

INSTRUCTOR'S MANUAL

Charles I. Jones

Macroeconomics

FOURTH EDITION

Anthony Laramie

BOSTON COLLEGE



W • W • NORTON & COMPANY • NEW YORK • LONDON

W. W. Norton & Company has been independent since its founding in 1923, when William Warder Norton and Mary D. Herter Norton first published lectures delivered at the People's Institute, the adult education division of New York City's Cooper Union. The firm soon expanded its program beyond the Institute, publishing books by celebrated academics from America and abroad. By midcentury, the two major pillars of Norton's publishing program—trade books and college texts—were firmly established. In the 1950s, the Norton family transferred control of the company to its employees, and today—with a staff of four hundred and a comparable number of trade, college, and professional titles published each year—W. W. Norton & Company stands as the largest and oldest publishing house owned wholly by its employees.

Copyright © 2018, 2014, 2011, 2008 by W. W. Norton & Company, Inc.

All rights reserved.

Printed in the United States of America.

Assistant Media Editor: Sam Glass

Production Manager: Eric Pier-Hocking

Composition: Westchester Publishing Services

W. W. Norton & Company, Inc.

500 Fifth Avenue, New York, N.Y. 10110-0017

wwnorton.com

W. W. Norton & Company Ltd.

Castle House, 75/76 Wells Street, London W1T 3QT

1 2 3 4 5 6 7 8 9 0

TABLE OF CONTENTS

Part 1 Preliminaries

Chapter 1 Introduction to Macroeconomics	1
Chapter 2 Measuring the Macroeconomy	7

Part 2 The Long Run

Chapter 3 An Overview of Long-Run Economic Growth	16
Chapter 4 A Model of Production	24
Chapter 5 The Solow Growth Model	35
Chapter 6 Growth and Ideas	45
Chapter 7 The Labor Market, Wages, and Unemployment	53
Chapter 8 Inflation	62

Part 3 The Short Run

Chapter 9 An Introduction to the Short Run	71
Chapter 10 The Great Recession: A First Look	79
Chapter 11 The IS Curve	85
Chapter 12 Monetary Policy and the Phillips Curve	95
Chapter 13 Stabilization Policy and the AS/AD Framework	104
Chapter 14 The Great Recession and the Short-Run Model	116
Chapter 15 DSGE Models: The Frontier of Business Cycle Research	123

Part 4 Applications and Microfoundations

Chapter 16 Consumption	132
Chapter 17 Investment	137
Chapter 18 The Government and the Macroeconomy	144
Chapter 19 International Trade	151
Chapter 20 Exchange Rates and International Finance	158
Chapter 21 Parting Thoughts	163

CHAPTER 1

Introduction to Macroeconomics

CHAPTER OVERVIEW

This is a conventional first textbook chapter: it defines macroeconomics, it mentions a few interesting topics, it says what a model is, and it lays out the book's separation into Long Run, Short Run, and Applications and Microfoundations. It is quite a short chapter with few surprises, so rather than summarizing it, I will instead talk a little about what makes this book different and lay out a few different ways you can use it in your course.

WHAT MAKES THIS BOOK DIFFERENT?

It offers solid long-run growth coverage—including endogenous growth—while simplifying the New Keynesian business cycle dramatically, and it does all this without any calculus. Chad shows how long-run macroeconomic growth models have evolved and how tweaking the assumptions of the model can lead to new and interesting insights and policy conclusions. Moreover, Chad easily deduces a short-run model from the long-run model and therefore links short-run and long-run economic analyses. By streamlining the coverage while teaching surprisingly solid microfoundations, Chad's text offers you a solid chance to spend more time on intelligent, model-driven policy discussions about growth and business cycles.

HOW TO USE THIS TEXTBOOK

CONVENTIONAL ONE-SEMESTER CLASS

In this day and age of assessment, we are ever conscious of what we teach, how we teach it, who our students are, what

our students learn, and how they learn. Most students who have recently had a principles course and who are comfortable with a little algebra should be able to handle Chapters 1–14 in a semester. How much time you spend on these chapters, whether you omit coverage of any of these chapters, and the nature and skill level of your students will influence your coverage of the later chapters.

Moreover, if you want to leave room for a few supplementary articles, a nontechnical book, or a major empirical project or two, then you might have to tread lightly over some of the math in the growth- and labor-market models, which are self-contained and don't directly come up again later in the semester. Advice on how to do this is given in later chapters of this manual.

This fourth edition of the book provides an innovative chapter on dynamic stochastic general equilibrium (DSGE) models. This chapter provides a bridge between long-run economic growth and short-run economic fluctuations, and it fits in nicely at the end of Part 3 of the textbook to remind us of the links between the long run and the short run. I'd recommend that you make time in the semester to include Chapter 15 as a capstone to a semester course.

ONE-QUARTER COURSE OR ONE-SEMESTER COURSE WITH MANY OUTSIDE READINGS AND PROJECTS

Chapters 1–4 (Introduction through the basics of growth and productivity), 8–11, 15 (inflation, business cycles, and DSGE models), and two of the following: Chapters 5, 6.1–6.3, and 7; or 12–14 and 18–20.

TWO-QUARTER COURSE OR TWO-SEMESTER COURSE

The entire book—one quarter on long-run growth, labor markets, inflation, consumption, and investment (Chapters 1–8,

16, and 17); one quarter on short-run business cycles, the Great Recession, monetary policy, the Phillips curve, fiscal policy, the aggregate demand/aggregate supply model, DSGE models, international trade, exchange rates, and international finance (Chapters 9–15, 18–21)—with enough time for a supplementary book each quarter and a few articles and data projects. This would be a great way to teach this course.

CHAPTERS THAT MAY BE OMITTED

I include this list because instructors often want to know if they can leave out a chapter without omitting facts or theories that come back in later chapters. These chapters each build on previous chapters, but none are directly used in later chapters:

- 6 Growth and Ideas (the last growth chapter)
- 7 The Labor Market, Wages, and Unemployment
- 15 Dynamic Stochastic General Equilibrium (DSGE) Models
- 16 Consumption
- 17 Investment
- 18 The Government and the Macroeconomy
- 19 International Trade
- 20 Exchange Rates and International Finance
- 21 Parting Thoughts

In particular, the International Trade chapter (19) is independent of the Foreign Exchange chapter (20), so you can choose just one or the other depending upon your needs.

For math-averse students, Chapter 5 (Solow) may be omitted if necessary, while key parts of Chapter 6 (Growth and Ideas) may be covered without difficulty (Sections 6.1–6.3). This means instructors can still teach the economics of ideas (a largely math-free topic) yet avoid the math of the Solow model.

HOW TO USE THIS INSTRUCTION MANUAL

Chad provides excellent summaries at the end of each chapter, and the student study guide performs much the same function. This instruction manual does something different: it is written to help you do a better job teaching with this innovative textbook.

In this manual, we walk through each chapter from beginning to end, discussing how you might approach topics that students often find troublesome—for instance, the Solow steady state, making sense of the three ways to measure gross domestic product (GDP), or what the Fisher equation really means.

Also, we sometimes recommend that you organize your lecture differently than the text does—some topics just flow together particularly well when you're up there at the chalkboard. We always try to point out which topics you can safely

gloss over or omit, and we often mention an illustration or two that might make your lectures a bit more relevant.

Every chapter in this manual also has a sample lecture that you can use, written on a topic with which students typically have a tough time. Finally, each chapter of this manual also contains a few case studies, often building on Chad's own case studies. In the case studies, we provide some additional facts or theories that might help to flesh out a lecture or provoke classroom discussion. We hope you find this manual useful in getting the most out of Charles Jones's *Macroeconomics*.

SAMPLE LECTURE: GIVING YOU ALL THE ANSWERS UP FRONT

Of great concern to the economics profession is the economic literacy of our students. In particular, do our students really understand the subject matter or do they simply borrow an understanding for the course? One of my teaching objectives is to ensure, as much as possible, that students own an understanding of economics. To that end, I begin the introductory class with a set of unfolding questions. I start with the most basic question, What is economics? The better students respond with the textbook definition given in Principles, which is fine. But then I ask the question, Would your brother or sister, friend or parent understand that answer? Most students respond by saying no. Loosely following the late great Robert Heilbroner, I'll say that economics is the study of the economy (and I'll get a laugh) and students will relax. But then that compels the question, What is the economy? We go around on different definitions, and we work up to the point, again following Heilbroner, that the economy is a set of social institutions/relationships devised to produce and distribute goods and bads. Then we pull that definition apart (to produce—to transform nature into something useful; to distribute—to decide who gets what; the goods and the bads—things that are literally good and/or bad.)

So, the next question is, Why study economics? Because of the economic problem. What economic problem? Scarcity. What is scarcity? Not having enough resources or goods to meet needs and desires. What causes scarcity? Resource constraints inherent in nature and the process of social interaction that create wants and desires for goods. Again, via modified Heilbroner, How does a society, regardless of space and time, confront scarcity? People must be induced to work more when they want to work less; people must be induced to consume less when they want to consume more; and technology (the art of production) must be modified/improved. What economic system does most of the world use today to confront scarcity? Students will say capitalism or markets. What are markets? Markets are the process whereby buyers and sellers interact to determine prices and quantities. What two approaches do we have for studying markets? Microeco-

nomics, the study of the individual parts of the economy, and macroeconomics, the study of the economy as a whole with emphasis on factors like economic growth, economic fluctuations, unemployment, inflation, and international economic relations.

Microeconomics is rooted in the writings of Adam Smith in *An Inquiry into the Nature and Causes of the Wealth of Nations* (1776) (I like to say the full title—it sums up what most of economics is about). Smith showed that markets promote order and stability by allowing individuals to freely express self-interest through markets and that the expression of self-interest promotes the social good. (Most students will be familiar with the “invisible hand” but not familiar with its strong political implications.) Of course, if Smith is correct, then markets, as a set of institutions, become a set of goods that promote social welfare. Well, what about macroeconomics? Where did it come from?

Macroeconomics’ origins can be traced to the Great Depression, the writings of John Maynard Keynes, World War II, and the Employment Act of 1946. If anything, macroeconomics was the consequence of market failures as evidenced by the Great Depression. To illustrate the market failures, Keynes invoked fallacies of composition in reasoning, like the paradox of thrift (that wage deflation in isolation can stabilize a labor market, but wage deflation in the economy as a whole will do little to reduce unemployment and may actually destabilize the economy). Keynes’s ideas were too revolutionary to gain acceptance, but World War II taught my parents’ generation that government coordination of the economy to ensure high levels of spending and the national defense of the United States ended the Great Depression. The World War II generation, wanting to eliminate future unemployment, had the Employment Act of 1946 passed. According to this legislation, government should pursue policies to promote maximum employment, production, and purchasing power. In addition, this legislation created the Council of Economic Advisors and the Joint Economic Committee to advise the president and Congress on the economy. Subsequently, macroeconomics, along with microeconomics, became part of every core economics curriculum. Although there is little disagreement as to how to teach microeconomics, tension remains as to how to teach macroeconomics. In particular, conflict occurs over whether to emphasize the long run or the short run. Chad’s textbook gives you the flexibility of emphasizing either concept or both.

Today, the global economy continues to recover from the Great Recession—the greatest recession since the Great Depression. Clearly the emphasis in policy has shifted to the short run, but long-run concerns remain. The U.S. unemployment rate rose from 4.6 percent in 2007 to 5.8 percent in 2008 and 9.6 percent in 2010 (the year after the Great Recession officially ended); it declined from 7.4 percent in 2013 to 5.3 in 2013 and 4.9 percent in June 2016. While the financial markets have largely recovered, still fresh in the public’s

mind is that the Dow Jones Industrial stock index, along with many other stock indexes, lost 40 percent of its value in a matter of weeks; housing prices in many markets collapsed; record numbers of bankruptcies and foreclosures were recorded; banks, insurance companies, and brokerage houses became insolvent as their assets proved insufficient to cover their liabilities; and a chain of bankruptcies threatened the strength and stability of the United States and global economies. Prior to the financial crisis, the price of crude oil rose from under \$70 in August 2007 to over \$140 by July 2008. Two of the big three U.S. automakers were on the brink of bankruptcy. Unprecedented steps were taken by the Federal Reserve and the U.S. Treasury to bail out the financial sector and to save the automakers. An economic stimulus bill was passed that included tax credits for first-time homebuyers, cash for clunkers, tax cuts, and funding for so-called shovel-ready projects (to name a few). The economic stimulus bill, combined with the War on Terrorism and the downturn in the economy, subsequently increased the federal government budget deficit from around \$160 billion in 2007 to about \$460 billion in 2008 and over \$1.5 trillion in 2010 to almost \$1.4 trillion in 2011. Moreover, despite bailouts and the stimulus, we have seen the money supply (M2) grow by 8 percent in 2009, 2.5 percent in 2010, 7.3 percent in 2011, 8.5 percent in 2012, and about 6 percent in 2015. The threat of worldwide recession remains even as oil prices have collapsed, and the Federal Reserve contemplates the speed at which short-term interest rates should increase as corporate profits remain weak. Even as of this writing in 2016, the recovery remains slow and fragile, and the debate over austerity versus stimulus continues to rage (see John Cassidy, “The Reinhart and Rogoff Controversy: A Summing Up,” *New Yorker*, available at <http://www.newyorker.com/online/blogs/johncassidy/2013/04/the-rogooff-and-reinhart-controversy-a-summing-up.html>). This experience, now compounded by the Greek financial crisis, the European refugee crisis, and Brexit, has taken the economics profession by surprise and is currently causing us to reevaluate what we think about how economies work.

In this course, we’ll spend the first half of the semester talking about why some countries are richer than others and why the average person today lives so much better than someone one or two hundred years ago. A generation ago, such topics would barely have been mentioned, but with the rise of globalization, the spread of markets around the world, and a new concern about global growth prospects, a new emphasis in economics has emerged.

In the second half of the semester, we’ll talk about economic busts and booms, which economists often call the “business cycle” or “economic fluctuations.” The book’s goal is to provide a framework for understanding the nature, causes, and solutions to both short-run and long-run fluctuations.

A generation ago, the business cycle section would’ve been almost the whole course. Back then, many macroeconomists

thought they could control the overall level of GDP on a year-to-year basis. That's certainly what the textbooks taught back then. In those days, we spent the semester talking about how to control the demand for goods and services in the economy. Back then, we thought we actually *could* control things.

Today's macroeconomics is largely about teaching macroeconomists—myself and my colleagues—to be humble. We'll learn that the Federal Reserve can have an impact on the average rate of inflation. There are increases in the overall price level, but at the same time we'll see that the Federal Reserve has a limited impact on reducing the average rate of unemployment—the fraction of workers who can't find jobs. (The Federal Reserve might be able to temporarily reduce the unemployment rate below some “natural” rate but subsequently risk high inflation without any long-run reduction in the unemployment rate.)

One point to take away from the semester is this: the Federal Reserve might be able to smooth out the bumps in the road—emphasis on “might”—but it can't make the trip go any faster. For the average American to have a better standard of living in the long run, we must focus on something other than interest-rate policy.

That's why we'll spend quite a bit of time in the first half of the semester on the “supply side” of the economy: the supply of people willing to work; the supply of machines, equipment, and natural resources; and the supply of useful, practical ideas. Economists tend to think that if you have a good supply of those four things—people, machines, natural resources, and ideas—then in a market economy, those “inputs” will usually get combined to create “outputs” that we really want, like cars and movies and doctor's appointments and books and vacations and food. By spending time in the first half of the semester talking about the supply side, the hope is that when you're voting or when you're serving in government, you'll remember that how well people live doesn't depend on whether there's a *demand* for goods—as you learned in Principles or by talking with your friends, people's demands are basically unlimited. The key problem of economics is scarcity—and the miracle of long-term economic growth is that most of the things people want are a little bit less scarce each year.

SAMPLE LECTURE: MODELS AND THEIR SOLUTIONS

In section 1.2, Chad offers the four-step approach that unifies macroeconomics: document the facts, develop a model, compare the predictions of the model with the original facts, and use the model to make additional predictions. Students in intermediate theory still can be a little uncertain and ill at ease in developing models. One possible way to make students comfortable in the process of developing models is to

remind them that central to their study in Principles was the supply and demand (the market) model. A quick review of that supply and demand model goes a long way in clearing up the vocabulary used throughout much of the text (and economics, in general). For example, describing the market model as a process whereby buyers and sellers interact to determine price and quantity provides a structural model where the buyer's behavior is modeled as a demand equation, the seller's behavior is modeled as a supply equation, and the model of solved is by specifying an equilibrium equation, that is, in general functional form (an idea that is good to introduce early on) where demand is $Q_d = Q_d(P, \text{NPDs})$, supply is $Q_s = Q_s(P, \text{NPDs})$ (where the NPDs = the relevant nonprice determinants of demand or supply and where an example or two of the respective NPDs quickly refreshes students' memories), and where equilibrium is $Q_d = Q_s$. After specifying the model, remind students that the model has to be signed (and explain what that means)—putting a “−” under “P” in the demand equation and a “+” under P in the supply equation—meanwhile explaining what the signs mean. A quick graph illustrates the equilibrium solution; the equilibrium price and quantity are shown as endogenous variables; and the NPDs are the exogenous variables that determine equilibrium levels. As a further example, you might consider moving the market analysis into specific functional form, where $Q_d = a - bP$ and $Q_s = \alpha + \beta P$, the NPDs are reflected in the slope and intercept parameters, and the equilibrium price and quantities are $P^* = (a - \alpha)/(b + \beta)$ and $Q_d^* = a - bP^*$ and $Q_s^* = \alpha + \beta P^*$. Students quickly learn that much of what they were doing in principles is nicely summarized in Figure 1.6: the parameters/exogenous variables determine the solutions to the endogenous variables, equilibrium price, and quantity, and tweaking those parameters/exogenous variables modifies the solutions to the models.

CASE STUDY: HOW MUCH WOULD YOU PAY TO GET RID OF RECESSIONS?

Given that the U.S. economy has just emerged from the so-called Great Recession and is perhaps teetering on the brink of another recession, Nobel Prize-winner Robert Lucas's question, How much would you pay to get rid of recessions? remains apropos. Lucas's answer to this question was, “Not much.”

As is well described in “After the Blowup” by John Cassidy (*New Yorker*, January 11, 2010), Lucas won the Nobel Prize, in part, for reinventing the notion that markets are self-regulating. So Lucas's answer is not surprising. Lucas noticed that consumer spending—the part of our incomes we use to buy happiness—doesn't really change that much for the average person from year to year. It only fluctuates from year to year by about 1.5 percent (aside: that's the standard deviation of real consumption) for the average person. There's

a strong annual upward trend of about 2 percent, but around that trend there's a small wiggle, averaging about 1.5 percent per year.

So how much would you, personally, be willing to pay for an insurance policy that promised that you'd never risk those 1.5 percent up-and-down shocks to your consumer spending?

Lucas ran some estimates and found that the average person would be willing to pay about 0.06 percent per year for an insurance policy like that. For a person earning \$50,000 per year, it would cost \$30 annually to guarantee a steady growth in his or her standard of living. Even when considering that it is hard to buy goods when you lose your job—you just might not be able to borrow the money to put food on the table—he found that in the United States, unemployment insurance benefits are usually good enough that the average person still wouldn't want to pay a lot for insurance to get rid of his or her consumption risk. This suggests that modern unemployment insurance is pretty good insurance already.

