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Growth in the Long Run

Why are some countries so rich and others so poor? This question has fascinated economists since sharp differences in living standards among countries began to emerge in the past four hundred years. Indeed, the modern study of economics is often said to begin in 1776 with the publication of Adam Smith's *An Inquiry into the Nature and Causes of the Wealth of Nations*, which, as the title suggests, poses this very question. Over the intervening centuries, we have made some progress in trying to understand the causes of differences in wealth and welfare, but it would be an exaggeration to claim that we have solved the riddle.

This chapter describes the theories that are now most commonly used to explain long run growth and disagreements among economists about the usefulness of these theories. As we have seen in earlier chapters, the main differences often boil down to the *key assumptions* underlying these various models. We will also discuss the policy relevance of theories of long run growth, using a well-known study of East Asian growth as an example. Finally, we will consider Vietnam's growth experience in light of these theories. Does growth theory help us understand Vietnam's growth patterns, and is so, what are their implications for economic policy?

Measuring Economic Progress

Economic growth generates the resources needed to achieve improvements in people's living standards. One of the main points that Adam Smith wanted to make in *The Wealth of Nations* is that national wealth is best understood as a *flow* of income rather than as a *stock* of valuable assets like gold. At the end of the eighteenth century, the dominant view was a nation's wealth consisted of its stocks of precious metals. Gold was needed to finance armies and navies, and hence was a vital source of national power. Governments acquired gold by imposing taxes and fees on domestic producers and traders. In order to increase the size of the tax take, governments created monopolies and protected domestic businesses from foreign competition with tariffs, quotas and import restrictions. The aim of the "mercantile system," as Smith called it, was to increase domestic gold stocks and reduce the ability of the country's competitors to acquire wealth. To this day, governments often confuse stocks of wealth with flows of income. They are not the same.

Smith argued that mercantilism imposed limits on national wealth by restricting the size of export markets and hence opportunities to specialize and realize economies of scale in production. Underlying Smith's view is a shift in policy objectives from the acquisition of hard currency (accumulating stocks) to achieving higher levels of productivity in industry (increasing flows). Smith's view eventually won out. We now measure economic progress in terms of the growth of gross domestic product (GDP) rather than stocks of gold.

GDP growth is certainly a better measure of improvements to human well-being than changes in national stocks of gold and silver. Income per capita is closely associated with most measures of well-being, for example child survival and life expectancy at birth. Yet GDP growth is not the only way to measure economic progress, and on its own it is far from complete. Simon Kuznets, who pioneered national income accounting in the United States in the 1930s, famously remarked that we should not confuse the quantity with the *quality* of growth.[1] Economic expansion does not necessarily mean that everyone is better off. Growth may disproportionately accrue to the rich. For example, the richest one percent of the U.S. population captured 65 percent of the increase in GDP from 2002 to 2007 (Atkinson, Piketty, and Saez 2011, 9). Or growth may consist of the production of too many guns and cigarettes and not enough education and healthcare. National accounts record income flows but do not take into account the depletion of stocks of natural resources or degradation of ecosystems. For example, the Indonesian economy is growing quickly but net national saving—in other words, gross domestic saving less depletion of natural resources—is negative, which means that growth will come to a halt when the country runs out of natural resources.[2] GDP figures do not tell us anything about the sustainability of growth, or the extent that growth in the present is achieved at the expense of growth or living standards in the future.

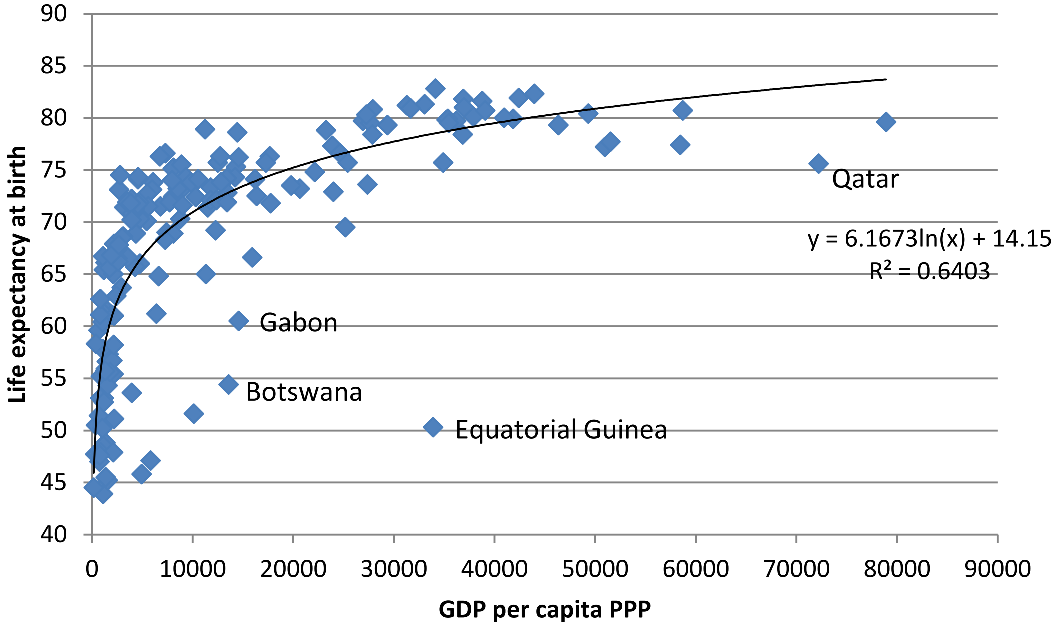
Amartya Sen has made a strong case against using GDP as the main measure of development progress. He argues that income is just a means to an end rather than an end in itself. The aim of development is not to consume more goods, but rather to create possibilities for people to make the most of their lives. He calls the range of possibilities open to a given person his or her "capabilities," which cannot be measured directly but which are influenced by a wide range of factors including income, health and access to education. "The contribution of economic growth," he writes, "has to be judged not merely by the increase in private incomes, but also by the expansion of social services (including, in many cases, social safety nets) that economic growth may make possible" (Sen 1999, 40).

The capability approach is one of the main inspirations of the Human Development Index, an annual measure of development progress produced by the United Nations Development Program (UNDP) that combines income per capita with a measure of health (life expectancy) and education (adult literacy and school enrolment rates). For most countries the relationship between HDI scores and GDP per capita is very close. This is not surprising since income is part of the HDI, but it is also reflects the typically rapid progress that developing countries make in improving health and education indicators as average incomes rise (Kenny 2005). There are two big exceptions to this overall pattern: oil exporting countries, and countries with a very high prevalence of HIV/AIDS. In Figure 1, Qatar and Equatorial Guinea represent the former, and Botswana the latter. Gabon is both heavily dependent on oil exports and has been hard it by the AIDS epidemic.

[1] "[D]istinctions must be kept in mind between quantity and quality of growth, between its costs and return, and between the short and the long run…Goals for 'more' growth should specify more growth of what and for what" (Kuznets 1962, 29).

[2] The World Bank publishes annual estimates of genuine saving, which adjusts net domestic saving to take into account depletion of natural resources, environmental degradation and spending on education as a proxy for human capital formation.

Figure 1. Life expectancy and GDP per capita, 2008



Source: Authors' calculations from UNDP data (http://hdr.undp.org/en/statistics)

National income comparisons over time and space also raise the difficult issue of converting national currencies into a common standard or *numeraire*. This turns out to be more complicated than simply converting income levels from various national currencies into US dollars at market exchange rates. Market exchange rates may over or under-estimate national income depending on a range of other factors, including the size of capital flows, currency speculation and locally specific factors that influence prices of non-tradeable goods and services. For example, Vietnam's GDP per capita in 2010 was $1,174 at market exchange rates. However, in 2010 $1,174 would buy more goods and services in Vietnam than in the United States, largely because labor is cheaper. At the time of this writing, one kilogram of tomatoes cost about US$0.60 in Ho Chi Minh City, Vietnam, and about $4.80 in the Cambridge, Massachusetts in the United States. At market exchange rates, one US dollar will buy many more tomatoes in Ho Chi Minh City than in Cambridge. Therefore, market exchange rates result in an *under-estimation* of purchasing power in Vietnam. To get around this problem, economists calculate "purchasing power parity" (PPP) exchange rates based on the domestic prices of a "basket" of comparable goods. PPP exchange rates result in estimates of income that more accurately represent levels of living. For example, the International Monetary Fund (IMF) estimates Vietnam's 2010 per capita income at PPP rates at $3,134, more than 2.5 times per capita income at market exchange rates. Although PPP exchange rates are not without problems themselves, most economists accept that if used carefully they represent an improvement over income conversions using market exchange rates.[3] We need always to bear in mind that inter-country and inter-temporal estimates of GDP are approximations rather than facts, and to refrain from drawing conclusions based on very small observed differences.

[3] One of the main problems is identifying consistent baskets of goods across countries given great differences in tastes and consumption patterns, and changes in consumption patterns over time.

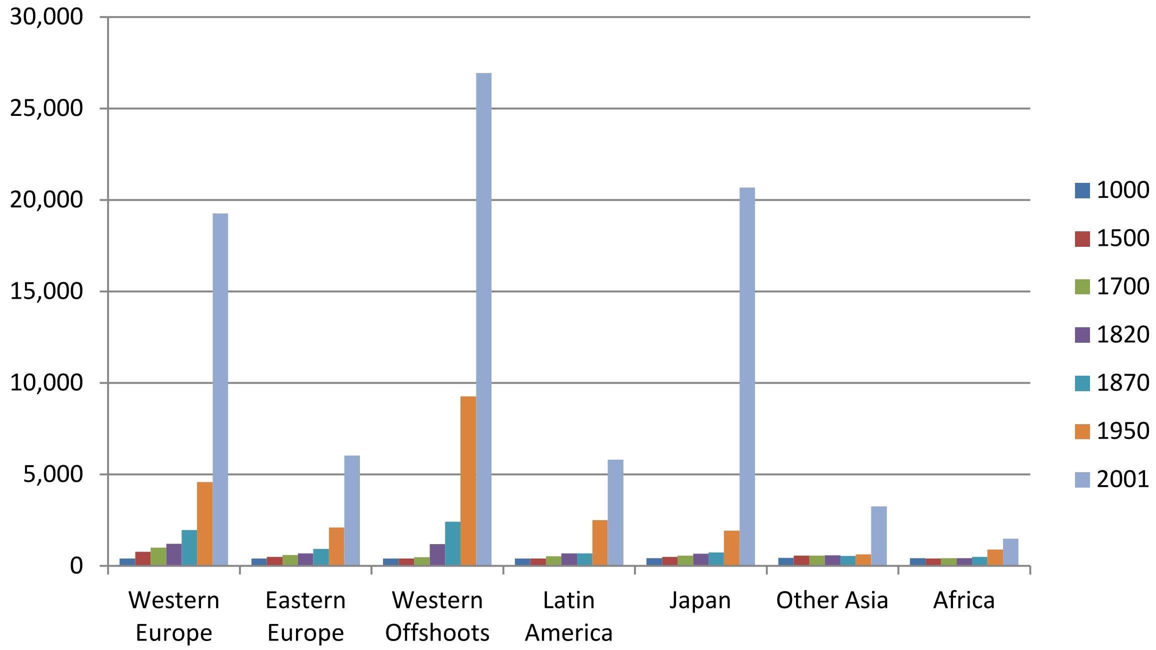
Growth over the centuries

The literature on long run patterns of economic growth has blossomed in recent years with the publication of cross-country, time series estimates of GDP and its components for a large number of countries. Until the 1980s, standardized national incomes accounts were available for only a few European and North American countries for recent years. Simon Kuznets was once again the pioneer in compiling long time series estimates for North America and European countries (Kuznets 1971). The statistical detective work required to extend these time series back in time and to include developing countries was continued by others, most notably Angus Maddison, who produced the first global estimates of GDP stretching back to the first millennium of the Common Era (C.E.) (Maddison 1991; Maddison 1995; Maddison 2005). Maddison's long time series covering every region of the world provide a fascinating window on the trajectory of global growth and the factors that contributed to the acceleration of growth since the 19th century.

