Introduction to Modern Economic Growth: Parts 1-4

Daron Acemoglu

Department of Economics,

Massachusetts Institute of Technology

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Preface

This book is intended to serve two purposes:

(1) First and foremost, this is a book about economic growth and long-run economic development. The process of economic growth and the sources of differences in economic performance across nations are some of the most interesting, important and challenging areas in modern social science. The primary purpose of this book is to introduce graduate students to these major questions and to the theoretical tools necessary for studying them. The book therefore strives to provide students with a strong background in dynamic economic analysis, since only such a background will enable a serious study of economic growth and economic development. It also tries to provide a clear discussion of the broad empirical patterns and historical processes underlying the current state of the world economy. This is motivated by my belief that to understand why some countries grow and some fail to do so, economists have to move beyond the mechanics of models and pose questions about the fundamental causes of economic growth.

(2) In a somewhat different capacity, this book is also a graduate-level introduction to modern macroeconomics and dynamic economic analysis. It is sometimes commented that, unlike basic microeconomic theory, there is no core of current macroeconomic theory that is shared by all economists. This is not entirely true. While there is disagreement among macroeconomists about how to approach short-run macroeconomic phenomena and what the boundaries of macroeconomics should be, there is broad agreement about the workhorse models of dynamic macroeconomic analysis. These include the Solow growth model, the neoclassical growth model, the overlapping-generations model and models of technological change and technology adoption. Since these are all models of economic growth, a thorough treatment of modern economic growth can also provide (and perhaps should provide) an introduction to this core material of modern macroeconomics. Although there are several good graduate-level macroeconomic textbooks, they typically spend relatively little time on the basic core material and do not develop the links between modern macroeconomic analysis and economic dynamics on the one hand and general equilibrium theory on the other. In contrast, the current book does not cover any of the short-run topics in macroeconomics, but provides a thorough and rigorous introduction to what I view to be the core of macroeconomics. Therefore, the second purpose of the book is to provide a graduate-level introduction to modern macroeconomics.

The selection of topics is designed to strike a balance between the two purposes of the book. Chapters 1, 3 and 4 introduce many of the salient features of the process of economic growth and the sources of cross-country differences in economic performance. Even though these chapters cannot do justice to the large literature on economic growth empirics, they provide a sufficient background for students to appreciate the set of issues that are central to the study of economic growth and also a platform for further study of this large literature.

Chapters 5-7 provide the conceptual and the mathematical foundations of modern macroeconomic analysis. Chapter 5 provides the microfoundations for much of the rest of the book (and for much of modern macroeconomics), while Chapters 6 and 7 provide a quick but relatively rigorous introduction to dynamic optimization. Most books on macroeconomics or economic growth use either continuous time or discrete time exclusively. I believe that a serious study of both economic growth and modern macroeconomics requires the student (and the researcher) to be able to go between discrete and continuous time, and choose whichever one is more convenient or appropriate for the set of questions at hand. Therefore, I have deviated from this standard practice and included both continuous-time and discrete-time material throughout the book.

Chapters 2, 8, 9 and 10 introduce the basic workhorse models of modern macroeconomics and traditional economic growth, while Chapter 11 presents the first generation models of sustained (endogenous) economic growth. Chapters 12-15 cover models of technological progress, which are an essential part of any modern economic growth course.

Chapter 16 generalizes the tools introduced in Chapter 6 to stochastic environments. Using these tools, Chapter 17 presents a number of models of stochastic growth, most notably, the neoclassical growth model under uncertainty, which is the foundation of much of modern macroeconomics (though it is often left out of economic growth courses). The canonical Real Business Cycle model is presented as an application. This chapter also covers another major workhorse model of modern macroeconomics, the incomplete markets model of Bewley. Finally, this chapter also presents a number of other approaches to modeling the interaction between incomplete markets and economic growth and shows how models of stochastic growth can be useful in understanding how economies transition from stagnation or slow growth to an equilibrium with sustained growth.

Chapters 18-21 cover a range of topics that are sometimes left out of economic growth textbooks. These include models of technology adoption, technology diffusion, the interaction between international trade and technology, the process of structural change, the demographic transition, the possibility of poverty traps, the effects of inequality on economic growth and the interaction between financial and economic development. These topics are important for creating a bridge between the empirical patterns we observe in practice and the theory. Most traditional growth models consider a single economy in isolation and often after it has already embarked upon a process of steady economic growth. A study of models that incorporate cross-country interdependences, structural change and the possibility of takeoffs will enable us to link core topics of development economics, such as structural change, poverty traps or the demographic transition, to the theory of economic growth.

Finally, Chapters 22 and 23 consider another topic often omitted from macroeconomics and economic growth textbooks; political economy. This is motivated by my belief that the study of economic growth would be seriously hampered if we failed to ask questions about the fundamental causes of why countries differ in their economic performances. These questions inexorably bring us to differences in economic policies and institutions across nations. Political economy enables us to develop models to understand why economic policies and institutions differ across countries and must therefore be an integral part of the study of economic growth.

A few words on the philosophy and organization of the book might also be useful for students and teachers. The underlying philosophy of the book is that all the results that are stated should be proved or at least explained in detail. This implies a somewhat different organization than existing books. Most textbooks in economics do not provide proofs for

many of the results that are stated or invoked, and mathematical tools that are essential for the analysis are often taken for granted or developed in appendices. In contrast, I have strived to provide simple proofs of almost all results stated in this book. It turns out that once unnecessary generality is removed, most results can be stated and proved in a way that is easily accessible to graduate students. In fact, I believe that even somewhat long proofs are much easier to understand than general statements made without proof, which leave the reader wondering about why these statements are true.

I hope that the style I have chosen not only makes the book self-contained, but also gives the students an opportunity to develop a thorough understanding of the material. In line with this philosophy, I present the basic mathematical tools necessary for the development of the main material within the body of the text. My own experience suggests that a "linear" progression, where the necessary mathematical tools are introduced when needed, makes it easier for the students to follow and appreciate the material. Consequently, analysis of stability of dynamical systems, dynamic programming in discrete time and optimal control in continuous time are all introduced within the main body of the text. This should both help the students appreciate the foundations of the theory of economic growth and also provide them with an introduction to the main tools of dynamic economic analysis, which are increasingly used in every subdiscipline of economics. Throughout, when some material is technically more difficult and can be skipped without loss of continuity, it is marked with a "*". Only material that is tangentially related to the main results in the text or those that should be familiar to most graduate students are left for the Mathematical Appendices.

I have also included a large number of exercises. Students can only gain a thorough understanding of the material by working through the exercises. The exercises that are somewhat more difficult are also marked with a "*".

This book can be used in a number of different ways. First, it can be used in a one-quarter or one-semester course on economic growth. Such a course might start with Chapters 1-4, then depending on the nature of the course, use Chapters 5-7 either for a thorough study of the general equilibrium and dynamic optimization foundations of growth theory or only for reference. Chapters 8-11 cover the traditional growth theory and Chapters 12-15 provide the basics of endogenous growth theory. Depending on time and interest, any selection of Chapters 16-23 can be used for the last part of such a course.

Second, the book can be used for a one-quarter first-year graduate-level course in macroeconomics. In this case, Chapter 1 is optional. Chapters 3, 5-7, 8-11 and 16 and 17 would be the core of such a course. The same material could also be covered in a one-semester course, but in this case, it could be supplemented either with some of the later chapters or with material from one of the leading graduate-level macroeconomic textbooks on short-run macroeconomics, fiscal policy, asset pricing, or other topics in dynamic macroeconomics.

Third, the book can be used for an advanced (second-year) course in economic growth or economic development. An advanced course on growth or development could use Chapters 1-11 as background and then focus on selected chapters from Chapters 12-23.

Finally, since the book is self-contained, I also hope that it can be used for self-study.

Acknowledgments. This book grew out of the first graduate-level introduction to macroeconomics course I have taught at MIT. Parts of the book have also been taught as part of a second-year graduate macroeconomics course. I would like to thank the students who attended these lectures and made comments that have improved the manuscript. I owe a special thanks to Monica Martinez-Bravo, Samuel Pienknagura, Lucia Tian Tian and

especially to Georgy Egorov, Michael Peters and Alp Simsek for outstanding research assistance. In fact, without Georgy, Michael and Alp's help, this book would have taken me much longer and would have contained many more errors. I also thank Lauren Fahey for editorial suggestions and help with the references. I would also like to thank Pol Antras, Kiminori Matsuyama, James Robinson, Jesus Fernandez-Villaverde and Pierre Yared for very valuable suggestions on multiple chapters, and George-Marios Angeletos, Binyamin Berdugo, Olivier Blanchard, Francesco Caselli, Melissa Dell, Leopoldo Fergusson, Peter Funk, Oded Galor, Hugo Hopenhayn, Simon Johnson, Chad Jones, Christos Koulovatianos, Omer Moav, Eduardo Morales, Ismail Saglam, Ekkehart Schlicht, Patricia Waeger and Jesse Zinn for useful suggestions and corrections on individual chapters.

Please note that this is a preliminary draft of the book manuscript. The draft certainly contains mistakes. Comments and suggestions for corrections are welcome.

Version 3: February, 2008.

Part 1

Introduction

CHAPTER 1

Economic Growth and Economic Development: The Questions

1.1. Cross-Country Income Differences

There are very large differences in income per capita and output per worker across countries today. Countries at the top of the world income distribution are more than thirty times as rich as those at the bottom. For example, in 2000, GDP (or income) per capita in the United States was over $34000. In contrast, income per capita is much lower in many other countries: about $8000 in Mexico, about $4000 in China, just over $2500 in India, only about $1000 in Nigeria, and much much lower in some other sub-Saharan African countries such as Chad, Ethiopia and Mali. These numbers are all in 2000 US dollars and are adjusted for purchasing power party (PPP) to allow for differences in relative prices of different goods across countries.[1] The cross-country income gap is considerably larger when there is no PPP-adjustment. For example, without the PPP adjustment, GDP per capita in India and China relative to the United States in 2000 would be lower by a factor of four or so.

Figure 1.1 provides a first look at these differences. It plots estimates of the distribution of PPP-adjusted GDP per capita across the available set of countries in 1960, 1980 and 2000. A number of features are worth noting. First, the 1960 density shows that 15 years after the end of World War II, most countries had income per capita less than $1500 (in 2000 US dollars); the mode of the distribution is around $1250. The rightwards shift of the distributions for 1980 and for 2000 shows the growth of average income per capita for the next 40 years. In 2000, the mode is slightly above $3000, but now there is another concentration of countries between $20,000 and $30,000. The density estimate for the year 2000 shows the considerable inequality in income per capita today.

Part of the spreading out of the distribution in Figure 1.1 is because of the increase in average incomes. It may therefore be more informative to look at the logarithm (log) of income per capita. It is more natural to look at the log of variables, such as income per capita, that grow over time, especially when growth is approximately proportional as suggested by Figure 1.8. This is for the simple reason that when $x(t)$ grows at a proportional rate, $\log x(t)$ grows linearly, and if $x_1(t)$ and $x_2(t)$ both grow by the same proportional amount, $\log x_1(t) - \log x_2(t)$ remains constant, while $x_1(t) - x_2(t)$ increases.

