Inequality between countries

Evidence and economic theory

Chapter 2 on
Democracy, Institutions and Economic Policy

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Translation financed by the UOC

PID_00258398

2. Inequality between countries. Evidence and economic theory

1. Introduction

What factors explain the wealth inequality that exists between nations? Why have some countries grown steadily for decades to reach very high levels of economic development while others have not? What are the causes of economic growth? From the very outset of the discipline of political economy, from Adam Smith's studies, these are the questions that economists and, in general, social scientists have diligently tried to answer from different analytical perspectives. Growth experts have dedicated a great deal of effort to searching for strategies that can lift a country out of poverty but that are also economically sustainable. Apart from the intellectual appeal that these questions may hold, deeper practical reasons justify their importance. The welfare and living conditions of the vast majority of citizens in the poorest countries depend, to a large extent, on the growth potential of their economies and, consequently, on the ingenuity of experts in providing suitable formulas for economic policy.

Economic progress and the social transformations resulting from a period of sustained economic growth tend to benefit all citizens,

including the poorest sectors. Although there have undoubtedly been cases where growth episodes have disproportionately favoured the more privileged classes, a continuous increase in wealth has also provided gains to families with fewer resources, so much so that it has become, for some academics (Collier 2007; Rodrik 2007), the most powerful instrument for systematically reducing poverty. The combination of historical evidence and the more contemporary experiences of countries around the world seems to point in this direction. A major historical phenomenon contributing to the material advancement of modern societies was the Industrial Revolution. Thanks to the technological innovations introduced by this phenomenon, the economic well-being of the industrialised nations began to increase systematically from the nineteenth century to levels far higher than those that had been previously reached at any other time in history. But the most advantaged social groups did not entirely monopolise these increases in wealth; in fact, data on economic inequality and quality of life in England during the years before and after the Industrial Revolution suggest that it was the lower-skilled workers who reaped the greatest gains from the economic changes (Clark 2007). For example, the differences between the rich and the poor in terms of living standards such as health, life expectancy, literacy or infant mortality decreased considerably compared to the differences that existed in the pre-industrial era. Regarding the most recent empirical information on the importance of growth in reducing poverty, Rodrik (2007) highlights the fact that, today, the highest incidence of poverty is found in those countries that have had the lowest rates of growth since the start of the Industrial Revolution.

The redistribution of wealth from the richest to the poorest sectors of society represents the main alternative means for eradicating poverty. However, while this other option may have positive effects on the welfare of individuals at the lower ends of the income distribution spectrum, without economic growth the effectiveness of such redistribution to improve the material conditions of the most disadvantaged groups living in the poorest countries is limited. In the best-case scenario, full equality of income would mean that all individuals of a certain society would enjoy, at best, an income equal to the average income of the economy. But if this is not enough to guarantee minimum levels of welfare, then global economic growth is clearly an essential requirement to end the problems of deprivation and scarcity of resources that are suffered by many of the people in the developing world.

Economic development is a multidimensional phenomenon that encompasses various aspects of *material* well-being. It has to do not only with the wealth of nations, but also with increases in life expectancy, a constant decrease in infant mortality rates and improvements in access to health and education, among other aspects. Economic progress leads to rises in the basic living conditions of society as a whole. However, average income and its growth rates are the main indicators of economic development that are usually used in empirical analyses. There are two reasons for that. First, empirical analysis is made easier by restricting the complex nature of this process to a smaller series of variables. Second, and in line with the data observed, the other aspects of well-being, such as health or education, are strongly associated with the average income level of the country, which can therefore serve as an overall indicator of other development aspects. This part of the book focuses on this last progress dimension and analyses the economic, political and institutional factors that explain the differences observed between countries and over time (within the same country) in terms of per capita income levels and growth rates.

Table 2.1 Per capita income

According to one of the most influential growth-theory economists, Robert Lucas (1988), the study "of economic development is simply the problem of accounting for the observed pattern, across countries and across time, in levels and rates of growth of per capita income". Per capita income is equal to the total income or production of a society, divided by its population. The information on the income (or production) on which the data sources used in this book are based refers to the gross domestic product (GDP), that is, the market price value of all final goods and services produced within the national territory by national and foreign production factors (labour, capital, etc.) within a specific period. To facilitate comparison between countries, the value of national income or production is converted to a common currency, usually US dollars. In addition, the prices used in the calculation of said value are referenced to a base year in order to discount inflation, so that the final data refer to real per capita income (purchasing capacity).

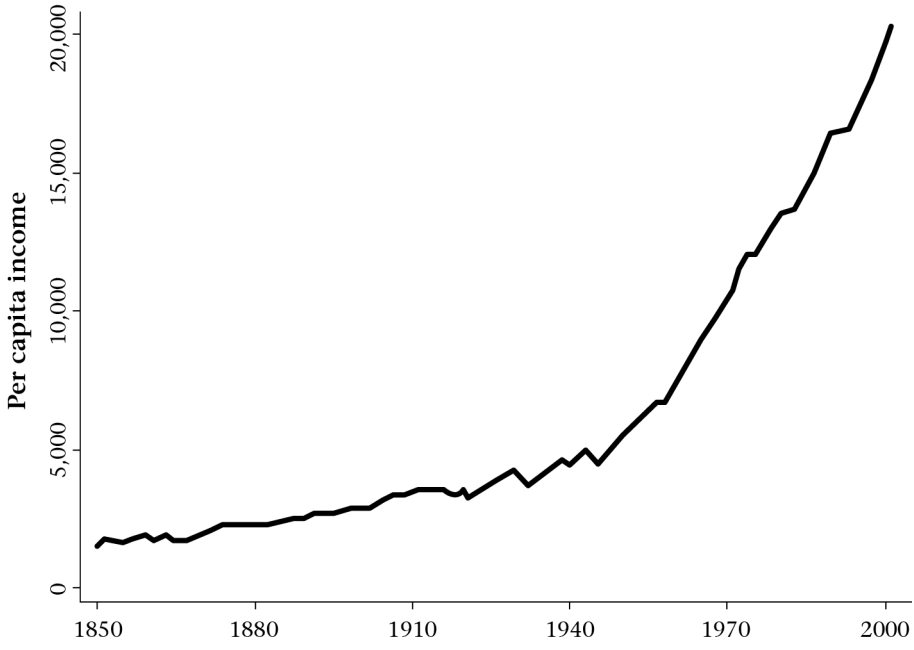
2. The "facts" of development: temporal evolution and divergence between countries