Maddison finds that nothing much happened in the first millennium and a half of the Common Era (C.E.). By 1500, Western Europe had begun to pull ahead of the other regions of the world, including China (Figure 2). Major developments in shipping and navigation made possible a twenty-fold increase in world trade between 1500 and 1820, which in turn permitted European producers to specialize and gave European consumers access to imported luxuries like teach, coffee, sugar and silk. Improved transportation also contributed to the conquest and colonization of the Americas.

From 1820, the world has been on what can only be described as a growth juggernaut (Figure 3). Global GDP expanded 54-fold and GDP per person has risen nine-fold. From the capabilities perspective, life expectancy for the world as a whole rose from 26 years in 1820 to 66 years in 2002 (Maddison 2005, 6). The industrial revolution that began in the early 19th century in Europe has transformed the world economy. Growth was propelled by rapid technological change combined with massive investment in production and transport equipment. Cheaper, quicker transport propelled domestic and international trade, which permitted specialization and the realization of economies of scale in manufacturing and agriculture.

Figure 2. GDP per capita in 1999 USD, PPP



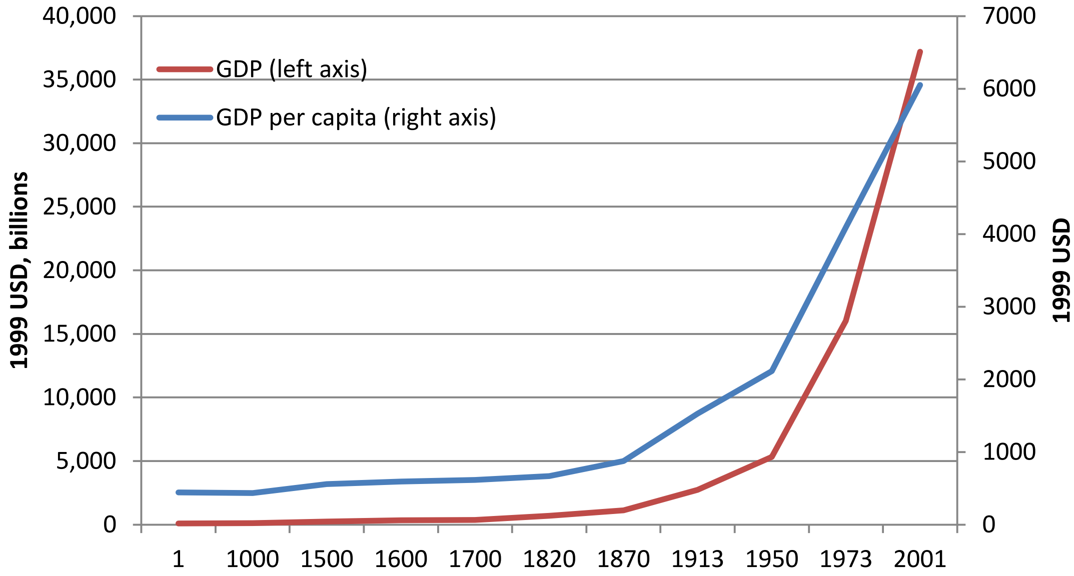
Source: Maddison 2006

However, the industrial revolution did not arrive everywhere at the same time. Productivity grew much faster in Europe and the "Western Offshoots" than in the rest of the world. Incomes diverged as the leading countries sprinted ahead of the pack. Bourguignon and Morrisson estimate that global inequality increased sharply from 1820 to 1990 (Bourguignon and Morrisson 2002). Global inequality is probably still at record highs, though as we will see below, whether it continues to increase or begins to improve depends largely on what happens in China and India over the next several decades.

Global growth accelerated in the final quarter of the nineteenth century, but was derailed by two world wars and the Great Depression in the first half of the twentieth. The brief period between the Second World War and the oil-food crisis of 1973 was the "Golden Age" of capitalism. World per capita income grew at three percent per annum from 1950 to 1973, the most rapid in history *in all regions of the world*. Trade also expanded at unprecedented rates. Some of this growth was due to post-war reconstruction and satisfying pent up consumer demand from the years of the Great Depression of the 1930s and the war. The pace of technological change was rapid, and high profits rates provided savings for reinvestment in new plant and equipment. In Western Europe and North America, Keynesian demand management and increased public spending on social protection reduced the frequency and severity of recessions. There were no major financial crises in the United States during this period because of banking regulations imposed in the 1930s. The United States ran large trade surpluses which were recycled into investment flows, mostly to Western Europe. The US also underwrote a stable system of exchange rates based on a fixed dollar-gold conversion rate (Marglin 1990).

Economic growth for the world as a whole has slowed since 1973, the period that Maddison refers to as the "neo-liberal order." But the slower global average conceals increasing variation among countries and regions. The developing countries of Asia have narrowed the GDP gap with the advanced countries, led by explosive growth in China, and more recently accelerated growth in India. Growth in Africa, Latin America and the Middle East has slowed under the neo-liberal order. The Latin American debt crisis of the 1980s brought growth to a halt in that region for more than a decade. Real GDP collapsed in Eastern Europe and the former Soviet Union after 1990, and the Eastern European countries did not regain 1990 GDP levels until 2003. The countries of the former Soviet Union did not reach the same milestone until 2007. The neo-liberal order has also been punctuated by regular financial crises and frequent and sharp recessions (1974-75, 1982, 1991, 2001 and 2009), which have slowed average growth for the period.

Figure 3. World GDP and GDP per capita, 1999 USD, PPP



Source: Maddison 2006

The industrial revolution transformed production and living standards in the countries that took part in it over the past two hundred years. This includes countries that began the process relatively late, for example Japan and the newly industrializing countries of East Asia like Taiwan and South Korea. Countries that have not benefited from rapid economic growth fell further behind. This includes many countries—many of which are in Latin America—that have enjoyed short periods of good performance interspersed with periods of stagnation and even decline. One of the main lessons from the last two centuries is that while the rate of growth is important, the capacity of a given country to raise the living standards of its citizens depends largely on its capacity to *sustain* growth over a long period of time. Small differences in growth rates make a big difference if compounded over many years.

The global distribution of income can therefore be characterized—in the words of one prominent contribution to the debate—as "divergence, big time" (Pritchett 1997). Countries that have not had an industrial revolution have remained poor, while others have revolutionized productivity and income levels. In 2008, GDP per employed worker in Tanzania was $1,572, less than *one-fortieth* of the level of the United States.[4]

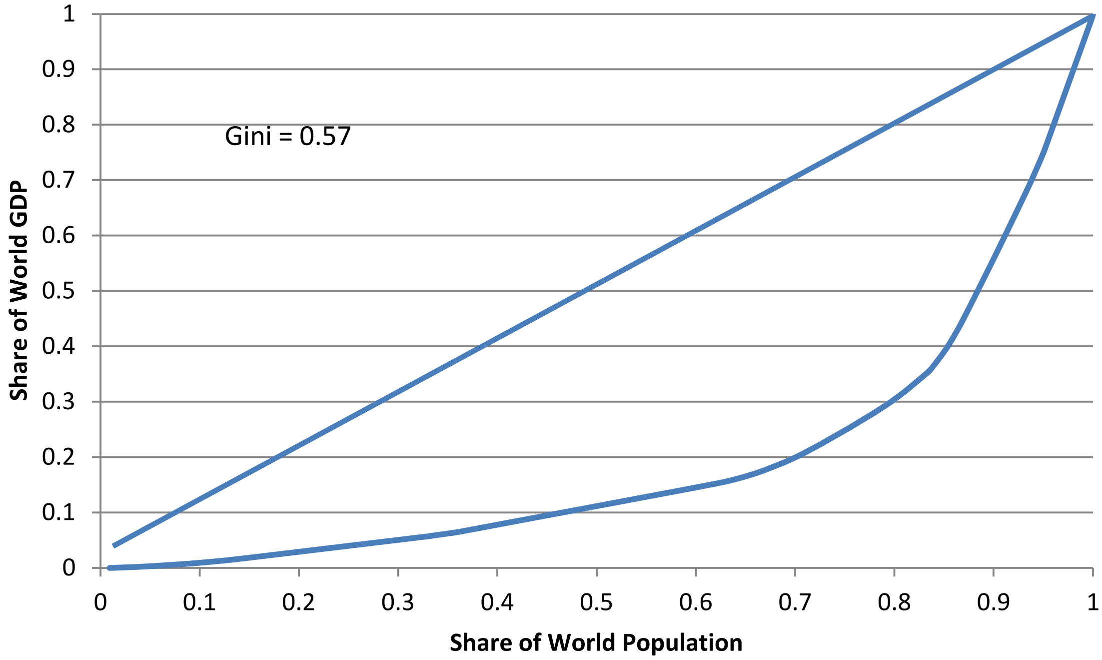
And yet within this pattern of overall divergence we find considerable evidence of convergence among certain groups of countries. William Baumol was the first economist to identify "convergence clubs," in other words groups of countries in which income levels have shown a tendency to converge. The most obvious convergence club is the group of advanced industrialized countries, in which productivity levels have caught up with the United States over the past 50 years (Baumol 1986). The existence of convergence clubs is important, because it provides some evidence for the idea that technology, ideas and policies do "spill over" from the productivity leader to other countries. There are some "advantages of backwardness" that enable late-developing countries to grow more quickly than the technological leader as long as policies are conducive to investment, the acquisition of technology and knowledge and the realization of scale economies (Gerschenkron 1962).

We also need to bear in mind that the fact of a growing gap between the richest and poorest countries does not mean that the world is necessarily becoming a more unequal place. How can this be? Let's conduct a simple experiment. Lorenz curves are a graph that plots cumulative income on the vertical axis and the share of population on the horizontal axis. The resulting curve measures the degree of inequality. Perfect equality would consist of a straight line leaving the origin at a 45 degree angle. The distance from the Lorenz curve to the 45 degree line is the level of inequality. The ratio of the area above the Lorenz curve to the triangle under the 45 degree line is the *gini coefficient*. Our experiment consists of plotting global Lorenz curves using *per capita* GDP at purchasing power parity exchange rates. Since we do not have data for individuals or households, we use per capita income at the national level *weighted by population*. This is not a perfect substitute for household data, since it ignores within country inequality. But it does give us an approximate measure of the degree of global inequality.

We have conducted this experiment for two years: 2000 and 2010 (Figures 4 and 5). The data are taken from the IMF World Economic Outlook. In 2000, the global gini coefficient was 0.57, which is a very high level of inequality. The poorest two quintiles (40 percent of world population received about eight percent of income, while the richest ten percent commanded about 45 percent. The richest five percent controlled about one-quarter of the world's GDP. Yet the situation has changed markedly just ten years later. By 2010, the global gini had fallen to 0.46, and the share of the bottom two quintiles had risen to 9.5 percent, while that of the top ten percent had dropped to about 40 percent of global income. The richest five percent also lost some ground, down from 25 to 22 percent of GDP. This striking result is almost entirely due to rapid growth in China, the largest country by population in the world, and the fastest growing. Growth in China averaged more than ten percent per annum over this period, a rate at which the economy doubles over seven years.