Quite possibly, the average poor person in the United States would pay more than \$30 per year for that kind of insurance policy. For poorer people, every dollar counts more. But Lucas was trying to come up with an *average* estimate of how much the *typical* American would pay to get rid of business cycles. And he just couldn't find a way to make that number look big.

Economists David Romer and Lawrence Ball¹ think that Lucas is missing the point entirely. They think that the big cost of economic fluctuations isn't the fact that you can't go to restaurants as often during a recession but that you might not have a job. They've run some estimates based on what they think the average person is like and they find that economic fluctuations have a much higher cost than Lucas believes. They agree that the average person doesn't get hit hard on the consuming side during a recession, but they think that people really don't like going in and out of the workforce. They find that people would rather work a steady 40-hour week than work 45 hours most of the time with some random layoffs thrown in. And of course, surveys and common sense do show that people hate being out of work.

Over the course of fifty years, the economics profession has gone from the notion that business cycles could be tamed (Samuelson and the Keynesians) to the ideas of Lucas and others that markets are self-regulating and that government intervention has ill or nil effects. In light of current events, you will be challenged throughout this course with questions regarding what should be done to end recessions and reduce unemployment.

For a nice review of the current debate, see the aforementioned *New Yorker* article.

1. Laurence Ball and David Romer, "Real Rigidities and the Non-neutrality of Money," *Review of Economic Studies* 57, no. 2 (April 1990): 183–203.

CASE STUDY: THE OECD REPORT ON INCOME INEQUALITY AND ECONOMIC GROWTH

Chad, in section 1.1, examines some of the big questions in macroeconomics. Some students might be wondering where income inequality fits into macroeconomics, as, in recent years, the issue of income inequality has risen to the forefront of both political and economic discussions. A good primer on this topic can be found in the report published in December 2015 by the OECD, *Income Inequality: The Gap Between Rich and Poor* (see: <http://www.oecd.org/social/income-inequality-9789264246010-en.htm>). In section 4.1 of the report, a summary of what economists "think about inequality is provided." First, the Kuznets hypothesis is discussed. Economic growth, through industrialization and the development specializations, raises living standards above the subsistence levels and generates ever-widening gaps in the income distribution that are then moderated by redistributive fiscal policies. With economic development, over time, inequality is expected to rise and then fall. However, in looking back over the last 100 years or so, as economies have developed, inequality has fallen, then increased. Second, in attempting to provide a link between economic growth and inequality, a "complex and dynamic" relationship is considered that depends upon (where Sara Voitchovsky's insights are mentioned) how different income groups behave and how different income groups interact. For example, inequality affects how the poor invest in education, how the middle class demand goods and services, or how the rich save and investment and alter the direction of public investment or services. Inequality also affects the way groups interact by altering trust (which impacts transaction costs), social capital (creating insider and outsider networks), social unrest (increasing governance costs), and volatility (generating sudden policy shifts). In short, the report hedges on the issue of income equality, arguing that inequality is the by-product of an incentives-driven process that stimulates growth while recognizing the rising income inequality can generate underinvestment in education and skills, as, for example, evidenced in the decline in numeracy skills of low-income people as income inequality increases. The OECD suggests that the solution to the dual problem of growth and income inequality is a radical rethink of the educational process: providing more equal and meaningful educational opportunity to the poor.

REVIEW QUESTIONS

1–3. Based on personal preference.

4. Ingredients: Inputs, the model itself, and outputs. We can call these "exogenous variables," "equations or words," and "endogenous variables," respectively. The best short summary of the power of models is Robert Lucas's speech "What Economists Do." It is available widely on the Web.

This is possibly his best line: “I’m not sure whether you will take this as a confession or a boast, but we are basically storytellers, creators of make-believe economic systems.” Lucas explains that if you want to be a matter-of-fact person who understands how the world works, you actually need to be creative and imaginative.

EXERCISES

1–2. Based on personal preference.

3. (a) From www.stanford.edu/~chadj/snapshots.pdf (data is available through 2010):

Ethiopia: 1.9 percent
India: 8.9 percent
Mexico: 28.5 percent
Japan: 75.6 percent

(b) Botswana’s per capita growth rate between 1960 and 2010 was about 6.07 percent. China’s per capita growth rate was somewhere between 4.38 percent (as reported on “Snapshots,” from 1953 to 2010) and about 6.02 percent (between 1960 and 2010, if calculated from the data provided by Chad on the related Excel spreadsheet).

(c) Population as of 2010, biggest to smallest: USA (313.7 million), Indonesia (242.3 million), Brazil (196.7 million), Nigeria (162.5 million), Bangladesh (156.5 million), Russia (148.2 million).

(d) Government purchases are larger in poor countries, while investment expenditures are higher in rich countries.

(e) Although there are many exceptions, it appears that money in poorer countries has less value per unit compared to rich countries. This is largely because some poor countries have a history of high inflation, so that one unit of their currency becomes worth very little compared to the dollar. High inflation is rare in rich countries and much more common in poor countries.

4. Based on personal preference.

5. This is a worked exercise. Please see the text for the solution.

6. (a) $\bar{a}$ tells us how the quantity of labor supplied responds to wages. Informally, it tells us how sensitive workers are to wages when deciding how much to work.

(b) This is the same as in 5: quantity of labor supplied, quantity of labor demanded, equilibrium labor supply, and

the wage. (Of course, you could just collapse this to equilibrium labor supply and equilibrium wage without losing much interest.)

$$(c) \quad w^* = (\bar{f} - \bar{\ell}) / (1 + \bar{a}) \\ L^* = (\bar{f} - w^*)$$

Now might be a good time to review the importance of the associative rule—students often forget about the importance of parentheses when doing algebra.

(d) If $\bar{\ell}$ increases, the wage falls, and the equilibrium quantity of labor increases. This is just what we expect: the labor supply increased exogenously, and workers were willing to work the same hours at a lower wage. In equilibrium, firms decided to hire more workers at a new, lower wage.

(e) This is an increase in demand: the quantity and wage of labor will both rise in equilibrium. The wage rises a bit, to which workers respond by supplying more labor.

7. (a) Q^D = demand for computers = $F(P, \bar{X})$

$\bar{X}$ is exogenous and captures consumers’ understanding of how to use computers.

Q^S = supply of computers = $G(P, \bar{Y})$

$\bar{Y}$ is exogenous and captures the manufacturing skill of the computer industry.

In equilibrium $Q^S = Q^D = Q^*$, so this model is really two equations and two variables. If the demand and supply functions are straight lines, then there must be a unique solution.

(b) Q^D = demand for classical music = $F(P, \bar{X})$

$\bar{X}$ is exogenous and captures consumers’ interest in classical music.

Q^S = supply of classical music = $G(P, \bar{Y})$

$\bar{Y}$ is exogenous and captures the technology for recovering and cleaning up old classical music recordings.

(c) Q^D = demand for dollars = $F(P, \bar{X})$

$\bar{X}$ is exogenous and captures the domestic and foreign beliefs about the relative safety of the dollar versus the yen, the euro, and the pound.

Q^S = supply of dollars = $G(P, \bar{Y})$

$\bar{Y}$ is exogenous and captures the Federal Reserve’s supply of currency.

CHAPTER 2

Measuring the Macroeconomy

CHAPTER OVERVIEW

By and large, this is a conventional “What is gross domestic product (GDP)?” chapter. Jones runs through the production, expenditure, and income approaches, and emphasizes that the labor share in the United States is roughly constant (well worth emphasizing, since it helps justify the Cobb-Douglas production function that plays a major role later).

There’s a particularly clear discussion of how to compare GDP numbers across countries; even if you don’t plan to cover international topics in your course, this is probably worth discussing, since cross-country GDP comparisons are so central to the economic growth chapters (and many students have an intuition that prices differ across countries).

Interest rates and the unemployment rate are deferred to later chapters, so you can focus your energies on an intellectual triumph that we economists usually take for granted: the definition of GDP.

2.1 Introduction

Chad starts off by emphasizing just how hard it is to measure “an economy.” What should we include? What should we leave out? How can we add up things that are wildly dissimilar—automobile production and grocery store employment and resales of homes and on and on—into one number that tells us what is happening?

Simon Kuznets found a reasonable way to do this and was awarded the 1971 Nobel Prize in economics largely for creating the definition of GDP that we use today. Economists and citizens take GDP for granted—but it really is one of the great intellectual contributions to economics. What did we ever do without it? Bad macro policy—that’s what we did without it. Throughout this chapter, you may

want to look for ways to emphasize how many *bad* ways there are to count economic activity—this lets students know that you’re not just belaboring the obvious. In addition, you may want to emphasize that the system of national accounts constitutes a set of accounting identities—statements that are true by definition. These definitions are important in framing questions and finding answers. For example, if we define “spending” as $C + I + G + NX$, then we will ask how C , I , G , and NX changed to cause spending to change. In contrast, if we define “spending” as the money supply times velocity ($M \times V$), then we will ask how the money supply and velocity changed to cause spending to change. Definitions are an essential part of economic theory. The national accounts provide ample definitions for asking questions.

A useful analogy comes from medicine. How can you tell whether a human being is healthy? Doctors have settled on a few key variables for summing up human health: body temperature, blood pressure, heart rate, and breathing rate. The first two of the vital signs could be measured in a number of ways—so doctors had to settle on the one best way to measure body temperature and blood pressure. Over the centuries, many different “vital signs” were put forward as being the key to measuring health, but only these four passed the test. Even today, many doctors push to include a fifth or sixth vital sign—oxygen levels in the blood, pupil size, emotional distress, pain—but the profession as a whole resists these efforts.

So too with GDP: we’re always tinkering with ways to improve the GDP measure. We remind students of its limitations; we look at other numbers as well, but we keep coming back to GDP because it seems to be one of the vital signs of the nation’s economic health. GDP is also the most complicated vital sign to explain—not unlike blood pressure in that regard—so we spend a whole chapter explaining it.

2.2 Measuring the State of the Economy

Let's start with Chad's phrasing of the definition of GDP: "Gross domestic product is defined as the market value of the final goods and services produced in an economy over a certain period." The words of this definition that can be emphasized are "market value," "final," "services," and "produced."

By emphasizing "market value," we stress that GDP is valued in some currency, such as dollars, and that unlike quantities of goods cannot be added up to measure the nation's output.

By highlighting "final" I emphasize that one key to accurately measuring GDP is to *avoid double counting*. I like to use examples in which common sense conflicts with Kuznets's GDP measure, as in the sample lecture below.

By highlighting "produced" I emphasize that GDP doesn't include sales of used items (such as homes and cars) and doesn't include purely financial transactions (such as buying stocks or moving money between bank accounts). Moreover, GDP is a flow. A flow represents an economic variable that is measured through time, for example, how much income was earned or spent last week. In contrast, economic variables measured at a point in time are called stocks. These variables are found in our balance sheets (our statements of assets, liabilities, and net worth). How much money you hold is a question about an economic stock.

By highlighting "services" I emphasize that a large part of economic activity in the United States isn't about making things—it's about providing valuable services. If we leave out the ambiguous "housing services" part of GDP, the remaining service items—transportation, medical care, tourism, and "other"—add up to about \$3.5 trillion, about one-fourth of our \$13 trillion U.S. economy. Consumer services represent the largest category of consumer spending in the United States, about two-thirds of total consumer spending. In short, consumer services are almost half (around 47 percent) of GDP.

PRODUCTION = EXPENDITURE = INCOME

A clear example about Homer and Marge running a farm makes the point that if you measure correctly, there are three equivalent ways to measure GDP. You can remind students that this is the same "circular flow" idea they saw back in Principles: you can take the economy's pulse when products flow to final users, when revenue flows to firms, or when income flows to the firm's workers, owners, and lenders.

It may be worth emphasizing that Chad's "profits" are what Principles texts often call "accounting profits." They're different from "economic profits," which don't come into play at all when measuring GDP (recall that the difference between accounting and economic profits is the opportunity cost of the entrepreneur's time and the investor's capital). It's worth

remembering that GDP is by and large an accounting measure, using accounting intuition.

The rhetoric of macroeconomists often confuses students. A case in point arises here. Macroeconomists often use the terms "real income," "output," and "GDP" interchangeably. Since the value of output, as realized through sales, is distributed in the form of various incomes, output, GDP, and income are identical.

THE EXPENDITURE APPROACH TO GDP

Here we run through *C*, *I*, *G*, and *NX* just as in Principles. Fortunately, Chad places less emphasis on the minutiae of the four categories and instead focuses on how these shares have changed over time—and by emphasizing time series, he gives the students stylized facts for macroeconomic theory to explain.

In one case he begins a theoretical explanation immediately. He draws attention to the rise in the U.S. consumption share, noting that it could reflect the fact that it's been easier for average consumers to borrow in recent decades. Alternatively, the rise in today's consumption share could reflect an expected rise in future income.

A few points that might be worth noting include the following:

- It's always worth emphasizing the difference between government purchases (measured in GDP) and government spending (which is what the media cares about, and what matters for many fiscal policy questions, but is not a formal category of GDP). As Chad notes, Social Security, Medicare, and interest on the debt are not included in *G*. They are transfer payments, and in practice most Social Security and all Medicare payments are used to purchase *C*, consumer goods and services.
- It's worth noting that composition of spending is sensitive to where the economy is during the business cycle. During the current downturn in the economy, we see investment's share of GDP falling, as consumption and government purchases' shares are increasing.

It's also worth emphasizing what *NX* really does: it makes sure we count everything exactly once. For example, *C* contains all *purchases* of consumer goods within the United States, not all *production* of consumer goods within the United States. So, some of the *C* in GDP is really produced in Germany or China or Canada—and if our final measure of GDP is really going to measure U.S. *production*, we must subtract that to make sure it doesn't show up in our final number.

So, when an American buys a \$400 Chinese TV from the local appliance store, it shows up twice on the right-hand side of the national income identity: as +\$400 in *C* and again as -\$200 in *NX*. That's how we make sure that the portion of the TVs produced abroad doesn't show up in U.S. *gross domestic product*.

The surprise is that *C*, *I*, *G*, and *NX* all reflect *purchases* by different groups, but they are defined in such a way that they sum up to U.S. *production*.

THE INCOME APPROACH TO GDP

This section gives just enough information for students to learn that the labor share is fairly stable across time within the United States. The only point I might emphasize is that the two forms of business income (net operating surplus and depreciation) are actually one item: income going to owners of capital, which we might call “gross operating surplus of business.” The “depreciation” item is imputed (that is, scientifically made up) based on assumptions about the decay of the U.S. capital stock.

And just why is there an item called “indirect business taxes” if so many other forms of taxes—income and payroll taxes, in particular—don’t show up here? The easy answer is probably the right one: it’s because the creators of the national accounts are following accounting methods. In accounting terms, the answer to “Who pays a sales-type tax?” is empirically ambiguous: in the typical case, the customer “pays” the tax, since it’s added onto the bill, but in reality, the business owner sends the proceeds on to the government. By lumping these ambiguous taxes together, we reduce the ambiguity of the other income categories.

THE PRODUCTION APPROACH TO GDP

Once again, this gives you another chance to emphasize the importance of counting everything exactly once. In the production method, you have only two choices:

1. Either only measure *final goods and services*, or
2. Only measure the *value added at each stage of production* as a good moves from firm to firm to final purchaser.

Why bother with choice number 2? For an economist (or businessperson) trying to figure out which industries are most productive, it is useful to know which industries add the most value to their inputs. In Chad’s example, you could use the value-added method to answer the question, “Where does most of a car’s value come from—the raw materials or the assembly of those materials?” In the diamond jewelry industry, the answer might be quite different (if the “raw” material is cut diamonds).

I often emphasize that when measuring the size of a local economy, common sense and economic sense are likely to conflict. Common sense says, “Measure the size of the local economy by adding up the sales of all the local businesses.” But that would include massive double counting—just think of all the products that are sold from one local business to the next before they reach their final user (farm products are

a good example, as is anything locally made and then sold in a local store).

Economic sense says something different: “Measure the size of the local economy by summing up the *value added* by each local business.” To do that, you need to know the cost of each company’s outputs and inputs, and then just sum all the values of the outputs while subtracting the sum of all the values of the inputs.

WHAT IS INCLUDED IN GDP AND WHAT IS NOT?

Of course, we must explain the limitations of GDP—Chad’s discussion differs from many by pointing to recent research showing that health matters more than is measured in GDP, while environmental degradation likely matters very little. In addition, you might emphasize the importance of leisure as a good that is excluded from GDP.

In this fourth edition of the textbook, Chad provides a case study in which a nation’s welfare is linked to consumption (government and personal) per person, life expectancy, leisure, and consumption inequality. The resulting measure of welfare is contrasted to relative per capita GDP. When comparing the welfare measures across countries, two important results emerge. First, relative to the United States, in developed countries like those of Northern Europe, welfare rises in comparison to per capita GDP because of (1) more government consumption, (2) more leisure, (3) higher life expectancy, and (4) less consumption inequality. Second, in poorer countries relative welfare decreases in comparison to relative per capita GDP for the opposite reasons. Chad’s case study complements and provides results similar to the United Nations Development Programme’s Human Development Index (available at <http://hdr.undp.org/en/statistics/hdi>).

2.3 Measuring Changes Over Time

Now we get to the distinction between nominal and real GDP. In Section 2.3.1, Jones runs through a simple apples-and-computers example, yielding what you really need to cover: Nominal GDP and Real GDP.

In Sections 2.3.2, 2.3.3, and 2.3.5, he runs through the various types of price indexes—Laspeyres, Paasche, and chain-weighted. If you want to avoid these price-index details, that’s easy: just cover 2.3.1 to teach the old standby of “Real GDP in Year X Prices.” Then use the basic equation at the beginning of 2.3.1 (nominal GDP = real GDP × price level) to back out the price level.

From there, proceed directly to 2.3.4 and to the definition of inflation, which is probably what you care about anyway. Chain weighting doesn’t ever come up again aside from a parenthetical reference between equations 2.3 and 2.4.

Chad's coverage of the three types of price indexes is quite clear and brief, so if you do want to cover it, it shouldn't take more than half an hour in class.

2.4 Comparing Economic Performance across Countries

Students often have a strong intuition that prices vary across countries, and since cross-country GDP comparisons will play a major role in the next four chapters, it may be worthwhile to spend a little time on this section. There is one particular point that I would expand on a bit with most students, and that is the meaning of the final equation in this section:

$$\text{real Chinese GDP in U.S. prices} = (\text{U.S. price level} / \text{Chinese price level}) \times \text{Chinese nominal GDP}$$

The easiest way to make sense of this equation is to first convert Chinese nominal GDP from yuan into dollars. Students can then see, given the exchange rate, how much those many trillion yuan are worth in dollars. Then you can point out that goods cost less in China than in the United States, and therefore those dollars purchase more goods than they would have purchased in the United States. If those dollars purchase more goods, real GDP in China is increased. This real Chinese GDP in U.S. dollars can then simply be found by dividing China's nominal dollar GDP by the ratio of the Chinese price level to the U.S. price level (multiplying nominal dollar GDP by the ratio of the U.S. price level to the Chinese price level).

The key takeaway here should be that if prices are "lower" in China than in the United States, then Chinese real GDP is higher than Chinese nominal GDP.