The process of economic development that has led modern societies to reach current levels of wealth is a relatively recent phenomenon that took place during the past two centuries of the history of humankind. Before the nineteenth century, the average standard of living in the global economy had not experienced any upward trend (Clark 2007). According to data compiled by Maddison (2003), between the year 1 AD and 1820, the average growth rate of world per capita income was not above 0.05. In Western European countries, it was around 0.1 per cent. It was from the late eighteenth and early nineteenth centuries, as a result of the advances in production that led to the Industrial Revolution and the fall in fertility associated with the demographic transition of the time, that significant increases began to be observed in the average wealth of modern societies.

Figure (2.1) shows the evolution of per capita income in all of those societies since 1850. To create the graph, the Maddison database (2003) has been used, which provides annual data, starting from that year, on per capita income in different countries[1]. Considering the whole period analysed in the graph, the first stages of economic modernisation were characterised by moderate but constant rises in average income. From the start of the First World War until the end of the Second World War, the GDP per capita of developed nations continued to progress although it was more irregular owing to the economic crises caused by the two wars and the Great Depression of the 1930s. The end of the Second World War spawned the "golden age" of economic growth (Helpman 2004), which lasted until the 1973 oil crisis. During these years (1950–1973), the most advanced economies experienced the greatest expansion in their history, with an average growth rate during the period of 4 per cent per year. As a result, the per capita income of these economies almost tripled from $4,500 (in constant 1990 dollars) in 1950 to about $11,400 in 1973. In the eighties and nineties, despite the slowdown in

1 Data on GDP (per capita) refer to GDP (per capita) measured in 1990 international, or Geary-Khamis, dollars. The countries included in the chart are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States. For more information on this historical economic development database, which covers a worldwide sample of nations, see Maddison (2003).

Figure 2.1 Historical evolution of the average income of developed countries



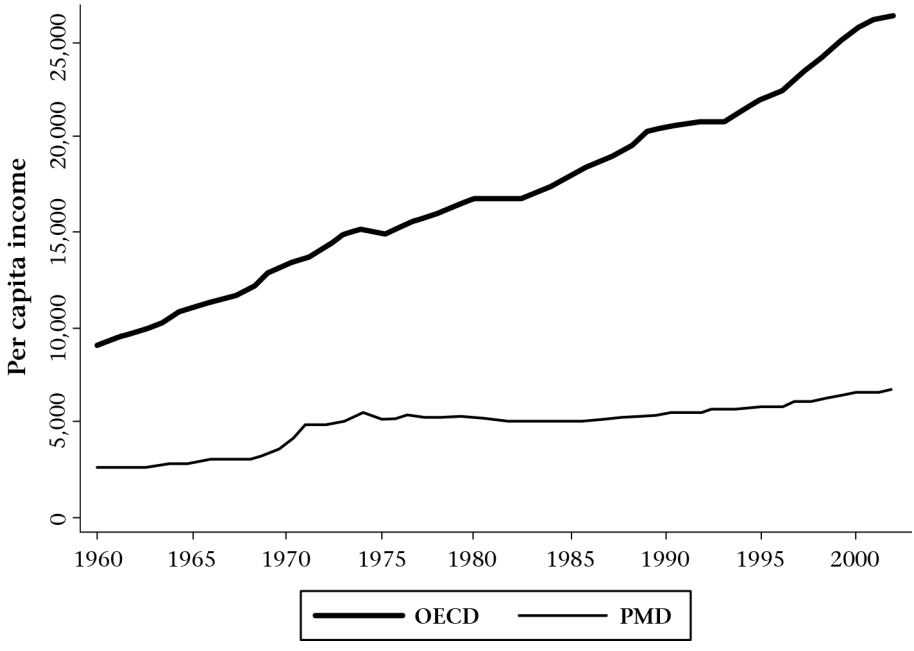
SOURCE: Maddison (2003).

economic growth (the average rate of which fluctuated around 1.88 per cent), the per capita income of the group of most developed countries continued its general growth trend until 2001, the last year for which information is available in Maddison (2003).

The economic trajectory of the rest of the world's countries has been radically different. Although until the nineteenth century the differences in material conditions between these and the group of more advanced nations were barely significant, they began to widen with the Industrial Revolution (Clark 2007, Helpman 2004). The economic opportunities offered by new production techniques and advances in knowledge were not exploited in the same way in the different regions of the planet. While the main European nations managed to lift and continuously raise their living standards, most of the economies of Latin America, Africa and Asia were left behind in the overall economic development process. Far from decreasing such disparities during the twentieth century and, in particular, during the golden period of growth after the Second World War, inequality between countries increased considerably.