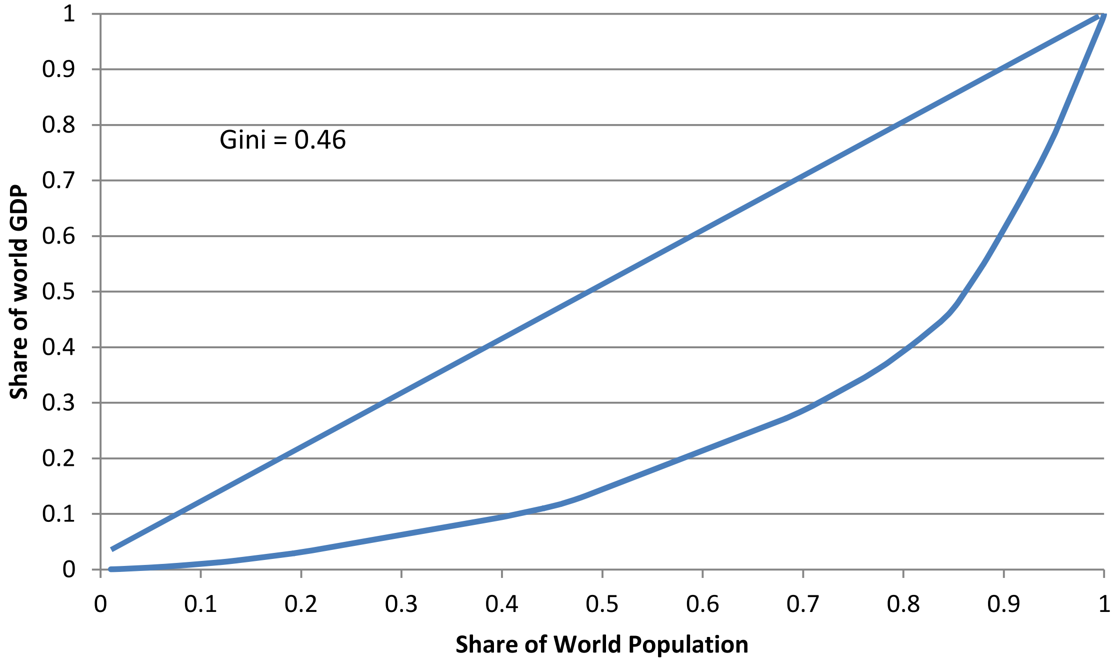
[4] World Bank World Development Indicators (WDI), in 1990 PPP dollars.

Figure 4. A World Lorenz Curve, 2000



Source: Authors' calculations from IMF data

Figure 5. A World Lorenz Curve, 2010



Source: Authors' calculations from IMF data

Thus, even as the gap between the richest and poorest countries widens, the overall distribution of income in the world appears to be improving. In short, we are witnessing divergence of the top from the bottom within an overall pattern of convergence in world incomes. These trends will continue if China and India can sustain rapid growth over the coming decade. As we have seen, high rates of growth are good, but sustaining growth over the long period is better.

The Solow Model

Does economic theory shed light on the trends described in the previous section? One of the main themes of this book is that macroeconomic models must be understood in terms of their *key assumptions*. Economic models simplify the real world to focus on the interaction of variables of interest to economists. The question is whether the assumptions made and resulting simplifications of reality clarify or obscure important economic relationships. The growth models described in the rest of this chapter use different assumptions to focus on different aspects of economic reality. These assumptions imply different beliefs about the main factors the drive economic growth and development.

We begin with the neoclassical growth model, which was first set out more than fifty years ago but remains the most influential approach to the economics of growth. The model was first introduced by the American economist Robert Solow (1956) and is therefore commonly known as the Solow model. Solow starts out with the usual neoclassical assumptions: this is a Say's Law world, in which savings always equals investment and the labor force equals employment (in other words, there is no unemployment and no problem of effective demand) because wages and returns to capital adjust to equate supply and demand. Returns to scale are assumed to be constant and there are diminishing returns to the factors of production (if you hold labor constant and add capital, output per unit of capital falls). The model is constructed in continuous, logical time.

Neoclassical growth theory reaches four main conclusions: i) the rate of capital accumulation does affect the long run *level* of income; ii) the rate of capital accumulation does not affect the growth rate; iii) the growth rate is determined by the rate of growth of the labor force and technological change, both of which are exogenous or external to the model; and, iv) given equal rates of saving and technological change, countries with lower capital output ratios (developing countries) will growth faster than countries with higher capital output ratios (rich countries); v) hence there should be *convergence* in levels of income per worker.

The model consists of a neoclassical production function in which two inputs, capital (K) and labor (L) are combined to produce a single output (Y). The capital-output ratio and labor-output ratio adjust depending on the relative scarcity of capital and labor. To simply the model, there is no government, no trade and no international capital movements. The stock of capital (K) grows at a constant rate determined by the proportion of income that is saved (s) out of national income (Y) less a constant rate of depreciation of the capital stock (δK):

$$\dot{K} = \frac{dK}{dt} = sY - \delta K. \qquad \text{x.1}$$

The growth of the labor force is exogenous and is represented by a constant exponential function L_0e^{nt}, in which L_0 is the initial labor force, n is the growth rate and t is time measured in years. So, for example, if the labor force is growing at a constant two percent per annum, the size of the labor force will double in about 35 years.

A Cobb-Douglas production function homogeneous of degree one is chosen to reflect constant returns to scale and diminishing returns to the factors, such that $0 < \alpha < 1$:

$$Y = F(K, L) = K^{\alpha} L^{1-\alpha}, \qquad \text{x.2}$$

where α is the partial elasticity of output with respect to capital (K) and (1- α) is the partial elasticity of output with respect to labor (L). Constant returns to scale (the constraint that the two partial elasticities sum to one) implies that doubling capital and labor will result in a doubling of output. Decreasing returns to scale would apply if supplies of an irreplaceable input (such as land) were scarce or fixed. In the Ricardian system, for example, the area of high productivity land is fixed, forcing farmers to bring lower quality land into production as the population increases. Conversely, *increasing returns to scale* would imply that the supply of some inputs only become available in sufficient quantities when output passes a certain threshold level. As we shall see later in this chapter, endogenous growth theory is based on the idea that some kinds of knowledge or technology only emerge when the capital stock passes some threshold level.

Workers are paid a wage (w) and the cost of capital is rent (r). Profit maximizing firms will hire labor until the wage is equal to the marginal productivity of labor, and rent is equal to the marginal productivity of capital:

$$w = \frac{\partial F}{\partial L} = (1 - \alpha)\frac{Y}{L}\ ;\ r = \frac{\partial F}{\partial K} = (\alpha)\frac{Y}{K}. \qquad \text{x.3}$$

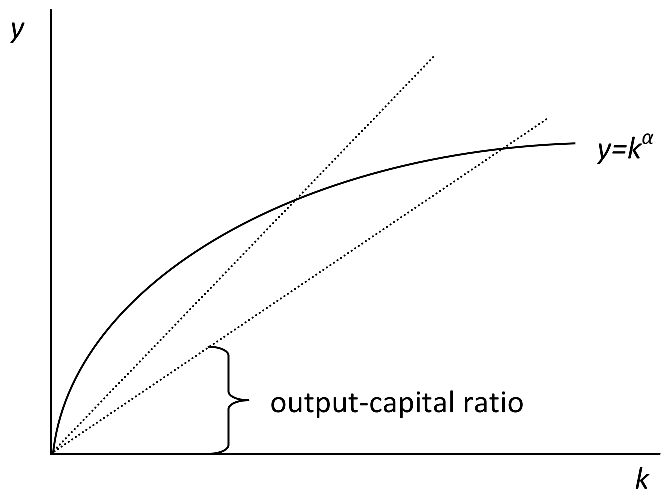
If labor is abundant, the wage will fall and the labor-output ratio will rise. This also implies that the distribution of income is thus given by the technical parameters of the model.

We are most interested in the effects of growth on output per worker, which is the main yardstick that we use to measure economic progress. The first step is to divide the production function by L to rewrite it in per capita terms:

$$y = k^{\alpha}, \qquad \text{x.4}$$

where $y=Y/L$ and $k=K/L$. With α assumed to be less than one, the resulting production function will exhibit diminishing returns to capital, as shown in Figure 6. As income rises, the output-capital ratio falls. Less output is generated from each additional unit of capital. The process will continue until r is equal to the marginal productivity of capital. This assumes that there is a wide variety of techniques available to produce the economy's single good, and that selection of the profit maximizing technique is based on the sole criteria that the wage is equal to the marginal productivity of labor and rent is equal to the marginal productivity of capital.

Figure 6. Cobb-Douglas Production Function



Rewriting the capital accumulation equation in per worker terms, we get:

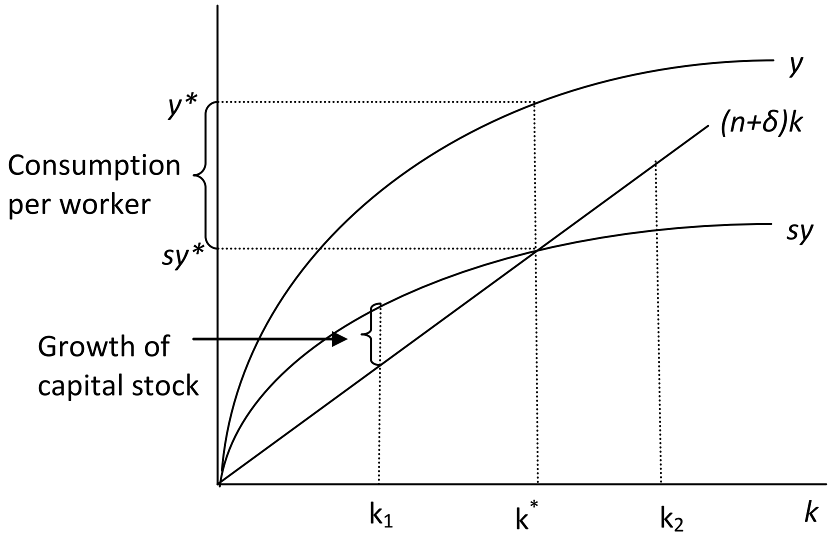
$$\dot{k} = \frac{dk}{dt} = sy - (n + \delta)k, \quad \text{x.5}$$

where y is output per worker. Capital per worker increases with the savings rate and decreases with the growth of the labor force and the rate of capital depreciation. The *sy* term in equation x.5 is the same shape as the production function in Figure 6, although at a lower level because savings is equal to output less consumption (assuming saving always equals investment and a closed economy). The second term, $(n+\delta)k$, can be interpreted as the amount of investment per worker required to hold capital-labor ratio constant (labor force growth and depreciation both reduce the level of capital per worker). As shown in Figure 7, the difference between these two lines is growth of capital per worker. Given a constant rate of savings as a share of output, savings will plateau as the output capital ratio falls. At k_1 investment per worker is growing faster than the replacement amount, but at k_2 depreciation and labor force growth are in excess of savings per worker. At k^* capital per worker is constant. This the steady state value of capital per worker.

At the steady state, output per worker is y^*, which includes consumption per worker over and above saving per worker. Thus income and consumption per worker are constant at the steady state. There is no more economic growth.