Compare actual, uncorrected, right-off-the-website U.S. prices (in dollars) for certain goods and services against actual, uncorrected, right-off-the-website Chinese prices (in yuan) for the same goods and services. Convert those yuan prices into dollars at the actual, uncorrected nominal dollar/yuan exchange rate, and you've got a commonsense measure of where prices are lower. Add in a big budget and dozens of well-meaning bureaucrats, and you've got the United Nations International Comparisons Program.

If goods and services cost less in China than in the United States (in fact they do, after you convert yuan into dollars), then that means the price level is lower in China than in the United States. So, while China's nominal GDP may look relatively small at \$5.8 trillion (when converted into dollars), when adjusting for relative prices, the Chinese real GDP is relatively large at \$10.8 trillion.

Figuring out *why* the same goods and services are more or less expensive in some countries than in others is a task usually left to international economics, so I won't attempt even a quick explanation here. Chad closes this section (and for prac-

tical purposes, the chapter) by noting that the same goods and services are often cheaper in the poorest countries—haircuts are a classic example. Also, the *Economist's* Big Mac Index is always worth a mention, since students can grasp that idea quickly.

So, though on paper the world's wealthiest countries may appear 100 times richer than the world's poorest countries, the actual difference is closer to 30 times richer. That is still a massive difference that demands explanation—and that is the topic of the next few chapters.

2.5 Concluding Thoughts

Just as a reminder, there are two popular topics that Chad (mercifully) leaves out of this chapter in order to get us away from the economic anatomy and toward the economic models that are our field's strength. These are the Consumer Price Index (CPI) and how price indexes measure quality changes. Chad provides coverage of the former in Chapter 8, while this manual provides some coverage on quality changes when discussing that chapter.

You may want to mention these topics in class at some point, to let the students know you'll come back to them:

- The Consumer Price Index's "basket" method is different from the other price indexes covered in this chapter. (The CPI is used to index tax brackets and Social Security payments, so it has policy relevance.)
- It's difficult to measure changes in quality over time (key in a new-economy world). The Census Bureau's hedonic price indexes for computers and Alan Greenspan's speech on the falling real price of cataract surgery come to mind.

Finally, students might be interested to know that national accounts provide a wealth of useful definitions that can be used as a starting point for analyzing important questions such as what causes the national budget deficit and what role the national budget deficit plays in affecting national savings and gross savings.

SAMPLE LECTURE: PRODUCTION, EXPENDITURE, AND INCOME IN A TRUCK ECONOMY

In this lecture, you can tie together all three GDP measurement methods in a simple economy with one output good. Since I find that most misunderstandings and most of the insights in national income accounting come from the production/value-added method, we'll use Chad's example of steel being used to make trucks. Let's consider the economy of Pickupia. The only two companies in Pickupia produce steel (SteelCo) and trucks (TruckCo).

	SteelCo		TruckCo
Wages	70	Wages	250
Sales Tax	0	Sales Tax	30
Cost of Inputs	0	Cost of Inputs	100
+ Profit	30	+ Profit	120
Total Steel Sales	100	Total Truck Sales	500

There are four different customers for TruckCo's trucks:

Pickupia's consumers buy \$200 worth of trucks for personal use;

Pickupia's businesses buy \$100 worth of trucks to haul products and workers;

Pickupia's government buys \$150 worth of trucks to haul products and workers; and

Foreign countries buy \$50 worth of trucks for unknown reasons.

Pickupia's consumers also import \$100 worth of other goods and services from foreign countries.

This is a complete description of the Pickupia economy. Now, let's work out the GDP measures based on the expenditure, income, and production methods.

Expenditure:

$$\text{GDP} = C + I + G + \text{total exports} - \text{total imports}$$

$$\begin{aligned} \text{GDP} &= (200 \text{ on trucks} + 100 \text{ on imports}) \\ &+ 100 + 150 + 50 - 100 \text{ on imports} = 500 \end{aligned}$$

There's no trick here—just a reminder that C includes all purchases by domestic consumers, regardless of whether those goods are made here or overseas.

Income:

total wages: 320

total sales tax (an "indirect tax"): 30

total profits: 150

total income = 320 + 30 + 150 (assuming no depreciation of capital) = 500

(This 64 percent wage share is close to the true U.S. value, which may be a surprise to many students who suspect that the vast majority of GDP is profits.)

Production:

Value Added by SteelCo: Somehow, it gets its raw ore for free, so its value added is just:

$$\text{revenue} - \text{cost of inputs} = 100 - 0 = 100.$$

Value Added by TruckCo:

$$\text{revenue} - \text{cost of inputs} = 500 - 100 = 400$$

$$\begin{aligned} \text{total domestic production} &= \text{value added by all firms} \\ &\text{in the economy} = 100 + 400 = 500 \end{aligned}$$

Emphasize how different this answer is from "common sense." If I wanted a commonsense answer to how much is produced in this economy, I'd add up SteelCo's 100 in sales plus TruckCo's 500 in sales to get my answer: 600.

The commonsense answer—which is what you'd get if you just surveyed both businesses and added their answers—turns out to be completely wrong, because it double counts the steel. Making sure you count everything exactly once is the key to a good accounting system—and that's harder to do than you might think.

CASE STUDY: CAPITAL GAINS—WHY AREN'T THEY PART OF GDP?

If you buy a share of Microsoft stock for \$100 and then sell it a year later for \$150, common sense tells you that you've earned \$50. The \$50 increase is called a "capital gain." Similarly, if you bought a house for \$100,000 and sell it two years later for \$125,000, that \$25,000 sure feels like income to you—it's money you can spend just as if you had received a \$25,000 bonus at work.

But economists' measure of GDP doesn't include capital gains at all—so we have a case of "economists versus common sense." If we focus on the income approach to GDP, we include labor income, capital income, and a few adjustments. "Capital gains" sounds a lot like "capital income," so why aren't capital gains counted as part of capital income?

The short answer is that capital gains can't be part of capital income because capital gains (or losses) merely reflect a change in the *future* profitability of an asset. For example, a stock price might rise because people believe their company will earn more profits in the future. And if those people are correct, those future profits will show up in *future* GDP.

Of course, stock prices rise and fall for many reasons, and in a course on asset pricing you can cover that topic. But the main point holds: a rise in the price of a home, a painting, or the collection of machines and workers we call "Microsoft" doesn't reflect any *current-year production*. And remember, GDP is all about *current-year production*.

Capital gains aren't part of the government's measure of "national income," but many capital gains are still taxed by the state and federal *income* tax.

CASE STUDY: ROBERT HALL AND "INTANGIBLE CAPITAL"

According to some economists—most prominently Robert Hall¹ of Stanford—the previous case study is completely wrong for an economically important reason. Hall shows that

1. Robert E. Hall, "The Stock Market and Capital Accumulation," *American Economic Review* 9, no. 5 (December 2001): 1185–1202.

under some fairly strict assumptions (inter alia, that a company's stock price doesn't reflect either future monopoly profits or changes in the rate of time preference), changes in the stock price must reflect changes in the size of the nation's total stock of capital. That would mean that an increase in a stock's price must reflect corporate investment, while stock price decreases must reflect decay of past corporate investment.

But clearly, stock prices change too often and by too large an amount to reflect changes in the physical amount of corporate capital—roughly measured by the *I* part of GDP—so Hall argues that many changes in stock price must reflect changes in the stock of the nation's “intangible capital.”

Intangible capital might include a corporation's ability to create new ideas, its form of corporate organization, its ability to motivate employees to work hard, and many other things that a corporation can do today to help it to produce more output in the future. That, after all, is what investment goods do, right? What we call “investment goods” are just products we create today in order to reap a benefit down the road. Perhaps we can think of “intangible investment” as services we create today in order to reap a benefit in the future.

In Hall's view, then, the rise in the stock market in the late 1990s reflected the market's guess that modern technology would enable firms to create much more output in the future with very few workers—something that sounds quite a bit like the “new economy” in a nutshell. Of course, since the NASDAQ (a tech-heavy stock market index) plummeted by 75 percent between 2000 and 2003, the big question is, Where did all of that intangible capital go? Did hundreds of billions in “intangible capital” somehow get destroyed?

There is much literature on “intangible capital,” also known as “organizational capital.” In the future, economists may find a coherent, practical way to include these important forms of investment activity in the *I* part of GDP.

If Hall's view has merit, then accurately measured GDP should include some portion of capital gains income. If these improved measures are even half as volatile as the stock market, then GDP is much more volatile than we currently believe.

CASE STUDY: “ONE QUARTER OF GDP IS PERSUASION”

As we saw before, services are about one-quarter of U.S. GDP. That means that much economic activity isn't about making things but about interacting with other people. There are two other ways of slicing up GDP that might be of interest:

1. John Wallis and Nobel laureate Douglass North estimate that “transactions costs, that is, expenditures to negotiate and enforce contracts, rose from a quarter of national

income in 1870 to over half of national income in 1970” (cited in McCloskey and Klammer, 1995).²

Transaction costs include attorneys' fees, the cost of the legal system, most of the cost of running the nation's banking and financial systems, auditors, office workers who do accounts payable and receivable, locks on doors, security guards, and almost anything else that makes it possible for you to (1) keep your property, (2) feel enough trust to transfer your property to someone else, or (3) receive property from someone else. Transaction costs aren't just part of *G*: as the list above shows, there are a lot of private-sector purchases involved, so they show up in *C*, *I*, and *NX* as well. According to Wallis and North, about half of GDP gets spent just so that we can interact and exchange with each other.

2. McCloskey and Klammer go further: they estimate how much of GDP is just devoted to “sweet talk,” or persuasion. Even when a person is providing information, much of the work isn't just about giving raw data but about selling the audience on the data. “Why should I listen to you?” That's the question persuasion answers. The father of economics himself noted the importance of persuasion. Adam Smith, in his *Lectures on Jurisprudence*, noted, “Everyone is practicing oratory on others through the whole of his life” (cited in McCloskey and Klammer).

Broadly, McCloskey and Klammer want to count all human communication that isn't about providing either information (for example, telephone operators or college professors) or commands (such as much of the work of police officers and CEOs). They count lawyers, actors, and members of the clergy; three-quarters of the work done by salespeople, therapists, and job supervisors; and half the work done by police officers, technical writers, and nurses. Their rough estimate is the title of their paper: one-quarter of GDP is persuasion.

CASE STUDY: ACCOUNTING FOR CHANGES IN PROFITS: THE GREAT RECESSION AND ITS AFTERMATH

The national income and product accounts are a wonderful device. Not only are these accounts used to measure an economy's performance but the accounts can be used to structure economic analyses—just like the financial accounts of any business. For example, these accounts can be used to measure savings, the source of wealth creation—where gross sav-

2. Donald McCloskey and Arjo Klammer, “One-Quarter of GDP Is Persuasion,” *American Economic Review* 85, no. 2 (May 1995): 191–95.

John Joseph Wallis and Douglass North, “Measuring the Transaction Sector in the American Economy, 1870–1970,” in S. L. Engerman and R. E. Gallman, eds., *Long-Term Factors in American Economic Growth* (Chicago: University of Chicago Press, 1986).

Table 1. CORPORATE PROFITS (2014)—DERIVED FROM TABLE 5.1 FROM THE NATIONAL INCOME AND PRODUCT ACCOUNTS OF THE UNITED STATES (BILLIONS OF DOLLARS, AUTHORS' CALCULATIONS)

Line 4, Table 5.1	Domestic business savings	699
Line 16, Table 1.12	+ Net dividends	860
Line 4, Table 7.5	+ Corporate business consumption of fixed capital	1467.3
Equals	= Corporate Profits⁴	3026.3
22, Table 5.1	Gross Private Domestic Investment	2860
Line 25, Table 5.1	Gross government investment	595.8
Line 10, Table 5.1	– Net government saving	–799.2
Line 32, Table 5.1	+ Government current account balance net	–5
Line 17, Table 5.1	– Government consumption of fixed capital	516.8
Equals	= Government Budget Deficit	873.2
Line 35, Table 5.1	Net Lending or Net Borrowing (–), NIPAs	–401.6
Line 28, Table 5.1	+ Capital account transactions (net) ¹	0.5
Equals	Current Account Balance	–401.1
Line 32, Table 5.1	Government Capital Account Transactions (net)	–5
Line 16, Table 1.12	Net dividends	860
Line 14, Table 5.1	Private consumption of fixed capital	2229.9
Line 4, Table 7.5	Corporate business consumption of fixed capital	1467.3
Equals	Noncorporate Consumption of Fixed Capital	762.6
Line 9, Table 5.1	Personal Saving	620.2
Line 42, Table 5.1	Statistical Discrepancy	–212
Equals	Corporate Profits = Gross private domestic investment + Government Budget Deficit + Current Account Balance – Government Capital Account Transactions (net) + Net dividends – Noncorporate Consumption of Fixed Capital – Personal saving – Statistical discrepancy	3026.3

ings, the sum of private savings, public savings, and foreign savings equals gross domestic private investment. In addition, a less well-known use of the national income and product accounts is accounting for business or corporate profits. For example, if GDP measured in terms of income can be approximated as the sum of “wages,” “wage taxes,” “profits,” “profits taxes,” and recognizing that GDP in terms of expenditures is given as the sum of consumption, invest-

ment, government purchases, and net exports. Recognizing that GDP measured in income equals GDP in expenditures, adding and subtracting government transfers payments to the expenditure side, and solving for profits yields the following: Profits = Investment + Government Purchases + Transfer Payments – Wage Taxes – Profit Taxes + Net Exports + Consumption – Wages – Transfer Payments.³ Using the National Income and Product Accounts of the United States, corporate profits can be similarly accounted for as described in Table 1. Using data on the right-hand side of the corporate profit equation, Laramie and Mair (2016, see note 3) show that gross domestic private investment decreased in 2007 through 2009, and, therefore, made negative contributions to the growth in corporate profits, and that these decreases were dampened by increases in the government budget deficit. Since the beginning of the economic recovery in 2009, gross domestic private investment has made positive contributions to the growth in corporate profits, but these increases have been significantly dampened by decreases in the government budget deficit and increases in personal savings. For example, Laramie and Mair show that in 2013, corporate profits increased by 2.42 percent, while investments, the government budget deficits, and personal savings’ contributions to the growth rate in corporate profits were 5.16 percent, –18.13 percent (fiscal drag effect), and –12 percent (as household savings continued to increase through the economic recovery), respectively.

REVIEW QUESTIONS

1–4. These essentially summarize the entire chapter, so I will refrain from answering them.

EXERCISES

1. (a) Real GDP 2015 is \$16,348.9 billion, nominal GDP 2015 is \$17,947 billion—these numbers are different because real GDP is valued in 2009 (chained) prices whereas nominal GDP is valued in 2015 (current) prices.

(b) Real GDP 1970 is \$4,722 billion; nominal GDP 1970 is \$1075.9 billion.

3. This accounting identity has been attributed to M. Kalecki (1943), *Studies in Economic Dynamics*, Allen and Unwin, and Jerome Levy. See S. J. and D. A. Levy (1983), *Profits and the Future of American Society*, New York, Harper and Row. Kalecki, a colleague of Keynes, a progenitor of early business cycle theory, took this accounting identity and turned it into a theory of profits by noting that businesses cannot predetermine their profits, but they can determine how much they spend, and, therefore concluded that profits are determined by profits and augmented by the other right-hand-side variables.

4. This definition is the same as the BEA’s Table 1.12 definition of corporate cash flow plus net dividends plus capital transfers (net).

(c) The ratio of real GDP 2015 to real GDP 1970 is 3.46; the ratio of nominal GDP 2015 to nominal GDP 1970 is 16.68.

(d) The difference between the two ratios can be explained by inflation factor between 1970 and 2015, reflected in the growth of the GDP deflator. Letting P_t = GDP deflator in time t , and Y_t = Real GDP in time t , we know that $P_{2015} Y_{2015} / P_{1970} Y_{1970} = 16.68$, and that $Y_{2015} / Y_{1970} = 3.46$, so that $P_{2015} / P_{1970} = 4.82$; that is, the GDP deflator has grown by a factor of 4.82.

2. This is a worked exercise. Please see the text for the solution.

3. (a) GDP rises by \$2 million (final sale price of computers).

(b) GDP rises by the \$6,000 commission (capital gains—an increase in the price of an asset like a home, car, or painting—are not part of GDP since the asset wasn't produced that year. They aren't part of national income, either).

(c) No impact. This is a government transfer payment, not a government purchase of a good or service. If the government hired the unemployed and paid them to dig ditches or program in C++, then their wages would count as a government purchase.

(d) No impact. I rises by \$50 million, but NX falls by \$50 million, so the two effects cancel out and have no impact on GDP.

(e) U.S. GDP rises by \$50 million; NX rises by \$50 million. (Incidentally, this has no impact on European GDP for the same reason as in part (d)).

(f) GDP rises by \$25,000; NX falls by \$100,000 but C rises by \$125,000. The store added \$25,000 of value to the U.S. economy, so it shows up in GDP.

4. Real GDP in 2020 in 2018 prices: 5,950; 19 percent growth between 2019 and 2020

Real GDP in 2018 in 2010 prices: 6,500

Real GDP in chained prices, benchmarked to 2020: 6,483
(Note: output of apples and computers didn't change between 2018 and 2019, so the average of the Paasche and Laspeyres zero growth rates is still zero.)

5.

	2020	2021	Percent change 2020–2021
Quantity of oranges	100	105	5
Quantity of boomerangs	20	22	10
Price of oranges (dollars)	1	1.10	10
Price of boomerangs (dollars)	3	3.10	3.33
Nominal GDP	160	183.7	14.8
Real GDP in 2020 prices	160	171	6.9
Real GDP in 2021 prices	172	183.7	6.8
Real GDP in chained prices, benchmarked to 2021	171.9	183.7	6.85

Here GDP growth only shows a tiny difference between the various methods.

6. We'll use Chad's shortcut from Section 2.3:

$$\text{growth in nominal GDP} = \text{growth in price level (a.k.a. inflation)} + \text{growth in real GDP}$$

This isn't exact, as Chad notes, but it's good enough for our purposes. This implies

$$\text{growth in nominal GDP} - \text{growth in real GDP} = \text{inflation rate.}$$

All we need to do is add in our three definitions of "growth in real GDP" and we'll have our three answers:

Paasche: 14.8 percent – 6.9 percent = 7.9 percent

Laspeyres: 14.8 percent – 6.8 percent = 8 percent

Chained: 14.8 percent – 6.85 percent = 7.95 percent

7. (a) Without taking relative price differences into account, India's economy is 11.8 percent the size of the U.S. economy (119 trillion rupees/61)/16.5 trillion = \$1.95 trillion/\$16.5 trillion.

(b) Given that prices in the United States are higher by a factor of 3.57 (= 1/.28), and India's GDP in U.S. dollars in U.S. prices equals \$1.95 trillion, India's GDP in U.S. prices is $1.95 \times 3.57 = \$6.96$ trillion. Taking relative price differences into account, India's economy is 42.2 percent of the U.S. economy (\$6.96 trillion/\$16.5 trillion).

(c) The numbers are different because many consumer goods—food, haircuts, and medical visits—are very cheap in India when you are measuring in U.S. dollars. This is usually true in poor countries. As we'll see in Chapter 20, when we look at *The Economist's* "Big Mac Index" of exchange rates, the same McDonald's hamburger is much cheaper in poor countries than in rich countries when you compare prices in U.S. dollars. Wages, rents, and taxes cost less in poor countries, which makes it cheaper to produce a hamburger or a haircut or even a doctor's visit.

