP is relative to the United States *in the year 2017* for both lines.

fallen to less than 1 out of 12. If the distribution had remained unchanged from its 1960 level, more than 4 billion people would fall below this poverty threshold today. Instead, because of economic growth, only about 500 million do. One of the major reasons for this has been the rapid economic growth in India and China, which together account for more than a third of the world's population.[5]

3.5 Some Useful Properties of Growth Rates

As we develop models of economic growth, three simple properties of growth rates will prove extremely valuable. These properties are summarized below.

Growth rates of ratios, products, and powers: Suppose two variables x and y have average annual growth rates of g_x and g_y, respectively. Then the following rules apply:

1. If $z = x/y$, then $g_z = g_x - g_y$.
2. If $z = x \times y$, then $g_z = g_x + g_y$.
3. If $z = x^a$, then $g_z = a \times g_x$.

In these expressions, g_z is the average annual growth rate of z.

These simple rules explain how to compute the growth rate of (1) the ratio of two variables, (2) the product of two variables, and (3) a variable that is raised to some power.[6] For example, suppose $g_x = 0.02$ and $g_y = 0.02$, so that x and y are both growing at 2 percent per year. What must then be true about the ratio x/y? If both the numerator and denominator are growing at the same rate, then surely the ratio must be constant. This is exactly what the first rule implies.

Now suppose $g_x = 0.05$ instead. In this case, the numerator grows faster than the denominator, so we would expect the ratio to grow as well. In fact, rule 1 says

[5] For a more sophisticated version of this argument, see Xavier Sala-i-Martin, "The World Distribution of Income: Falling Poverty and . . . Convergence, Period," *Quarterly Journal of Economics*, vol. 121 (May 2006), pp. 351–97. The paper shows that the conclusion holds up even if we account for how the income distribution within countries may have changed.

[6] These rules should be thought of as approximations that are very good when growth rates are small. With the aid of calculus, they can be shown to hold exactly for instantaneous growth rates. Consider the second rule, for the product of two variables. In this case, we have

$$\frac{z_{t+1}}{z_t} = \frac{x_{t+1}}{x_t} \times \frac{y_{t+1}}{y_t}.$$

Now notice that $z_{t+1}/z_t = (1 + g_z)$, and that a similar expression holds for x and y. Therefore,

$$(1 + g_z) = (1 + g_x)(1 + g_y) = 1 + g_x + g_y + g_x g_y.$$

Then $g_z \approx g_x + g_y$ as long as $g_x g_y$ is small. You can check that this approximation works well by plugging in some numbers.

the growth rate of the ratio should equal $g_x - g_y = 0.05 - 0.02 = 0.03$, so the ratio of x to y will now grow at 3 percent per year.

Next, consider the second rule. If $g_x = 0.04$ and $g_y = 0.02$, what will the growth rate of $z = x \times y$ be? Surely z must grow faster than x, since we've multiplied x by something that is growing. Rule 2 says that the growth rate of the product of two variables is the *sum* of the two growth rates.