From Figure 7 it is apparent that an increase in the savings rate will increase capital and output per worker. The *sy* and *y* curves move upward, establishing a new steady state at a higher level of income where *sy* cuts the $(n+\delta)k$ line. This is the first conclusion of neoclassical growth theory: income per capita is determined by the savings rate. But income *per capita* growth comes to a halt regardless of the level of savings at the steady state, because at this point capital and income are growing at the same rate as the labor force. Hence the second conclusion: the rate of savings and investment does not affect the long run rate of growth. Growth in the long run is set by the growth rate of the labor force.

Figure 7. The Solow Model



The third conclusion of the model is that long run (steady state) growth rate is determined by the rate of growth of the labor force and the rate of depreciation. This result also follows from the assumption of diminishing returns to capital. In Figure 7, an increase in the rate of labor force growth is represented by counter-clockwise rotation of the *(n+δ)k* line. Given a constant rate of saving, a higher output-capital ratio is required to hold capital per worker constant. At the resulting steady state, output growth is higher (but of course there is no growth in per capita output).

The final conclusions of the model are that per capita growth slows at higher levels of capital per worker. Once again, this is given by the assumption of diminishing marginal returns to capital. If poor countries have lower capital-output ratios than rich countries, the model predicts *convergence* in per capita income between the two groups. This does not mean that all countries will wind up with the same levels of per capita income, because countries have different rates of saving and labor force growth. But the gap between rich and poor countries will narrow. This is consistent with the empirical observation that successful developing countries tend to grow more quickly than mature economies. It does not explain the absence of a more general trend of income convergence, a topic to which we shall return later in the chapter.

The prediction that economic growth per capita comes to a halt in the long run is not realistic. Rich countries continue to achieve real income growth per person, in other words, income growth more rapid than growth of the labor force. Solow's solution is to introduce technological progress (A) explicitly into the production function. This is usually done in the form of a "labor augmenting" production function, such that:

$$Y = F(K, AL), \qquad \text{x.6}$$

in which is technological innovation directly increase the productivity of labor. This version is consistent with the neoclassical case of steady economic growth under constant returns to scale and diminishing returns to the factors of production.[5]

Like population growth, technological change is assumed to occur at a constant rate. It therefore it is also expressed as an exponential function $A_0e^{\theta t}$, where θ (theta) represents the "growth rate" of technological change. For example, if θ increases at a rate of three percent per year, then the productivity of the average worker also increases by three percent. This can be achieved through labor-augmenting technological change, for example changing from mechanical adding machines to electronic calculators. Alternatively, it could mean that the average worker possesses more knowledge or improved skills (commonly referred to as the accumulation of human capital).

To see the effects of technological change on the Solow diagram, we express the production function by the number of "effective workers" (AL) rather than workers (L) in the previous version:

$$y_e = k_e^{\propto}, \qquad \text{x.7}$$

where y_e is output per effective worker (Y/AL) and k_e is capital per effective worker (K/AL). The capital accumulation equation therefore becomes:

$$\dot{k}_e = \frac{dk_e}{dt} = sy_e - (\theta + n + \delta)k_e. \qquad \text{x.8}$$

The introduction of technology does not change the mechanics of the Solow diagram, but it does slightly alter the interpretation. At the steady state, output *per effective worker* is constant, but output per worker grows by θ, or the rate of technological change. Note that a rise in θ lowers the long run level of income *per effective worker*, but this does not mean lower income per worker at the steady state since the y_e curve would lie below the *sy* (actual income per worker) curve.

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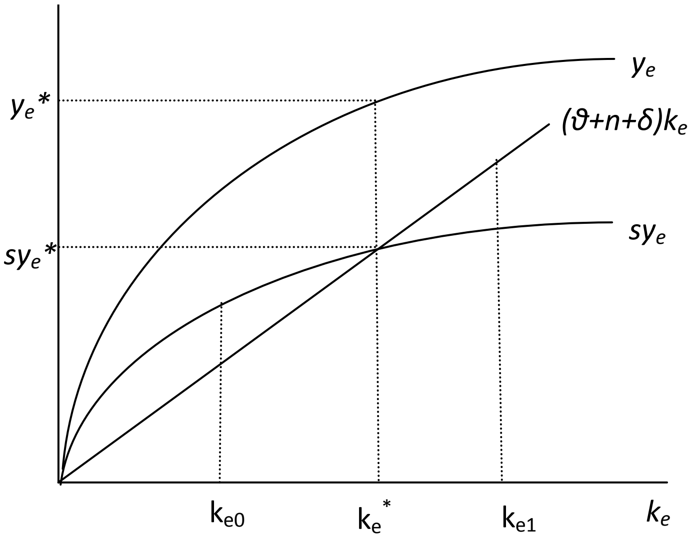
[5] There are three ways to introduce the technology variable into the two factor, neoclassical production function: i) in a "Hicks neutral" or linear manner, or $Y=AF(K,L)$, such that the ratio of the marginal product of capital and the marginal product of labor are unchanged; ii) in the labor-augmenting or "Harrod-neutral" form discussed in the text; or, iii) in the capital augmenting "Solow-neutral" form, $Y=F(AK,L)$, in which inventions raise the productivity of capital. In the specific case of the Cobb-Douglas production function, these three versions of neutrality produce identical results, and therefore are not addressed in more detail here.

Figure 8. The Solow Diagram with Technological Change



Solow (1957) used his neoclassical growth model to estimate the contribution of capital, labor and technology to economic growth in the United States over a forty year period. In doing so he launched the often controversial sub-discipline of "growth accounting." In order to understand the uses of growth accounting we must first recognize its limits. The aggregate production function proposed by Solow is an extension of the firm-level production function of neoclassical microeconomics to the macroeconomy. Firm-level production functions relate physical outputs (for example, wheat or maize) to inputs (land, labor and capital) and describe the efficient input-output combinations of factors and technologies across similar firms (cross-section analysis) or over time (time series analysis). It is important to remember that production functions, whether macro or micro, do not *explain* technological change. The many factors that contribute to production other than using more capital and labor—such as better management and organization, advances in knowledge and skills, improvements to equipment and increasing returns to scale—are bundled together in the catch-all category of total factor productivity. The model does not help us sort through these factors and identify the most important ones.

The aggregate production functions deployed in neoclassical growth theory share the limitations of micro production functions. They raise other issues as well. While firm-level production functions measure inputs and outputs in natural units (for example, land, labor-days, kilograms of seed and fertilizer and bushels of wheat), the aggregate production function expresses output and capital in monetary terms. But since the prices of capital goods depend on the interest rate, there is no logically consistent method to value capital independently and therefore calculate the interest rate based on the marginal product of capital.[6] The same aggregation problem applies to output, since the economy described in the aggregate production function produces one good, which is both consumed and is used as a capital good, and to labor, which can be measured in terms of a

[6] This was the question asked by Joan Robinson that launched a debate that raged for two decades on the measurement of capital and the meaning of aggregated capital stocks (Robinson 1953). For a summary see (Cohen and Harcourt 2003)

physical input (time) but which is not homogeneous in quality (Felipe and McCombie 2005).

Solow recognized these conceptual problems, but maintained that the aggregate production function is a useful analogy or thought experiment rather than a theoretically consistent model of the macroeconomy. His immediate concern was the empirical problem of disaggregating the relative contributions to growth of capital deepening (rising capital-labor ratios) and technological change. In other words, he sought to separate movement along the production function due to increases in capital per worker from an upward shift in the production function resulting from technological change.[7] As represented in Figure 9, the question is how much of economic growth (from y_1 to y_2) is the result of movement along the $f(k)_1$ curve and how much is due to a shift from $f(k)_1$ to $f(k)_2$?

Solow begins his growth accounting exercise with a Hicks-neutral aggregate production function of the form:

$$Y = AF(K, L) = AK^{\alpha}L^{1-\alpha}, \qquad \text{x.9}$$

where A is the total factor productivity term.[8] The assumption of constant returns to scale turns out to be mathematically convenient, since it removes the need to estimate the partial elasticity of output with respect to capital (α) empirically. Under the assumption of perfect competition, the value of α is equal to the share of capital in national income (and $1-\alpha$ is labor's share).[9] Taking logs and differentiating Equation x.9 we get:

$$\frac{\dot{Y}}{Y} = \alpha\frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} + \frac{\dot{A}}{A}, \qquad \text{x.10}$$

Or, in words, the growth of output is equal to capital's share of output times the growth of capital, plus labor's share of output times the growth of the labor force, plus the growth of total factor productivity. If we can find values for α in the national accounts, growth of capital and growth of the labor force, then it is a simple calculation to assign a value to the final term, which represents the shift to the function $f(k)_2$ from $f(k)_1$ in the figure.

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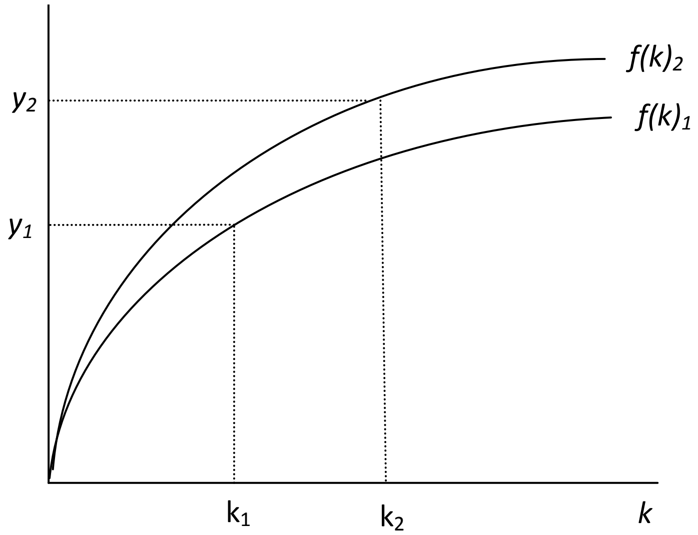
[7] Interestingly, Solow even in this early article included human capital accumulation within his definition of technological change (R. Solow 1957). The implications of separating out the effects of human capital more explicitly are discussed below.

[8] Recall that in the Hicks-neutral production function technical change does not affect the marginal rate of technical substitution, which is the ratio of the marginal product of capital to the marginal product of labor.

[9] This result follows from Euler's theorem, which states that if $Q = f(K,L)$ is linearly homogeneous, then $K\frac{\partial Q}{\partial K} + L\frac{\partial Q}{\partial L} = Q$. In a competitive economy, each factor is assumed to be paid the amount of its marginal product.. Therefore, national income is equal to the amount of each factor used times its marginal product. In this case $\frac{K(\frac{\partial Q}{\partial K})}{Q} = \alpha$, or the partial elasticity of output with respect to capital is equal to the share of capital in output.

Figure 9. Growth accounting



The productivity growth term in Equation x.9 is generally thought of as a measure of technological change, but its residual nature (everything left over that has not yet been captured) means that it includes a wide range of effects including measurement error, increasing returns to scale (since constant returns to scale are assumed), improvements to the quality of labor and movements of labor from low to higher productivity activities. Because of the multifarious nature of these effects and our inability to disentangle them, some economists refer to the coefficient as a "measure of our ignorance" rather than a measure of technical change (Abramovitz 1956).