That means that although India is a very poor country, the Indian economy is not one-tenth the size of the U.S. economy. It is closer to one-third.

8. (a) \$5.68 trillion/\$16.2 trillion = 35 percent

(b) (\$5.86 trillion/1.307)/\$16.2 trillion = 27.7 percent

(c) The numbers are different because many goods are more expensive in Japan than in the United States.

9. (a) If fewer people have homes, then the average person must be worse off when it comes to homeownership—after

all, now people must share homes or live in less desirable places. People will be working to rebuild things that they already had before. This is a loss, not a benefit. It is likely that if there hadn't been an earthquake, most of the people rebuilding these lost homes would have been able to build something new and valuable, rather than rebuilding something old and valuable.

(b) Measured GDP will likely rise—people will want to work hard and quickly to rebuild homes, or they will pay a high price to have other workers rebuild their homes. These wages for workers and purchases of materials (which are mostly wages for other workers, probably) all show up in GDP.

This question illustrates a famous parable in economics, the “fallacy of the broken window.”⁵ If a person breaks a shop window, the shop owner must pay to repair that window. If we only look at the direct effect, we will only notice that the person who broke the window has “created new jobs” in the windowmaking industry. That’s true, but what

we don’t see is that if the window hadn’t been broken, the shop owner would have bought a new suit later that week. Now, he doesn’t get the suit since he must replace his window. So, he would’ve “created new jobs” in the suitmaking industry, but now he won’t get that new and valuable suit. Instead, he’ll spend his scarce dollars replacing something old and valuable.

So, our earthquake is like the broken window: workers who could have created something new instead must replace something. It would have been better for citizens if the earthquake had not happened.

5. Henry Hazlitt, *Economics in One Lesson*, Chapters 1 and 2.

CHAPTER 3

An Overview of Long-Run Economic Growth

CHAPTER OVERVIEW

This short chapter lays out the basic facts of the wealth of nations. Chad makes it clear that higher GDP per person usually means real improvements in people's lives—something that more than a few undergrads might need to remember.

He also covers the simple and increasingly common mathematical shortcuts that macroeconomists and finance professors use to think about growth rates. You'll get to use these shortcuts in the growth and inflation chapters, and they'll likely come in handy in unexpected places elsewhere—it's surprising how often we unconsciously use these shortcuts.

This chapter shouldn't take more than an hour to cover—even with plenty of examples. Push your students to read it rather than just listen to it, since the stylized facts come back time and again in the rest of the growth chapters.

3.1 Introduction

Chad starts off with an excellent gimmick: describing a very poor country and asking the reader to guess which country it is. It turns out to be the United States of 100 years ago. There are many ways to emphasize the surprise of economic progress, and Chad hits a few of them quite quickly: higher levels of education, greater life expectancy, and vast numbers of new goods.

When I teach about long-term economic change, I use the same word that Robert Lucas used repeatedly and without shame: “miracle.” In fact, he said that the goal of economic growth research should be to create “a theory of economic miracles” (“Making a Miracle,” *Econometrica* [1993]: 253). When something wonderful that has never happened before

in human history begins to happen, not once but repeatedly in many countries, the word “miracle” seems entirely appropriate. So, you may want to emphasize that over the next four chapters, your students are going to learn a little about where miracles come from.

3.2 Growth over the Very Long Run

This section covers the broad sweep of prehistory and history. We learn that prosperity is a new phenomenon, and that growth in living standards started at different times in different places. Argentina, China, Ghana, the United Kingdom, Japan, and the United States receive particular attention, if you are looking for countries to highlight with additional data or online photos.

We also learn that centuries-long peaks and valleys have occurred in the past—which raises the question of whether the developed world's current prosperity could be just another local maximum. (Two case studies that follow cover the Roman economy's golden age and collapse—a cautionary tale as well as one of the great puzzles of human history.)

Finally, Chad introduces the term “Great Divergence,” coined by Harvard's Lant Pritchett to summarize the enormous new gap in living standards between the world's richest and poorest inhabitants.

An expanded case study later in the chapter looks at whether the world really is experiencing a great divergence: as Steven Parente and Nobel Prize-winner Ed Prescott have shown in their work, and as Xavier Sala-i-Martin has shown in separate work, the rapid growth in East and South Asia throws doubt on the Great Divergence—or at least makes a strong case for nuance.

3.3 Modern Economic Growth

Here, Chad defines growth rates and shows how to calculate them. In my experience, the growth rate students understand best is the interest they earn on money at the bank—they probably were taught about that back in elementary and secondary school—so you may want to start with that intuition and expand upon it. A sample lecture on interest rates and growth rates appears later in this chapter of the manual and is further illustrated in a worked exercise at the end of the chapter.

Through the rest of this section, Chad shows that when variables are growing exponentially (that is, at roughly constant growth rates), it's often handier to look at them in a ratio scale, which economists usually call the log scale. The terms “ratio scale” and “log scale” are both widely used (Microsoft Excel uses the term “logarithmic scale” in its graphing tools, while the term “ratio scale” has tens of thousands of Google hits), so it is a good idea to familiarize students with them.

The benefit of using a ratio scale, of course, is that constant growth always looks like a straight line. That makes breaks in trend growth quite easy to see—breaks that would be invisible if the y -axis were measured the usual way. In both long-term growth and inflation, we'll see examples of such breaks, so a little practice now will pay off quite soon.

The last equation in this section shows how to back out annualized growth rates from long-term data: it requires taking a fractional exponent, but since most students have either high-tech calculators or Excel readily available, it's not technically difficult.

If we start with the constant growth rule

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

and consider a case where we know the start and end values, but don't know $\bar{g}$, we can rearrange this to get:

$$(y_t / y_0)^{1/t} - 1 = \bar{g}.$$

Remind your students that because growth is exponential, if they're calculating a ten-year growth rate, they can't just take the total growth rate $(y_{2020} - y_{2010})/y_{2010} = \bar{g}$ and divide by 10. That will result in a number that's too big: it'll include the compounding.

For example, consider the case where a worker's wage doubles in ten years. What was the average annual growth rate? “Common sense” would tell us that it had to grow 10 percent per year: $[(2-1)/1]/10$. But the rule of 70 tells us that if something doubles in ten years, considering compounding, it must've grown 7 percent per year—so which is it? An exact calculation gets us 7.177 percent—pretty close to the rule of 70's guideline.

3.4 Modern Growth around the World

Here, Chad presents some more stylized facts. The British used to have the world's highest GDP per capita of any large

country, but since about 1900 the United States has been on top (tiny Luxembourg's GDP is actually higher). Other rich countries are about 25 percent below the U.S. peak.

He also shows that cross-sectionally, rich countries have grown faster in recent decades (although the relationship isn't perfect), and a dozen or so countries have had declines in GDP per capita since 1960.

3.5 Some Useful Properties of Growth Rates

Here, Chad runs through the shortcuts that are increasingly common in intermediate macro texts. It is an exceptionally transparent section, with plenty of clear examples.

The one thing you may want to do before you begin this is point out that one of the simplest ideas in economics—the law of diminishing returns—can't be explained with straight lines. The law of diminishing returns—whether we're talking about the utility from consumption or the efficiency of production—implies a falling slope as the variable gets bigger.

The easiest way to talk about diminishing returns ends up being exponents—in particular, exponents between 0 and 1. You may want to use the example of a square root—which students probably should recall from algebra courses. Or, you may want to skip straight to the cube root—which is part of the Cobb-Douglas production function that figures prominently in Chapters 4 and 5.

Show them that an exponent between 0 and 1 means diminishing returns, while an exponent of 1 means constant returns. That way, at least they'll understand that there's a reason you're teaching them these rules about the growth of variables raised to a power.

3.6 The Costs of Economic Growth

Chad is quite sanguine about the benefits of economic growth and emphasizes that in the views of most macroeconomists, the world's poor need more growth rather than less. He briefly mentions the Kuznets-type relationship (a U-shaped relationship) between living standards and environmental health: middle-income countries are the dirtiest. If this relationship holds, then the way to reduce pollution is for all countries to be either poor or rich. Chad's preference between the two options is rather clear.

3.7 Conclusion and a Long-Run Road Map

Chad closes with Lucas's famous quote: “Once one starts to think about [economic growth], it is hard to think about anything else.” You may want to consider assigning your

students a nontechnical essay by Lucas entitled, “The Industrial Revolution: Past, Present, and Future,” available at <https://www.minneapolisfed.org/publications/the-region/the-industrial-revolution-past-and-future>.

SAMPLE LECTURE: INTEREST RATES AND GROWTH RATES

Suppose you have \$100 in 2016 that you want to deposit. You can earn 5 percent annual interest at the bank (compounded annually, to make the math easy). That means that at the end of the year, you’ll have this much money:

$$y_{2017} = 100 + 0.05 \times 100 = 100 + 5 = 105.$$

You start off with 100, you earn five bucks in interest, and you wind up with 105 at the end. If we wanted to turn this into a general formula, we’d write it this way:

$$y_{2017} = y_{2016} + g \times y_{2016}.$$

This is the general way to know how much money you’ll have in a year if it grows at g percent per year. There are two ways we can rewrite this to get some good insights. First, let’s see how to calculate a growth rate (here, the interest rate) when you only have information on raw balances. Isolate the g term on one side to get

$$(y_{2017} - y_{2016})/y_{2016} = g.$$

I tell my students this: “The growth rate is the change over where you started.” With that, it’s always easy to calculate a growth rate if you have raw data. If you can answer, How much did this variable change this month/year/century?, and, What did it start off as?, then you can calculate a percentage growth rate over that period. Examples include height, income, employment levels, and crime levels.

You may want to emphasize how the growth rates that come out of this calculation must be shifted over two decimal places if you want to report them as percentages. For example, “0.02” becomes “2 percent.” I’ve seen “0.02 percent” show up as an exam answer all too often.

Some students make these decimal point errors because they don’t know what they’re doing, while others do so because they don’t realize that reporting in proper units is the mathematical equivalent of using good grammar: it’s polite, and it helps your reader understand you. Badger them a little now—it’ll save you a lot of corrections on the final exam, and it may save you thousands if your student becomes an analyst at your bank.

Here is a second way to rewrite the above equation. A little factoring gets us

$$y_{2017} = y_{2016}(1 + g).$$

With this version, we can easily ask what happens if this grows at the same percentage rate, g , for many periods.

That’s what Section 3.3.2 does, with an exceptionally clear example: population growth. Let’s call the starting period “time 0” and the ending period “time t .” If $t = 1$, then we’ve got the previous equation. If $t = 2$, we have $y_2 = y_1(1 + g)$ and $y_1 = y_0(1 + g)$. That quickly collapses to $y_2 = y_0(1 + g)^2$.

Emphasize that only the $1 + g$ gets squared, not the y_0 : many students forget the order of operations, particularly when exponents are in the mix.

If we let t be any number, rather than just 1 or 2, this yields something Chad comes back to repeatedly—the constant growth rule:

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

Note that the “ t ” means the same thing on both sides of the equal sign: it is the number of years of growth, when growth starts in period 0. (Students often have trouble knowing whether to count periods inclusive or exclusive of the initial period—Chad’s symmetric “ t ” notation makes it easy to see the right answer.)

In Section 3.3.3, Chad teaches what may well be one of the most useful concepts your students learn this semester: the rule of 70. If something grows at a rate of X percent per year, it takes $70/X$ years to double. So, something that grows at 10 percent per year doesn’t take ten years to double; it only takes seven.

Whether they’re thinking about retirement planning, economic growth, or inflation, the rule of 70 (or 72) comes in handy. Any shortcut that gives students a good intuition for a counterintuitive idea like exponential growth can only be a good thing.

The hardest thing about the rule of 70 is getting the units right: if something grows at 5 percent, it takes about $70/5$ years to double, not $70/.05$ years.

The second-hardest thing about the rule of 70 is figuring out what happens when something doubles again and again. If your standard of living grows 5 percent per year on average (a reasonable estimate of China’s growth in recent decades), then living standards double every fourteen years. But how long does it take for living standards to be eight times higher?

14 years for 2 times.

28 years for 4 times.

42 years for 8 times more than the starting value.

Even with good students, many will think the progression is 2, 4, 6, 8 (so 56 years until octupling) rather than 2, 4, 8, 16. Humans just seem to have bad intuition for continuous exponential growth. The rule of 70 can help us overcome that.

CASE STUDY: RULE OF 70 VERSUS THE RULE OF 72

Having finance students, either double majoring or minoring in economics, in this class is quite common. Many finance

professors will “correct” our economics students’ use of the rule of 70, and, instead, insist that the rule of 72 be used in class. As a result, students will often ask you which rule they should use: the rule of 70 or rule of 72. A quick Google of “rule of 70 vs rule of 72” will generate the sort of explanations given below, if this question comes up in your class. You can refer to a simple example and give the sort of “it depends” answer with which economic students have become familiar. In the table below, various growth rates are provided in the first column, the actual number of years for an initial amount to double is provided in the second column, the rule-of-70 approximation is in the third column, the error in the rule-of-70 approximation is in the fourth column, the rule-of-72 approximation is the fifth column and the rule-of-72-approximation error is in the last column. An examination of this table reveals four conclusions you can share with your students: (1) For growth rates less than 5 percent, the rule of 70 generates a smaller approximation error than the rule of 72; (2) For a growth rate of 5 percent, the approximation error is about the same for both rules; (3) For growth rates greater 5 percent, the rule of 72 generates a smaller approximation error than the rule of 70, and (4) The rule of 72, when 72 is divided by an integer, generates more whole numbers than does the rule of 70. In discussing the average (per capita) growth rates of most countries, we expect growth rates to be 5 percent or less, and the rule of 70 works as the best approximation (in these cases).

	Years	Rule	Rule	Rule	Rule
		of 70	of 70	of 72	of 72
Growth Rate	to Double	70/g	Error	72/g	Error
1.00%	69.66	70.00	−0.34	72	−2.34
2.00%	35.00	35.00	0.00	36	−1.00
3.00%	23.45	23.33	0.12	24	−0.55
4.00%	17.67	17.50	0.17	18	−0.33
5.00%	14.21	14.00	0.21	14.4	−0.19
6.00%	11.90	11.67	0.23	12	−0.10
7.00%	10.24	10.00	0.24	10.29	−0.04
8.00%	9.01	8.75	0.26	9	0.01
9.00%	8.04	7.78	0.27	8	0.04
10.00%	7.27	7.00	0.27	7.2	0.07

EXPANDED CASE STUDY: PEOPLE VERSUS COUNTRIES

In Figure 3.7—a typical “convergence”-style graph—it looks like the rich countries are growing faster than the poor countries, which implies a massive increase in long-term global inequality. If present trends continue, the rich countries will tend to pull further away from the poor countries—and the miracle of compounding really will create unimaginable differences between rich and poor countries.

But in Figure 3.8 Chad points to the famous result, showing that if we measure economic progress on a per-person

rather than a per-country basis, a different picture emerges: living standards have dramatically risen for the median human over the past four-plus decades.

Recent market-oriented economic reforms in China and India apparently caused much of this, which created massive new middle and lower-middle classes where none existed before. Tens of millions of people in these countries now live in a world where owning a car or taking a trip on an airplane is no longer a dream. And while it might not be reality, either, at least it’s a real possibility. A quick Googling of “China” or “India” and “traffic” will yield enough hits to convince your students that life really has changed in these countries, countries that Westerners used to think of as bicycle nations.

Another part of the explanation for the difference between Figures 3.7 and 3.8 is this: while there are many countries that have grown slowly, relatively few people live in those countries. Africa, the poorest inhabited continent by far, has quite a low population density, and a quick glance at the map will confirm that it has many small countries. So, while conventional wisdom might point to “overpopulation” as a reason for Africa’s plight, Africa has fewer people per square mile than any inhabited continent except Australia. Thus, Africa weighs heavily when we look at the country level, but it receives less weight when we look at the human level.

In a footnote, Chad refers to Sala-i-Martin’s *Quarterly Journal of Economics* piece, “The World Distribution of Income: Falling Poverty, and . . . Convergence, Period.” That article demonstrates that Figure 3.8’s result is quite robust compared to what you believe about income inequality within the countries of the world. So overall, Sala-i-Martin’s story is an optimistic one about the recent past of GDP per capita. But the future may not be as rosy: as Sala-i-Martin notes, if Africa doesn’t start growing quickly quite soon, enough people in Africa will be poor enough that global income inequality will start rising again.

A broader point to make in this case study is that for most purposes, what we should really focus on is people, not countries. Thus, good news for India and China, if broadly shared within these countries, is really good news for one-third of all of humanity. It’s not just good news for one-ninetieth of the world’s countries.

EXPANDED CASE STUDY: GROWTH RATES IN A FAMOUS EXAMPLE

As another opportunity to teach about diminishing returns, consider asking your students how much GDP rises as employment rises by 1 percent, 10 percent, or 100 percent. Fixing this idea in their heads now will create some surprise when they see that in the Solow model of Chapter 5, endogenous capital formation takes us from a world of diminishing returns to a factor into a world of constant returns to scale.

CASE STUDY: THE ANCIENT ROMAN ECONOMY

Peter Temin's 2006 article "The Economy of the Early Roman Empire"¹ showed that the successful Roman economy was built on a few key innovations (cement, arches, and so on) combined with surprisingly developed labor and financial markets.

Though the Hollywood stereotype is that Roman success was built on forced labor, and although slavery was indeed very common, most public works in Rome were built by paid labor. Some of those paid laborers were free, some enslaved—but slaves generally kept their wages. Indeed, Roman slavery, while brutal and contrary to modern ideas of human rights, was generally less brutal than American slavery.

(Students may be interested to know that a Roman gladiator—a type of slave—had only about a 10 percent chance of dying in any given fight. It was expensive to kill such highly trained performers. Indeed, individual gladiators had their own separate fan bases, so the owner of a gladiator wouldn't want to place his popular investment at such a high risk of depreciation. But note that if a gladiator has a 10 percent chance of dying per fight, and he fights 10 times, he only has a $0.9^{10} = 35$ percent chance of surviving to an 11th fight. Thus, gladiator careers were probably quite short, all the same.)

Another important economic fact about the Roman Empire is that the Pax Romana created a free-trade area throughout the Mediterranean, something that does not exist today. And as economists can predict, where there is free trade, there is specialization and exchange—unique goods were created throughout the Roman Empire and beyond and were traded everywhere in developed markets.

CASE STUDY: THE FALL OF ROME AND THE END OF CIVILIZATION

The widely praised book *The Fall of Rome and the End of Civilization*, written in 2006 by archeologist Bryan Ward-Perkins, shows that once the Roman empire collapsed in the west in the 400s a collapse in living standards soon followed. Importantly, the collapse in living standards apparently occurred *after* the collapse of government, *after* the barbarian invasions.

Some of your better-read students may have heard ideas such as "empires collapse from within," "Rome weakened from within before the barbarians came and destroyed it," and the like. That could be true politically—Gibbon surely thought so—but economically, the records appear quite clear. The quality of pottery in the homes of the poor, the existence of tile rather than thatched grass roofs, the long-distance trad-

ing networks, all held up until the decades after the forced retirement of the last western Roman emperor, Augustulus.

Another interesting piece of evidence includes ice core samples from Greenland. These samples show that during the period of the western Roman Empire, pollution levels were quite high—but after the fall of the western empire, the air became much less sooty. This is more evidence that something major occurred.