Various empirical studies on international inequality, focused on the second half of the twentieth century, have confirmed the existence of enormous differences in income between countries. Thus, for example, Parente and Prescott (1993) point out that, during the period 1960–1985, the richest 5 per cent of nations had an average income per person that was 29 times higher than that of the poorest 5 per cent. Pritchett (1997) and Sala-i-Martin (1996) conclude that the economic gap separating poor countries from more prosperous industrial societies has widened over time. As can be seen in Figure (2.2), the average per capita income of the OECD[2] countries has been growing significantly during the 42 years

Figure 2.2. Evolution of average income, 1960–2002. OECD and least developed countries (LDCs)



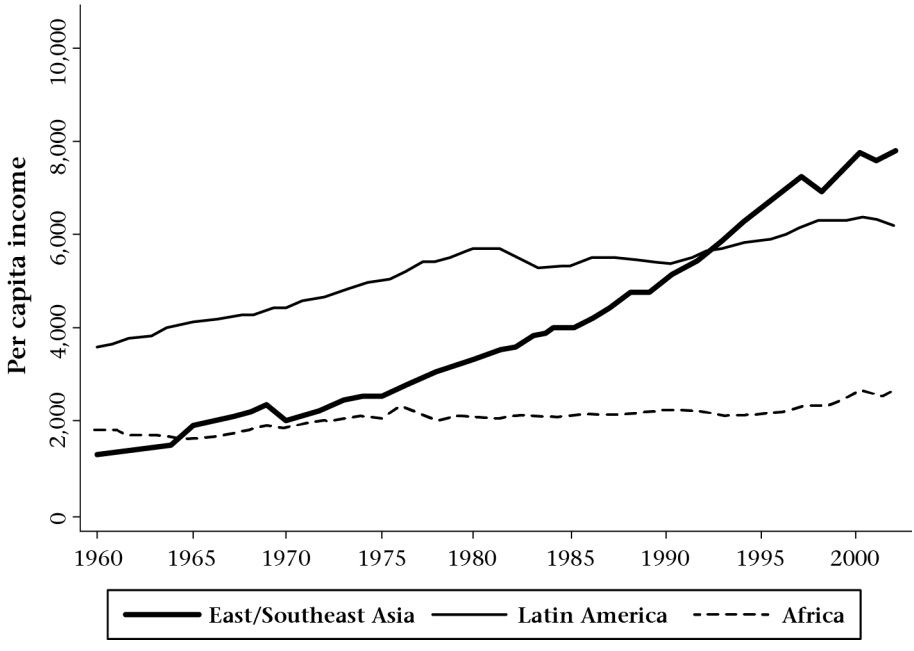
SOURCE: Penn World Table 6.2.

2 The OECD (Organisation for Economic Co-operation and Development) countries included in the analysis correspond to the 21 richest members of the organisation with data on per capita income, namely Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, Holland, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, Australia, New Zealand, Canada, the United States and Japan. The category of least developed countries (LDCs) contains the other nations of the world.

covered by the period 1960–2002, while that of the remaining least developed nations has risen only slightly. The economic distance between these two groups of countries has increased accordingly; the per capita income ratio of OECD countries compared to that of other countries has gone from 3.6 in 1960 to 4.0 in 2002[3].

The evolution of all of the least developed economies reflects a near stagnation in income, but this does not mean that the trend is the same in each of the societies considered. In fact, Figure (2.3), which shows the evolution in three different regions of the

Figure 2.3 Evolution of average income, 1960–2002. Latin America, Africa and East/Southeast Asia



SOURCE: Penn World Table 6.2.

3 Data on levels and growth of per capita income are taken from the Penn World Table database, version PWT6.2, built by Alan Heston et al. (2006). For a detailed description of this database, see Summers and Heston (1991), and for more information on the PWT6.2 version, see the web page http://pwt.econ.upenn.edu/. Regarding the definition of the variables, the level of per capita income is the real gross domestic product (GDP) per person in constant international prices based on the year 2000, and the growth of income refers to the real growth of the previous variable.

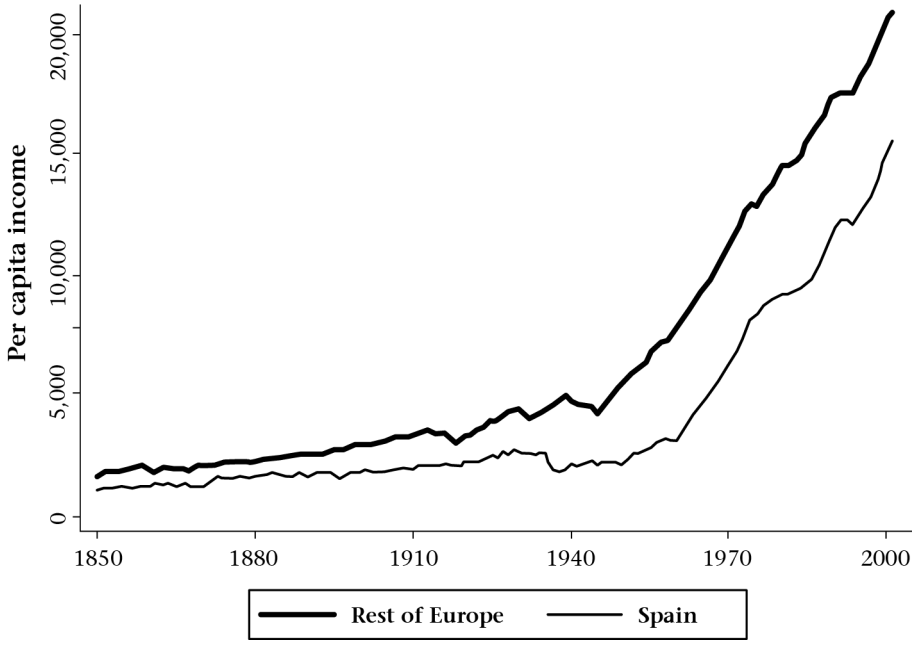
world (Asia, Latin America and Africa), indicates that, within the least developed countries category, experiences of growth are very diverse, as other empirical analyses have shown. Of particular interest is the extraordinary development of per capita income in the economies of Southeast and East Asia, which grew at an annual rate of 3.5 per cent during the period 1960–2002, well above the corresponding global average rate of 1.9 per cent annually. The most notable cases are Malaysia (which has grown on average at an annual rate of 4.6 per cent), Thailand (4.7 per cent), South Korea (5.9 per cent), China (5.7 per cent), Singapore (5 per cent) and Taiwan (6.4 per cent). In these last four countries, the reduction in the economic gap that, in 1960, distanced them from the OECD countries has been spectacular. For example, while in 1960 the per capita income of South Korea represented 16 per cent of the OECD per capita income, in 2002 it accounted for 65 per cent.