Solow's main conclusion was that the increase in the capital-labor ratio accounted for less than ten percent of growth in the United States in the first half of the century, meaning that upwards of 90 percent represented shifts to higher level production functions (R. Solow 1957). Other authors supported Solow's finding, notably Abramovitz (in the article cited above) and Denison (Denison 1962). Subsequent work concentrated on analyzing the components of total factor productivity growth, or in other words explaining the unexplained residual. Jorgenson and Griliches (Jorgenson and Griliches 1967) claimed that they could explain the entire residual by adjusting the measurement of capital and labor to take into account technical change "embodied" in capital goods and changes in the skill level of the labor force. The authors concluded on this basis of this work that viewing total factor productivity growth as somehow separate from investment in physical capital and skills is misleading. Denison (Denison 1968) factored in the effects of education, and in addition estimated the effects of increasing returns to scale and structural shifts in employment from low to higher productivity activities. These observations would later form part of the new neoclassical theories that emerged in the 1980s and 1990s, discussed below.

Early work on total factor productivity in the developing countries was surveyed by Nadiri (Nadiri 1972), who noted in his review that capital accumulation appears to be more important—and hence total factor productivity growth less important—in developing than industrialized countries. While this finding depends on the weights assigned to capital and labor in the Cobb-Douglas production function, it may also reflect the nature of capital accumulation in developing economies. For example, if developing countries invest more in public infrastructure projects that do not yield high rates of return, but which are necessary to stimulate future growth, then total factor productivity may be suppressed in the medium term. Highways, electrical power grids, water and sanitation systems, ports and airports are capital intensive investments that are necessary for growth but do not generate much growth themselves. This is an important point that must be kept in mind when comparing rates of investment and incremental capital-output ratios in rich and poor countries.

Growth accounting fell out of favor in the 1970s and 1980s. The debate over the relative importance of capital accumulation and technological change in the growth process was subsumed by measurement issues. While some of these issues could be resolved through more careful use of the statistical evidence, others were entirely dependent on initial assumptions, and therefore irresolvable. Our confidence in models that posit constant returns to scale, diminishing returns to the factors of production, perfectly competitive markets and full employment depends on our assessment of the realism of these assumptions. It was not until the 1980s that neoclassical growth models began to relax some of these strong assumptions, as we shall see in the following sections. Moreover, growth accounting was never intended to explain growth in the sense of clarifying the causes of technological change or high rates of investment. Growth decompositions described the *proximate* causes of economic growth such as labor force growth rates, physical investment and technological change, but not the *fundamental* causes of growth. Growth accounting could not answer important questions about the nature of innovation and technological change or explain why saving rates differ across countries.

Nevertheless, growth accounting enjoyed a revival in the 1990s as economists sought to understand rapid growth in East Asia. In a widely discussed paper, Alwyn Young argued that rapid economic growth in the region was due almost entirely to factor accumulation (more capital and labor) rather than productivity growth (Young 1995). He called his paper "The Tyranny of Numbers" to imply that he was just reporting facts and not making value judgments. Young reached a similar conclusion for China in a later paper (Young 2003). The American economist Paul Krugman popularized Young's conclusions, going so far as to equate Asia's growth to that of the Soviet Union in the first half of 20th century (Krugman 1994). In both cases, he argued, increases in output could be fully explained by growth of the labor force, rising education levels and investment in physical capital. Countries like Korea, Taiwan and Singapore achieved high rates of investment but technological change had been unspectacular. The implication was that growth would eventually stall in Asia as it had done in the Soviet Union when diminishing returns to capital set in.

When the East Asian financial crisis hit in 1997, some observers argued that the crisis was an inevitable consequence of an inefficient growth model that relied too heavily on investment in physical capital and did not encourage innovation. In retrospect, this critique of East Asia's growth performance was overly pessimistic. Moreover, the origins of the East Asia financial crisis lie in financial deregulation and irresponsible borrowing and lending rather than a slowdown in productivity growth. Indeed, by the time of the crisis East Asia's newly industrialized countries were among the most innovative in the world. By 2005, Korea, Taiwan and Singapore all ranked among the top 25 countries in the world in terms of patents per million of population.[10] Korean and Taiwanese manufacturers had entered into technology sharing agreements with some of the world's leading companies, a development that signaled their arrival at the global technological frontier. Research and development spending as a share of GDP is also high in these countries, with Korea ranked fifth in the world and Taiwan tenth in 2010. Using the same metric, Singapore is ranked thirteenth and China twenty-second.[11] Technological change is a key factor in the success of these countries, and has been for several decades.

If innovation is such an important part of the East Asia development story, why did Young, Krugman and others find little evidence of it in their growth accounting models? (Hsieh 2002)makes the case that governments in the region overestimate physical capital investment, which results in low Solow TFP residuals. Output may also be underestimated in countries with large unenumerated (informal) sectors. The Young-Krugman argument can also be challenged on theoretical as well as empirical grounds. No matter how much information we have about investment in physical capital, it is not possible to separate out the effects of *more* capital equipment from *better* capital equipment—better in the sense that more sophisticated technology is embodied in it. The television in your home today is most likely much more technologically sophisticated than the one you owned ten years ago. It is thinner, has a sharper picture and connects to a wider range of input devices. But the prices of the two televisions were probably not very different in real terms. So do you have more capital in your living room or better capital? How much more and how much better? As Nicholas Kaldor pointed out in 1957, in countries where the rate of investment is low the rate of technological progress is also low, and *vice versa*. He concludes that "any sharp or clear-cut distinction between the movement along a 'production function' with a given state of knowledge, and a shift in the 'production function' caused by a change in the state of knowledge is arbitrary and artificial" (Kaldor 1957, 596). We will examine some of the implications of this insight in the final section of this chapter.

[10] Economist Intelligence Unit (2009) A New Ranking of the World's Most Innovative Countries, http://graphics.eiu.com/PDF/Cisco_Innovation_Methodology.pdf. Ranking for East Asian countries include Japan in first place, Korea in seventh, Singapore in seventeenth and China ranked thirty-fourth.

[11] The Royal Society (2011) Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st Century, London. http://royalsociety.org/uploadedFiles/Royal_Society_Content/Influencing_Policy/Reports/2011-03-28-Knowledge-networks-nations.pdf. In absolute terms (rather than as a share of GDP) China is ranked second behind the United States in R&D spending.

Unconditional and Conditional Convergence

One of the main conclusions of the Solow model is that developing countries will normally grow more quickly than rich ones. This result is given by the assumption of diminishing returns to capital. As countries use more capital per worker, the marginal output from each additional unit of capital will fall. Once an economy reaches its steady state level of income, growth is equal to the global or exogenously given rate of technological change. To the extent that low income countries use less capital per worker, they should grow more quickly than rich countries. Global per capita incomes will therefore tend to converge.

The 1950s was a time of great optimism about prospects for economic development. The leaders of the newly independent nations of Asia and Africa believed that political domination by the colonial powers had been the main obstacle to economic progress. Now that they had defeated imperialism, they could embark on the road to industrialization and economic and military power. The rapid pace of economic growth in most developing countries after World War II lent support to the idea that the developing world would quickly close the gap with Europe and North America. The Solow model reflects the optimism of that that era.

However, it is important to remember that the Solow model *does not* predict that all countries will have the same level of income at the steady state. Countries that save and invest a larger share of national income, or which achieve a higher elasticity of output with respect to capital, or where labor force growth is slower, will achieve higher incomes in the steady state. These caveats open up the possibility that some poor countries will grow slowly because they are close to their steady state income levels *even though they are still poor*. In the Solow model, the rate of convergence (Ω) to the steady state level of income as capital per worker increases is given by:

$$\Omega = (1 - \alpha)(n + \theta + \delta), \qquad \text{x.11}$$

such that a larger elasticity with respect to capital (α) slows the rate of convergence, while more rapid labor force growth, exogenous technological change and depreciation *accelerates* it. This is evident from Figure 8, in which the rate of labor force growth, technical change and depreciation rotates the ($n + \theta + \delta$) line counterclockwise such that the steady state is reached at an earlier point on the production function. Conversely, a higher α raises the level of income for each value of capital per worker, which means that the steady state is reached at higher levels of income. If depreciation rates and exogenous technical change are the same everywhere, then the convergence rate is set in individual countries by the labor force growth rate and the elasticity of output with respect to capital, or capital's share of national income.

Thus the Solow model does not rule out the possibility of slow-growing poor countries, but the conditions required to make poor countries grow slowly are not realistic. Actual differences in labor force growth rates between rich and poor countries are not large enough to equalize rates of growth. There is also no evidence that returns to capital are systematically higher in poor countries. Therefore, it is safe to conclude that under most feasible scenarios, the Solow model predicts that poor countries will grow faster than rich ones.

But that is not what we find in the real world. This chapter began with a discussion of the global distribution of income, which recounted the remarkable rise of Europe and the Western Offshoots beginning in the 18th century. The industrial countries form a "convergence club," in which member countries have systematically caught up with productivity in the lead country (the USA). The newly industrialized countries of East Asia constitute another convergence club, this time centered on Japan. But the history of global economic growth is not one of global convergence. Some of the poorest countries of the world have grown more slowly than developed countries, which means that the gap between the richest and poorest has actually widened.

Economists were reminded of the historical fact of divergence in the 1970s, when low and lower middle income countries as a group suffered a growth slowdown that lasted until the 1990s (see Table 1). Indeed, the poorest countries (countries supposedly farthest from the steady state) grew more slowly than lower middle and middle income countries. While growth recovered in the 2000s—largely driven by South and East Asia—it was the better off countries that grew fastest. The optimism symbolized by the Solow model was difficult to sustain in the face of this evidence.

Table 1. Growth of GDP per capita by income category

	1961-1970	1971-1980	1981-1990	1991-2000	2001-2010
high income	n/a	2.7	2.5	2.0	0.9
upper middle	3.2	3.6	1.2	2.7	5.3
lower middle	3.0	2.3	1.8	1.7	4.4
low income	1.2	(0.5)	0.1	0.4	3.1

Table 2. Developing country GDP growth by region (percent per annum)

	1966-1969	1970-1979	1980-1989	1990-1999	2000-2009
East Asia & Pacific	5.1	7.2	7.7	8.2	8.9
Latin America & Caribbean	5.5	5.7	1.9	2.8	3.1
Middle East & North Africa	7.3	6.4	2.3	4.3	4.3
Sub-Saharan Africa	3.9	4.1	2.2	2.0	4.6

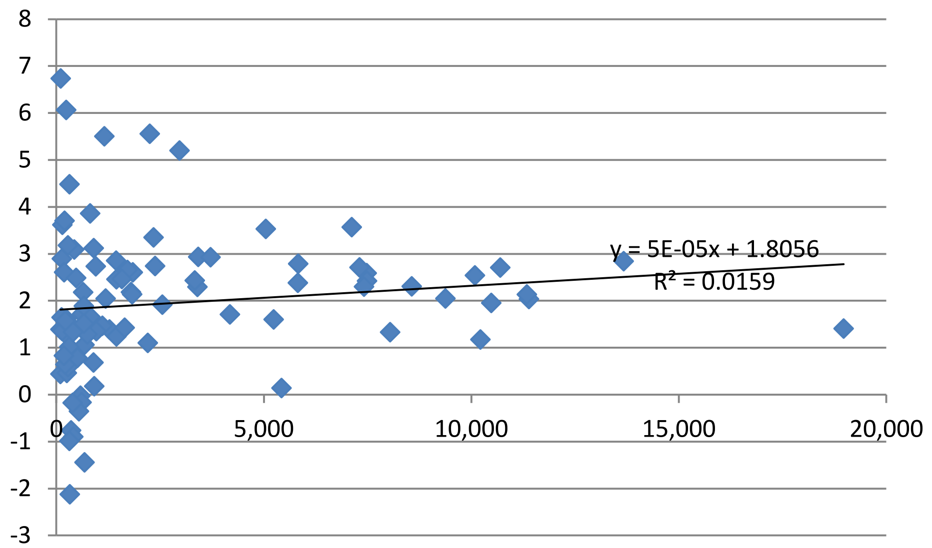
Source: World Development Indicators

In the language of growth economics, the income levels of rich and poor countries did not converge in absolute terms, or "unconditionally." Unconditional convergence means that income growth per capita is faster in poor countries regardless of investment rates, labor force growth, the elasticity of output with respect to capital and other intervening factors. Unconditional convergence can be tested simply by estimating a linear equation in which the growth rate per capita (g) is the dependent variable and the independent variable is the initial level of income per capita (y_1):

$$g = \alpha + \beta y_1. \qquad \text{x.12}$$

If the beta (β) coefficient is found to be significantly negative, then income levels could be said to be converging (hence this result is often referred to as “beta convergence”). Any non-negative coefficient would constitute evidence of divergence. As shown in Figure 10 below, there is in fact no relationship between the rate of economic growth over the long period and initial income per capita in 1960.[12] The figure also reveals that performance of developing countries (as of 1960) has been extremely varied, with some (mostly Asian) countries recording exceptionally high rates of growth, and others achieving no growth or even contracting over the period.