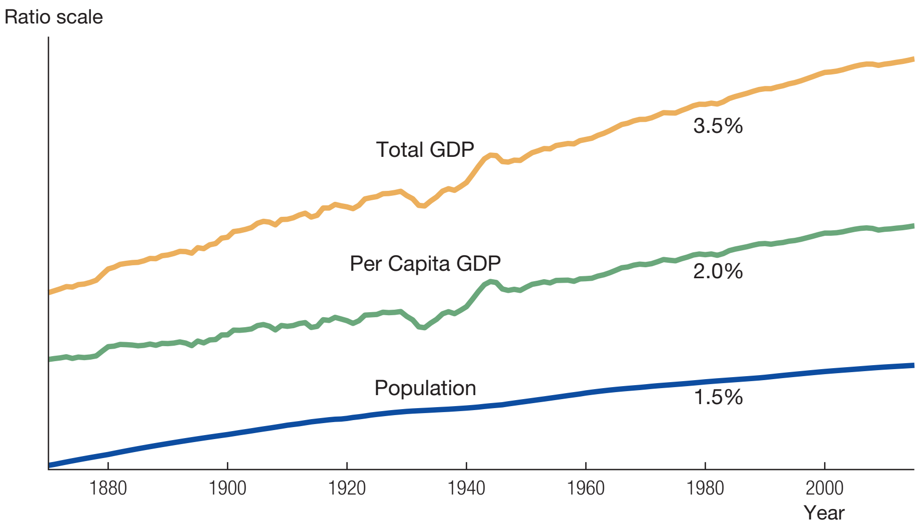
These first two rules illustrate an elegant property of growth rates: growth rates obey mathematical operations that are one level "simpler" than the operation on the original variables. Division of the variables becomes subtraction of the growth rates; multiplication of the variables becomes addition of the growth rates.

As rule 3 shows, this same kind of simplification occurs when we look at exponentiation. To begin with a simple example, suppose y grows at rate g_y. What is the growth rate of $z = y^2$? Since $y^2 = y \times y$, we can apply our multiplication rule to see that $g_z = g_y + g_y = 2 \times g_y$. Similarly, the growth rate of y^3 will be $3 \times g_y$ and the growth rate of y^{10} will be $10 \times g_y$. This result generalizes to any exponent, including negative ones.

Table 3.1 shows some ways to apply these rules, and Figure 3.9 gives a practical example. Total GDP in an economy is equal to the product of per capita GDP and the population. Therefore the growth rate of GDP is the *sum* of the growth rates of per capita GDP and population. This can be seen graphically in the figure in the three different slopes. We will use these growth rules extensively in the chapters that follow, so you should memorize them and be prepared to apply them.

FIGURE 3.9

U.S. Population, GDP, and Per Capita GDP



Sources: Angus Maddison, "Statistics on World Population, GDP and Per Capita GDP, 1 AD–2006 AD," and the Bureau of Economic Analysis.

The growth rate of total GDP is the sum of the growth rate of per capita GDP and the growth rate of the population.

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TABLE 3.1

Examples of Growth Rate Calculations

Suppose x grows at rate $g_x = 0.10$ and y grows at rate $g_y = 0.03$. What is the growth rate of z in the following cases?

$z = x \times y$	$\Rightarrow$	$g_z = g_x + g_y = 0.13$
$z = x/y$	$\Rightarrow$	$g_z = g_x - g_y = 0.07$
$z = y/x$	$\Rightarrow$	$g_z = g_y - g_x = -0.07$
$z = x^2$	$\Rightarrow$	$g_z = 2 \times g_x = 0.20$
$z = y^{1/2}$	$\Rightarrow$	$g_z = 0.5 \times g_y = 0.015$
$z = x^{1/2}y^{-1/4}$	$\Rightarrow$	$g_z = 0.5 \times g_x - 0.25 \times g_y = 0.0425$

CASE STUDY

Growth Rules in a Famous Example, $Y_t = A_t K_t^{1/3} L_t^{2/3}$

This well-known example incorporates one of the key equations of macroeconomics, which we will return to often in coming chapters. For now, we'll see how it illustrates our growth rules.

Suppose we have an equation that says a variable Y_t is a function of some other variables A_t, K_t, and L_t. In particular, this function is

$$Y_t = A_t K_t^{1/3} L_t^{2/3}.$$

What is the growth rate of Y_t in terms of the growth rates of A_t, K_t, and L_t?