[1] All data are from the Penn World tables compiled by Summers and Heston. Details of data sources and more on PPP adjustment can be found in the References and Literature Section at the end of this chapter.

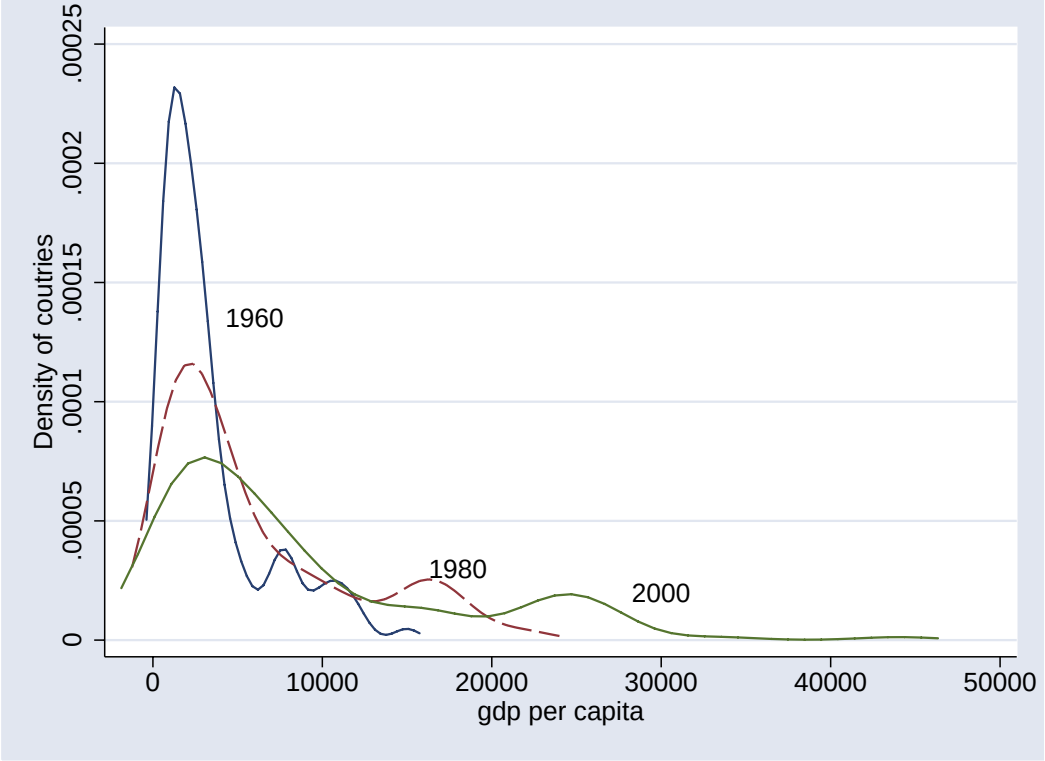

Figure 1.1. Estimates of the distribution of countries according to PPP-adjusted GDP per capita in 1960, 1980 and 2000.

Figure 1.2 shows a similar pattern, but now the spreading-out is more limited. This reflects the fact that while the absolute gap between rich and poor countries has increased considerably between 1960 and 2000, the proportional gap has increased much less. Nevertheless, it can be seen that the 2000 density for log GDP per capita is still more spread out than the 1960 density. In particular, both figures show that there has been a considerable increase in the density of relatively rich countries, while many countries still remain quite poor. This last pattern is sometimes referred to as the "stratification phenomenon", corresponding to the fact that some of the middle-income countries of the 1960s have joined the ranks of relatively high-income countries, while others have maintained their middle-income status or even experienced relative impoverishment.

Figures 1.1 and 1.2 demonstrate that there is somewhat greater inequality among nations. An equally relevant concept might be inequality among individuals in the world economy. Figures 1.1 and 1.2 are not directly informative on this, since they treat each country identically regardless of the size of its population. An alternative is presented in Figure 1.3, which shows the population-weighted distribution. In this case, countries such as China, India, the United States, and Russia receive greater weight because they have larger populations. The picture that emerges in this case is quite different. In fact, the 2000 distribution looks less spread out, with thinner left tail than the 1960 distribution. This reflects the fact that in

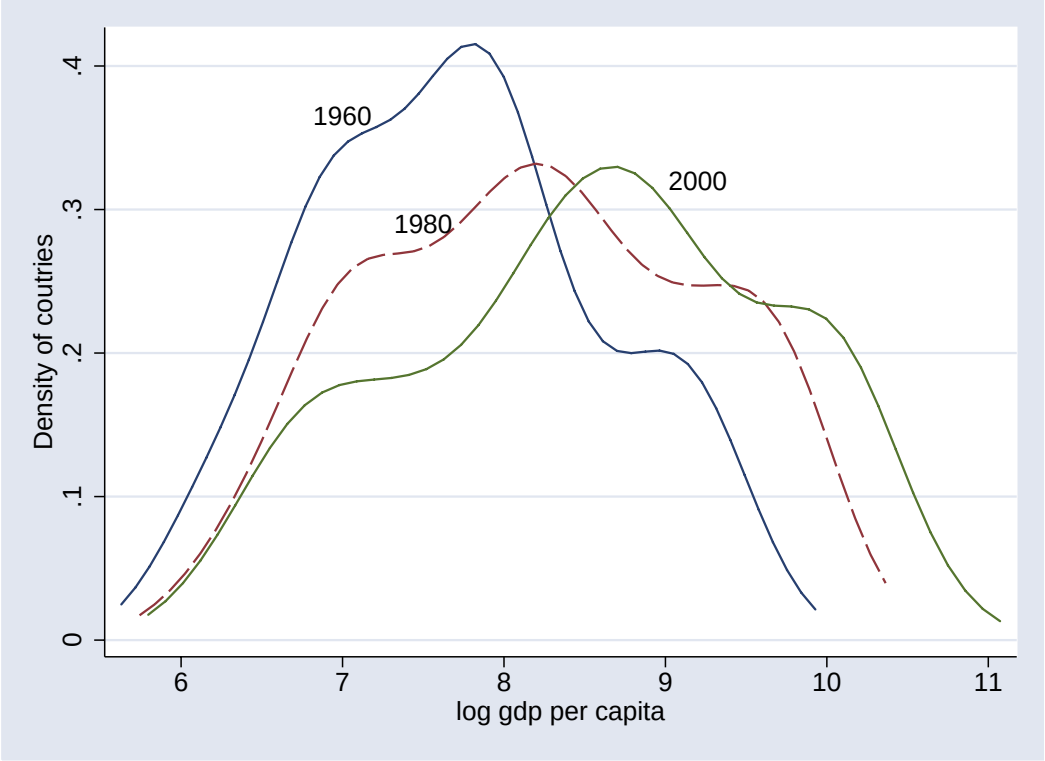

Figure 1.2. Estimates of the distribution of countries according to log GDP per capita (PPP-adjusted) in 1960, 1980 and 2000.

1960 China and India were among the poorest nations in the world, whereas their relatively rapid growth in the 1990s puts them into the middle-poor category by 2000. Chinese and Indian growth has therefore created a powerful force towards relative equalization of income per capita among the inhabitants of the globe.

Figures 1.1, 1.2 and 1.3 look at the distribution of GDP per capita. While this measure is relevant for the welfare of the population, much of growth theory focuses on the productive capacity of countries. Theory is therefore easier to map to data when we look at output (GDP) per worker. Moreover, key sources of difference in economic performance across countries are national policies and institutions. So for the purpose of understanding the sources of differences in income and growth across countries (as opposed to assessing welfare questions), the unweighted distribution is more relevant than the population-weighted distribution. Consequently, Figure 1.4 looks at the unweighted distribution of countries according to (PPP-adjusted) GDP per worker. Since internationally comparable data on employment are not available for a large number of countries, "workers" here refer to the total economically active population (according to the definition of the International Labour Organization). Figure 1.4 is very similar to Figure 1.2, and if anything, shows a greater concentration of countries in the relatively rich tail by 2000, with the poor tail remaining more or less the same as in Figure 1.2.

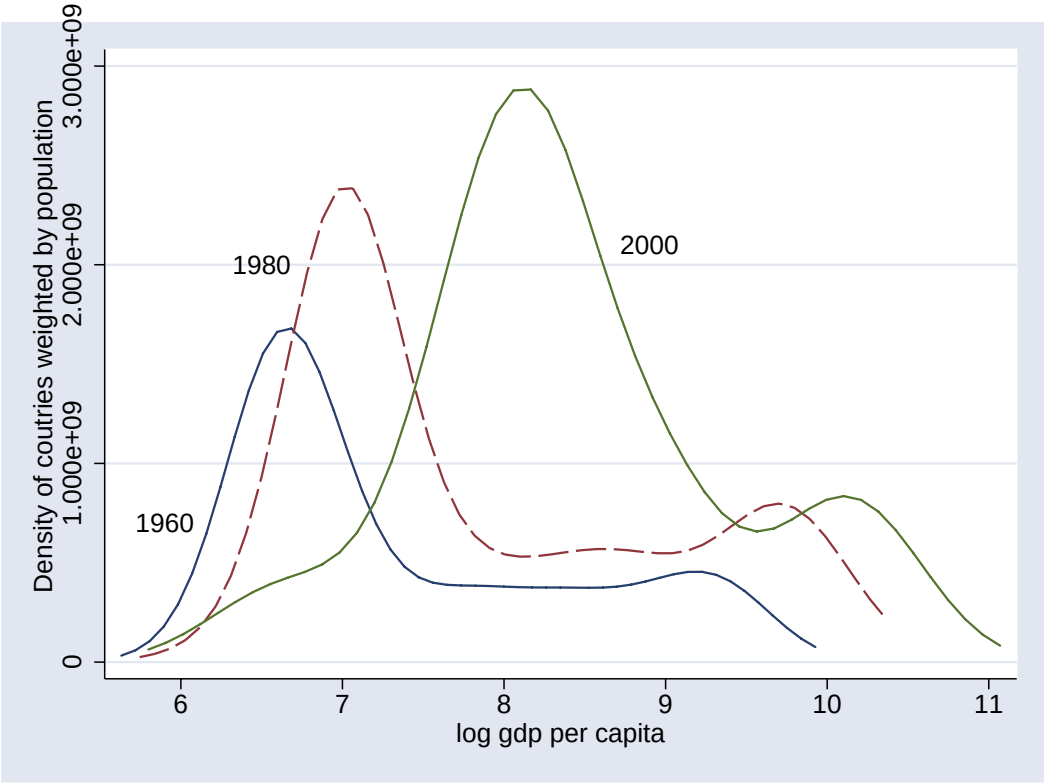

Figure 1.3. Estimates of the population-weighted distribution of countries according to log GDP per capita (PPP-adjusted) in 1960, 1980 and 2000.

Overall, Figures 1.1-1.4 document two important facts: first, there is a large amount of inequality in income per capita and income per worker across countries as shown by the highly dispersed distributions. Second, there is a slight but noticeable increase in inequality across nations (though not necessarily across individuals in the world economy).

1.2. Income and Welfare

Should we care about cross-country income differences? The answer is *definitely yes*. High income levels reflect high standards of living. Economic growth sometimes increases pollution or it may raise individual aspirations, so that the same bundle of consumption may no longer make an individual as happy. But at the end of the day, when one compares an advanced, rich country with a less-developed one, there are striking differences in the quality of life, standards of living and health.