Figure 10. Income per capita 1960 and GDP growth per capita 1961-2010



Source: World Development Indicators

As noted above, the absence of *unconditional convergence* does not necessarily constitute conclusive evidence against the Solow model. Per capita growth rates in poor countries that are equal to or lower than those posted by rich countries could be the result of rapid labor force growth or other factors. Output per worker in the steady state also varies with the savings rate and labor force growth. If we could account for the absence of unconditional convergence because of differences in savings rates and labor force growth, then we could say that convergence is *conditional*. In other words, income levels are not in fact converging, but we can explain the absence of convergence in terms consistent with the Solow model. If saving rates, labor force growth rates and depreciation were identical across all countries, then unconditional convergence would be the result.

At first glance, saving and labor force growth rates do not differ enough between countries to explain the absence of unconditional convergence. The gaps between rich and poor countries are too large to be explained by these factors. One of the most important contributions to the debate in recent years is an article by Mankiw, Romer and Weil (Mankiw, Romer, and Weil 1992), in which the authors argue that the problem is not with the theory underlying the Solow model, but with the definition of capital. They propose an “augmented Solow model” in which human capital is included as follows:

[12] The graph reports per capital income in 1960 and average growth per capita 1961-2010 for a sample of 95 countries for which data are available. Oil exporting countries have been excluded from the sample.

$$Y = AF(K, H, L) = K^{\alpha} H^{\beta} A L^{1-\alpha-\beta}, \quad \text{x.13}$$

where H is human capital proxied by secondary school enrolment rates. Since $\alpha + \beta < 1$ the model exhibits diminishing returns to all capital and therefore converges to a steady state as in the original Solow model. According to the authors, investment in physical and human capital and growth of the labor force explains 80 percent of differences in per capita income across countries. Incomes *conditionally* converge once we account for population growth, investment rates and human capital. As in the Solow model, technology is a public good that is available to everyone, and it lies outside of the model. It is important to remember that conditional convergence does not mean that poor countries are actually catching up. Because investment in physical and human capital and labor force growth rates differ, countries do not arrive at the same steady state level of income. The main conclusion of the model is that poor countries are poor because they underinvest in education, not just because of low levels of capital per worker.

Mankiw, Romer and Weil's augmented Solow model implies that slow-growing poor countries arrive at their steady state incomes at low levels of human capital per worker. Essentially the argument is that income differences are explained by the assumption that poor countries will continue to underinvest in education and skills, and therefore they are already close to their steady state levels of income. Statistically, the authors compound this result by assigning an elasticity of output with respect to physical and human capital ($\alpha + \beta$) of two-thirds, or twice the level of the original Solow model. In effect, this amounts to saying that human and physical capital are all that matter, and poor countries will arrive at their steady state income levels without much of either.

There are two problems with this conclusion. First, if human capital is so scarce, and earns such large profits in low income countries, then we would expect wages for skilled labor to be much higher in poor than in rich countries (Ros 2001, 57). But in fact engineers, chemists and other skilled professionals make more money—even in purchasing power parity terms—in the US and Europe than in Africa and India. That is why they move in large numbers to rich countries, not the other way round.

The second problem follows the same logic. If physical capital is so scarce in the developing world and yields extremely high rates of return, then we should see massive capital flows from rich to poor countries. Although foreign direct investment into the developing world has increased over the past few decades, it is still the case that international capital movements flow mostly between rich countries.

Much of the empirical work on economic growth over the past two decades has consisted of testing Solow-type conditional convergence models with an ever-increasing array of explanatory variables. These models are often referred to as Barro regressions after the economist most closely associated with their development (Barro 1991). Table 3 presents some of the most frequently cited papers and the issues that they have addressed. One criticism often leveled against this work is that it only addresses the proximate (surface) causes of growth, and not ultimate or fundamental factors. For example, the finding that civil war is bad for growth is not very enlightening. Surely we knew that already. Another problem is that the direction of causality is often unclear. Is it war that causes slow growth or the other way round?

It is also apparent from the table that different authors often come up with contradictory results, often using the same data! Sachs and Warner (Sachs and Warner 1995) argue that trade liberalization is good for growth, while Rodriguez and Rodrik (Rodríguez and Rodrik 2000) fail to find any link at all. Forbes (Forbes 2000)believes that inequality promotes growth, while Alesina and Rodrik (A. Alesina and Rodrik 1994) reach the opposite conclusion. Much of the confusion can be attributed to the uncritical (and sometimes very sloppy) use of unreliable data. For example, inequality measures are notoriously difficult to use in cross-country comparisons, since the sampling methods adopted in each country differ so much. But this fact that has gone completely unnoticed in the growth regression literature.

Table 3. Empirical work on factors related to growth

Variable	Finding	Citation
Corruption	Corruption lowers investment and therefore the rate of economic growth	(Mauro 1995)
Capital Account Liberalization	Liberalization accelerates growth during periods of stability and slows it during periods of instability	(Eichengreen and Leblang 2003)
Democracy	Democracy linked to rule of law, human capital formation and free markets, which are good for growth; but liberalize the economy first	(Barro 1996a); (Persson and Tabellini 2006)
Political instability	Instability is bad for growth	(Barro and Lee 1994)
Education	Not clear if education causes growth or growth causes education	(Bils and Klenow 2008)
Engineering education	More engineering students is good for growth, more law students bad	(Murphy, Shleifer, and Vishny 1991)
Ethno-linguistic fractionalization	Fractionalization is bad for policy, institutions and growth	(A. F. Alesina et al. 2003)
Fertility	Lower fertility rates are good for growth	(Barro 1996b)
Government consumption	Less government consumption is good for growth	(Barro 1996b)
Rule of law	Rule of law is good for growth	(Barro 1996b)
Stock markets	The existence of a stock market is good for growth	(Beck and Levine 2004)
Financial market development	Deeper financial markets are good for growth	(Ross Levine 2005)
Latitude	Being far from the equator is good for growth	(Sala-I-Martin 1997)
Trade liberalization	Openness to trade is closely associated with growth	(Sachs and Warner 1995)
Trade liberalization	No relationship between trade and growth	(Rodríguez and Rodrik 2000)
Intellectual property rights	Enforcement of intellectual property rights encourages innovation and growth	(Barro and Sala-i-Martin 1997)

Variable	Finding	Citation
Spanish colonialism	Former Spanish colonies grow more slowly	(Sala-I-Martin 1997)
Inequality	Inequality is good for growth	(Forbes 2000)
Inequality	Inequality is bad for growth	(A. Alesina and Rodrik 1994)
Real exchange rate	Undervalued exchange rate is good for growth	(D. Rodrik 2009)
Real exchange rate	Variability and distortions are bad for growth	(Dollar 1992)
Price level	High prices are bad for growth	(Dollar 1992)
Religion	Buddhist and Confucian countries grow faster	(Barro 1996b)
Religion	Muslim countries grow faster	(Barro 1996b); (Sala-I-Martin 1997)
Religion	Protestant countries grow faster	(Barro 1996b)
Religion	Protestant countries grow slower	(Sala-I-Martin 1997)
Social infrastructure	Good institutions are good for growth	(Hall and Jones 1999)
Social development	Civil community, including newspapers, a strong middle class and social mobility, are good for growth	(Temple and Johnson 1998)
War	Long wars are bad for growth	(Barro and Lee 1994)

Finally, the results are cross-country growth regressions are notoriously fragile, a point made early in the development of this literature by Levine and Renelt (R. Levine and Renelt 1992). They replicated the Barro's 1991 study and find that only the ratio of investment to GDP and the initial level of per capita income are robust. The significance of many of the variables tested in the table above—such as trade, government consumption, population growth, inflation and political instability—depends on the inclusion of other variables or the inclusion or exclusion of certain countries or certain time periods. In other words, the links between growth and the variables in question are neither as direct nor as consistent as the authors claim. Many years and millions of growth regressions have not succeeded in providing clear policy lessons beyond standard recommendations to save, invest, educate and trade.

Endogenous Growth

In the 1980s, a new and more radical answer to the non-convergence problem was proposed in the literature. These economists noted the problems with the Solow model discussed above. Poor countries were not growing faster than rich ones, and differences in the rate of return on capital were not as large as predicted by the model. Capital was not flooding into the developing world to take advantage of the huge rates of return implied by Solow and later by Mankiw, Romer and Weil (Lucas 1988).They proposed that countries that invest a larger share of national income in physical and human capital would not just achieve a higher level of steady state income as in the Solow model, but would also continue to *grow* faster. This implies that the long run rate of growth is endogenous to the model—in other words, the growth rate is not simply a reflection of external factors like the growth of the labor force and the global rate of technological change.

The main idea of endogenous growth theory is that technological change prevents diminishing returns to capital from setting in as the capital stock grows. Without diminishing returns there is no steady state, and hence we no longer expect convergence in income between rich and poor countries. Several different models have been proposed to represent this basic concept.

Romer (1986) based his model on the observation that some kinds of knowledge are nonrivalrous, meaning that they cannot be "used up" like normal goods and services. When you drink a cup of coffee, it is no longer available for someone else to drink (or for you to drink later). Unlike cups of coffee, ideas can be used by many people at the same time or even far into the future. For example, the original steam engines developed in the 18th century were simple devices used to pump water out of coal mines. Over time, inventors improved upon these early designs to make the machines more powerful, reliable and energy efficient, eventually making possible the mechanized factories and explosive productivity growth of the industrial revolution. Thus the fixed costs of invention paid off in the form of higher productivity. The productivity impact of the original invention was felt long into the future, and in a wide range of activities that were unrelated to pumping water out of mines.

The nonrivalrous nature of ideas means that the returns to some innovations are not entirely captured by the innovator (or the company financing the research and development). Knowledge that "spills over" from firm to firm has economic value—so much value in fact that although returns to capital may be diminishing for individual companies, they are constant or increasing for the economy as a whole. The accumulation of inventions costs time and money, but these innovations deliver benefits to everyone, not just to the people who came up with the original ideas. Inventions are therefore a form of positive externality. As knowledge spreads, companies and individual inventors make use of it to create new products, improve old ones, or make production more efficient. The Solow model's assumption of constant returns to scale may not be an accurate description of the relationship between the amount of capital and labor employed and the productivity of labor. Moreover, unlike the Solow model, the rate of technological change affects the growth rate, not just the level of income in the steady state (there is no steady state).