In contrast, economic performance in Latin America and Sub-Saharan Africa has not been as encouraging. Rather, the general income trend in African countries has been one of stagnation throughout the period studied, with real economic disasters such as Somalia, Liberia or the Democratic Republic of the Congo (formerly Zaire), which have had average annual contractions of –1.8, –2.3 and –4.1 per cent, respectively. After a degree of economic expansion during the 1960s and 1970s, growth in many Latin American countries slowed in the 1980s, even reaching negative annual rates. These data corroborate, as do other empirical studies (Pritchett 1997), the enormous diversity of economic development experiences occurring within the group of least developed countries. Further proof of this lies in the fact that the range of growth rates of the countries included in the Figure (2.3) — showing average rates from 1960 to 2002 — ranges from –4.1 per cent to 9.8 per cent.

2.1. Economic development in Spain

The average wealth of the Spanish economy has followed a path similar to that of the main European nations, although always with a certain delay, which intensified between 1930 and 1950. This period was marked by the relatively long stagnation of the 1930s, the Spanish Civil War and the prolonged economic autarky of the post-war period. According to the Maddison (2003) data, shown in Figure (2.4), in the year 1850 the average Spanish income was around $1,000 (1990 constant dollars), compared to the European

Figure 2.4 Economic development in Spain (and Europe) since 1850[4]



SOURCE: Maddison (2003).

average of $1,600. The later development of the Spanish economy was characterised by a moderate volatility in per capita income (ranging from $1,100-$1,300) until the early 1870s. The restoration of the Spanish monarchy in 1876 gave way to a period of relative political stability in Spain that coincided with a steady phase of economic expansion. Growth accelerated during the 1920s and the average income exceeded the $2,700 barrier in 1929. However, the economic distance compared to the most industrialised European nations began to expand gradually from 1886.

After 1929, Spanish society entered a phase of crisis and stagnation that lasted until 1950 and was unable to recover the standard of living achieved in 1929 until 1955. The causes of this recession were diverse; some, such as the 1929 Wall Street Crash, were of an

4 The European countries included in the "rest of Europe" average calculation are Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland and the United Kingdom.

international nature that also caused considerable losses of welfare in the main European powers. However, the readjustment and subsequent recovery of these economies after the economic crash occurred within a shorter time period than it did in Spain. Another major factor that intensified the economic depression in Spain during the 1930s was the destruction of resources and of the productive framework that sparked off the Spanish Civil War. The War caused a considerable decline in per capita income, which in 1938 fell to 1900 levels. As for the sectoral composition of the economy according to the employment of the labour force, the proportion of the active population in industry fell to 22 per cent in 1940 (the 1920 level), and the relative proportion of agricultural workers increased, exceeding 50 per cent of the total employed population (Boix 2004).

The economic stagnation continued even after the Civil War had ended and lasted throughout the 1940s. It was only after 1950 that a slight positive trend in the average Spanish income was seen once again. By contrast, as shown in Figure (2.4), the rest of Europe's economies all managed to recover very quickly after the end of the Second World War in 1945 before going on to reach the highest growth rates in its history. As a result, there was a strong relative decline in the Spanish economy compared to that of the group of most advanced European nations. For example, differences in per capita income widened significantly, reaching $4,000 in 1955 — more than double the 1929 gap. While in 1929 the average income in Spain represented around 60 per cent of the average income of the rest of Europe, in 1955 it was 41 per cent.

Economic historians specialising in the case of Spain usually consider that the Spanish economy's slow recovery was due, in the first instance, to the highly interventionist policies of the Franco regime after the end of the Civil War. During its first 15 years, the Franco regime introduced a regulatory framework through which the State controlled prices, foreign trade, the financial system, the labour market and the production of certain goods (Boix 2004; Tortella 1994). It also increased the State's direct participation in production through a significant expansion in public corporations. Autarky and economic isolation, along with the over-regulation of the markets, seem to have been the main causes behind the stagnation experienced by the Spanish economy until well into the 1950s. The time sequence defined by the change of economic policy through the introduction of the Stabilization Plan in 1959 and the subsequent economic boom of the 1960s — the strongest in Spanish history —support this hypothesis.

The 1959 Stabilization Plan contained a series of fiscal, monetary and market regulation measures aimed at macroeconomic stabilisation and the liberalisation of the economy. Policies were implemented to encourage foreign trade and foreign investment. In short, with this Plan, the previous stage of complete economic isolation and the extensive interventionism of the State in the economy was ended. The Spanish economy grew rapidly after the Plan was adopted and, from 1960 to 1975, maintained an annual average growth rate of almost 7 per cent, well above the average rate recorded by the European powers during the same period. Spain's per capita income more than doubled from $3,000 to more than $8,300 (1990 dollars). During this period of high economic growth, the income differential compared to the rest of Europe only decreased by around $400 (from $4,800 to $4,400), but the average Spanish income went from representing 39 per cent of the average European income — one of the lowest percentages in the entire historical data series — at the start of the 1960s to 65 per cent in 1975. The economic development experienced by the Spanish economy during these years was not only evident in positive changes in material conditions, but also in major, structural socioeconomic changes. For example, the services and construction sectors became increasingly important compared to the agricultural sector in terms of national production and in the proportion of the population employed. In 1960, agriculture accounted for 23 per cent of total production and employed 41 per cent of the labour force; in 1975, those figures fell to 10 per cent and 23 per cent, respectively (Boix 2004).