Figures 1.5 and 1.6 give a glimpse of these differences and depict the relationship between income per capita in 2000 and consumption per capita and life expectancy at birth in the same year. Consumption data also come from the Penn World tables, while data on life expectancy at birth are available from the World Bank Development Indicators.

These figures document that income per capita differences are strongly associated with differences in consumption and differences in health as measured by life expectancy. Recall

Figure 1.4. Estimates of the distribution of countries according to log GDP per worker (PPP-adjusted) in 1960, 1980 and 2000.

also that these numbers refer to PPP-adjusted quantities, thus differences in consumption do not (at least in principle) reflect the fact that the same bundle of consumption goods costs different amounts in different countries. The PPP adjustment corrects for these differences and attempts to measure the variation in real consumption. Therefore, the richest countries are not only producing more than thirty times as much as the poorest countries, but are also consuming thirty times as much. Similarly, cross-country differences in health are quite remarkable; while life expectancy at birth is as high as 80 in the richest countries, it is only between 40 and 50 in many sub-Saharan African nations. These gaps represent huge welfare differences.

Understanding how some countries can be so rich while some others are so poor is one of the most important, perhaps *the* most important, challenges facing social science. It is important both because these income differences have major welfare consequences and because a study of these striking differences will shed light on how the economies of different nations function and sometimes how they fail to function.

The emphasis on income differences across countries implies neither that income per capita can be used as a "sufficient statistic" for the welfare of the average citizen nor that it is the only feature that we should care about. As we will discuss in detail later, the efficiency properties of the market economy (such as the celebrated *First Welfare Theorem* or Adam

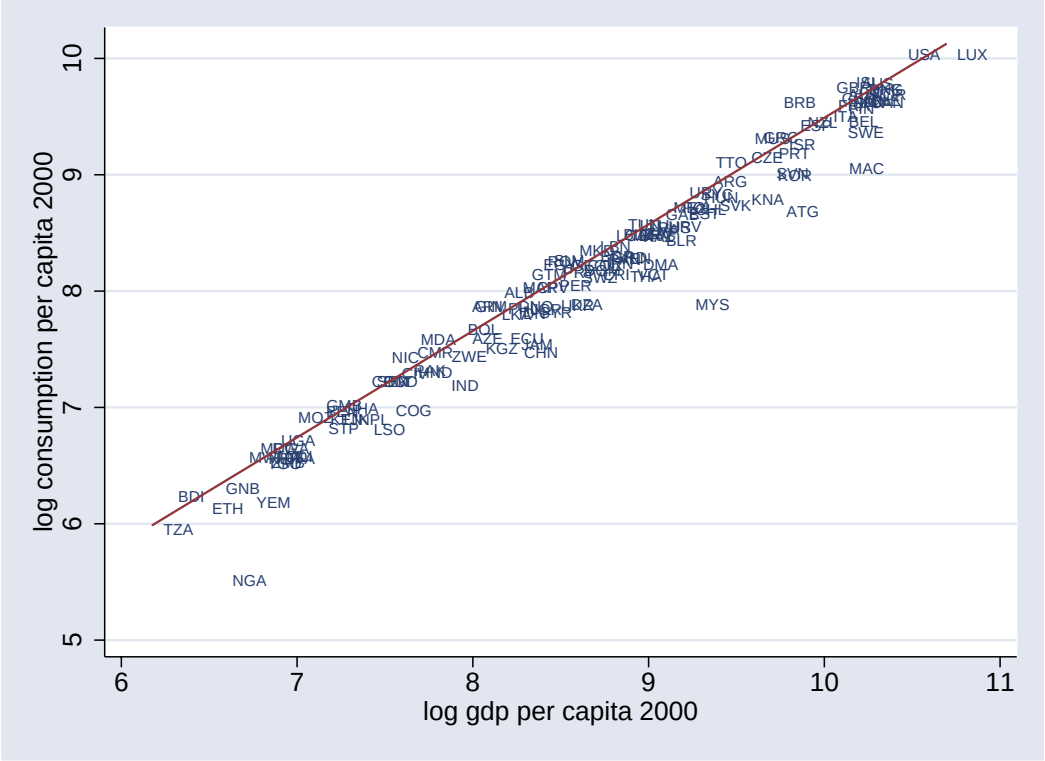

Figure 1.5. The association between income per capita and consumption per capita in 2000.

Smith's *invisible hand*) do not imply that there is no conflict among individuals or groups in society. Economic growth is generally good for welfare but it often creates "winners" and "losers." Joseph Schumpeter's famous notion of *creative destruction* emphasizes precisely this aspect of economic growth; productive relationships, firms and sometimes individual livelihoods will often be destroyed by the process of economic growth because growth is brought about by the introduction of new technologies and creation of new firms, replacing existing firms and technologies. This process creates a natural social tension, even in a growing society. Another source of social tension related to growth (and development) is that, as emphasized by Simon Kuznets and discussed in detail in Part 7 below, growth and development are often accompanied by sweeping structural transformations, which can also destroy certain established relationships and create yet other winners and losers in the process. One of the important questions of political economy, which will be discussed in the last part of the book, concerns how institutions and policies can be arranged so that those who lose out from the process of economic growth can be compensated or prevented from blocking economic progress via other means.

A stark illustration of the fact that growth does not always mean an improvement in the living standards of all or even most citizens in a society comes from South Africa under Apartheid. Available data (from gold mining wages) illustrate that from the beginning of

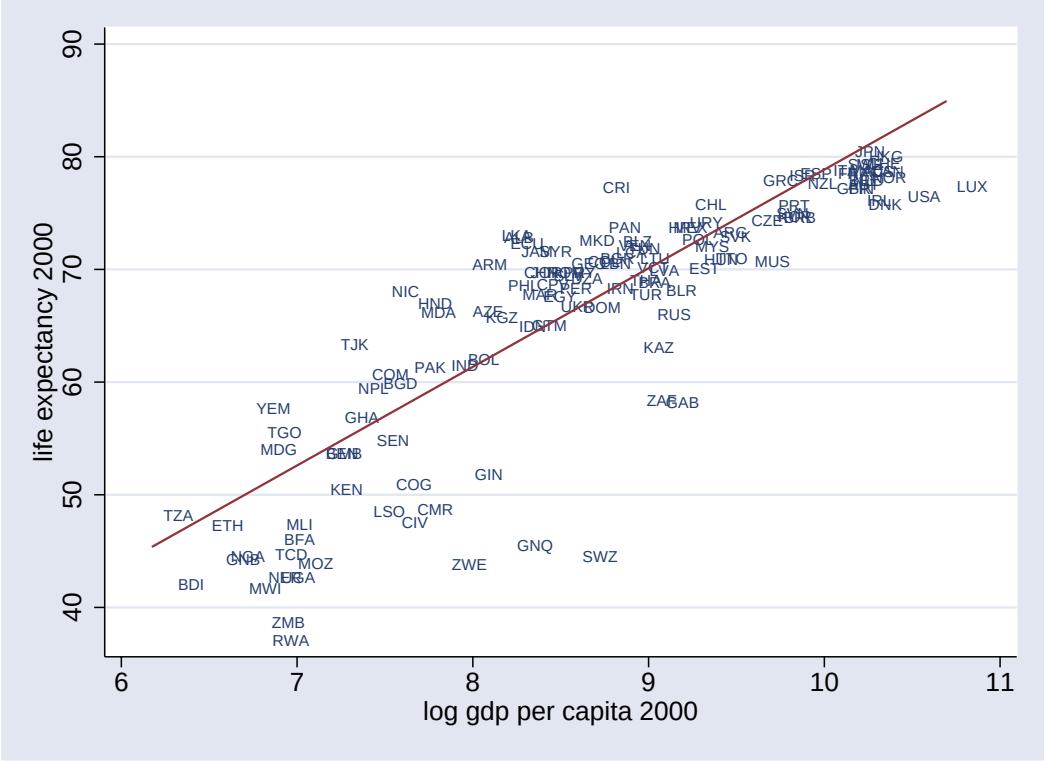

Figure 1.6. The association between income per capita and life expectancy at birth in 2000.

the 20th century until the fall of the Apartheid regime, GDP per capita grew considerably but the real wages of black South Africans, who make up the majority of the population, likely fell during this period. This of course does not imply that economic growth in South Africa was not beneficial. South Africa is still one of the richest countries in sub-Saharan Africa. Nevertheless, this observation alerts us to other aspects of the economy and also underlines the potential conflicts inherent in the growth process. Similarly, most existing evidence suggests that during the early phases of the British Industrial Revolution, which started the process of modern economic growth, the living standards of most workers may have fallen or at best remained stagnant. This pattern of potential divergence between GDP per capita and the economic fortunes of large numbers of individuals and society is not only interesting in and of itself, but it may also inform us about why certain segments of the society may be in favor of policies and institutions that do not encourage growth.

1.3. Economic Growth and Income Differences

How could one country be more than thirty times richer than another? The answer lies in differences in growth rates. Take two countries, A and B, with the same initial level of income at some date. Imagine that country A has 0% growth per capita, so its income per capita remains constant, while country B grows at 2% per capita. In 200 years' time country B will

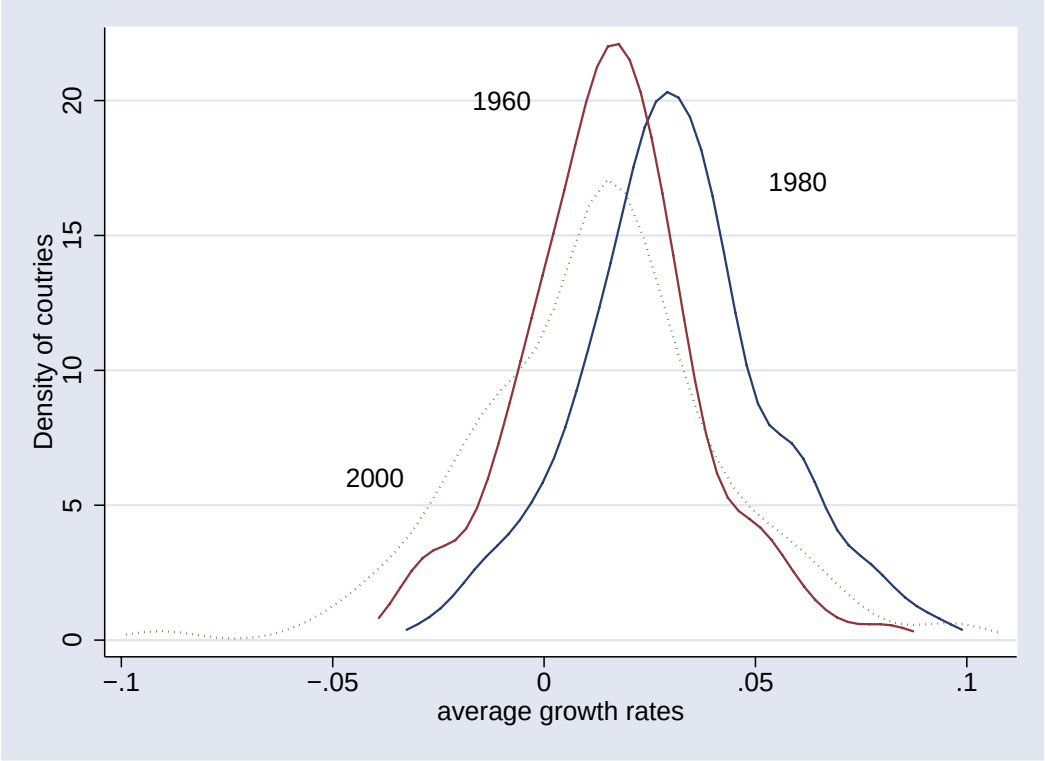

Figure 1.7. Estimates of the distribution of countries according to the growth rate of GDP per worker (PPP-adjusted) in 1960, 1980 and 2000.

be more than 52 times richer than country A. Therefore, the United States is considerably richer than Nigeria because it has grown steadily over an extended period of time, while Nigeria has not (and we will see that there is a lot of truth to this simple calculation; see Figures 1.8, 1.10 and 1.12).