Ward-Perkins says that after the collapse of the western empire, living standards fell to genuinely prehistoric levels: things became worse than in the still relatively poor Greek and Etruscan civilizations. The scale of the calamity was then unprecedented and perhaps can only be compared to modern North Korea. Even modern Zimbabwe, where land and capital confiscations have destroyed productivity under Robert Mugabe's regime, seems an inadequate comparison.

What is the lesson to take away from this? Let's at least consider Ward-Perkins's conclusion: economic interdependence was a key to Roman prosperity. When the empire fell, it was more dangerous and more difficult to trade with foreigners, so less trade occurred. That means less specialization occurred.

It also means that the magic of Adam Smith's pin factory—where each person specializes in one small task and lets others produce other goods and other services—went away. Western Europeans went to a genuine Robinson Crusoe economy, with every family—or at best every village—for itself. Surely this quaint, medieval world must have looked charming to an outsider, but it was a very poor world all the same.

REVIEW QUESTIONS

1. The first sustained economic growth occurred in England in the late 1700s and spread across western Europe over the next few decades. A thousand years ago, living standards were quite equal across countries—Robert Lucas summed it up by saying incomes differed by a factor of maybe two. Today, living standards differ by a factor of 30, perhaps as high as 50, across countries.

2. The average forty-year-old today in the United States is about twice as rich as the same person thirty-five years ago. This is confirmed by applying the rule of 70: living standards grew about 2 percent per year, so $70/2 = 35$ years.

The text notes that South Korea and Japan have grown at between 4 percent and 6 percent per capita per year in recent decades. Let's take 5 percent as the average. By the rule of 70, that would mean it would take $70/5 = 14$ years to double. At that rate, in twenty-eight years it would quadruple, and in forty-two years it would octuple. Thirty-five years is in between—so let's say incomes have increased by about six times over that period. (In fact, 1.05^{35} is about 5.62, so this rough estimate only slightly overstates.)

1. Peter Temin, "The Economy of the Early Roman Empire," *Journal of Economic Perspectives* 20, no. 1 (Winter 2006): 133–51.

3. This is an exciting and active area of research. I'll let you try out some answers on your own, but I generally direct students to two things: (a) the development of trade and markets; and (b) a shift in epistemology—the Galileo example.

4. The rule of 70 gets us in the ballpark of the right answer, and it makes it easy to remember just how powerful a force compound growth really is.

The ratio scale helps us to see when something is growing at a constant percentage rate. In a normal, nonratio scale, something that grows 2 percent just goes up and up, and it's hard to see if the growth rate is constant or not. In a ratio scale, a constant growth rate is a straight line.

They'll naturally be used together whenever you're discussing fairly constant exponential growth: the first takes care of the simple math and the second takes care of the simple graphs.

5. The growth rate of population plus the growth rate of GDP per capita equals the growth rate of GDP.

6. The costs are environmental losses and perhaps the loss of the simpler lives our ancestors used to live. The benefits include longer lives for almost everyone, greater health, and the ability to explore other cultures through travel, reading, and multimedia.

EXERCISES

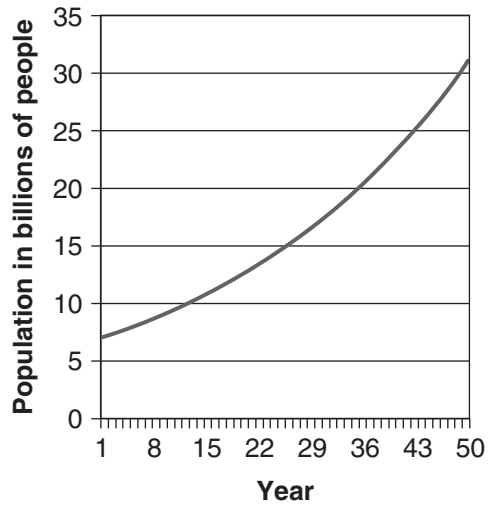
1. 2050 is thirty-six years from 2014.

- (a) \$2,146
- (b) \$3,060
- (c) \$6,156
- (d) \$12,221

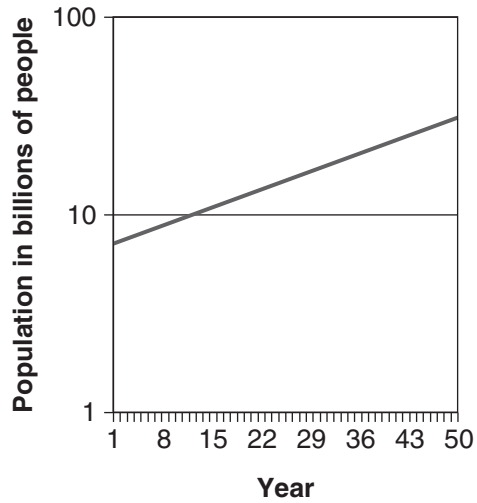
So, if Ethiopian living standards grew as fast as in China or South Korea—6 percent per year, in thirty-six years people there wouldn't be as well off as in Mexico today.

2. (a) 135 billion

(b) Now: 7 billion. One year: 7.21 billion. Two years: 7.43 billion. Ten years: 9.41 billion. Twenty-five years: 14.66 billion. Fifty years: 30.69 billion.



(c)



(d)

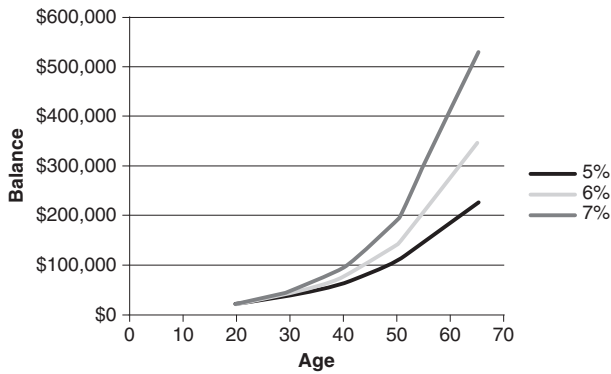
3. This is a worked exercise. Please see the text for the solution.

4. (a) Age 25: \$33,455. Age 30: \$44,771. Age 40: \$80,178. Age 50: \$143,587. Age 65: \$344,115.

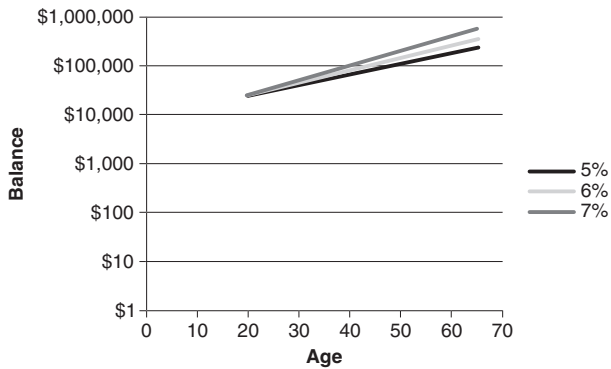
(b) 5 percent: Age 25: \$31,907. Age 30: \$40,722. Age 40: \$66,332. Age 50: \$108,048. Age 65: \$224,625.

(c) 7 percent: Age 25: \$35,063. Age 30: \$49,178. Age 40: \$96,742. Age 50: \$190,306. Age 65: \$525,061.

The shift from 5 percent to 7 percent more than doubles the value of the retirement portfolio by age 65.

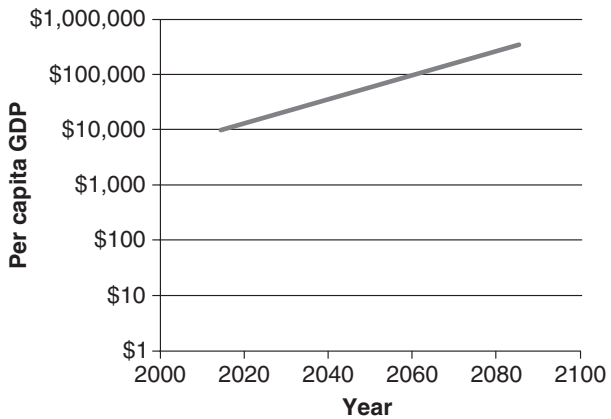


(c)

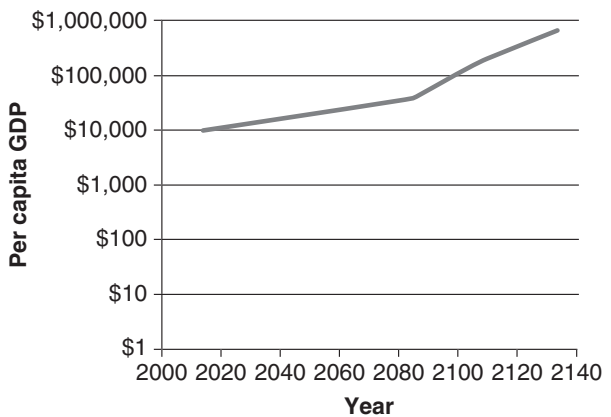


(d)

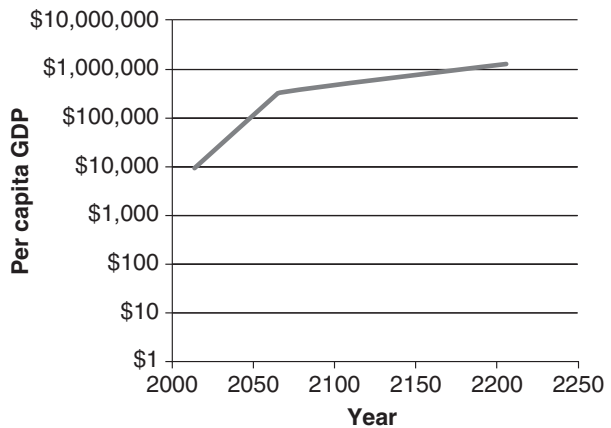
5.



(a)



(b)



(c)

6. This is a worked exercise. Please see the text for the solution.

7. Note:

Country	1980	2014	Ave. Annual Growth Rate
United States	29,288	51,958	1.70%
Canada	24,716	43,376	1.67%
France	22,557	37,360	1.50%
United Kingdom	20,044	38,083	1.91%
Italy	19,912	34,876	1.66%
Germany	19,617	45,320	2.49%
Japan	19,147	35,574	1.84%
Ireland	12,845	52,186	4.21%
Mexico	11,954	15,521	0.77%
Brazil	5,297	17,459	3.57%
Indonesia	2,249	9,797	4.42%
Kenya	2,049	2,971	1.10%
China	1,578	12,514	6.28%
India	1,169	5,451	4.63%
Ethiopia	690	1,505	2.32%

8. This is an essay question.

9. These are all approximations. (Note: students often have problems with this question because they fail to recognize the equation as a growth process as the initial value of x and y are implied as 1.) It might help to remind students of this point and that g_x is 4 percent and g_y is 2 percent.

(a) 6 percent

(b) 2 percent

(c) -2 percent

(d) 3 percent

(e) 4 percent

(f) 0 percent

10. (a) $(1/3) \times g_k$

(b) $(1/3) \times g_k + (2/3) \times g_l$

(c) $g_m + (1/3) \times g_k + (2/3) \times g_l$

(d) $g_m + (1/4) \times g_k + (3/4) \times g_l$

(e) $g_m + (3/4) \times g_k + (1/4) \times g_l$

(f) $(1/2) \times (g_m + g_k + g_l)$

(g) $(1/4) \times g_k + (1/4) \times g_l - (3/4) \times g_m$

11. (a) Time 0: 2. Time 1: 2.04. Time 2: 2.081. Time 10: 2.44. Time 17: 2.8. Time 35: 4.

(b) Time 0: 1. Time 1: 1.05. Time 2: 1.1025. Time 10: 1.638. Time 17: 2.29. Time 35: 5.52.

(c) Time 0: 1.68. Time 1: 1.73. Time 2: 1.78. Time 10: 2.20. Time 17: 2.66. Time 35: 4.33.

12. This method always yields a larger answer. That's because it forgets about the miracle of compound growth.

For example, if this method is used to measure a variable that doubles in ten years, it concludes that the variable must have grown 10 percent per year. In reality, it only grew 7 percent per year. Seven percent annual growth is all you need to double in ten years—not 10 percent.

13. (a) About 260 years $(= \ln(51000/300)/\ln(1.02))$

(b) About \$86 $(= 51000/(1.03)^{216})$. That is not plausible—people could not have lived on that tiny amount. This is very strong evidence that the U.S. economy has not grown at a 3 percent rate for 216 years.

CHAPTER 4

A Model of Production

CHAPTER OVERVIEW

This chapter puts the Cobb-Douglas production function front and center in our study of economic growth. At the same time, it provides the opportunity to tell your students an honest yet understandable general equilibrium story as well as the chance to show how productivity accounting can give real insight into the reasons why some countries are so rich while others are so poor.

4.1 Introduction

The real world looks complex and often incomprehensible, so can we hope to explain it with just a few simple equations? In many cases, the answer seems to be a surprising yes. Macroeconomists make “toy models” of a complex world and then check to see if the model matches the real world. We push a lever inside the toy model (raise the savings rate) and watch what happens (the economy grows faster for a while, then slows down). If that matches what seems to happen in the real world, then we trust the model a bit more. That gives us some faith that the model will give us good answers even when we can’t easily compare the model to the data, such as when a government tries a new economic policy.

In practice, what macroeconomists do is build many different toy models of the economy and then compare them to some key facts about the real world. This textbook tells us about the models that have survived that brutal contest.

4.2 A Model of Production

This covers the workhorse model of macroeconomics, the Cobb-Douglas production function. It is widely used at

the World Bank, by many branches of the U.S. government and by economists around the world. Chad uses the explicit form $Y = \bar{A} \times K^{1/3} \times L^{2/3}$ throughout, so you can dispense with the alphas. He illustrates the constant returns property before taking us to a simple general equilibrium setup.

The only real maximization problem to consider is profit maximization for the firm. Since Chad assumes labor and capital are in fixed supply, it’s a very straightforward setup. He assumes no calculus, so you can just hand students the formula for the marginal product of labor or capital, show that it’s intuitive, and then move on to the real economics that grow out of the model.

There are a few immediate payoffs: we can show students that when markets are competitive, labor productivity determines wages. So when productivity rises, so does the typical worker’s wage. This goes against a lot of people’s quasi-Luddite intuition, so it may be a point worth driving home. Also, as I show below, you can test the “toy model” by seeing if it gets labor’s share of income right—and the toy model passes the test pretty well.

Finally, we show students a real general equilibrium model. In practice, that means we can show them that under some plausible assumptions, the interest rate and the average wage depend on the shape of the production function and the supply of production factors. This Solow-type world depends much less on demand-side forces like animal spirits, preference parameters, and the like. Students often come to macroeconomics with the folk wisdom that macroeconomic outcomes like wages and prices are about psychology: optimism, pessimism, manias, greed, and the like. Here, and in the next four chapters, we abstract from these ideas and focus our energies on the supply-side factors, such as the supply of savings, the supply of ideas, and the supply of labor.

4.3 Analyzing the Production Model

Here, we take the model to the data. First, we check to see if differences in capital per worker can explain why some countries are richer than others. In other words, was Marx right—is modern capitalism mostly about “Das Kapital”? The answer is a clear no. As Lucas long ago noted, capital differences just can’t do the job. Poor countries have less capital than rich ones, to be sure, but differences in capital aren’t big enough to explain differences in output per worker (as long as our model is the right one).

At this point, we turn to the neglected term in the production function, which now rightly takes its place at center stage: A . If we’re going to stick with this model, then A —which growth scholar Moses Abramovitz called “a measure of our ignorance”—deserves to be a focus of our attention. And if our model is right, then A —also known as the Solow residual—differs by a factor of 10 between the richest and poorest countries. This is a massive difference.

4.4 Understanding TFP Differences

Our model seems to be telling us that if we put 100 machines per worker in Japan and 100 machines per worker in China, we’re going to get a lot more output in Japan. Why?

This brings us to the list of possible reasons why the residual differs so much across countries. Human capital, genuine technological differences, and market-oriented institutions all get their due. You likely have well-formed opinions on which of these is most important, and Chad refers to some of the leading authors in this literature if you’re looking for supplemental readings.

4.5 Evaluating the Production Model

Our model tells us that differences in living standards are caused by one of two things: differences in capital per worker and differences in how efficiently that capital is used. The data tell us that the second cause is more important. Inefficiency is the cause of global poverty—not a lack of machines and equipment. This implies that the cure for global poverty will be found when we find ways to make workers in poor countries just as efficient as workers in places like Japan, France, and Canada.

SAMPLE LECTURE: EXAMPLES OF PRODUCTION FUNCTIONS

A good approach for students to become acquainted with the characteristics of the Cobb-Douglas production function is to consider what sort of production functions do not fit the diminishing returns and constant-returns-to-scale assumptions. For example, in Table 4.1 below, we illustrate a linear production function. With some numerical examples, we easily show that the assumptions of diminishing returns and constant returns to scale are violated.

Table 4.1

$$a) Y = bK + cL$$

hold L constant, $L = 0$

hold K constant, $K = 0$

let $b = 1$

Y	K	MP_K	Y	L	MP_L
1	1	1	1	1	1
2	2	1	2	2	1
3	3	1	3	3	1
4	4	1	4	4	1
5	5	1	5	5	1
6	6	1	6	6	1
7	7	1	7	7	1
8	8	1	8	8	1
9	9	1	9	9	1
10	10	1	10	10	1

scale, let $b = c = 1$

Y	K	L
2	1	1
4	2	2
8	4	4
16	8	8
32	16	16
64	32	32

Moreover, we consider a nonlinear production function in Table 4.2. In this case, each exponent is equal to 1, and again we show that the diminishing returns and scale assumptions are violated.

Table 4.2

Cobb-Douglas Production Function

$$Y = \bar{A}K^bL^c$$

let $A = b = c = 1$

Hold L constant, $L = 1$

Hold K constant, $K = 1$

$y = K$

Y	K	MP_K	Y	L	MP_L
1	1	1	1	1	1
2	2	1	2	2	1
3	3	1	3	3	1
4	4	1	4	4	1
5	5	1	5	5	1
6	6	1	6	6	1
7	7	1	7	7	1
8	8	1	8	8	1
9	9	1	9	9	1
10	10	1	10	10	1

Scale: $a = b = c = 1$

Y	K	L
1	1	1
4	2	2
9	3	3
16	4	4
25	5	5
36	6	6
49	7	7
64	8	8
81	9	9
100	10	10

Finally, in Table 4.3 we present the popularized Cobb-Douglas production function presented in the textbook. We easily show that both diminishing returns and constant returns to scale are evidenced.