The boom cycle — marked by strong, sustainable growth, full employment and controlled inflation — enjoyed by the most advanced European nations since the end of the Second World War and Spanish society since 1960 ended abruptly with the international shocks of 1973 that were associated with the price of raw materials and, in particular, of oil. The pace of growth slowed in the developed capitalist economies to almost half the post-war rate. Unemployment and inflation rates rose to double or triple the average values of the previous decades (Frieden 2006). In the case of Spain, these shocks, which adversely affected all of the European economies, coincided with the democratic transition and profoundly affected the Spanish economy. The economy slowed during the consequent global recession but also remained stagnant throughout the next decade and, in some years, experienced negative growth rates. The cycle change was more acute in Spain than in the rest of Europe, bearing in mind that the performance

of the Spanish economy in previous years had produced relatively higher average income gains. The economic recovery was slower in Spain and the average growth rate of 1975–1985 was higher for the European powers. As a result, the process of convergence that had begun in 1960 was stopped in its tracks; in fact, the existing gap between the Spanish economy and that of the other more powerful countries around it began to widen once again, with the income differential widening from $4,400 to $6,100 (1990 dollars).

Table 2.2 The economic crisis of 2008–2009 and its effects on the economic convergence of Spain with the rest of Europe

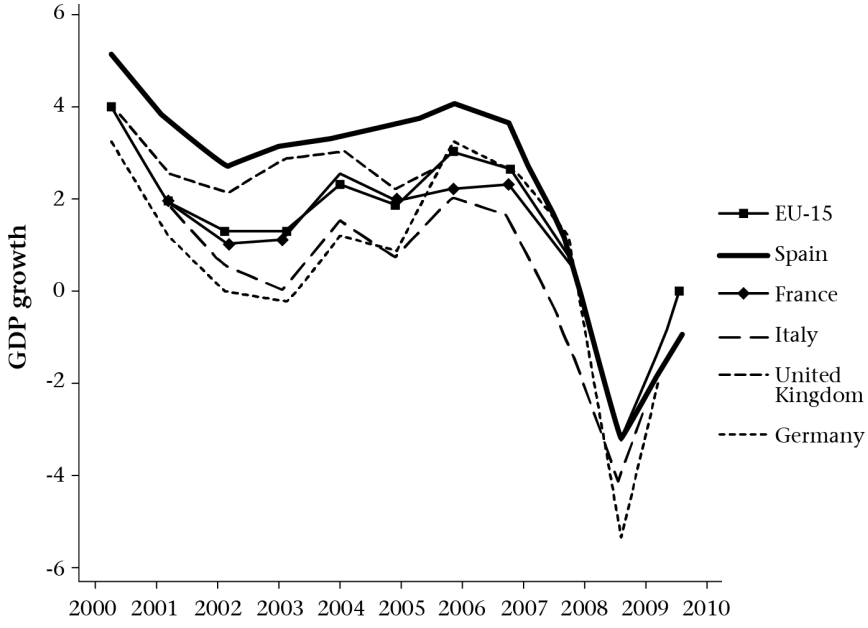
During 2008 and 2009, Spain suffered a serious economic crisis. Between the first quarter of 2008 and the first quarter of 2009, the annual rate of GDP growth fell by almost six points, from 2.7 per cent to –3.0 per cent, while the unemployment rate almost doubled from 9. 6 per cent of the active population in the first quarter of 2008 to 17.4 per cent just 12 months later. Although the Spanish crisis was undoubtedly a reflection of the serious global financial crisis unleashed by the tensions in the US real-estate market, the Spanish situation had certain particularities. Unlike in other economies, the economic expansion of the past decade in Spain had been based on a spectacular increase in domestic consumption, which contributed to the unsustainable expansion of sectors relatively protected from international competition, such as construction.

The economic crisis currently affecting the Spanish economy is one more instance in which we can detect the empirical regularity that we mentioned earlier. This international crisis has affected almost all European economies in a similar way. However, what seems to differentiate the case of Spain is its probable duration.

Figure (2.5) shows the evolution of the economic growth rate from 2000 to 2008 for the six major European economies and for the EU-15 average, as well as the Eurostat (the EU's statistical office) growth forecasts for 2009 and 2010, as of October 2009. First, in line with the historical pattern detected, Spain grew during the boom period of the 2000s at a sustained rate that was higher than that of its European counterparts: Spain's economic growth rate during these years exceeded the European average (EU-15) by between 1 and 2 points. Second, during the financial crisis years, the reductions in the growth rate are not particularly different in the case of Spain. For the year 2009, when the

Between 1986 and 2001, the last data on which information on per capita income is available in the Maddison database (2003), the average Spanish income managed to maintain a positive trend — except during the recession of the early nineties (1992 and 1993) — with an average growth rate of almost 3 per cent. Income disparity compared to the European average decreased significantly to $5,400 and — for the first time in history — Spanish income per capita was equivalent, in 2001, to almost 75 per cent of the average

Figure 2.5. GDP growth rate in the main European economies (2000–2010)



effects of the crisis are seen more acutely, the fall in Spanish GDP is similar to that of countries like the United Kingdom, France or Germany. Third, however, what does seem specific to the Spanish case is that Spain's emergence from the crisis will be slower compared to that of the main European economies, as indicated by the 2010 growth forecasts. Once again, it therefore seems that the particular longevity of crises in the Spanish case serves to halt the process of convergence seen during the boom phases of the economic cycle.

income of the most developed European countries. According to OECD data (*OECD in Figures*, various years), the pattern of high growth in Spain compared to that of its neighbouring countries was repeated in successive years until the current 2009 recession, thus bringing about a further reduction in the existing economic distances.