Here's where we apply our growth rules. Our second rule says that the growth rate of the product of certain variables is the sum of the variables' growth rates.[7] So

$$g(Y_t) = g(A_t) + g(K_t^{1/3}) + g(L_t^{2/3}).$$

(We write Y_t, A_t, and so on in parentheses here rather than as a subscript to avoid the awkward notation that would result.) Next, we can use the third rule to compute the growth rates of the last two terms in this expression: the growth rate of a variable raised to some power is equal to that power times the growth rate of the variable. Therefore, we have

$$g(Y_t) = g(A_t) + \tfrac{1}{3} \times g(K_t) + \tfrac{2}{3} \times g(L_t).$$

And that's the answer we are looking for. As we will see in later chapters, this equation says that the growth rate of output Y can be decomposed into the growth rate of a productivity term A and the contributions to growth from capital K and labor L.

[7] Although the original rule applied to the product of two variables, it applies equally well to three or more variables. For example, if $z = wxy$, then $g(z) = g(w) + g(xy) = g(w) + g(x) + g(y)$.

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3.6 The Costs of Economic Growth

When we consider economic growth, what usually comes to mind are the enormous benefits it brings: increases in life expectancy, reductions in infant mortality, higher incomes, an expansion in the range of goods and services available, and so on. But what about the costs of economic growth? High on the list of costs are environmental problems such as pollution, the depletion of natural resources, and even global warming. Another by-product of economic growth during the past century is increased income inequality—certainly across countries and perhaps even within countries. Technological advances may also lead to the loss of certain jobs and industries. For example, automobiles decimated the horse-and-buggy industry; telephone operators and secretaries have seen their jobs redefined as information technology improves. More than 40 percent of U.S. workers were employed in agriculture in 1900; today the fraction is less than 2 percent.

The general consensus among economists who have studied these costs is that they are substantially outweighed by the overall benefits. In the poorest regions of the world, this is clear. When 20 percent of children die before the age of 5—as they do in much of Africa—the essential problem is not pollution or too much technological progress, but rather the absence of economic growth.

But the benefits also outweigh the costs in richer countries. For example, while pollution is often associated with the early stages of economic growth—as in London in the mid-1800s or Mexico City today—environmental economists have documented an inverse-U shape for this relationship. Pollution grows worse initially as an economy develops, but it often gets better eventually. Smog levels in Los Angeles are substantially less today than they were 30 years ago; one reason may be that cars in California produce noxious emissions that are only 5 percent of their levels in the mid-1970s. Technological change undoubtedly eliminates some jobs, and there is no denying the hardship that this can cause in the short run. But as we will see in Chapter 7, the unemployment rate in the United States today—at least before the recent recession—is on par with the levels in the 1960s. Jobs disappear, but new ones are created. The decline in agriculture and the demise of the family farm are the flip side of the tremendous rise in agricultural productivity.

It is indisputable that economic growth entails costs, especially in certain times and certain places and for certain people. In general, however, these costs are more than offset by the benefits of economic growth.[8]

3.7 A Long-Run Roadmap

In this chapter, we have seen some of the key empirical facts related to economic growth. We have also been introduced to important tools that will help us in the coming chapters as we build models of how an economy behaves over the long run.

[8] For more on the costs and benefits of growth, see the following: E. J. Mishan, *The Costs of Economic Growth* (New York: Praeger, 1993); Charles I. Jones and Dietrich Vollrath, *Introduction to Economic Growth* (New York: Norton, 2013), Chapter 9; and William Nordhaus, "Lethal Model 2: The Limits to Growth Revisited," *Brookings Papers on Economic Activity*, vol. 2 (1992), pp. 1–59. The facts about smog in California are from the California Air Resources Board, "Fact Sheet: Reducing Emissions from California Vehicles," February 23, 2004.

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The next three chapters are primarily concerned with developing theories that help us understand the facts of economic growth. Chapter 4 focuses on explaining differences in levels of income across countries using production functions. Chapter 5 develops one of the canonical models of macroeconomics, the Solow growth model. And Chapter 6 studies the economics of knowledge itself to provide a richer understanding of the sources of growth and income differences. The last two chapters of the "long run" section of this book then turn away from economic growth to consider the labor market and the determination of wages and the unemployment rate in the long run (Chapter 7) and the long-run determinants of inflation (Chapter 8).