Table 4.3

$Y = \bar{A}K^bL^c$					
let $A = 1$, $b = (1/3)$, $c = (2/3)$					
hold L constant, $L = 1$			hold K constant, $K = 1$		
Y	K	MP_K	Y	L	MP_L
1	1	1	1	1	1
1.259921	2	0.259921	1.587401	2	0.587401
1.44225	3	0.182329	2.080084	3	0.492683
1.587401	4	0.145151	2.519842	4	0.439758
1.709976	5	0.122575	2.924018	5	0.404176
1.817121	6	0.107145	3.301927	6	0.37791
1.912931	7	0.095811	3.659306	7	0.357378
2	8	0.087069	4	8	0.340694
2.080084	9	0.080084	4.326749	9	0.326749
2.154435	10	0.074351	4.641589	10	0.31484
Scale					
Y	K	L			
1	1	1			
2	2	2			
3	3	3			
4	4	4			
5	5	5			
6	6	6			
7	7	7			
8	8	8			
9	9	9			
10	10	10			

SAMPLE LECTURE: RUNNING SOME EXPERIMENTS—SHIFTING PARAMERS

Back in Chapter 1, Chad described the research methods of macroeconomics: (1) document the facts; (2) develop a model; (3) compare the model's predictions with the original facts; and (4) use the model to make other predictions . . . to be tested. A good calisthenics to prepare students for this process is learning how the parameters/exogenous variables solve the model and how shifts or changes in the parameters result in changes to the model's solutions. Shifting the parameters in the production model not only provides an excellent calisthenics but also helps students to distinguish between the sort of partial equilibrium analysis they are used to in principles from the sort of macroeconomics to which they are exposed in this course. To help students learn how parameter shifts affect the model's solutions, restate the production model:

- (1) $Y = \bar{A} K^{(1/3)} \times L^{(2/3)}$;
- (2) $w = MP_L = (2/3)(Y/L)$;
- (3) $r = MP_K = (1/3)(Y/K)$;
- (4) $L = \bar{L}$; and
- (5) $K = \bar{K}$,

where the model has five equations and five unknowns and three parameters (ignoring the distribution parameters): $\bar{A}$, $\bar{L}$, and $\bar{K}$. In addition, recall that per capita output can be written as

$$(6) \ Y/L = \bar{A}(K/L)^{(1/3)}$$

Once the model is set up, consider a simple numerical example: let $\bar{A} = \bar{L} = \bar{K} = 1$, and solve the model: $Y = Y/L = 1$, $w = 2/3$, $r = 1/3$. The solution to the model can be easily illustrated in four graphs: (a) the production function (labor on the horizontal axis); (b) the per capita output function; (c) the labor market—where labor demand is the MP_L and labor supply is $\bar{L}$; and (d) the capital goods market—where capital demand is the MP_K and capital goods supply is $\bar{K}$. Given this basic set up, let each of the parameters change, in turn, holding the other parameters constant, and illustrate graphically the consequence of each change. For example, let $\bar{L} = 2$. The result is $Y = 1.59$, $Y/L = 0.79$, $w = 0.53$, and $r = 1.06$. Due to the assumption of diminishing returns, output increases at a decreasing rate and per capita output decreases. The increase in labor supply creates an excess supply of labor, this drives the real wage rate down to 0.53 to eliminate the excess supply of labor, and the increase in the supply of labor makes capital more productive, increasing capital's marginal product and increasing the demand for and price of capital goods. Here students learn that the labor and capital goods markets are interrelated and that the interrelationships of markets are commonly studied in macroeconomics. You can repeat this exercises by resetting labor's value back to one and letting $\bar{K} = 2$. You will show that $Y/L = 1.26$, $w = 0.84$, and $r = 0.42$. In this case, the increase in the supply of capital creates an excess supply of capital driving down the real price of capital, while the increase in the supply of capital makes labor more productive, increasing the demand for labor while driving up the real wage rate. Next consider the effect of technological change. Let $\bar{A} = 2$. The effect is such that $Y = Y/L = 2$, $w = 1.33$, and $r = 0.67$. Technological change increases the demand for both capital and labor, driving up the prices of capital and labor. Finally, consider the problem of scale. Let both capital and labor double. Because of the constant returns to scale assumption, $Y = 2$, $Y/L = 1$, $w = 0.66$, and $r = 0.33$. To test how well students really understand the model, you can tease out as to why the prices of labor and capital are unchanged following a doubling of the inputs. Most students will still be thinking in the partial equilibrium world, so you will have to be careful to explain that as the supply of labor increases, capital is more productive, increasing the demand for capital, and that as the supply of capital increases, labor is more productive, increasing the demand for labor (more of those interrelationships [interdependent shift factors]), and these combination of shifts leave factor prices unchanged.

SAMPLE LECTURE: WAGES IN GENERAL EQUILIBRIUM

Many macroeconomists think that a nation's economy is like this:

$$Y = \bar{A} \times K^{1/3} \times L^{2/3}.$$

Of course, this is just a model—it's a major oversimplification of how machines, workers, and technology combine to make all of the goods and services a real-world economy creates. But let's see if this oversimplification can take us somewhere interesting.

Here, Y is GDP, also known as “output,” K stands for the capital (machines, equipment, and tools) in the economy, and L is the amount of labor—think of it as the number of full-time workers. What is A ? We'll spend a lot of time thinking about that later—Chad Jones has had a major impact on the study of A —but for now, let's call it technology. If we spend a moment to look at this equation (and perhaps draw a chart or two), you can see that more capital creates more output, and more labor creates more output. And both capital and labor run into diminishing returns—so more inputs are always better, but the first input is worth more than the hundredth one.

So far, this doesn't really involve any economics—it's more of an engineering story: if I want to make a lot of stuff, it's no surprise to hear that I'll need lots of machines and lots of workers.

But here's a uniquely economic question we should care about: if you create a free-market system, will all of the workers get jobs, and will all of the machines get used? Or is a free-market system instead likely to create something like the Great Depression, where lots of workers and machines are unemployed? And perhaps most importantly, from the typical voter's point of view, how much will workers earn in a competitive economy? In the long-run framework, markets are assumed to operate as if an impersonal auctioneer is present. The auctioneer sets the price to equate quantity demanded and quantity supplied.

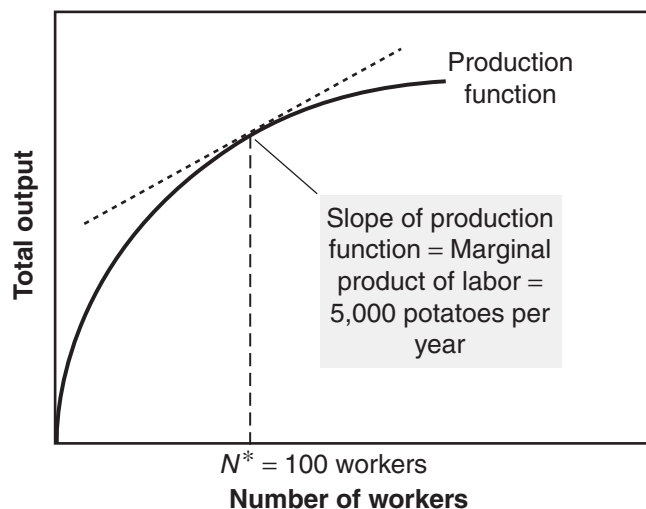
We can use the auctioneer metaphor to answer these questions. Let's think about this equation as telling us about how to grow potatoes. To keep it simple, let's only think about the plight of workers. What we'd like to know is how much these workers “sell” for and whether all of them will get sold. Of course, the price of workers is their wage—think of an annual wage.

When you studied microeconomics, you learned how prices get set in perfectly competitive markets: by supply and demand. But supply and demand is just for finding out the price of one product (potatoes or workers), assuming that you already know the price of apples, and workers, and machines, and everything else in the economy. What happens when you don't know the price of anything? What if you just have some “capital” and some “labor”? Will a competitive market create prices that ensure all the capital and labor get used?

(Note: To macroeconomists, “capital” generally refers to machines and equipment [not to stocks and bonds], and “labor” means any kind of worker [not just unionized workers]. Some students will think “capital and labor” means “the moneyed classes and the unions”—so a little explanation might be in order.)

To make things even more concrete, let’s consider a simple farm economy, with 100 workers and 10 farm owners. Capital and technology are fixed.

First, draw the production function. (Don’t draw the tangency line yet.)



Let’s assume an inelastic labor supply of 100 workers. Sounds like a recipe for exploitation, since even if the wage is bare minimum for survival, all the workers must still work.

ASSUMPTIONS

100 workers working full-time, regardless of the wage
 10 farms trying to hire the workers
 Diminishing returns to labor
 Marginal product of labor: 5,000 potatoes
 Start off with everyone working, 10 workers per farm.

Let’s also assume, quite reasonably, that farm owners start off trying to pay a wage of 3,000 potatoes per year—barely enough for a person to survive on. They might all meet at the general store one day and agree to keeping the wage at the bare minimum. Adam Smith knew these kinds of price-fixing schemes happened all the time. As he said in *Wealth of Nations*: “People of the same trade seldom meet, even for merriment and diversion, but the conversation ends in a conspiracy against the public.”

So, they agree on a wage of 3,000 per year. What happens next?

By the time the farm owners get back to their plots of land, they’ve done the math. Farmer #7, for example, reasons that

if he can hire one more worker at the going wage, he can get 5,000 more potatoes per year, but at a cost of only 3,000 potatoes per year. That’s a 2,000 potato profit per worker! So, he tries to hire one more worker.

But where can he get one more worker? Only from another farm! So, he tries to hire a worker away by offering 10 more potatoes a year—he breaks the general store agreement, but just this once . . .

Of course, this doesn’t happen just once. Farmer #2 and Farmer #8 and all the rest get the same idea—they’ll just get one or two more workers and make a lot of money. But the only way to get more workers is to bid up the wage just a bit, so the asking price goes from 3,000 to 3,010 to 3,040 and on and on—not because the owners are kind to the workers but because the owners are greedy. The owners fight against each other—acting in their individual self-interest—and unintentionally raise the wage of workers.

This cycle continues, each farmer bidding up the price of the cheap workers, until the wage is at 5,000. Why does it stop at this point? Because once the wage is 5,000, each farmer is content with the number of workers he or she has—the benefit of hiring one more worker is just equal to the cost of hiring one more worker. In economic jargon, we’d say that at this point, the marginal product of labor (benefit) equals the wage (cost).

That’s a surprising result, isn’t it? We’re concluding that in a competitive market, the wage depends on a fact of engineering, agriculture, and the nature of farming. The wage depends on how many more potatoes you could produce if you had one more worker. It doesn’t depend at all on how desperate workers are. *It’s this simple: Slope = Wage.*

So, we started off with an assumption—fixed labor supply—that made it look like workers would be ripe for exploitation. But there are two sides to a fixed number of workers: it also means that business owners can’t bring in workers to work at lower wages. The fixed labor supply puts farm owners in a ruthless competition against each other, which helps push farm wages far above the starvation level.

EXTRA TOPICS YOU COULD DEVELOP IN THIS LECTURE

A. In this model, how do you increase wages? You do so by getting rid of workers or by shifting the production function upward (through extra capital or technology). Both would make it more valuable to have one extra worker—which pushes up the wage for every single worker. So, how have wages increased in the rich countries over the last two centuries? Clearly, through the second method: by shifting the production function up. Anything that raises the slope raises the wage. In the real world, we obviously have many more workers, both in the rich countries and around the world—but wages have risen over the decades.

B. Why don't the farm owners stick to the agreement they made at the general store? Because they are trapped in a prisoner's dilemma (a concept many students will have seen in Principles or in an introductory political science class, if you're inclined to cover such a topic). Each farm owner hopes all of the other farm owners are "honorable" enough to stick to the agreement, but whether the other farm owners stick to the agreement or not, it's in each farm owner's self-interest to undercut the others. In competitive markets, firm/farm owners are playing a prisoner's dilemma against each other. In this course, we'll often return to the competitive markets assumption, so it's worth keeping this in mind as we start off.

C. So, am I saying the farm owners aren't making any profit? I am saying that they're not making any profit on their tenth worker—each farmer is just indifferent between hiring and firing that last worker. But they're making profit—or more accurately, a return on their capital equipment—on each of the other nine workers. How much of a profit? It's actually easy to draw that on this graph. (Just shift the tangency line down so that it crosses the origin, and it instantly becomes the "wage bill" line.) Now we can see how much (accounting) profit the farm owner makes on each worker at this wage. For any given number of workers, the gap between the production function and the wage bill line is the profit the farm owners would have if they hired that many workers.

CASE STUDY: LABOR'S SHARE OF OUTPUT ACROSS TIME AND ACROSS COUNTRIES

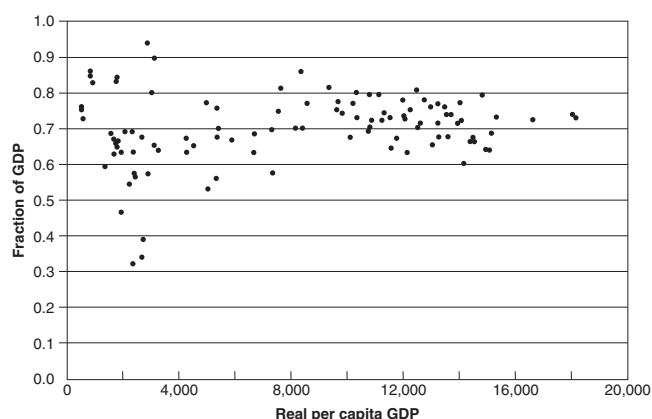
We're going to rely heavily on the Cobb-Douglas equation; in fact, we're going to treat it as a basic model of a national economy. If it's going to be so central, it would be nice to have some evidence that such a simple equation actually *can* sum up something as complex as an entire national economy. So is there a simple way to check and see if this equation actually makes some good predictions? Yes, there is. As Chad notes, the Cobb-Douglas model (combined with competitive markets) has a clear prediction about how much of a nation's income goes to the workers and how much goes to the firms. It's surprisingly simple, actually. Recall the function:

$$Y = \bar{A} \times K^{1/3} \times L^{2/3}.$$

Cobb-Douglas makes the following prediction: the exponent on labor is the fraction of the nation's income going to workers. That means that in every country in the world, about two-thirds of the income should go to the workers, and about one-third should go to owners of capital. In Chapter 2, he shows that in the United States, this share has been stable for decades. But can this possibly be true around the world?

As the chart below shows, the answer is a rough yes. Each dot represents one country, ranging from the richest to the

poorest. Only in the very poorest countries is there much of a difference from the two-thirds value our model predicts.



Estimates of labor share are derived using an adjustment to account for income of self-employed persons and proprietors, combined cross-country and time-series data. The adjustment involves assigning the operating surplus of private unincorporated enterprises to labor and capital income in the same proportions as other portions of GDP.¹

It turns out that the hardest thing to measure when looking at these data from different countries is the wages of small-business owners—for the most part individual farmers, people scraping out a bare existence on their own plots of land. It's hard to decide how much of a small farmer's income should count as "capital income" and how much as "wage income." But Gollin sweated the details for years to create this chart, and in doing so he gave good evidence that for the vast majority of countries, Cobb-Douglas does a good job predicting how much of GDP gets paid to workers. Our simple model passes a big test.

This is a surprising result—after all, we often hear in the news about how the power of workers seems to rise or fall in different countries or in different decades. You might think, for example, that western Europe, with its strong unions, would have a much higher labor share than the capitalist-friendly United States. But that isn't the case; all of the world's rich countries are right around the magical two-thirds labor share. Despite these findings, rising wage inequality remains an important source of increasing income inequality in the United States. The functional income distribution data does pick up this factor. (For example, see James Galbraith, *Created Unequal: The Crisis in American Pay* [New York: Free Press, 1998].)

1. Raw data are taken from United Nations (1994). Data on real per capita GDP are taken from the Penn World Tables, Version 5.6.

Douglas Gollin, "Getting Income Shares Right," *Journal of Political Economy* 110 (April 2002): 458–74.

CASE STUDY: THE QUALITY OF HUMAN CAPITAL

We all know that just sitting in a classroom isn't enough to make a person smart, and it certainly isn't enough to make a person rich. But when we talk about "human capital," it often sounds like economists are saying that if we can just give students more years of education, we can make those students more productive. But don't results matter? Recent work by Eric Hanushek and Dennis Kimko tell us that results do matter. Looking at data from dozens of countries, they find that even after they control for years of schooling and other important factors, "international math and science test scores are strongly related to [a nation's economic] growth."²

So, can we raise these math and science scores by spending more money on education in poor countries? William Easterly, in his excellent, readable book *The Elusive Quest for Growth* (Cambridge, MA: MIT Press, 2001) points out just how hard that is to do. In poor countries, it's hard for weak governments to keep track of teachers and resources. That means that teachers often show up half the time or less (but still get paid), and teachers often sell the books—and even the pencils!—meant for the students.

After all, just think about how much a box of 50 textbooks costs—perhaps \$2,500—and then consider that the annual salary of a teacher in a poor country is perhaps even less than that. How tempting is it for a teacher to sell those books on the black market (even for \$1,000) rather than give them to the students? The incentives to teach just aren't there.

The solutions to many of these institutional problems lie not in macroeconomics but in microeconomics. In your microeconomics courses you'll learn more about how to give people good incentives so that teachers will be more likely to educate their students.

CASE STUDY: WHAT PREDICTS GOOD LONG-TERM ECONOMIC PERFORMANCE?

Economists have put great effort into finding the root causes behind the massive differences we see in living standards across countries. After all, Adam Smith's classic book is called *The Wealth of Nations*. Over the centuries, geography, government policy, health, education, and many more factors have been proposed. Have economists come to a final conclusion? The answer is simple: no. After decades of work, no clear consensus has emerged.

So, although most economists will agree that the broad factors that Chad discusses as drivers of TFP play a big role in driving income differences—human capital, institutions, and technological innovations—there is much less con-

sensus about what those factors mean in practice. Is elementary education more important than college education? Are political rights more important than property rights in driving long-run growth? There is even less agreement about whether we need to include factors beyond these three—factors like geography, health, and culture.

Xavier Sala-i-Martin, Gernot Doppelhofer, and Ronald Miller have tried to do something about that: they ran literally millions of statistical tests, using data from 1960 to 2000, to see which factors consistently predicted good economic performance over those decades.³ They looked at 67 different factors and ranked them by how well they predicted good economic performance. Let's look at the top ten—which surely deserve more attention than we can provide. (Note: I'm omitting the log 1960 GDP measure, since that's the convergence variable, which we'll get into in Chapter 5. The plus or minus sign indicates whether more of that factor is good or bad for long-term performance.)

SALA-I-MARTIN, DOPPELHOFER, AND MILLER'S TOP 10

1. Whether a country is in East Asia (+)
2. Amount of K–6 schooling in 1960 (+)
3. Price of capital goods (–)
4. Fraction of tropical area (–)
5. Fraction of a nation's population living near a coastline in the 1960s (+)
6. Malaria prevalence in the 1960s (–)
7. A person's life expectancy in 1960 (+)
8. Fraction of the population that is Confucian (+)
9. Whether a country is in sub-Saharan Africa (–)
10. Whether a country is in Latin America (–)

Surprisingly, none of the top ten are what we think of as "institutional" variables, even though the authors used a number of tests to see if various measures of political freedom and capitalism were good predictors of economic performance. Those measures largely failed the test. One reason may be because, through no fault of their own, the authors didn't include any communist countries in their database (it's hard to get trustworthy long-term data on countries under communism; perhaps future researchers will go back into the archives and create good historical data on that).

So, the top ten are mostly about geography, disease, and longevity, with one bright light shining for human capital:

2. Eric Hanushek and Dennis D. Kimko, "Schooling, Labor-Force Quality, and the Growth of Nations," *American Economic Review* 90, no. 5 (December 2000): 1184–1208.

3. Xavier Sala-i-Martin, Gernot Doppelhofer, and Ronald Miller, "Determinants of Long-Term Growth: A Bayesian Averaging of Classical Estimates (BACE) Approach," *American Economic Review* 94, no. 4 (September 2004): 813–35.