Formally, Romer assumes that labor productivity is determined by the stock of knowledge (Ξ), such that aggregate output is given by:

$$Y = F(K, L, \Xi) = K^{\alpha} L^{1-\alpha} \Xi^{\eta}, \qquad \text{x.14}$$

where $\eta < 1$. An important implication of the Romer model is that firms may under-invest in research and development because they are not able to capture all of the benefits from innovation. This suggests that policies to encourage research and development, for example tax breaks for R&D spending or government-sponsored research, could accelerate the rate of growth.

Another approach is to drop labor completely from the model and assume that capital, including physical and human capital, receives all of national income. This could mean that factor payments are made to technology embodied in capital and to the skills embodied in labor, not labor *per se*. 'AK' models (Rebelo 1992) posit technical progress as a constant, constant returns to physical and human capital (α =1) and no population growth, in which:

$$Y = AF(K) = AK \quad . \qquad \text{x.15}$$

As long as investment is larger than depreciation, then growth is an increasing function of the investment rate. Long-run growth is endogenous to the model because it no longer depends on some unspecified residual. Investment affects the rate of growth directly, not just the long run level of income as in the Solow model. The main policy implication drawn from the model is that anything that reduces the rate of capital accumulation will have a direct and large impact on the rate of growth. For example, tax policies that discourage investment will reduce the rate of growth and the long-run level of income.

Other versions have also been proposed. Unfortunately, we have no way to test these various models empirically because they rely heavily on unobservable, abstract variables such as the stock of knowledge and technological progress. Recall that the Solow model never measured technological change, but rather assumed that the unexplained residual (that is, everything other than capital and labor) is a generalized measure of progress.

Another problem with endogenous growth models is that they imply *too much* divergence in incomes over time. As Solow has pointed out, even slight increasing returns to scale at moderate rates of investment would generate *infinite national output* in as little as 200 years (Solow 1994)! Although this problem is avoided in AK models with constant returns to scale, it is not apparent why returns to capital would be exactly equal to unity. Any shift towards diminishing or increasing returns to scale would completely undermine the conclusions of the model.

Alternative approaches to growth

Like all models in economics, growth models work out the implications of key assumptions. These assumptions in turn reveal value judgments that economists make when they think about the fundamental relationships that shape economic outcomes. Neoclassical growth models—both Solow-type and endogenous growth models—start from a Say's Law world in which savings always equals investment and there is no unemployment or unutilized capacity. All of the action is on the supply side, since it is assumed that there is a market for everything produced, savings are always mobilized in new investments and a job can be found for every willing worker. The distribution of income is not an important factor in these models, since it is assumed that wages are equal to the marginal productivity of capital and profits (rents) are equal to the marginal productivity of capital. Solow's model also assumes constant returns to scale and diminishing returns to the factors, assumptions that are abandoned by endogenous growth theorists.

Growth theories in the Keynesian tradition place more emphasis on aggregate demand in the long run. As Say's Law is not in force, investment is no longer automatically equal to saving, and so the rate of investment is once again an important factor in determining average productivity. Low rates of investment—regardless of the level of domestic saving—increase the rate of unemployment or underemployment of the labor force. Conversely, high rates of investment imply higher capacity utilization and more rapid productivity growth. We therefore need to inquire into the causes of investment, particularly investment in high productivity activities. Relaxing Say's Law also brings other potential growth bottlenecks to the fore, for example supplies of food and other essential goods and supplies of foreign exchange.

Many Keynesian models also reject the assumption of continuous substitution between the factors of production. In place of the Cobb-Douglas production function, these approaches assume fixed coefficient (Leontieff) technology, with technological progress embodied in the factors (new machines and high-skilled workers). Technical change is therefore endogenous in the sense that it cannot be separated from capital accumulation and learning. The assumption of fixed coefficient technology also means that low rates of investment generate unemployment and hence low productivity, since labor cannot seamlessly substitute for capital.

Various "structuralist" growth models have been proposed to describe the growth process in a world without Say's Law. Following Michal Kalecki, Arthur Lewis and Nicholas Kaldor, they examine the growth implications of shifting labor and capital from the low productivity traditional sector to the high productivity modern sector (Kalecki 1993; Lewis 1954; Kaldor 1957). The traditional sector is not synonymous with the agricultural sector, since some forms of agricultural production are capital intensive and achieve economies of scale in production. Many jobs in the traditional sector are low productivity service sector jobs like petty trade and domestic service. The main point is that the traditional sector is characterized by widespread underemployment. Growth is associated with movements of labor from the traditional to the modern sector.

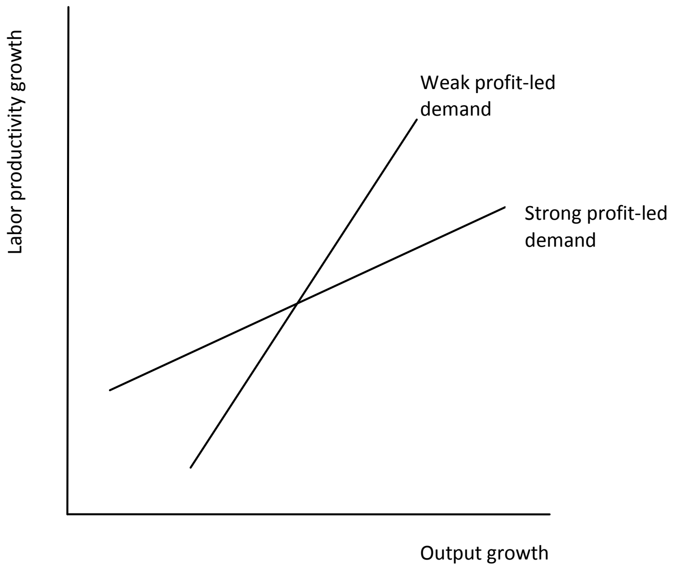
Ocampo, Rada and Taylor have recently proposed a simple structuralist model that explores the main growth issues raised in a dual sector economy (Ocampo, Rada, and Taylor 2009, Chapter 8). In this model, output growth in the modern sector responds to lower real wages and higher productivity growth. The key assumption is that investment is positively associated with a higher rate of profit and the price competitiveness of domestic production as compared to import substitutes or export competitors. Therefore, investment is inversely related to unit labor costs (labor inputs per unit of output). This is captured in the equation:

$$\widehat{X}_M = \widehat{A} + \alpha(\xi_M - \widehat{\omega}), \qquad \text{x.16}$$

where $\widehat{X}_M$ is the growth of output in the modern sector (M), ω is the real wage and ξ_M is labor productivity growth in the sector. $\widehat{A}$ is an intercept term, which captures the level (as opposed to the rate of change) of modern sector output. For example, investment in irrigation systems raises productivity on small farms, which in turn increases demand for fertilizer produced in the modern sector. This would result in an increase in $\widehat{A}$. If the parameter $\alpha > 0$, then productivity growth in excess of real wage growth is associated with faster output growth. This is "profit led" growth since rising profitability (productivity in excess of wage increases) drives investment and therefore aggregate demand. If $\alpha < 0$, growth is "wage led" growth, since growth speeds up when wages increase more than productivity. Profit led growth can be strong (larger positive alpha) or weak (smaller positive alpha) depending on the relationship between output and productivity growth.

The cases of strong and weak profit led growth are shown in Figure 11. Note that slow wage growth does not ensure strong profit led growth unless labor productivity is also rising in the modern sector. One reason to expect that profit led growth is more durable than wage led growth is the potentially damaging effects of foreign exchange constraints. Although not included in the model, reliance on domestic demand on the basis of wage led growth would make exports uncompetitive, which would lead either to dependence on imported capital or currency devaluation (and a lower real wage) or both.

Figure 11. Profits, productivity and output growth



A key assumption of the Ocampo, Rada and Taylor model is that the relationship between output growth and productivity growth in the modern sector goes in both directions, in other words more rapid output growth accelerates labor productivity growth. Formally:

$$\xi_M = \bar{\xi}_M + \gamma \hat{X}_M. \qquad \text{x.17}$$

In words, the rate of productivity growth is equal to the baseline rate of productivity growth plus output growth in the modern sector adjusted by the elasticity indicator γ (gamma). The elasticity indicator represents the impact of output growth on productivity in the modern sector following the relationship known as the Kaldor-Verdoorn Law (Kaldor 1967). Kaldor (who credited P.J. Verdoorn for the insight) argues that rapid growth in the modern sector creates scope for static and dynamic economies of scale. Static economies of scale are made possible by the growth in demand, which allows for larger units of production. Dynamic economies of scale relate to the improved technologies embedded in new plant and equipment, and by "learning by doing" effects. Kaldor's dynamic economies of scale are similar to the spillover effects described in endogenous growth models. The difference is that Kaldor links these effects to output in the modern sector rather than investment. However, the message is essentially the same: high rates of investment create demand for the products of the modern sector, and also accelerate the processes by which new machines replace old and skilled replaces unskilled labor. Good things tend to come together.

By definition labor productivity growth in the modern sector equals output growth less growth in the size of the sectoral labor force ($\xi_M = \hat{X}_M - \hat{L}_M$). If for the moment we assume no increase in real wages (to simplify the math), then growth of the labor force in the modern sector is:

$$\hat{L}_M = \hat{A} + (\alpha - 1)\xi_M. \quad \text{x.18}$$

Or in words, productivity growth is only associated with an increase in the labor force in the modern sector when growth is very strongly profit led ($\alpha > 1$). This is potentially relevant to the Vietnamese case, in which low levels of profitability in the state-owned modern sector have been accompanied by a slow rate of job growth. If demand is wage led ($\alpha < 0$), then the sector is not competitive and labor force growth will slow.

Unlike neoclassical models, structuralist models do not assume that labor is fully employed. Unemployment or unemployment is crowded into the traditional sector, with the implication that moving labor from the traditional to modern sectors does not decrease output from the former. In other words, returns to additional labor in the traditional sector are less than zero ($\sigma_T < 0$). Income growth in the traditional sector is equal to growth of the labor force plus the growth of productivity, which is in turn equal to the initial level of productivity in the traditional sector plus the growth of the traditional sector labor force adjusted for returns to scale:

$$\hat{Y}_T = \hat{L}_T + \xi_T = \bar{\xi}_T + (1 + \sigma_T)\hat{L}_T. \quad \text{x.19}$$

Note that a sigma of minus one ($\sigma_T = -1$) leaves income equal to the initial level of productivity regardless of additions to or subtractions from the labor force in the traditional sector. This implies that per capita income rises in the traditional sector as labor is withdrawn.

As shown above, given a positive alpha (profit led growth), higher productivity growth in the modern sector generates more rapid labor force growth in the modern sector. This may seem counter-intuitive at first glance: if productivity is rising quickly in the modern sector, won't modern sector employers need to hire fewer workers? No, because in this model productivity growth is associated with rapid output growth following the Kaldor-Verdoorn relationship. Higher productivity increases profits, stimulates investment and increases the competitiveness of the modern sector. This relationship does not hold if alpha is negative and growth is wage led (equation x.18). In this case, productivity growth is associated with slow or negative labor force growth in the modern sector.