In fact, even in the historically-brief postwar era, we see tremendous differences in growth rates across countries. This is shown in Figure 1.7 for the postwar era, which plots the density of growth rates across countries in 1960, 1980 and 2000. The growth rate in 1960 refers to the (geometric) average of the growth rate between 1950 and 1969, the growth rate in 1980 refers to the average growth rate between 1970 and 1989 and 2000 refers to the average between 1990 and 2000 (in all cases subject to data availability; all data from Penn World tables). Figure 1.7 shows that in each time interval, there is considerable variability in growth rates; the cross-country distribution stretches from negative growth rates to average growth rates as high as 10% a year.

Figure 1.8 provides another look at these patterns by plotting log GDP per capita for a number of countries between 1960 and 2000 (in this case, we look at GDP per capita instead of GDP per worker both for data coverage and also to make the figures more comparable to the historical figures below). At the top of the figure, we see US and UK GDP per capita increasing at a steady pace, with a slightly faster growth in the United States, so that the

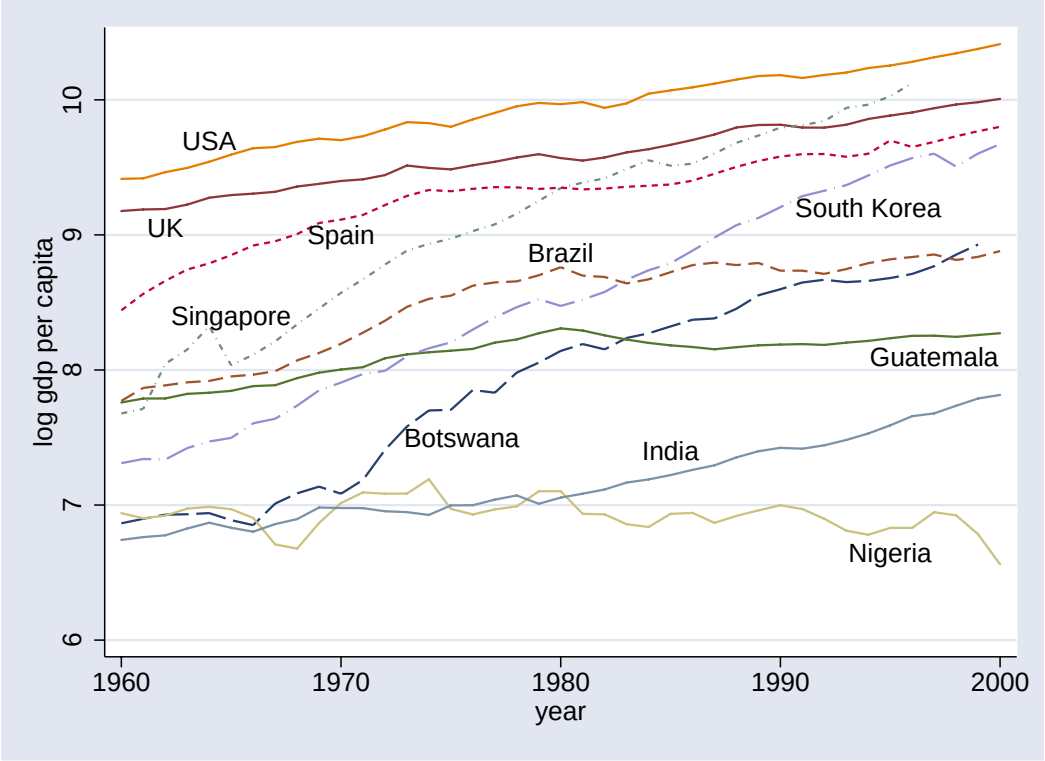

Figure 1.8. The evolution of income per capita in the United States, United Kingdom, Spain, Singapore, Brazil, Guatemala, South Korea, Botswana, Nigeria and India, 1960-2000.

log ("proportional") gap between the two countries is larger in 2000 than it is in 1960. Spain starts much poorer than the United States and the UK in 1960, but grows very rapidly between 1960 and the mid-1970s, thus closing the gap between itself and the United States and the UK. The three countries that show very rapid growth in this figure are Singapore, South Korea and Botswana. Singapore starts much poorer than the UK and Spain in 1960, but grows very rapidly and by the mid-1990s, it has become richer than both. South Korea has a similar trajectory, though it starts out poorer than Singapore and grows slightly less rapidly, so that by the end of the sample it is still a little poorer than Spain. The other country that has grown very rapidly is the "African success story" Botswana, which was extremely poor at the beginning of the sample. Its rapid growth, especially after 1970, has taken Botswana to the ranks of the middle-income countries by 2000.

The two Latin American countries in this picture, Brazil and Guatemala, illustrate the often-discussed Latin American economic malaise of the postwar era. Brazil starts out richer than Singapore, South Korea and Botswana and has a relatively rapid growth rate between 1960 and 1980. But it experiences stagnation from 1980 onwards, so that by the end of the sample Singapore, South Korea and Botswana have all become richer than Brazil.

Guatemala's experience is similar but even more bleak. Contrary to Brazil, there is little growth in Guatemala between 1960 and 1980 and no growth between 1980 and 2000.

Finally, Nigeria and India start out at similar levels of income per capita as Botswana but experience little growth until the 1980s. Starting in 1980, the Indian economy experiences relatively rapid growth, though this has not been sufficient for its income per capita to catch up with the other nations in the figure. Finally, Nigeria, in a pattern that is unfortunately all-too-familiar in sub-Saharan Africa, experiences a contraction of its GDP per capita, so that in 2000 it is in fact poorer than it was in 1960.

The patterns shown in Figure 1.8 are what we would like to understand and explain. Why is the United States richer in 1960 than other nations and able to grow at a steady pace thereafter? How did Singapore, South Korea and Botswana manage to grow at a relatively rapid pace for 40 years? Why did Spain grow relatively rapidly for about 20 years, but then slow down? Why did Brazil and Guatemala stagnate during the 1980s? What is responsible for the disastrous growth performance of Nigeria?

1.4. Origins of Today's Income Differences and World Economic Growth

The growth rate differences shown in Figures 1.7 and 1.8 are interesting in their own right and could also be, in principle, responsible for the large differences in income per capita we observe today. But are they? The answer is *no*. Figure 1.8 shows that in 1960 there was already a very large gap between the United States on the one hand and India and Nigeria on the other.

This can be seen more easily in Figure 1.9, which plots log GDP per worker in 2000 versus log GDP per capita in 1960 (in both cases relative to the US value) superimposed over the 45° line. Most observations are around the 45° line, indicating that the relative ranking of countries has changed little between 1960 and 2000. Thus the origins of the very large income differences across nations are not to be found in the postwar era. There are striking growth differences during the postwar era, but the evidence presented so far suggests that the "world income distribution" has been more or less stable, with a slight tendency towards becoming more unequal.

If not in the postwar era, when did this growth gap emerge? The answer is that much of the divergence took place during the 19th and early 20th centuries. Figures 1.10-1.12 give a glimpse of these 19th-century developments by using the data compiled by Angus Maddison for GDP per capita differences across nations going back to 1820 (or sometimes earlier). These data are less reliable than Summers-Heston's Penn World tables, since they do not come from standardized national accounts. Moreover, the sample is more limited and does not include observations for all countries going back to 1820. Finally, while these data include a correction for PPP, this is less reliable than the price comparisons used to construct the price indices in the Penn World tables. Nevertheless, these are the best available estimates for differences in prosperity across a large number of nations going back to the 19th century.

Figure 1.9. Log GDP per worker in 2000 versus log GDP per worker in 1960, together with the 45° line.

Figure 1.10 illustrates the divergence; it depicts the evolution of average income between five groups of countries, Western Offshoots of Europe (the United States, Canada, Australia and New Zealand), Western Europe, Latin America, Asia and Africa. It shows the relatively rapid growth of the Western Offshoots and West European countries during the 19th century, while Asia and Africa remained stagnant and Latin America showed little growth. The relatively small (proportional) income gap in 1820 had become much larger by 1960.

Another major macroeconomic fact is visible in Figure 1.10: Western Offshoots and West European nations experience a noticeable dip in GDP per capita around 1929. This is because of the famous Great Depression. Western offshoots, in particular the United States, only recovered fully from this large recession in the wake of WWII. How an economy can experience such a sharp decline in output and how it recovers from such a shock are among the major questions of macroeconomics. While the Great Depression falls outside the scope of the current book, we will later discuss the relationship between economic crises and growth as well as potential sources of volatility in economic growth.

A variety of other evidence suggests that differences in income per capita were even smaller once we go back further than 1820. Maddison also has estimates for average income for the same groups of countries going back to 1000 AD or even earlier. Figure 1.10 can be extended back using these data; the results are shown in Figure 1.11. Although these numbers

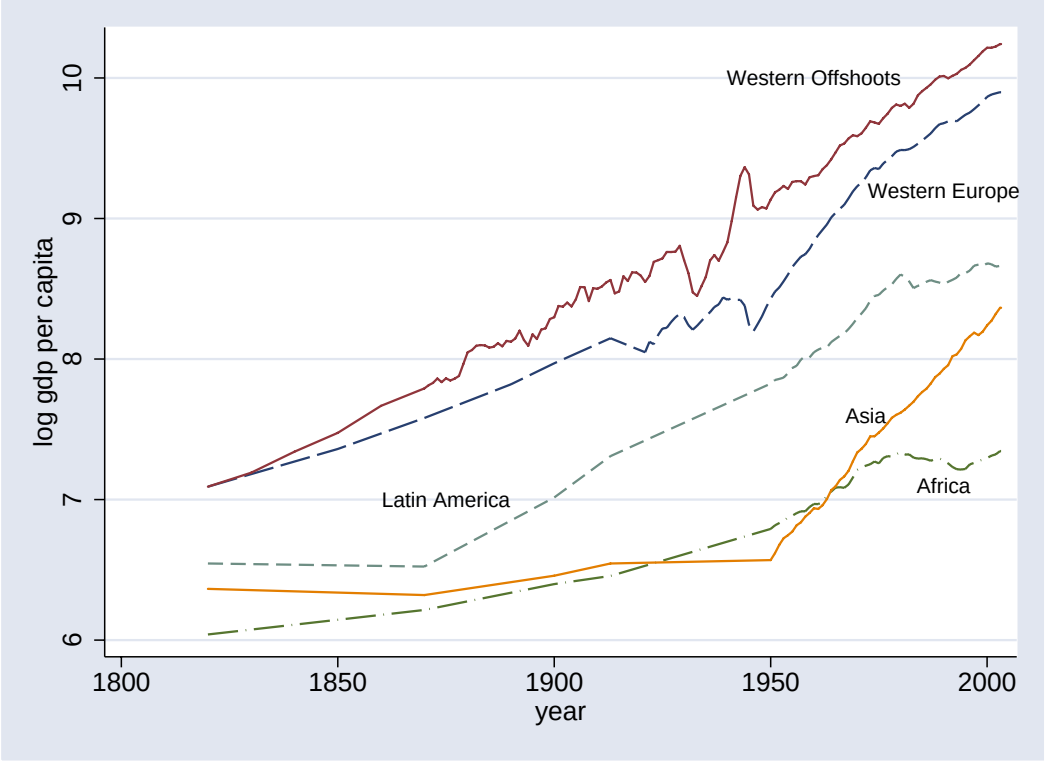

Figure 1.10. The evolution of average GDP per capita in Western Offshoots, Western Europe, Latin America, Asia and Africa, 1820-2000.