K–6 education. Other education measures like level of high school and college education generally seem to do poorly in these cross-country comparisons (as Sala-i-Martin said in 1996, “I just ran two million regressions”).⁴ Perhaps this is because too much education really can be wasteful for society as a whole, or perhaps because many governments just don’t know how to give people practical skills beyond reading and writing. Again, it will take good microeconomic studies to help sort out many of these questions that are so important for macroeconomic outcomes.

Regarding disease, health, and economic growth, the tropical regions of the planet are hotbeds of health-destroying infectious diseases. Modern growth researchers such as David Weil have considered the link between disease and economic growth and have found that indeed, sick people are worse workers, and people with short life spans won’t consider education a good long-run investment. Again, the incentive for investing in human capital—which we’ll look at again later in the text—appears to play a key role.

CASE STUDY: SETTLER MORTALITY AND EXTRACTIVE INSTITUTIONS

In a famous paper, Acemoglu, Johnson, and Robinson tried to find out whether institutions really do matter.⁵ In economics, it’s often hard to separate cause and effect—do countries have good economies because they have good governments, or is it vice versa? Or does high education really cause both? Acemoglu, Johnson, and Robinson try to get around these kinds of puzzles by looking at what happened to countries after 1492, when Europeans started colonizing the rest of the world.

Europeans quickly found that some countries were easier to colonize than others. In some countries—generally those near the equator—tropical diseases were so deadly that few Europeans went there. Other places, like North America, Australia, and New Zealand, were easier for Europeans to settle. Acemoglu, Johnson, and Robinson argue that in places where colonizers died at high rates, Europeans set up “extractive” government institutions—gold mines and slavery-intensive plantations, for example. These institutions required only a few Europeans to stick around and endure the deadly environment. In these countries, Europeans generally didn’t worry about creating incentives for long-term investments in education or about creating stable property rights. They just needed enough political power to control the mines, plantations, and other physical sources of wealth—that was all.

4. Xavier Sala-i-Martin, “I Just Ran Two Million Regressions,” *American Economic Review* 87, no. 2 (May 1997): 178–83.

5. Daron Acemoglu, Simon Johnson, and James A. Robinson, “The Colonial Origins of Comparative Development: An Empirical Investigation,” *American Economic Review* 91, no. 5 (December 2001): 1369–1401.

By contrast, in places that were less deadly to Europeans, many of them created institutions with strong property rights, personal freedoms, and mass education. This led, they argue, to centuries of prosperity for these countries. The combination of disease and power relations that existed centuries ago appears to have had very real implications for living standards hundreds of years later.

REVIEW QUESTIONS

1. Macroeconomic models are also “toy versions” of the real world that (hopefully) contain the key moving parts to give us an idea about how the real world really works.

In order to generate real insights, a model of ice cream production only needs a few key features in common with the real economy. For example, the more workers you have, the more ice cream you can produce, and if you have more machines, you can produce more, as well. If you get a new idea for improving the machines, you can make even more ice cream with fewer workers.

The model can easily capture positive and diminishing returns to a factor, constant returns to scale, and increasing returns to ideas, but it is incredibly simple. It helps us forget about the (hopefully) extraneous details about real life—the human emotions, the need for health care and nutrition, the distribution of income, natural resources, and so forth. Economics has progressed as a science when it has left things out. Economists are reluctant to add new tools to their toolkit—we work with the small number of tools we have.

2. Hire workers until the cost of one more worker (in wages) is just equal to the benefit of having one more worker (in extra output). When you have few workers, the cost of one more worker will be much less than the benefit. But as more workers arrive, the benefit of extra workers falls and falls, until extra workers aren’t worth the cost.

The same argument holds for capital: buy machines until the marginal rental cost of one more machine equals the marginal benefit of one more machine.

3. An equilibrium occurs when businesses want to hire exactly the number of workers they have and want to rent exactly the number of machines they have.

In our model the number of workers and machines in society is fixed (or perfectly inelastic)—so what really adjusts isn’t the quantity of machines and workers but the price of machines and workers. Prices adjust so that the quantity supplied equals the quantity demanded. (Later we’ll see that the price of output—ice cream—adjusts as well, to ensure that all output gets sold.)

4. This ice cream economy is a closed economy. The only thing people make is ice cream, and the only thing they consume is ice cream, and although workers and capital owners

may get paid in money, there's only one thing they can buy with that money: ice cream. That means that production (Y) must equal income (wages and rental payments).

More formally, $Y = w \times L + r \times K$,
output = total wages + total rental payments

(Note: if you want to keep the economy money-free at this point, the simplest way to do it is to assume that workers and capital owners get paid in ice cream. All real output, Y , goes to pay off the factors of production, $w \times L + r \times K$. None is kept for the owners of the firm—and incidentally, none is “sold” to any separate “public” either—since the workers are the public.)

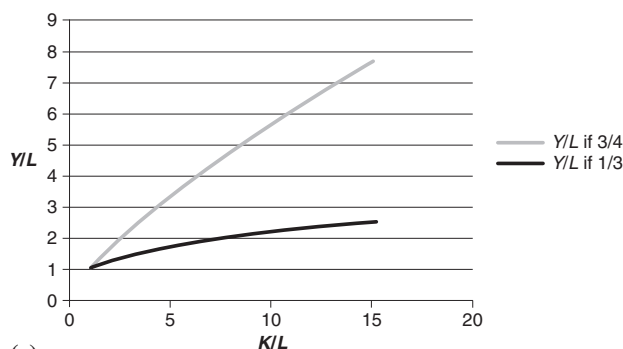
5. Capital differences really are huge across countries, but our model says that can't drive big income differences. Why? Because our usual model assumes that diminishing returns to capital set in rapidly. That's what the one-third exponent on capital means: capital just isn't that important. If you run through a simple example, you can show students that a 1 percent rise in capital causes only a 1/3 percent rise in output—a small effect.

The case study on labor shares shows that there's actually some good evidence of capital not being all that important in practice.

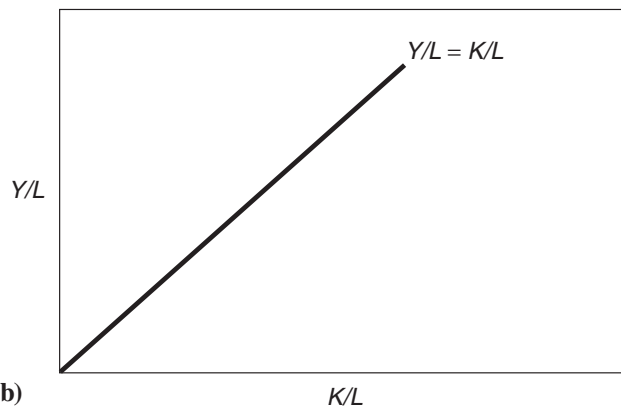
6. Your guess is as good as mine. But Douglass North's guess is probably better than both of our guesses put together.

EXERCISES

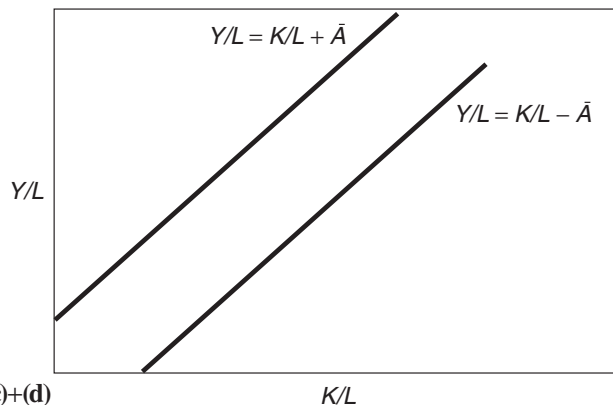
1. (a) Constant
- (b) Increasing
- (c) Increasing
- (d) Constant
- (e) In decreasing returns to scale, the K term has constant returns, but the $K^{1/3}L^{1/3}$ term has decreasing returns. When you put them together, the term with the exponents wins out: this production function has decreasing returns.
- (f) Decreasing returns to scale at the beginning, but moving toward constant returns as inputs increase (Hint: The $\bar{A}$ term gives a little extra productivity whose impact diminishes as K and L rise.)
- (g) Increasing returns to scale at the beginning, but moving toward constant returns as inputs increase



2. (a)



(b)



(c)+(d)

3. This is a worked exercise. Please see the text for the solution.

4. (a) $Y = \bar{A} K^{3/4} L^{1/4}$

Rule for hiring capital: $(3/4) \times Y/K = r$

Rule for hiring labor: $(1/4) \times Y/L = w$

Capital demand equals capital supply: $K = \bar{K}$.

Labor demand equals labor supply: $L = \bar{L}$.

(b) The interesting answers are as follows:

$r^* = (3/4)\bar{A} \times (L/\bar{K})^{1/4}$ (more workers or ideas equals a higher interest rate!)

$w^* = (1/4)\bar{A} \times (K/L)^{3/4}$ (more machines or fewer workers equals higher wages!)

(c) $Y/L = \bar{A} \times (K/L)^{3/4}$

5. (a)–(c) Please see the table below.

	Capital per person	Per capita GDP	Capital per person	Per capita GDP	Pre- dicted y*	Implied TFP to match data
United States	141842	51958	1	1	1	1
Canada	128667	43376	0.9071	0.8348	0.9680	0.8624
France	162207	37360	1.1435	0.7190	1.0457	0.6876
Hong Kong	159247	45095	1.1226	0.8679	1.0393	0.8351
South Korea	120472	34961	0.8493	0.6729	0.9470	0.7105
Indonesia	41044	9797	0.2893	0.1886	0.6614	0.2851
Argentina	53821	20074	0.3794	0.3864	0.7239	0.5337
Mexico	45039	15521	0.3175	0.2987	0.6822	0.4379
Kenya	4686	2971	0.0330	0.0572	0.3209	0.1782
Ethiopia	3227	1505	0.0227	0.0290	0.2833	0.1022

(d) As the text says, differences in TFP (“technology,” “ideas,” “residual”) are bigger than differences in capital in driving income differences. K/L differences are big, but in our model, capital runs into diminishing returns quickly, so it can’t matter that much.

6.

	Capital per person	Per capita GDP	Capital per person	Per capita GDP	Pre- dicted y*	Implied TFP to match data
United States	141,842	51,958	1	1	1	1
Canada	128,667	43,376	0.9071	0.8348	0.9295	0.8982
France	162,207	37,360	1.1435	0.7190	1.1058	0.6502
Hong Kong	159,247	45,095	1.1226	0.8679	1.0906	0.7958
South Korea	120,472	34,961	0.8493	0.6729	0.8847	0.7606
Indonesia	41,044	9,797	0.2893	0.1886	0.3945	0.4779
Argentina	53,821	20,074	0.3794	0.3864	0.4834	0.7992
Mexico	45,039	15,521	0.3175	0.2987	0.4230	0.7062
Kenya	4,686	2,971	0.0330	0.0572	0.0775	0.7379
Ethiopia	3227	1505	0.0227	0.0290	0.0586	0.4945

Since we now assume that capital doesn’t run into diminishing returns that quickly, the big capital differences now predict big output differences. With the change in the capital exponent, the implied total factor productivity coefficient increases for South Korea, Indonesia, Argentina, Mexico, Kenya, and Ethiopia.

Problems 5 and 6 are useful in showing students how a choice we make early on—the choice of exponent—has a big impact down the road when we try to draw conclusions from the model. Assumptions matter.

7. (a) In the first column, we’re now saying that the United States is X times richer than a particular country. In the second column, we’re saying that capital differences alone make the United States Y times richer than that country. In the third column, we’re saying that TFP differences alone make the United States Z times richer than that country.

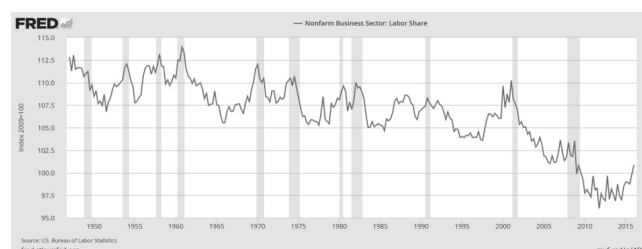
(b)

	Per capita GDP	Predicted y*	Implied TFP to match data
United States	1.00	1.00	1.00
Canada	1.20	1.03	1.16
France	1.39	0.96	1.45
Hong Kong	1.15	0.96	1.20
South Korea	1.49	1.06	1.41
Indonesia	5.30	1.51	3.51
Argentina	2.59	1.38	1.87
Mexico	3.35	1.47	2.28
Kenya	17.49	3.12	5.61
Ethiopia	34.52	3.53	9.78

(c) America’s bigger capital stock makes it 3.12 times richer than Kenya. America’s higher level of TFP makes it 5.61 times richer than Kenya.

(d) America’s bigger capital stock makes it 3.53 times richer than Ethiopia. America’s higher level of TFP makes it 9.78 times richer than Ethiopia.

8. (a)



(b) For the first quarter of 2016, the index was 100.878. The index from 1965 to 1980 was about 107.5, so labor’s share for the first quarter of 2016 was about 62.5 percent. The production can still be Cobb-Douglas, however the exponents on capital and labor have been shifting—with capital getting a higher share of income and labor getting a smaller share of income than in the past.

9. Olson is referring to the fact that even if people are individually smart, they may make poor (or nonsensical) group decisions. The classic simple example would be Condorcet's paradox, which many students will have seen in *Principles of Microeconomics* or an introductory political science course. But Olson is speaking much more broadly: he's noticing that while individual people are doing the best they can to be as productive as possible (even going so far as to migrate to the United States to improve their productivity), entire countries are foolishly leaving "big bills on the sidewalk" and staying poor.

This fact puzzles him, since it violates one of economists' favorite ideas: the Coase theorem. At its broadest level, the Coase theorem is the idea that if a group of people disagree about how to divide any valuable item, they should be able to negotiate a settlement that leaves everyone better off. (I'm intentionally oversimplifying so that Coase is as relevant as possible to the topic at hand.) So why can't people in poor countries come to some agreement to start acting more like the rich countries? If they need to change government poli-

cies, culture, or education levels, there ought to be a way to work things out, according to the (intentionally) naïve view of the Coase theorem.

Here is an example: countries like Singapore or China, which grew quickly in recent decades, created enough new wealth to compensate just about everyone who could possibly be hurt in the transition to prosperity. Few people in those countries would look back longingly to the "good old days" when they were poorer. Government bureaucrats, union officials, older workers, schoolteachers—almost all are better off now that their country has decided to pick up the "big bills." Few rational people would stand in the way of that kind of prosperity—it would be economically irrational. This makes it all the more puzzling that many countries leave those bills right there on the sidewalk. They spend time fighting over who will win and who will lose in the transition to prosperity (Will I lose my government job? Will I get laid off at the factory? Will my education in communist economics become worthless?) rather than creating the prosperity in the first place. This, to Olson, is a puzzle that deserves further study.

CHAPTER 5

The Solow Growth Model

CHAPTER OVERVIEW

Chad lays out the simplest possible version of the Solow model—with no technology growth and with no population growth—and works through it extensively. By the end of the chapter, your students should understand the catch-up principle, which he calls “The Principle of Transition Dynamics.” This principle helps explain why postwar or newly capitalist countries grow quickly for a while and then slow down. At the same time, students will understand why long-term growth in living standards in capitalist societies can’t really be explained by growth in capital. In addition, your students will learn the importance of assumptions in constructing models, how assumptions generate conclusions, and how “tweaking” assumptions will modify conclusions.

The math is surprisingly light—and since you’ve already worked out the model’s microfoundations in the last chapter, you should find it relatively painless to reach back and convert these “dynamic general equilibrium” results into insights about how wages (definitely) and interest rates (maybe) should change over time in the world’s transitional economies.

While this is the longest chapter of the book, it goes back and forth between model and data in an organic way that resists a simple breakdown into “model” and “application” units. I would suggest that you teach the chapter roughly the same way that Chad builds it out. If you absolutely have to omit some of this chapter, Sections 1–3, 5, 7, and 8 cover the “traditional” undergraduate Solow model.

5.1 Introduction

Chad’s introductory quote by Solow can’t be emphasized enough: many of your students will just be taking this course to get a grade, and they’ll be grinding through the models to

do okay on the midterm and final. But Solow’s quote—like many of the methodological comments that Chad slips in from time to time—might actually help sell your students on the idea that macroeconomic models really are a way to look at the real world.

The reason we keep using the Solow model is because it gives a lot of insights into a lot of different situations. For example, if we expand “capital” to mean “physical *and* human capital,” the Solow model’s main results hold. If we add in population growth and technology growth and even some migration, the results still hold. If we open up international capital flows, so that domestic savings needn’t equal domestic investment—well, things get a little tougher there, but since the Feldstein-Horioka savings puzzle (that a country’s savings rate tends to be quite close to its investment rate) is still with us, that seems to be a minor empirical matter, one that you can omit in this course without feeling too deceptive.

The key point I emphasize when introducing the Solow model is that we’re going to use it to explain where the capital stock comes from. Where did all of these machines and construction equipment and office buildings and factories come from? And why are they so much more common in some countries than in others?

We’re also going to learn why a higher savings rate can’t permanently raise a nation’s growth rate. In the media, we often hear that Americans spend too much and that if we only taxed capital less we could grow faster. There may be slivers of truth in each of these ideas, but can we save our way into a higher growth rate?

The Solow model says no, and the proof is ingenious: Solow takes a very simple assumption—diminishing returns to capital—and shows us that if we believe in the law of diminishing returns, then we can’t believe that higher savings cause higher permanent growth.

5.2 Setting Up the Model

Here, Chad sets up the simplest Solow model possible: no technology growth, no population growth, no government, and no international trade. He uses the metaphor that output is “corn,” so that saved corn becomes part of next year’s productive capital stock of seed corn.

PRODUCTION

Here is the Cobb-Douglas production function again, and the simplified national income identity: $GDP = Y = C + I$. You may want to remind students that I is what builds up the capital stock.

CAPITAL ACCUMULATION

This is the big one, in my experience.

$$K_{t+1} = K_t + I_t - \bar{d}K_t.$$

Next year’s capital stock equals last year’s plus your new investment, minus the amount of capital that wore out. Chad notes that in practice, $\bar{d}$ seems to be about 7 percent to 10 percent. We saw back in Table 2.2 that depreciation was roughly \$2.8 trillion in 2015, about 15.7 percent of gross domestic product (GDP)—so a lot of investment effort in the U.S. economy is devoted to just replacing this worn-out capital stock. This implies that the productive (i.e., nonhousing) U.S. capital stock is at least \$18 trillion.

The case study that accompanies this subsection conveys the intuition about what it means to be in a steady state. That’s because students will see that more capital means more depreciation. As I note in an expanded case study below, if you have extremely math-averse students, you could choose to cover this subsection rigorously and then hand-wave your way through the rest of the Solow model’s algebra.

LABOR, INVESTMENT, AND THE MODEL SUMMARIZED

Labor supply is mercifully fixed, and as usual, Chad assumes that people save a fixed percentage of their incomes.

I often point out that the fixed savings assumption seems to fit the real world quite well: some countries are high savers and some are low savers, but whatever a country’s saving rate is, it seems to keep it for decade after decade in most cases. Big tax changes, government reforms, changes in living standards—none seem to have overwhelming impacts on a nation’s savings rate. That’s why this is a big puzzle for macroeconomists to explain, but fortunately we keep that outside our model.