Other structuralist models explore these relationships under different assumptions, and consider other factors, such as the foreign exchange constraint (Thirlwall and Hussain 1982), the supply of wage goods from the traditional sector and income distribution effects (Kalecki 1993). The policy implications differ depending on the nature of the assumptions and the form of the relationships examined. However, the relaxation of Say's Law shifts the focus of structuralist models from the supply side to sources of aggregate demand. Most models in this group also reject the assumption of constant returns to scale for the economy as a whole in favor of increasing returns in the modern sector and decreasing returns in the traditional sector. This sets up the dynamic described above in which growth is driven by the movement of capital and labor from the traditional to the modern sector.

Policy implications

Vietnam has achieved remarkably rapid and consistent economic growth over the last two decades, ranging in most years between six and eight per cent. There were two period of slowdown, both of which were associated with external shocks, namely, the East Asian financial crisis of 1997-1998 and the global financial crisis of 2008-2009.

Do the theories discussed in this chapter shed light on Vietnam's growth experience? More importantly, can we learn lessons from growth theory that can help Vietnam's policy makers accelerate the rate of economic growth to deliver higher incomes and a better standard of living for the Vietnamese people?

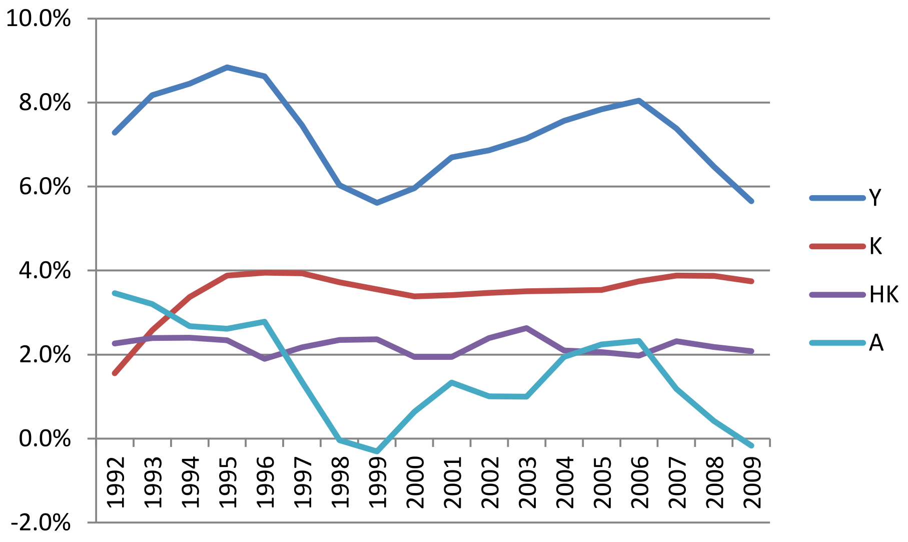
One of the main points that we have made in this chapter is that the conclusions of economic models flow from their key assumptions. Economic models simplify reality to focus on what the modeler views as the most important relationships in question. However, the decision to focus on some relationships draws our attention from other factors that may be of equal or greater importance. Models are not objective. They reflect the values and prejudices of the modeler.

Bearing these caveats in mind, we have conducted a growth accounting exercise based on an augmented Solow model to measure the contribution of labor, capital, human capital and total factor productivity in Vietnam from 1992 to 2009. Average years of schooling is used as a proxy for human capital accumulation. We assume that the elasticity of output with respect to capital (alpha) is 0.34, a depreciation rate of five percent and returns to human capital of ten percent per annum. All of the typical assumption of the Solow model apply: constant returns to scale and diminishing returns to the factors, Say's Law in effect and Cobb-Douglas production function.

The results are shown in Figure 12. We find that the contribution of capital is large and very consistent of time, and that the contribution of human capital is limited. The most interesting finding is the small contribution of total factor productivity, particularly in the most recent period when TFP has contributed nothing to economic growth. As discussed in this chapter, we need to treat these results with caution. The measurement of capital is always conceptually dubious, and there is reason to believe that developing countries may overestimate capital accumulation and underestimate GDP growth. Moreover, we cannot leap to the conclusion that slow TFP growth reflects an absence of technological change. Although TFP can be interpreted as a measure of technological change, it is more accurately described as a residual containing all unmeasured effects.

Nevertheless, other evidence does support the conclusion that Vietnam is not suffering from a lack of capital investment, but rather underinvestment in education and inefficiency in the modern sector. Investment as a share of GDP in Vietnam is among the highest in the region, and secondary and tertiary education enrolment rates are among the lowest. Some of the a large state-owned industrial conglomerates have performed poorly, investing heavily in land and financial ventures rather than the acquisition of new technology, skills and better management.

Figure 12. Growth accounting, Vietnam 1992-2009



From a structuralist perspective, Vietnam's industrial sector has underperformed relative to agriculture in terms of labor productivity growth over the past decade (Figure 13). This is both surprising and worrying, since growth of the labor force in the modern sector depends on own sector productivity growth. In structuralist models, economic growth in developing countries is driven by the shift of labor from low productivity agriculture to higher productivity jobs in the modern sector. Unlike the Solow model (but akin to endogenous growth models), structuralists assume increasing returns to scale in the modern sector and decreasing returns in the traditional sector. We would therefore expect productivity growth to be more rapid in industry than agriculture, but this pattern has yet to emerge in Vietnam. Although there are a number of possible interpretations of these statistics, close observation of large firms in Vietnam suggests two reasons why manufacturing is not achieving increasing returns. First, manufacturing for export is heavily dominated by labor intensive industries like garments and shoe production. No one has yet figured out how to mechanize hand sewing of garments and shoes to a degree that yields substantial economies of scale. Second, too many of Vietnam's large firms are not really large firms. They are actually collections or conglomerates of numerous small firms that also do not achieve economies of scale. In this connection, recall that before Vinashin was restructured the company consisted of 445 subsidiary firms and 20 joint ventures. The same can be said for many other state corporate groups.

Figure 13. Industrial and agricultural productivity growth, Vietnam 1997-2009

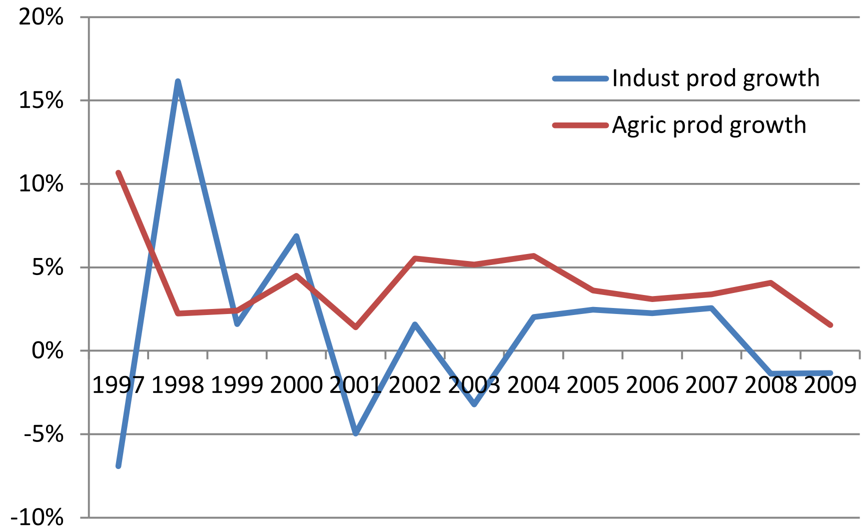
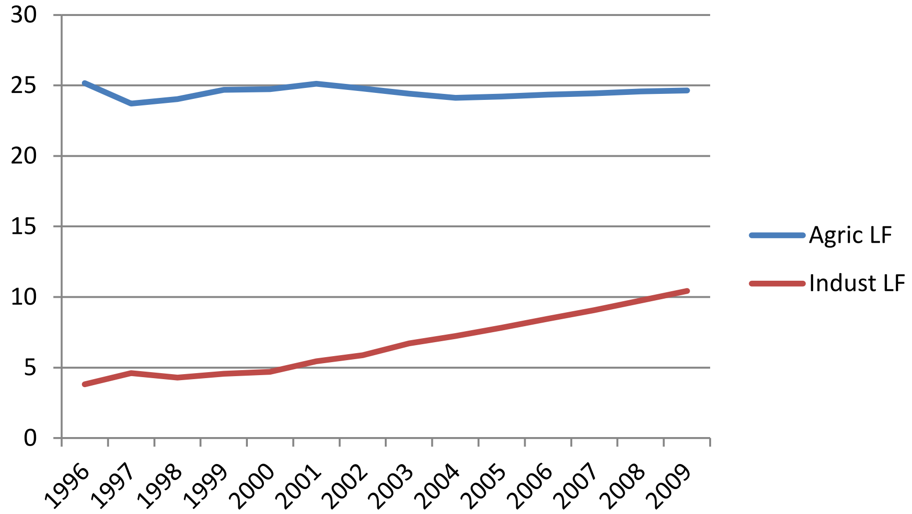


Figure 14. Agricultural and Industrial Labor Force, Vietnam



The slow rate of labor absorption in Vietnam's modern sector means fewer high wage jobs for Vietnamese workers, and also a slower rate of GDP growth. As shown in Figure 14, although the industrial sector labor force doubled in size from 1996 to 2009, it started from a small base. Meanwhile, the agricultural labor force has remained about the same size. The industrial and agricultural sectors are not perfect proxies for the modern and traditional sectors, since there are many high productivity agricultural activities (for example, large scale plantations) and low productivity jobs classified as industrial (for example, traditional handicrafts). Nevertheless, the statistics do suggest that accelerating growth in Vietnam will require increasing the rate of productivity growth in the modern sector and transferring labor from agriculture to industry at a more rapid rate.

The two perspectives discussed above arrive at similar policy conclusions, albeit from different routes. Both the neoclassical and structuralist models focus on productivity growth. This is to be expected, since all economists agree that economic growth in the end is generated by the growth of productivity, or output per person per day. The augmented Solow model emphasizes the contribution of education and skills, and the efficiency of capital investment. The policy recommendations that flow from this analysis include reform of the education system to increase participation and the quality of schooling and the strengthening of market mechanisms to achieve more efficient investment. The structuralist model places greater stress on increasing returns to scale in the modern sector and the capacity of this sector to absorb labor from low productivity traditional occupations. In addition to education reform and more efficient investment, structuralists would also advise industry policies to encourage investment in industries with greater potential to achieve increasing returns to scale, and to discourage the formation of state conglomerates that consist of numerous small and inefficient units.

Conclusion

The reader has probably realized by now that growth theory cannot tell us why some countries are rich and others are poor. We know that growth in the long run is related to the accumulation of capital, technological change, the acquisition of knowledge and skills and movements between sectors of capital and labor. It is easy to show how all of these factors combine to produce success. It is much more difficult to explain why some countries find it so difficult to acquire technology, accumulate knowledge and stimulate productive investment. Success is straightforward, but there are millions of different ways to fail.

Growth models cannot explain failure because every country has its own unique history, politics, society and set of natural and human endowments. We cannot expect a statistical model to capture the complexities of institutional development, political conflict and social and cultural change, and the ways that these factors combine to shape the process of economic development.

Still, growth theory has its uses. Models can help us focus on specific interactions of interest to policymakers if we are explicit about the assumptions (and the implications of these assumptions) and careful in the way that we use data. We must always remember that growth models do not yield certainties, but rather interpretations of reality that reflect our prior beliefs about the nature of economic change. If we keep these caveats in mind, growth models can help us to compare experiences across countries and identify obstacles to growth in specific situations.

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