are based on scattered evidence and informed guesses, the general pattern is consistent with qualitative historical evidence and the fact that income per capita in any country cannot have been much less than $500 in terms of 2000 US dollars, since individuals could not survive with real incomes much less than this level. Figure 1.11 shows that as we go further back, the gap among countries becomes much smaller. This further emphasizes that the big divergence among countries has taken place over the past 200 years or so. Another noteworthy feature that becomes apparent from this figure is the remarkable nature of world economic growth. Much evidence suggests that there was only limited economic growth before the 18th century and certainly before the 15th century. While certain civilizations, including Ancient Greece, Rome, China and Venice, managed to grow, their growth was either not sustained (thus ending with collapses and crises) or progressed only at a slow pace. No society before 19th-century Western Europe and the United States achieved steady growth at comparable rates.

Notice also that Maddison's estimates show a slow but steady increase in West European GDP per capita even earlier, starting in 1000. This assessment is not shared by all economic historians, many of whom estimate that there was little increase in income per capita before 1500 or even before 1800. For our purposes this is not central, however. What is important is that, using Walter Rostow's terminology, Figure 1.11 shows a pattern of *takeoff* into sustained growth; the economic growth experience of Western Europe and Western Offshoots

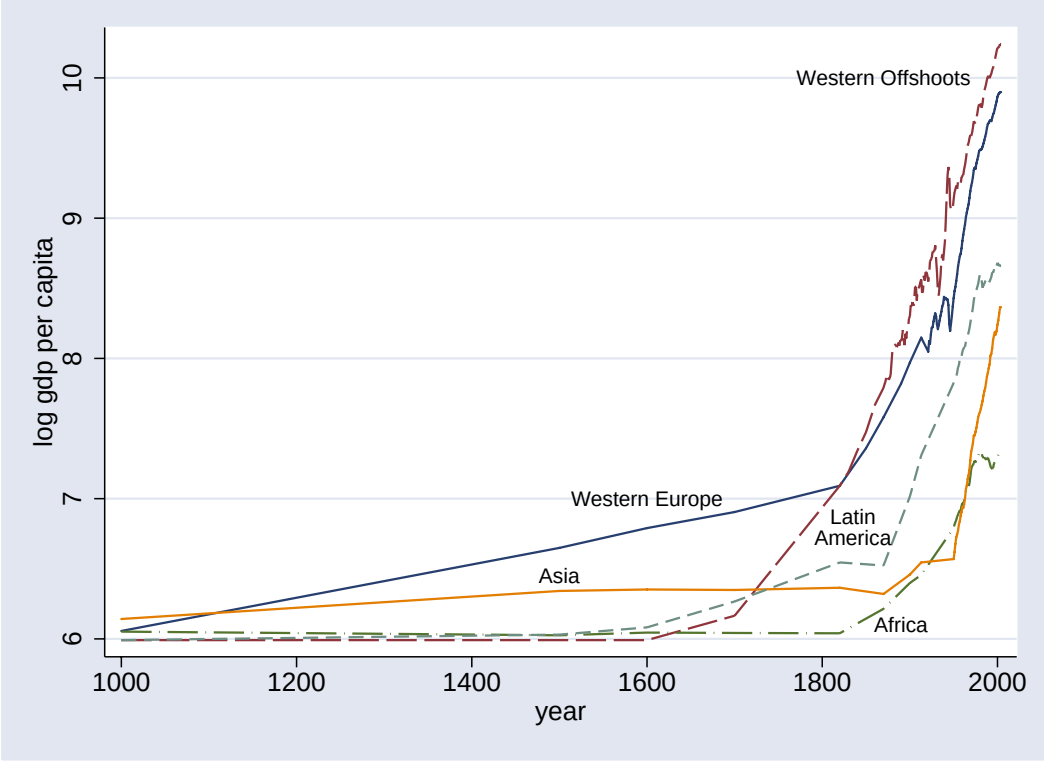

Figure 1.11. The evolution of average GDP per capita in Western Offshoots, Western Europe, Latin America, Asia and Africa, 1000-2000.

appears to have changed dramatically about 200 years or so ago. Economic historians debate whether there was a discontinuous change in economic activity that deserves the terms takeoff or Industrial Revolution. This debate is besides the point for our purposes. Whether or not the change was discontinuous, it was present and transformed the functioning of many economies. As a result of this transformation, the stagnant or slowly-growing economies of Europe embarked upon a path of sustained growth. The origins of today's riches and also of today's differences in prosperity are to be found in this pattern of takeoff during the 19th century. In the same time that much of Western Europe and its Offshoots grew rapidly, much of the rest of the world did not experience a comparable takeoff (or did so much later). Therefore, an understanding of modern economic growth and current cross-country income differences ultimately necessitates an inquiry into the causes of why the takeoff occurred, why it did so about 200 years ago and why it took place only in some areas and not in others.

Figure 1.12 shows the evolution of income per capita for the United States, Britain, Spain, Brazil, China, India and Ghana. This figure confirms the patterns shown in Figure 1.10 for averages, with the United States Britain and Spain growing much faster than India and Ghana throughout, and also much faster than Brazil and China except during the growth spurts experienced by these two countries.

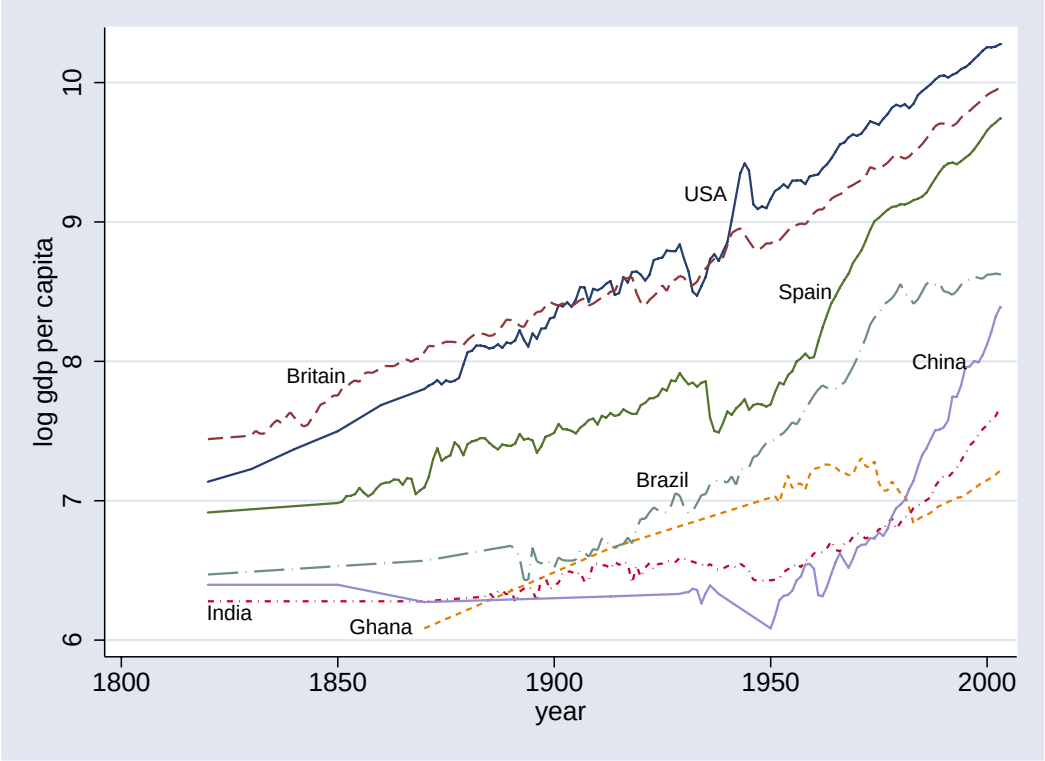

Figure 1.12. The evolution of income per capita in the United States, Britain, Spain, Brazil, China, India and Ghana, 1820-2000.

Overall, on the basis of the available information we can conclude that the origins of the current cross-country differences in income per capita are in the 19th and early 20th centuries (or perhaps even during the late 18th century). This cross-country divergence took place at the same time as a number of countries in the world "took off" and achieved sustained economic growth. Therefore understanding modern economic growth is not only interesting and important in its own right, but also holds the key to understanding the causes of cross-country differences in income per capita today.

1.5. Conditional Convergence

We have so far documented the large differences in income per capita across nations, the slight divergence in economic fortunes over the postwar era and the much larger divergence since the early 1800s. The analysis focused on the "unconditional" distribution of income per capita (or per worker). In particular, we looked at whether the income gap between two countries increases or decreases regardless of these countries' "characteristics" (e.g., institutions, policies, technology or even investments). Barro and Sala-i-Martin argue that it is instead more informative to look at the "conditional" distribution. Here the question is whether the income gap between two countries that are similar in observable characteristics is becoming narrower or wider over time. In this case, the picture is one of conditional convergence: in

the postwar period, the income gap between countries that share the same characteristics typically closes over time (though it does so quite slowly). This is important both for understanding the statistical properties of the world income distribution and also as an input into the types of theories that we would like to develop.

How do we capture conditional convergence? Consider a typical "Barro growth regression":

$$g_{t,t-1} = \beta \ln y_{t-1} + \mathbf{X}_{t-1}^T \boldsymbol{\alpha} + \varepsilon_t \tag{1.1}$$

where $g_{t,t-1}$ is the *annual* growth rate between dates $t-1$ and t, y_{t-1} is output per worker (or income per capita) at date $t-1$, and $\mathbf{X}_{t-1}$ is a vector of variables that the regression is conditioning on with coefficient vector $\boldsymbol{\alpha}$ (and $\mathbf{X}^T$ denotes the transpose of this vector, see Appendix Chapters A and B). These variables are included because they are potential determinants of steady state income and/or growth. First note that without covariates eq. (1.1) is quite similar to the relationship shown in Figure 1.9 above. In particular, since $g_{t,t-1} \simeq \ln y_t - \ln y_{t-1}$, eq. (1.1) can be written as

$$\ln y_t \simeq (1+\beta) \ln y_{t-1} + \varepsilon_t.$$

Figure 1.9 showed that the relationship between log GDP per worker in 2000 and log GDP per worker in 1960 can be approximated by the 45° line, so that in terms of this equation, β should be approximately equal to 0. This is confirmed by Figure 1.13, which depicts the relationship between the (geometric) average growth rate between 1960 and 2000 and log GDP per worker in 1960. This figure reiterates that there is no "unconditional" convergence for the entire world over the postwar period.