It should be clear at this point that the study of economic growth is of far more than academic interest. The United States of a century or two ago doesn't look that different from the poorest countries in the world today. But Americans today are more than 50 times richer on average than people in these poor regions. The rapid growth exhibited by Japan after World War II or by China in recent decades has the power to eliminate poverty there in a single generation: growing at 6 percent per year, incomes will double in 12 years, quadruple in 24 years, and increase by a factor of 8 in 36 years. At these rates, even a 50-fold gap could be closed in three generations.

In 1985, Robert E. Lucas Jr.—who would go on to win the Nobel Prize in Economics in 1995—delivered his now-famous Marshall Lectures at Cambridge University. These lectures, which laid out the facts of economic growth, much as in this chapter, were instrumental in stimulating an explosion of research on the subject in the decades that followed.[9] There is perhaps no better way to conclude this chapter than to let Lucas himself have the last word:

> I do not see how one can look at figures like these without seeing them as representing *possibilities*. Is there some action a government of India could take that would lead the Indian economy to grow like Indonesia's or Egypt's? If so, *what* exactly? If not, what is it about the "nature of India" that makes it so? The consequences for human welfare involved in questions like these are simply staggering: Once one starts to think about them, it is hard to think about anything else.[10]

3.8 Additional Resources

You may find these additional resources of interest. For articles published in academic journals, try Google Scholar (scholar.google.com): just type in the author's name and a word from the title of the paper. Many universities have online subscriptions to academic journals.

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[9] The other important stimulus was a set of papers by Paul Romer on the economics of ideas. This work will be discussed extensively in Chapter 6.

[10] "On the Mechanics of Economic Growth," *Journal of Monetary Economics*, vol. 22 (1988), p. 5.

Robert E. Lucas Jr., "Some Macroeconomics for the 21st Century," *Journal of Economic Perspectives*, vol. 14 (Winter 2000), pp. 159–68.

Much of the data in this chapter, especially from before 1950, is taken from an online data collection of Angus Maddison and his collaborators. See The Maddison-Project, www.ggdc.net/maddison/.

Data on per capita income and growth rates since 1950 for most of the countries in the world can be found in the "Country Snapshots" file, snapshots.pdf, available from www.stanford.edu/~chadj/snapshots.html.

CIA World Factbook, www.cia.gov/library/publications/the-world-factbook/.

CHAPTER REVIEW

SUMMARY

1. Viewed over the long course of history, sustained growth in standards of living is a very recent phenomenon. If the 130,000 years of human history were warped and collapsed into a single year, modern economic growth would have begun only at sunrise on the last day of the year.
2. Modern economic growth has taken hold in different places at different times. Since several hundred years ago, when standards of living across countries varied by no more than a factor of 2 or 3, there has been a "Great Divergence." Standards of living across countries today vary by more than a factor of 100.
3. Incomes in the poorest countries of the world are probably no more than twice as high as average incomes around the world a thousand years ago.
4. Since 1870, growth in per capita GDP has averaged about 2 percent per year in the United States. Per capita GDP has risen from about $3,600 in 1870 to more than $61,000 today.
5. Growth rates throughout the world since 1960 show substantial variation, ranging from negative growth in many poor countries to rates as high as 6 percent per year in several newly industrializing countries, most of which are in Asia.
6. Growth rates typically change over time. In Germany and Japan, growth picked up considerably after World War II as incomes in these countries converged to levels in the United Kingdom. Growth rates have slowed down as this convergence occurred. Brazil exhibited rapid growth in the 1950s and 1960s and slow growth in the 1980s and 1990s. China showed the opposite pattern.
7. Economic growth, especially in India and China, has dramatically reduced poverty in the world. In 1960, 2 out of 3 people in the world lived on less than $7 per day (in today's prices). By 2017, this number had fallen to only 1 in 12.

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