The evolution of economic development in Spain, in comparison with that of the main European nations, reveals an interesting historical pattern about the system that explains the increase in divergence from the late nineteenth century to the mid-eighties. As can be seen in the Figure (2.4) and deduced from the above discussion, the increases in the economic gap between Spain and the rest of Europe have been mainly due to the fact that European economies have managed to recover more quickly from the economic and political crises that occurred throughout the entire period. Both Spain and the most advanced European countries have suffered with similar frequency and intensity the recessions of the twentieth century: the crisis of 1929, the Spanish Civil War, the Second World War in the rest of Europe and the 1973 oil crisis. In times of prosperity the Spanish economy has either performed in parallel with the average development of the group of European nations or has surpassed it. However, the time taken by Spanish society to re-establish a sustained growth rate, such as after the 1929 Crash, the Civil War and the oil crisis, has been longer. In particular, the period after the most critical years of the crisis is when the economic gap has widened the most: Western Europe tends to return to the path of economic progress quite soon, while in Spain the economic paralysis seems to be prolonged.

What factors explain the relative levels of development seen across different countries? Why do some societies manage to take off economically and maintain a path of sustained progress, as is the case for some countries in Southeast Asia, but not others, such as, for example, most African countries? On what does economic growth depend? In the search for answers to these questions, some authors such as Rodrik (2007) suggest establishing a certain differentiation between the short-term growth causes and the systemic factors that determine economic development. The motive behind this suggestion is mainly inductive after observing the different experiences of emerging economies in recent decades: although in almost all regions of the world there have been numerous accelerated growth episodes, only a few East Asian economies have managed to converge progressively towards the income levels of

the richest industrial societies (Rodrik 2007: 43). One reason is that the economic policies, market reforms or socioeconomic variables that serve to boost a stagnant economy at a particular time may be totally ineffective for maintaining growth, which is what determines the level of economic progress that a society achieves. Long-term prosperity may require, as Rodrik points out, a deepening of the initial reforms or the establishment of institutions that maintain the productive potential. This part of the book is generally focused on analysing the reasons for long-term growth that may account for the differences between countries in terms of their average income levels.

3. Economic growth theories

In this section, the main economic growth models that economists have successively developed are presented in simplified form. In addition to presenting the theoretical advances that have arisen from the study of sources of economic growth, empirical evidence is also provided about the central hypotheses of these models[5].

3.1. The Harrod-Domar model

The Harrod-Domar model was developed independently by Roy Harrod and Evsey Domar in 1939 and 1946, respectively. The fundamental assumption of this model is that the growth in production or income of an economy is primarily derived from the level of investment, that is, from expenditure on the acquisition of capital assets, such as machinery, plants, factories or buildings. These assets are added to the stock of physical capital, thus increasing the future production capacity of the economy. Thus, the main source of growth depends on the accumulation of capital.

More formally, investment increases the national stock of physical capital, let's call it K, and replaces the part of it used in the productive process. If a fraction d of the stock of capital depreciates (machinery deteriorates with use, facilities become obsolete with the passage of time, etc.), then the accumulation of capital is derived from

$$K(t + 1) = (1 - \delta)K(t) + I(t). \qquad (2.1)$$

5 For a more detailed discussion of these models, see Ray Debraj (1998).

This equation tells us that the total amount of capital in the next year, $K(t + 1)$, is equal to the stock of capital in year t minus the fraction of capital goods that has been used in the productive process, $\delta K(t)$, plus the investment made in that year $I(t)$. To finally derive the key equation of this growth model, we introduce two core concepts: the savings rate, which refers to aggregate savings divided by income or total production, $S(t)/Y(t)$, and the capital-production ratio θ, which indicates the amount of capital needed to obtain a unit of product, which is represented by $K(t)/Y(t)$.

If we incorporate in (2.1) the market equilibrium condition according to which the investment is equal to the saving of an economy, use the above definitions and move certain terms, we obtain the Harrod-Domar equation[6]

$$g = \frac{s}{\theta} - \delta. \tag{2.2}$$

According to the equation (2.2), the overall growth rate of output g, defined by $[Y(t + 1) - Y(t)]/Y(t)$, depends on two important variables: the proportion of income allocated to savings (s) and capital returns ($1/\theta$). In the face of an increase in savings or in the rate at which capital generates production — that is, a decrease of θ — the growth rate g increases. The positive savings impact on the variation in the total production Y operates through investment and the accumulation of physical capital. Note that, in equilibrium, savings in an economy are dedicated entirely to investment.

So far we have focused on the variation of production or total income, that is, the growth of the total income of the economy (g), or, in an equivalent manner, the gross domestic product (GDP). When discounting the effect of the population increase, (2.2) can be expressed in per capita magnitudes (see appendix for a step-by-step development of the following equations). If the population (N) grows at a rate of n, so that $N(t + 1) = N(t)\ (1 + n)$ for all periods t, then the growth rate of per capita income $\hat{g}$ can be calculated with the following equation

$$\hat{g} = -\frac{s}{\theta}\delta - n. \tag{2.3}$$

6 The appendix shows in detail all the formal development necessary to arrive at equation (2.2), as well as a brief explanation of the basic concepts of macroeconomic equilibrium on which this growth model is based.

Income growth (per capita) continues to be a positive function of savings and of capital returns. But in addition to depending on the variables that determined the total income variation rate, the increase in per capita income also depends on the population change rate. As can be deduced from (2.3), when this rate increases, per capita growth is obviously lower.

Development economists have repeatedly applied, especially in the 1960s and 1970s, the Harrod-Domar model to poor economies in order to define the appropriate economic policies to achieve a specific growth rate (Easterly 2001). Of all the variables that influence growth according to the equations of this model (see equation 2.3), the rate of saving (or investment) is what has attracted the attention of specialists because it is a parameter that is easier to influence, especially in the short term. In general, it involved calculating what proportion of investment was necessary for the economy to grow at a previously established pace.