You may want to give intuition about the fixed savings rate by telling your students to imagine that a fixed number of workers go to the potato chip factory every day to make consumer goods, while the rest of the workers go to the

computer chip factory to make investment goods. So, if society is deciding it wants more computer chips (raising “ s ”), it is deciding that it is going to give up some potato chips, at least in the short run. Ultimately, the savings rate is simultaneously a decision about private family savings and about how many people are going to make consumer versus capital goods.

Students have pressed me on this issue a few times, so a little general equilibrium hand-waving might be appropriate on that point. In the simplest case, we’re thinking about a corn economy, so saving more literally means setting more corn aside to plant next year. Savings = Investment in a physical sense. For slightly more realistic coverage, consider the case study below.

5.3 Prices and the Real Interest Rate

As a simplifying assumption, the factor prices, the rental price of capital and the wage rate, are left out of the Solow model. As we know from the production model, firms adjust the employment of an input until the marginal product of the factor equals the factor price. This section of the chapter introduces students to the concept of the real rate of interest. The real interest rate is introduced again in Chapter 8 in the context of the Fisher equation.

Chad defines the real rate of interest as the amount a person can earn by saving a unit of output per year or the amount that has to be paid if a unit of output is borrowed. The interest rate is termed “real” because the inflation component of the earnings (or the expense) has been removed from the interest rate. To illustrate the role of the real rate of interest as a rental price of capital in the Solow model, Chad returns to the family farm metaphor. For example, the family farm may decide to forego consumption of some of its corn (foregone consumption equals savings) and set it aside as next year’s seed (investment). In this case, the savings becomes the investment, and the investment becomes the additional unit of capital, and the marginal product of that capital becomes the return on savings, the real rate of interest.

5.4 Solving the Solow Model

This is fully covered in a sample lecture to come.

5.5 Looking at Data through the Lens of the Solow Model

This innovative section speaks for itself—it shows that the Solow model does a good job explaining the real-world “capital intensity” of different economies, and it shows that TFP differences matter enormously, just as in Chapter 4. It’s a

practical undergraduate application of quantitative economic theory—the kind of thing we should see more of in our textbooks.

5.6 Understanding the Steady State

By now, you will have likely made this point in a lecture—that the reason Solow heads to a steady-state living standard is because diminishing returns to capital run up against a constant rate of depreciation.

5.7 Economic Growth in the Solow Model

There is no long-run growth in GDP per capita in the Solow model. Chad also notes that population growth doesn't change the story about GDP per capita (he leaves out the capital-diluting effect of population growth completely, so you don't ever have to mention " $n + \bar{d}$ " in your lecture).

5.8 Some Economic Experiments

This section covers two popular experiments showing how permanent policy changes have *temporary* effects on GDP growth rates but *permanent* effects on GDP levels. A permanent increase in the savings rate (perhaps caused by a fall in the budget deficit or some investment-targeted tax breaks) can't create a permanent increase in the economic growth rate; diminishing returns are to blame. It is likewise with a permanent fall in the depreciation rate (perhaps caused by better weather or cheaper repair methods).

5.9 The Principle of Transition Dynamics

In this section Chad illustrates the principle of transition dynamics. You may want to consider covering this material earlier than it appears in the book—perhaps after Section 5.4 or so. In Section 5.4, you can easily show how the growth rate is related to the difference between the steady capital stock and actual capital stock due to diminishing returns to capital. For example, assuming the actual capital stock is below the steady capital stock, the greater that difference, the greater the growth rate. This section shows in detail and with intuition how permanent changes in deep Solow parameters have only temporary out-of-steady-state changes on the growth rate. A simple Excel spreadsheet simulation, with time on the x -axis, can do wonders for building this kind of intuition. The case study provides an easy illustration by comparing high-saving South Korea with the low-saving Philippines. In an expanded case study below, we look at another transition

dynamic: a capital stock destroyed by war and then quickly rebuilt afterward.

Chad uses the Solow model to provide a possible explanation for differences in growth rates. For example, different countries experience different growth rates because of differences in each country's actual capital stock relative to its steady capital stock. He then uses this principle to make a quite remarkable conclusion: since the average poor country actually grows at the same rate as the average rich country, then it is likely that both kinds of countries are in similar positions relative to their steady states. Rich countries appear to be in high-TFP steady states, while poor countries are in low-TFP steady states. This gets us looking at deep parameters like TFP levels and savings rates as root causes of long-term differences in living standards. The average poor country frankly isn't on the road to prosperity—fast-growing China and India are oddities in that regard.

5.10 Strengths and Weaknesses of the Solow Model

These sections read clearly enough that many students will be tempted to skip the models and just read these two parts—let them know that would be a big mistake. In this chapter, more than most, I'd encourage you to assign quite a few homework questions so that students will develop Solow-style intuition, which will serve them well whenever they read news articles about economic performance in this or another country.

SAMPLE LECTURE

I can't emphasize the point Chad makes at the beginning of Section 5.4 enough: students need to spend some time working out the Solow model's steady state for themselves. I would set aside one hour for this section and some applications.

If you've already spent some time on the "Capital Accumulation" case study, you should remind your students that more capital means more depreciation. Double the capital, in fact, means double the depreciation. But since we have diminishing returns, double the capital will not mean double the new investment goods. Therefore, the more capital goods society creates, the harder it will become to replace the decaying capital goods. The key endogenous variable in this model is the capital stock—everything else depends on it—so let's focus on the capital accumulation equation:

$$\Delta K_{t+1} = \bar{s}Y_t - \bar{d}K_t.$$

The two halves of the right-hand side are the real story here. Every period, the change in capital comes from the war between savings (that is, investment) and depreciation. Our

production function tells us how output (Y) is produced by capital and labor, so let's substitute:

$$\Delta K_{t+1} = \bar{s}\bar{A}K_t^{1/3}\bar{L}^{2/3} - \bar{d}K_t.$$

The right-hand side of the equation gets you the two halves of the Solow diagram, Figure 5.1. As long as the first term is larger than the second term, new investment goods are winning in their battle against depreciation, so the capital stock rises. Chad does a great job explaining the intuition of this result—his presentation has the feel of well-honed lecture notes—so let me just mention that a case study below shows how this diagram can be used to explain the futility of some foreign-aid programs.

Solving for the steady state takes a little algebra (particularly, it requires some actions with exponents that might be unfamiliar to your students). As before, we're in steady state when $\Delta K = 0$, so we can start with the previous equation $\Delta K_{t+1} = \bar{s}\bar{A}K_t^{1/3}\bar{L}^{2/3} - \bar{d}K_t$; but in steady state, K is now something special: K^* . Solve for K^* and you're done:

$$K^* = (\bar{s}\bar{A}/\bar{d})^{3/2} \bar{L}.$$

This looks a little like “Saddle,” if you're into mnemonic devices. Higher depreciation hurts your long-term capital stock—there's no vulgar-Keynesian story here where you can break the capital stock to get richer in the long run—and everything else helps. Once you plug this into the production function and make it per capita, you get something simple and familiar:

$$y^* = Y^*/L^* = \bar{A}^{3/2}(\bar{s}/\bar{d})^{1/2}.$$

Comparing 5.7 with 5.9 yields some insights: technology matters more in the second equation, while savings and depreciation matter less. One reason is that capital just isn't all that useful in creating output, since it runs into diminishing returns. Another reason is that (as we'll see in the end-of-chapter exercises) higher technology levels raise GDP in two ways: directly by making existing capital more productive, and indirectly by raising the steady-state capital stock.

(Note: In the Solow model, steady-state living standards don't depend on the population size! Faculty often forget this point. The steady-state capital stock is endogenous with respect to labor supply.)

EXPANDED CASE STUDY: AN EXAMPLE OF CAPITAL ACCUMULATION

Chad's case study of capital accumulation emphasizes that “capital stock is simply the sum of past investments.” We'll run into many stock-and-flow metaphors, and this is probably your first chance to use that metaphor this semester. The river/dam/lake/evaporation metaphor is always a handy one in this context—evaporation can be a fixed percentage of the lake's volume, just like depreciation.

Chad runs through some actual numbers in Table 5.1, but rather than running it through the real production function, he picks a hypothetical case: start with a certain capital stock (1,000 units) and add 200 units of new investment each year. I find that when students' algebra is rusty, it helps to run through the first two rows of calculations by hand. Emphasize that the only “exogenous” variables here are $\bar{K}_0$ (one period) and I_t (all periods).

Let students know that if you give them a table with just those two facts (and the deep parameter of $\bar{d}$ the depreciation rate), they should be able to fill out a whole table, for thousands of periods. In the full Solow model, of course, we'll even make I_t endogenous, since that's what good economic theory does—it explains more by assuming less.

What we quickly see in Table 5.1 is that as the capital stock gets bigger every year, so does the amount of depreciation—an insight that explains why the full Solow model always heads toward a steady state. *More capital means more capital wearing out.* If you want to work out this non-Solow steady state, you may want to call it the “constant units of investment steady state.” That will contrast with the “constant percentage of investment steady state” that is key to Solow's model.

As we just noted, Chad's Table 5.1 shows that depreciation increases as the capital stock rises. But will this continue, or will it level off at some point?

Focus on Chad's case, where I_t stays the same every period. Just call it I in this case. You can run a simple Excel spreadsheet to chart some numbers, or if you like, you can proceed directly to the steady state. In this case, a steady state means that the capital stock will stay fixed at some value we'll call K^* . So, K_{t+1} will equal K_t , which will equal K^* , and the change in K will equal 0.

$$\Delta K = 0 = I - \bar{d}K^*$$

Solving this for K^* yields $K^* = I/\bar{d}$. So, for our example in Table 5.1, K_t would rise until K_t equals $200/0.1 = 2,000$. You may want to have the students see how K^* is impacted by a rise in I or a fall in $\bar{d}$. The fall in $\bar{d}$ will have an especially large impact on K^* .

So here, you can get many of the Solow model's insights at a low cost. This is a reminder that any change in plans that you stick with for a long time can have a massive permanent (“steady state”) impact. It's also a reminder that the fixed rate of depreciation drives so much in the Solow model and (presumably) in the real world.

An additional possibility is this: you could integrate the “Kindness of Strangers” case study (below) into this part of the lecture to show that a one-time massive gift of capital will have absolutely no impact on the steady-state level of capital. More capital means more capital wearing out.

In fact, you cover enough of Solow's big insights in this case study that if your students are extremely math averse, you could just make this the only rigorous, quantitative cov-

erage of steady states and convergence. After covering this, you could just hand-wave your way through the rest of this chapter without too much difficulty.

EXPANDED CASE STUDY: DO IMMIGRANTS CUT WAGES? ONE-TIME POPULATION INCREASES IN THE SOLOW MODEL

Chad worked out the model as an aggregate model in Section 5.4, and only at the end did he convert it to a per-capita model. If you take a moment to divide the equation (5.5) in the text ($\Delta K_{t+1} = \bar{s}Y_t - \bar{d}K_t$) by L , the fixed number of workers, you can instantly turn this into a per-capita Solow model.

That lets us look at Figure 5.1, the Solow diagram, in a new light. Now, the x -axis is capital per worker, and the y -axis is savings and depreciation per worker. With these, we can answer an important question: What happens if a lot of new workers show up one day? We've already seen from the last chapter that the instant effect (with a fixed capital stock) is that all the workers get jobs at new, lower wages—you're just moving down the fixed demand curve.

But in the long run, something interesting happens: K/L shifts sharply to the left in the Solow diagram, while the deep parameters of the model—reflected in the savings and depreciation curves—don't budge at all. That means that as soon as the immigrants arrive, they ease the force of diminishing returns to capital. Now we are back in a world where net investment is positive. In simpler terms, more labor makes capital more productive.

That builds up the capital stock until, in the new steady state, society is right back where it started. The immediate impact of immigrants is bad for wages but good for investors (since the interest rate rises). The long-term impact of immigrants is no impact on wages or the interest rate.

The surprising result here is that a big rise in the supply of labor has no impact whatsoever on the long-run wage. This result comes from the fact that our principles-level supply-and-demand story is a static model, while the Solow model is a dynamic model. In the dynamic model, a fall in the wage draws in more capital, which ironically raises the productivity of workers, raising their wages right back to the preimmigration level.

EXPANDED CASE STUDY: WAR, CAPITAL DESTRUCTION, AND RECOVERY

Germany, Japan, France, and England all suffered massive damage to their capital stocks during World War II, and all grew quickly in the decades after the war. Popular history gives much of the credit to the Marshall Plan, a U.S. aid plan for war-ravaged Europe (the classic Orson Welles film *The*

Third Man gives an idea of just how terrible things were in immediate postwar Western Europe). Though this aid likely prevented much suffering, the Solow model reminds us that whenever you destroy a country's capital stock, as long as the deep parameters haven't changed—as long as the savings and depreciation rates, and the level of technology are the same as before the war—then the economy will grow quite quickly and will converge to its old steady state.

As a rough estimate, that is just what happened after the war in western Europe. Western Europe was not quite as rich as the United States before World War II, and decades later, it is now about 75 percent as productive as the U.S. economy.

The more interesting case is Japan. It was much poorer than the United States before World War II—about 25 percent of prewar U.S. output per worker. But after the war, Japan grew extremely rapidly—growth built on a reputation for mass-produced low-quality goods. Now Japan is in the same economic league as western Europe, about 75 percent as productive as the United States. Why the change? That's a topic for a book in itself, but Solow tells us to look for big changes in technology, depreciation rates, and savings rates. You might ask students to read up on the subject to find out which of Solow's ideas explain Japan's new, higher postwar productivity level.

CASE STUDY: THE KINDNESS OF STRANGERS: FOREIGN AID IN THE SOLOW MODEL

Let's return to Figure 5.1, the classic Solow model chart. Consider a country that starts off in steady state, at K^* , and let's imagine that this country receives a massive gift of foreign aid, no strings attached, funded by (name of the celebrity-driven aid-concert-du-jour). Let's imagine that all of the aid is used to buy productive new capital equipment—no money is wasted, none is funneled into the secret bank accounts of government officials, and all is right with the world.

At this point, something wonderful happens: the economy is more productive! Since the capital stock is higher, GDP per person is higher, and living standards are higher. There's no doubt about that whatsoever.

But what will happen to the capital stock over the next few years? Remember: more capital means more capital depreciation. And at any point to the right of K^* , the amount of capital wearing out is greater than the amount of new investment capital that society is making each year. Machines are wearing out faster than they can be replaced, and the capital stock falls. People are still richer than before the gift of aid, but each year, they are a little less rich than before. The capital stock keeps declining until it is right back at its old level, K^* . Keeping the capital stock at the postgift level was just too wearying, too expensive.

The lesson is this: a temporary change in the capital stock only leads to a temporary change in living standards.

A bonus lesson is that the only way to keep society at the new higher postaid capital level would be to permanently change some deep parameter in the model—the savings rate, the depreciation rate, or the level of technology. That means that serious economic reform efforts should probably focus on these kinds of changes, if our goal is to permanently increase living standards in the world's poorest countries. Perhaps a wise society could use aid to buy some time to make long-lasting changes in those deep parameters.

CASE STUDY: HOW MORE SAVINGS CREATES MORE CAPITAL IN A MARKET ECONOMY

In a relatively realistic economy, with families making a decision to consume or save, there's a bit more to the story than in a world of corn.

As in the real world, let's assume there are families who consume and save, and who work as well. When it comes to saving, let's omit the middleman of banks and let's just remember that all the capital is really owned by the families. We could make it fancy and assume that families own firms indirectly through stocks, but it's easier if they just own the capital directly and rent the capital out each period to the firms.

There are two industries in the economy: the consumer goods industry and the investment goods industry. Both industries hire workers each period and rent capital each period. When the savings rate (exogenously) rises, families are demanding fewer consumer goods. That means fewer consumer goods get produced, which leaves lots of workers (and machines) with very little to do.

What do the families do with their extra savings? Well, they use them to buy investment goods from the investment goods industry, of course—and the investment goods industry expands, hiring the unused consumer-industry employees and renting the unused consumer-industry capital stock to make those new investment goods. The extra savings is just large enough to pay the extra salary to the extra workers and to pay the extra rent on the extra machines: $\Delta s \times Y = \Delta s \times (\text{wage} \times L + \text{interest rate} \times K)$.

If you want to tell an even more realistic story in which families own shares of stock, it goes like this: a boost in savings means that revenues fall in the consumer-goods industry. Families lend their savings to the consumer-good-producing and investment-good-producing firms (perhaps through banks). Firms in both industries use the funds to place orders for the only thing they can: extra investment goods, produced by the investment goods industry. The investment-goods industry rents (or, with some complication, buys) unused capital from the consumer goods industry for the period, and it hires the unused consumer-goods workers for the period. Now, the investment-goods industry has the means to make the extra investment goods.

Afterward, both the *C* and *I* industries are a little more profitable with their extra capital, so they have the means to pay a little more interest to the families.

So, just to review, where does that extra savings go? The firms borrow that extra supply of savings from families, and the funds get used (directly or indirectly) to pay the wages of the extra investment-good-producing workers and to pay the rent on the extra investment-good-producing capital. And those new investment goods will generate a stream of profits that will flow as interest payments for the savers. And that is how the industry expansion is funded by the high savings level.

In brief, the fall in demand for consumer goods plus the inelastic labor supply means consumer-industry workers and capital are going to wind up somewhere, and since there's only one place for them to go, they'll wind up making investment goods. This is worth keeping in mind when students worry about rising unemployment.

CASE STUDY: HOW LONG IS THE LONG RUN?

An interesting question arises in the Solow model. Suppose one of the determinants of the steady-state changes, or suppose the economy is out of the steady state. How long, how many years, does it take for the economy to adjust to the steady state? One way to give students a sense of this answer is to simulate the simple Solow model and then allow changes in the parameters. For example, given that $Y^* = (\bar{A})^{(3/2)} \times (\bar{s}/\bar{d})^{(1/2)} \times L$, let $L = \bar{A} = 1$. $\bar{s} = \bar{d} = .1$, show that $Y^* = 1$, show that if $\bar{K}_0 = 1$, $\bar{s}Y = \bar{d}K$, and $\Delta K = 0$, and the steady-state condition is satisfied. Now set up the production function, where $Y = \bar{A} \times K^{(1/3)} \times \bar{L}^{(2/3)}$, given values of $\bar{A}$, K , and $\bar{L}$, $Y = Y^*$. Now illustrate, using a spreadsheet, some out-of-steady-state situations. Consider the case where $K = 2 > K^* = 1$. Illustrate how the capital stock and the level of output decline over time. Given the parameters, the adjustment will take over fifty years to get within 1 percentage point of the steady-state capital stock. Consider the case where $K = .1 < K^* = 1$. Through the same exercise, students will see that adjustment to steady state will take over seventy years. Now let the parameters $\bar{s}$, $\bar{d}$, $\bar{A}$, and $\bar{L}$ change. For example, if s increases by 10 percent from 0.10 to 0.11, show how the capital stock and output grow over time. Students will learn that adjustment toward the steady state will take over fifty years with over half of the adjustment taking place in the first eleven years. Similar stories can be told for a 10 percent decline in the depreciation rate and a 10 percent increase in the level of employment. For those 10 percent shifts in the parameters, the first decade captures about half of the adjustment toward the steady state, but the adjustment toward the steady state goes on for decades. Given the amount of time involved in adjusting to the steady state, we can reasonably expect parameter shifts to shock that path over time.