While there is no convergence for the entire world, when we look among the "OECD" nations,[2] we see a different pattern. Figure 1.14 shows that there is a strong negative relationship between log GDP per worker in 1960 and the annual growth rate between 1960 and 2000 among the OECD countries. What distinguishes this sample from the entire world sample is the relative homogeneity of the OECD countries, which have much more similar institutions, policies and initial conditions than the entire world. This suggests that there might be a type of conditional convergence when we control for certain country characteristics potentially affecting economic growth.

This is what the vector $\mathbf{X}_{t-1}$ captures in eq. (1.1). In particular, when this vector includes variables such as years of schooling or life expectancy, using cross-sectional regressions Barro and Sala-i-Martin estimate β to be approximately -0.02, indicating that the income gap between countries that have the same human capital endowment has been narrowing over the postwar period on average at about 2 percent a year. When this equation is estimated using a panel data and the vector $\mathbf{X}$ includes a full set of country fixed effects, then the estimates of β become more negative, indicating faster convergence.

[2] "OECD" here refers to the initial members of the OECD club and excludes the more recent OECD members such as Turkey, Mexico and Korea.

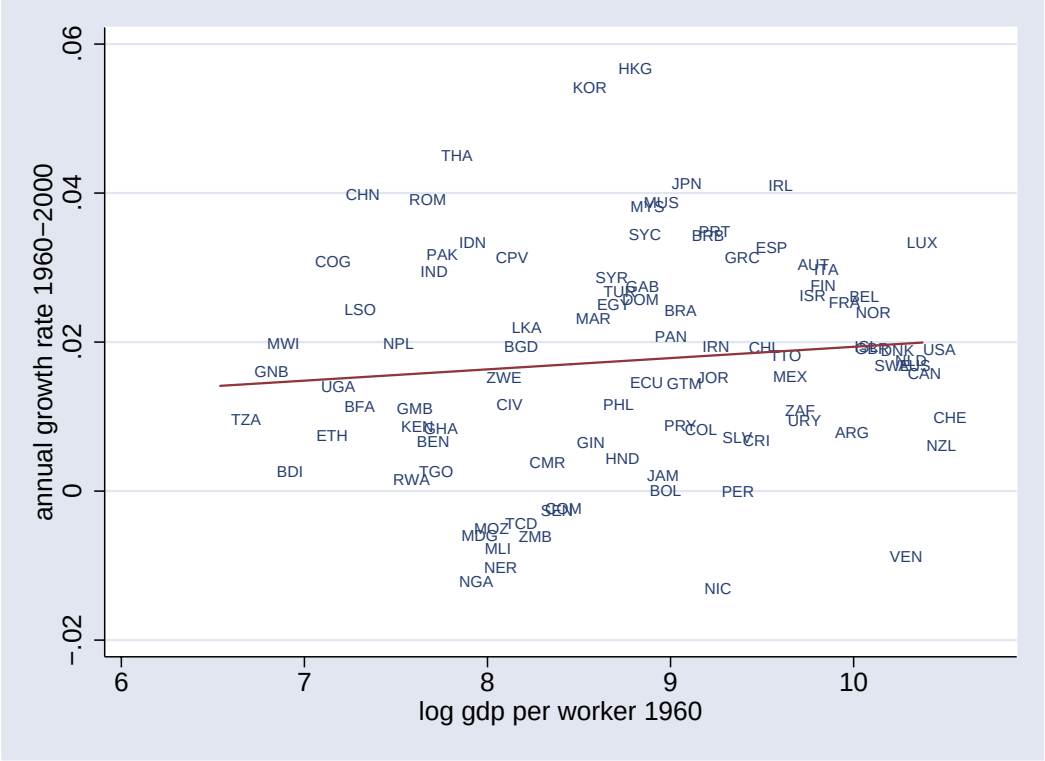

Figure 1.13. Annual growth rate of GDP per worker between 1960 and 2000 versus log GDP per worker in 1960 for the entire world.

In summary, there is no evidence of (unconditional) convergence in the world income distribution over the postwar era (in fact, the evidence suggests some amount of divergence in incomes across nations). But, there is some evidence for conditional convergence, meaning that the income gap between countries that are similar in observable characteristics appears to narrow over time. This last observation is relevant both for understanding among which countries the economic divergence has occurred and for determining what types of models we should consider for understanding the process of economic growth and the differences in economic performance across nations. For example, we will see that many growth models, including the basic Solow and the neoclassical growth models, suggest that there should be "transitional dynamics" as economies below their steady-state (target) level of income per capita grow towards that level. Conditional convergence is consistent with this type of transitional dynamics.

1.6. Correlates of Economic Growth

The discussion of conditional convergence in the previous section emphasized the importance of certain country characteristics that might be related to the process of economic growth. What types of countries grow more rapidly? Ideally, we would like to answer this

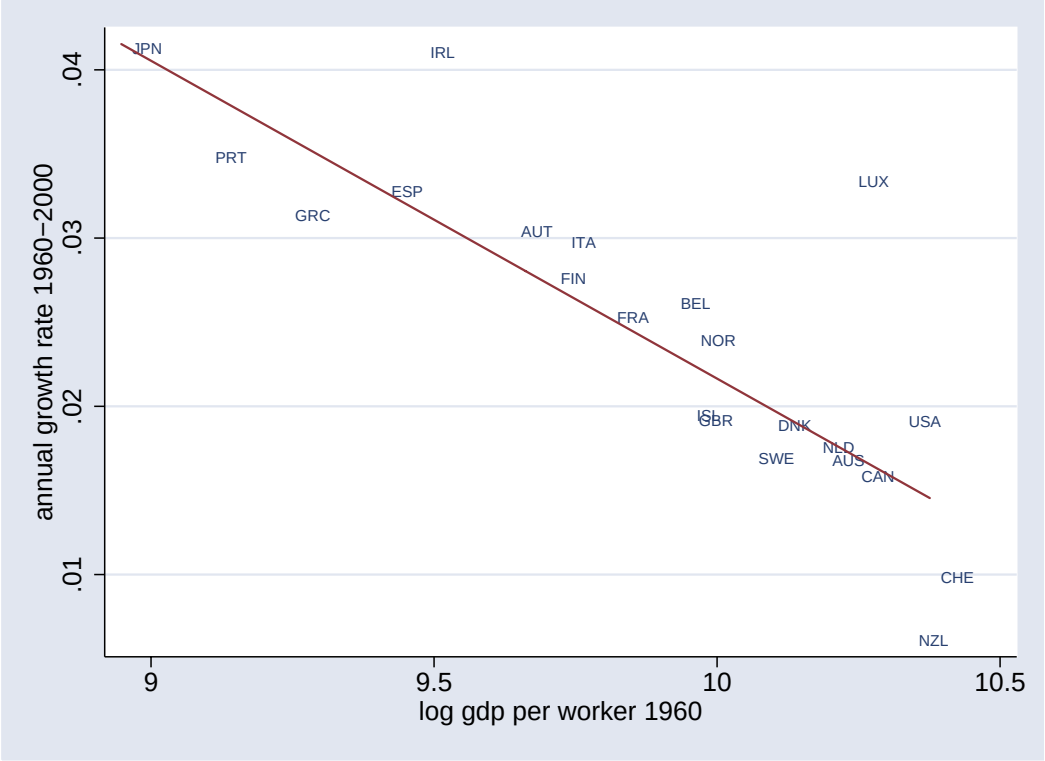

Figure 1.14. Annual growth rate of GDP per worker between 1960 and 2000 versus log GDP per worker in 1960 for core OECD countries.

question at a "causal" level. In other words, we would like to know which specific characteristics of countries (including their policies and institutions) have a causal effect on growth. A causal effect here refers to the answer to the following counterfactual thought experiment: if, all else equal, a particular characteristic of the country were changed "exogenously" (that is, not as part of equilibrium dynamics or in response to a change in other observable or unobservable variables), what would be the effect on equilibrium growth? Answering such causal questions is quite challenging, however, precisely because it is difficult to isolate changes in endogenous variables that are not driven by equilibrium dynamics or by some other potentially omitted factors.

For this reason, let us start with the more modest question of what factors correlate with post-war economic growth. With an eye to the theories that will come in the next two chapters, the two obvious candidates to look at are investments in physical capital and in human capital.

Figure 1.15 shows a strong positive association between the average growth of investment to GDP ratio and economic growth. Figure 1.16 shows a positive correlation between average years of schooling and economic growth. These figures therefore suggest that the countries that have grown faster are typically those that have invested more in physical capital and those that had greater human capital at the beginning of the postwar era. It has to be

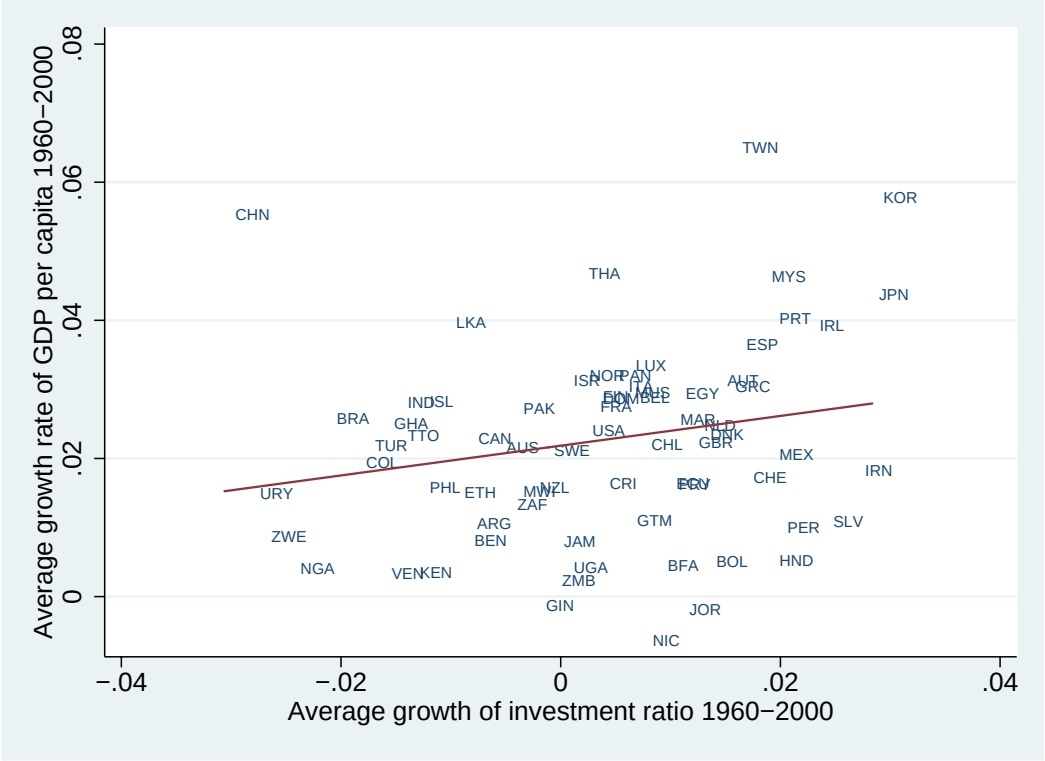

Figure 1.15. The relationship between average growth of GDP per capita and average growth of investments to GDP ratio, 1960-2000.

stressed that these figures do not imply that physical or human capital investment are the causes of economic growth (even though we expect from basic economic theory that they should contribute to output growth). So far these are simply correlations, and they are likely driven, at least in part, by omitted factors affecting both investment and schooling on the one hand and economic growth on the other.