However, one of the first objections to the Harrod-Domar model was that the savings rate is not a constant variable but is determined by the development process itself. In other words, the level of savings and, therefore, the investment efforts depend on the country's average level of income, meaning that poor economies have little chance of significantly increasing investment. Given that citizens of poor nations live at almost subsistence levels, it is unlikely that these countries could devote a high proportion of their production to savings. The implication was that economic growth through accumulation of capital in these countries required the financial assistance of advanced industrial societies. Thanks to aid or external credit, it would be possible to cut the "financial gap" that existed between the investment essential for economic take-off and the effective savings of the least developed nations (Easterly 2001)[7].

In general, the strongest criticisms of the Harrod-Domar theory have revolved around the idea that the variables that predict growth rates could, in turn, be influenced by the growth dynamic itself. We have just discussed the implications of this argument in the case of savings; however, if we focus on other factors, the model also generates inconsistencies that greatly reduce its explanatory

7 However, according to Easterly (2001), development aid programmes have not been as effective as expected. Experts and politicians in favour of this development approach did not take into account the fact that recipient governments could make personal use of the aid, so that they did not necessarily automatically lead to greater investment. In addition, Easterly provides evidence that calls into question the very link between investment and growth.

capacity for economic development. As we shall see next, Solow's theory starts precisely from *endogenisation*, that is, from the attempt to explain the other key variable of the model: the capital-production ratio (θ), that is, the physical capital returns.

3.2. The Robert Solow model

Robert Solow set out his ideas on economic growth in several articles published in 1956 and 1957. The innovation of his model compared to the theory of Harrod-Domar resides in the neoclassical idea of the *diminishing returns of individual production factors*. In the case of capital, this property tells us that capital increases, while keeping the other factors constant, generate an increasingly smaller increase in production as the latter increases. When there is a shortage of capital in the economy, an increase in capital stock induces a high growth in production. When the economy has abundant capital, additional capital increases translate into smaller increases in production. The Solow model assumes that the production that a society can generate is subject to this property of the diminishing returns of individual production factors.

The first essential element of the Solow model is a production function that specifies the effects of capital on the production or income of an economy. Let's suppose an aggregate production function with only two factors, capital and labour:

$$Y = F(K, N), \tag{2.4}$$

where Y represents aggregate production, K the capital stock and N the number of workers in the economy[8]. Function F indicates how many units of product are obtained with given amounts of capital and labour. A production function is a mathematical description of the process by which various types of factors (capital, labour, land) combine to produce a unit of product. The production function thus represents the state of technology in the economy.

8 As the number of workers represents a proportion of the total population, let's assume, in order to facilitate the compression of the model but without losing the generalisation, that this fraction is equal to 1, that is to say, that the working population is equal to the total population. All the results of the model would be maintained if we were to introduce in a more realistic manner the differentiation between the working population and the total population of a country.

If the production function satisfies the property of *constant returns to scale*, then there is an alternative way of expressing this function which relates per capita capital to per capita production[9], namely

$$y = f(k), \tag{2.5}$$

where $y = Y/N$ and $k = K/N$. The function (2.5) is characterised by the following relationships. First, $f(k)$ is a growing function of k: as per capita capital increases, average per capita production or income also increases. Second, $f(k)$ exhibits *decreasing returns* in k. If $F(K, N)$ presents diminishing returns in each of its factors, then $f(k)$ satisfies this property with respect to k. As can be seen in Figure (2.6), where the function (2.5) is represented, the idea of diminishing returns means that the increases in per capita production due to increases in per capita capital are becoming smaller as the value of k is higher.

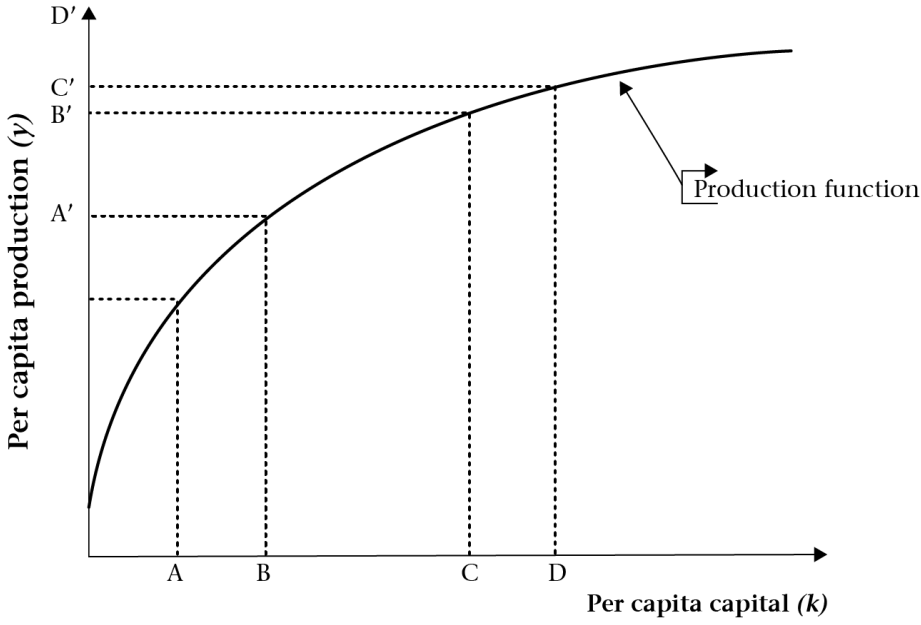
When the value of k is very low, for example at point A, an increase in per capita capital equal to distance AB generates an increase in per capita production equal to A'B'. When there is abundant capital in the economy in relation to labour, for example at point C, the same increase, now indicated by CD, causes a smaller increase in production, C'D'. The relationship between capital and per capita production shown in Figure (2.6) is central to the Solow growth model.