We will investigate the role of physical and human capital in economic growth further in Chapter 3. One of the major points that will emerge from our analysis there is that focusing only on physical and human capital is not sufficient. Both to understand the process of sustained economic growth and to account for large cross-country differences in income, we also need to understand why societies differ in the efficiency with which they use their physical and human capital. Economists normally use the shorthand expression "technology" to capture factors other than physical and human capital that affect economic growth and performance. It is therefore important to remember that technology differences across countries include not only genuine differences in production techniques and in the quality of machines used in production, but also differences in productive efficiency resulting from differences in the organization of production, from differences in the way that markets are organized and from potential market failures (see in particular Chapter 21 on differences in productive efficiency resulting from the organization of markets and from market failures). A

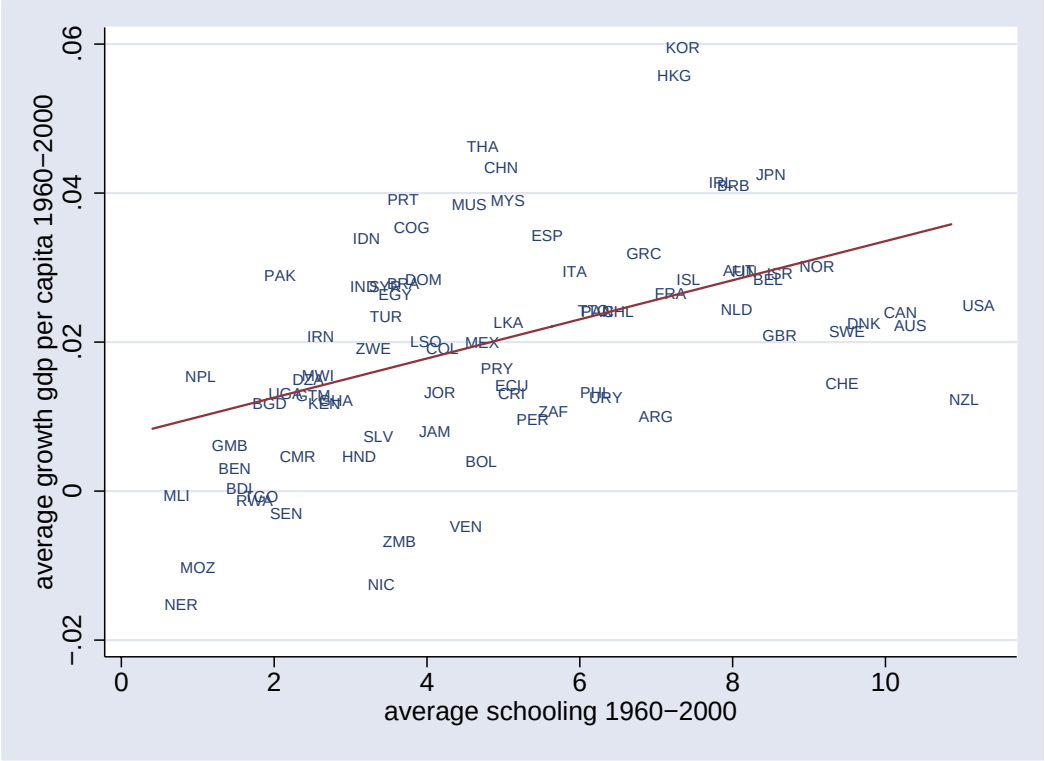

Figure 1.16. The relationship between average growth of GDP per capita and average years of schooling, 1960-2000.

detailed study of "technology" (broadly construed) is necessary for understanding both the world-wide process of economic growth and cross-country differences. The role of technology in economic growth will be investigated in Chapter 3 and in later chapters.

1.7. From Correlates to Fundamental Causes

The correlates of economic growth, such as physical capital, human capital and technology, will be our first topic of study. But these are only *proximate causes* of economic growth and economic success (even if we convince ourselves that there is an element of causality in the correlations shown above). It would not be entirely satisfactory to explain the process of economic growth and cross-country differences with technology, physical capital and human capital, since there are, presumably, reasons why technology, physical capital and human capital differ across countries. In particular, if these factors are so important in generating large cross country income differences and causing the takeoff into modern economic growth, why do certain societies fail to improve their technologies, invest more in physical capital, and accumulate more human capital?

Let us return to Figure 1.8 to illustrate this point further. This figure shows that South Korea and Singapore have managed to grow at very rapid rates over the past 50 years, while Nigeria has failed to do so. We can try to explain the successful performances of South Korea

and Singapore by looking at the correlates of economic growth—or at the proximate causes of economic growth. We can conclude, as many have done, that rapid capital accumulation has been a major cause of these growth miracles, and debate the relative roles of human capital and technology. We can simply blame the failure of Nigeria to grow on its inability to accumulate capital and to improve its technology. These answers are undoubtedly informative for understanding the mechanics of economic successes and failures of the postwar era. But at some level they will also not have answered the central questions: how did South Korea and Singapore manage to grow, while Nigeria failed to take advantage of the growth opportunities? If physical capital accumulation is so important, why did Nigeria not invest more in physical capital? If education is so important, why are education levels in Nigeria still so low and why is existing human capital not being used more effectively? The answer to these questions is related to the *fundamental causes* of economic growth.

I will refer to potential factors affecting why societies end up with different technology and accumulation choices as the fundamental causes of economic growth. At some level, fundamental causes are the factors that enable us to link the questions of economic growth to the concerns of the rest of social sciences and ask questions about the roles of policies, institutions, culture and exogenous environmental factors. At the risk of oversimplifying complex phenomena, we can think of the following list of potential fundamental causes: (i) luck (or multiple equilibria) that lead to divergent paths among societies with identical opportunities, preferences and market structures; (ii) geographic differences that affect the environment in which individuals live and that influence the productivity of agriculture, the availability of natural resources, certain constraints on individual behavior or even individual attitudes; (iii) institutional differences that affect the laws and regulations under which individuals and firms function and thus shape the incentives they have for accumulation, investment and trade; and (iv) cultural differences that determine individuals' values, preferences and beliefs. Chapter 4 will present a detailed discussion of the distinction between proximate and fundamental causes and what types of fundamental causes are more promising in explaining the process of economic growth and cross-country income differences.

For now, it is useful to briefly return to the contrast between South Korea and Singapore versus Nigeria, and ask the questions (even if we are not in a position to fully answer them yet): can we say that South Korea and Singapore owe their rapid growth to luck, while Nigeria was unlucky? Can we relate the rapid growth of South Korea and Singapore to geographic factors? Can we relate them to institutions and policies? Can we find a major role for culture? Most detailed accounts of post-war economics and politics in these countries emphasize the role of growth-promoting policies in South Korea and Singapore—including the relative security of property rights and investment incentives provided to firms. In contrast, Nigeria's postwar history is one of civil war, military coups, extreme corruption and an overall environment failing to provide incentives to businesses to invest and upgrade their technologies. It therefore seems necessary to look for fundamental causes of economic growth that make contact with these facts. Jumping ahead a little, it already appears implausible that luck can be the

major explanation for the differences in postwar economic performance; there were already significant economic differences between South Korea, Singapore and Nigeria at the beginning of the postwar era. It is also equally implausible to link the divergent fortunes of these countries to geographic factors. After all, their geographies did not change, but the growth spurts of South Korea and Singapore started in the postwar era. Moreover, even if we can say that Singapore benefited from being an island, without hindsight one might have concluded that Nigeria had the best environment for growth because of its rich oil reserves.[3] Cultural differences across countries are likely to be important in many respects, and the rapid growth of many Asian countries is often linked to certain "Asian values". Nevertheless, cultural explanations are also unlikely to provide the whole story when it comes to fundamental causes, since South Korean or Singaporean culture did not change much after the end of WWII, while their rapid growth performances are distinctly post-war phenomena. Moreover, while South Korea grew rapidly, North Korea, whose inhabitants share the same culture and Asian values, had one of the most disastrous economic performances of the past 50 years.

This admittedly quick (and partial) account suggests that we have to look at institutions and policies that affect incentives to accumulate physical and human capital and improve technology to develop a better understanding of the fundamental causes of economic growth. Institutions and policies were favorable to economic growth in South Korea and Singapore, but not in Nigeria. Understanding the fundamental causes of economic growth is, in large part, about understanding the impact of these institutions and policies on economic incentives and why, for example, they have been growth-enhancing in South Korea and Singapore, but not in Nigeria. The intimate link between fundamental causes and institutions highlighted by this discussion motivates the last part of the book, which is devoted to the political economy of growth, that is, to the study of how institutions affect growth and why they differ across countries.

An important caveat should be noted at this point. Discussions of geography, institutions and culture can sometimes be carried out without explicit reference to growth models or even to growth empirics. After all, this is what many non-economist social scientists do. However, fundamental causes can only have a big impact on economic growth if they affect parameters and policies that have a first-order influence on physical and human capital and technology. Therefore, an understanding of the mechanics of economic growth is essential for evaluating whether candidate fundamental causes of economic growth could indeed play the role that they are sometimes ascribed. Growth empirics plays an equally important role in distinguishing among competing fundamental causes of cross-country income differences. It is only by formulating parsimonious models of economic growth and confronting them with

[3]One can then turn this around and argue that Nigeria is poor because of a "natural resource curse," i.e., precisely because it has abundant and valuable natural resources. But this is not an entirely compelling empirical argument, since there are other countries, such as Botswana, with abundant natural resources that have grown rapidly over the past 50 years. More important, the only plausible channel through which abundance of natural resources may lead to worse economic outcomes is related to institutional and political economy factors. This then takes us to the realm of institutional fundamental causes.

data that we can gain a better understanding of both the proximate and the fundamental causes of economic growth.

1.8. The Agenda

The three major questions that have emerged from the brief discussion so far are:

(1) Why are there such large differences in income per capita and worker productivity across countries?
(2) Why do some countries grow rapidly while other countries stagnate?
(3) What sustains economic growth over long periods of time and why did sustained growth start 200 years or so ago?

In each case, a satisfactory answer requires a set of well-formulated models that illustrate the mechanics of economic growth and cross-country income differences, together with an investigation of the fundamental causes of the different trajectories which these nations have embarked upon. In other words, in each case we need a combination of theoretical models and empirical work.

The traditional growth models—in particular, the basic Solow and the neoclassical models—provide a good starting point, and the emphasis they place on investment and human capital seems consistent with the patterns shown in Figures 1.15 and 1.16. However, we will also see that technological differences across countries (either because of their differential access to technological opportunities or because of differences in the efficiency of production) are equally important. Traditional models treat technology (and market structure) as given or at best as evolving exogenously like a blackbox. But if technology is so important, we ought to understand why and how it progresses and why it differs across countries. This motivates our detailed study of endogenous technological progress and technology adoption. Specifically, we will try to understand how differences in technology may arise, persist and contribute to differences in income per capita. Models of technological change will also be useful in thinking about the sources of sustained growth of the world economy over the past 200 years and why the growth process took off 200 years or so ago and has proceeded relatively steadily since then.

Some of the other patterns we encountered in this chapter will inform us about the types of models that have the most promise in explaining economic growth and cross-country differences in income. For example, we have seen that cross-country income differences can only be accounted for by understanding why some countries have grown rapidly over the past 200 years, while others have not. Therefore, we need models that can explain how some countries can go through periods of sustained growth, while others stagnate.

Nevertheless, we have also seen that the postwar world income distribution is relatively stable (at most spreading out slightly from 1960 to 2000). This pattern has suggested to many economists that we should focus on models that generate large "permanent" cross-country differences in income per capita, but not necessarily large "permanent" differences in growth rates (at least not in the recent decades). This is based on the following reasoning:

with substantially different long-run growth rates (as in models of endogenous growth, where countries that invest at different rates grow at permanently different rates), we should expect significant divergence. We saw above that despite some widening between the top and the bottom, the cross-country distribution of income across the world is relatively stable over the postwar era.

Combining the post-war patterns with the origins of income differences related to the economic growth over the past two centuries suggests that we should look for models that can account both for long periods of significant growth differences and also for a "stationary" world income distribution, with large differences across countries. The latter is particularly challenging in view of the nature of the global economy today, which allows for free-flow of technologies and large flows of money and commodities across borders. We therefore need to understand how the poor countries fell behind and what prevents them today from adopting and imitating the technologies and the organizations (and importing the capital) of the richer nations.

And as the discussion in the previous section suggests, all of these questions can be (and perhaps should be) answered at two distinct, but related levels (and in two corresponding steps). The first step is to use theoretical models and data to understand the mechanics of economic growth. This step will shed light on the proximate causes of growth and explain differences in income per capita in terms of differences in physical capital, human capital and technology, and these in turn will be related to some other variables such as preferences, technology, market structure, openness to international trade and perhaps some distortions or policy variables.

The second step is to look at the fundamental causes underlying these proximate factors and to investigate why some societies are organized differently than others. Why do societies have different market structures? Why do some societies adopt policies that encourage economic growth while others put up barriers against technological change? These questions are central to a study of economic growth and can only be answered by developing systematic models of the political economy of development and looking at the historical process of economic growth to generate data that can shed light on these fundamental causes.

Our next task is to systematically develop a series of models to understand the mechanics of economic growth. I will present a detailed exposition of the mathematical structure of a number of dynamic general equilibrium models that are useful for thinking about economic growth and related macroeconomic phenomena, and I will emphasize the implications of these models for the sources of differences in economic performance across societies. Only by understanding these mechanics can we develop a useful framework for thinking about the causes of why some countries are growing and some others are not, and why some countries are rich and others are not.

1.9. References and Literature

The empirical material presented in this chapter is largely standard and parts of it can be found in many books, though interpretations and exact emphases differ. Excellent introductions, with slightly different emphases, are provided in Jones's (1998, Chapter 1) and Weil's (2005, Chapter 1) undergraduate economic growth textbooks. Barro and Sala-i-Martin (2004) also present a brief discussion of the stylized facts of economic growth, though their focus is on postwar growth and conditional convergence rather than the very large cross-country income differences and the long-run perspective emphasized here. Excellent and very readable accounts of the key questions of economic growth, with a similar perspective to the one here, are provided in Helpman (2005) and in Aghion and Howitt's new book (2008). Aghion and Howitt also provide a very useful introduction to many of the same topics discussed in the current book.

Much of the data used in this chapter come from Summers-Heston's Penn World tables (latest version, Summers, Heston and Aten, 2005). These tables are the result of a very careful study by Robert Summers and Alan Heston to construct internationally comparable price indices and internationally comparable estimates of income per capita and consumption. PPP adjustment is made possible by these data. Summers and Heston (1991) give a very lucid discussion of the methodology for PPP adjustment and its use in the Penn World tables. PPP adjustment enables us to construct measures of income per capita that are comparable across countries. Without PPP adjustment, differences in income per capita across countries can be computed using the current exchange rate or some fundamental exchange-rate. There are many problems with such exchange-rate-based measures. The most important one is that they do not make an allowance for the fact that relative prices and even the overall price level differ markedly across countries. PPP-adjustment brings us much closer to differences in "real income" and "real consumption". Information on "workers" (active population), consumption and investment are also from this dataset. GDP, consumption and investment data from the Penn World tables are expressed in 1996 constant US dollars. Life expectancy data are from the World Bank's World Development Indicators CD-ROM, and refer to the average life expectancy of males and females at birth. This dataset also contains a range of other useful information. Schooling data are from Barro and Lee's (2002) dataset, which contains internationally comparable information on years of schooling.

In all figures and regressions, growth rates are computed as geometric averages. In particular, the geometric average growth rate of output per capita y between date t and $t+T$ is

$$g_{t,t+T} \equiv \left(\frac{y_{t+T}}{y_t}\right)^{1/T} - 1.$$

The geometric average growth rate is more appropriate to use in the context of income per capita than the arithmetic average, since the growth rate refers to "proportional growth". It can be easily verified from this formula that if $y_{t+1} = (1+g)\, y_t$ for all t, then $g_{t+T} = g$.

Historical data are from various works by Angus Maddison, in particular, Maddison (2001, 2005). While these data are not as reliable as the estimates from the Penn World tables, the general patterns they show are typically consistent with evidence from a variety of different sources. Nevertheless, there are points of contention. For example, as Figure 1.11 shows, Maddison's estimates show a slow but relatively steady growth of income per capita in Western Europe starting in 1000. This is disputed by some historians and economic historians. A relatively readable account, which strongly disagrees with this conclusion, is provided in Pomeranz (2001), who argues that income per capita in Western Europe and the Yangtze Valley in China were broadly comparable as late as 1800. This view also receives support from recent research by Allen (2004), which documents that the levels of agricultural productivity in 1800 were comparable in Western Europe and China. Acemoglu, Johnson and Robinson (2002 and 2005) use urbanization rates as a proxy for income per capita and obtain results that are intermediate between those of Maddison and Pomeranz. The data in Acemoglu, Johnson and Robinson (2002) also confirms the fact that there were very limited income differences across countries as late as the 1500s and that the process of rapid economic growth started sometime in the 19th century (or perhaps in the late 18th century). Recent research by Broadberry and Gupta (2006) also disputes Pomeranz's arguments and gives more support to a pattern in which there was already an income gap between Western Europe and China by the end of the 18th century.

The term *takeoff* I used in Section 1.4 is introduced in Walter Rostow's famous book *Stages of Economic Growth* (1960) and has a broader connotation than the term "Industrial Revolution," which economic historians typically use to refer to the process that started in Britain at the end of the 18th century (e.g., Ashton, 1968). Mokyr (1990) contains an excellent discussion of the debate on whether the beginning of industrial growth was due to a continuous or discontinuous change. Consistent with my emphasis here, Mokyr concludes that this is secondary to the more important fact that the modern process of growth *did* start around this time.

There is a large literature on the "correlates of economic growth," starting with Barro (1991). This work is surveyed in Barro and Sala-i-Martin (2004) and Barro (1999). Much of this literature, however, interprets these correlations as causal effects, even when this is not warranted (see the further discussion in Chapters 3 and 4).

Note that while Figure 1.15 looks at the relationship between the average growth of investment to GDP ratio and economic growth, Figure 1.16 shows the relationship between average schooling (not its growth) and economic growth. There is a much weaker relationship between growth of schooling and economic growth, which may be for a number of reasons. First, there is considerable measurement error in schooling estimates (see Krueger and Lindahl, 2000). Second, as shown in some of the models that will be discussed later, the main role of human capital may be to facilitate technology adoption, thus we may expect a stronger relationship between the level of schooling and economic growth than the change in schooling

and economic growth (see Chapter 10). Finally, the relationship between the level of schooling and economic growth may be partly spurious, in the sense that it may be capturing the influence of some other omitted factors also correlated with the level of schooling; if this is the case, these omitted factors may be removed when we look at changes. While we cannot reach a firm conclusion on these alternative explanations, the strong correlation between the level of average schooling and economic growth documented in Figure 1.16 is interesting in itself.

The narrowing of income per capita differences in the world economy when countries are weighted by population is explored in Sala-i-Martin (2005). Deaton (2005) contains a critique of Sala-i-Martin's approach. The point that incomes must have been relatively equal around 1800 or before, because there is a lower bound on real incomes necessary for the survival of an individual, was first made by Maddison (1992), and was later popularized by Pritchett (1996). Maddison's estimates of GDP per capita and Acemoglu, Johnson and Robinson's estimates based on urbanization confirm this conclusion.

The estimates of the density of income per capita reported above are similar to those used by Quah (1994, 1995) and Jones (1996). These estimates use a nonparametric Gaussian kernel. The specific details of the kernel estimates do not change the general shape of the densities. Quah was also the first to emphasize the stratification in the world income distribution and the possible shift towards a "bi-modal" distribution, which is visible in Figure 1.3. He dubbed this the "Twin Peaks" phenomenon (see also Durlauf and Quah, 1994). Barro (1991) and Barro and Sala-i-Martin (1992) emphasize the presence and importance of conditional convergence and argue against the relevance of the stratification pattern emphasized by Quah and others. The estimate of conditional convergence of about 2% the year is from Barro and Sala-i-Martin (1992). Caselli, Esquivel and Lefort (1996) show that panel data regressions lead to considerably higher rates of conditional convergence.

The first economist to emphasize the importance of conditional convergence and conduct a cross-country study of convergence was Baumol (1986). However, Baumol used the available data at the time, which were of lower quality than the Summers-Heston data. This also made him conduct his empirical analysis on a selected sample of countries, potentially biasing his results (see De Long, 1991). Barro's (1991) and Barro and Sala-i-Martin's (1992) work using the Summers-Heston data has been instrumental in generating renewed interest in cross-country growth regressions.

The data on GDP growth and black real wages in South Africa are from Wilson (1972). Wages refer to real wages in gold mines. Feinstein (2004) provides an excellent economic history of South Africa. The implications of the British Industrial Revolution for real wages and living standards of workers are discussed in Mokyr (1993). Another example of rapid economic growth with falling real wages is provided by the experience of the Mexican economy in the early 20th century (see Gómez-Galvarriato, 1998). There is also evidence that during this period, the average height of the population might have been declining as well, which is often associated with falling living standards, see López Alonso and Porras Condy (2003).

There is a major debate on the role of technology and capital accumulation in the growth experiences of East Asian nations, particularly South Korea and Singapore. See Young (1994) for the argument that increases in physical capital and labor inputs explain almost all of the rapid growth in these two countries. See Klenow and Rodriguez-Clare (1996) and Hsieh (2001) for the opposite point of view.

The difference between proximate and fundamental causes will be discussed further in later chapters. This distinction is emphasized in a different context by Diamond (1996), though it is also implicitly present in North and Thomas's (1973) classic book. It is discussed in detail in the context of long-run economic development and economic growth in Acemoglu, Johnson and Robinson (2006). I will revisit these issues in greater detail in Chapter 4.

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