The second core element of the Solow model is an equation that formalises the dynamics of the economy that operates via capital accumulation. This equation also establishes the effects of production on capital. As in the Harrod-Domar model, capital stock increases with investment in the following manner: $K(t + 1) = (1 - \delta) K(t) + sY(t)$. As before, we have made use of the market equilibrium condition (2.A.1), $I(t) = S(t)$, as well as the assumption that the total savings $S(t)$ constitute a proportion of the national product, $S = sY(y)$. After performing a series of algebraic operations (see appendix), we obtain the fundamental equation from which the Solow model predictions about income and long-term per capita growth are derived, namely

$$\Delta k = sy(t) - (n + \delta)k(t), \tag{2.6}$$

9 The appendix to this chapter gives the mathematical derivation for obtaining this per capita production function.

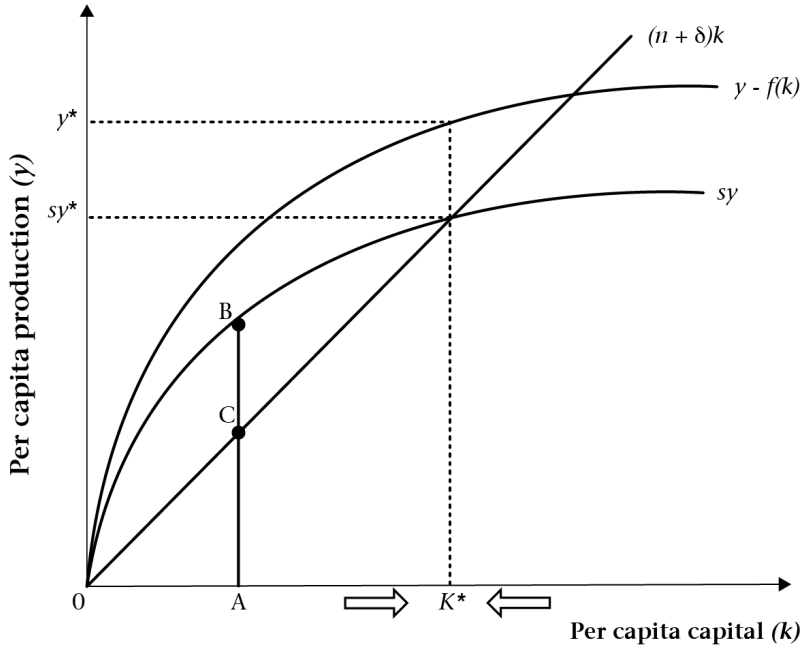
Figure 2.6 Diminishing returns on capital



where $\Delta k = k(t + 1) - k(t)$, n indicates the population growth rate and δ the capital depreciation rate. According to equation (2.6), the variation of per capita capital, $\Delta k = k(t + 1) - k(t)$, is positive if the investment (or saving) per capita, $sy(t)$, is greater than the volume of investment required just to compensate for the negative effects of capital depreciation and population growth. To maintain a given level of average capital in the economy, an amount of investment is necessary such that, on the one hand, it replaces the capital that has become obsolete or that has been used in the productive process (δk) and, on the other, increases the stock of capital just to compensate for the population growth (nk). Adding both effects, the volume of investment essential for k to be maintained at a given value is equal to $(n + \delta)k$. When the investment is greater (or lower) than this required volume, the per capita capital will rise (or decrease) accordingly. In order to better understand the implications of equation (2.6), it is represented in Figure (2.7).

Figure (2.7) first reproduces the per capita production function $y = f(k)$, represented in the previous graph. As explained above, average production grows with per capita capital, but the increase is smaller the higher the value of k. Next, the two components to

Figure 2.7 Evolution of capital and production



the right of equation (2.6) are shown. First, the *sy* curve is the per capita investment. This curve has the same shape as the production function and is below it since it is a proportion *s* of the per capita production. Second, the line $(n + \delta)k$ indicates both the effects of the capital depreciation and the population growth rate, which, as shown in the chart, increase in proportion to per capita capital.

According to equation (2.6), the change in per capita capital is the difference between, on the one hand, investment and, on the other, the capital depreciation and the capital increase necessary to compensate for increases in the population. This difference is given in Figure (2.7) by the distance between the curve *sy* and the line $(n + \delta)k$. When the difference between these two terms is positive, such as, for example, the distance BC at point A, per capita capital expands so that $k(t + 1) > k(t)$. As a result, production and investment increase in the following period. However, as the level of *k* rises, increases in production and investment are increasingly smaller due to the property of decreasing returns described above, while the effects of depreciation and population growth continue to increase in proportion to capital. Thus, the economy is approaching an average capital level k^* such that the investment only grows to

replace the depreciated capital and compensate for the population increase, so that the per capita capital remains constant. When the economy starts from a volume of capital above k^*, the opposite happens: the investment is not high enough to cover the decreases in k due to depreciation and the increase in the population, so that the per capita capital is reduced period by period, $k(t + 1) < k(t)$, and so on until the economy converges towards k^*.

Thus, k^* is the long-term balance of per capita capital, that is, once the economy has reached this volume of average capital, it no longer varies and remains constant over time. In addition, k^* is the level towards which it converges irrespective of the initial value from which it originates. Exactly the same can be said about the production or per capita income that corresponds to k^*, namely, $y^* = f(k^*)$. If per capita capital stabilises at a given point, then there is a level of long-term balance in terms of production or per capita income, which defines the steady state of the economy, towards which it converges. In summary, in this version of Solow's model there is no long-term growth of per capita income, although total income Y does grow at a rate equal to the growth of the population.

The main conclusions of this simple version of the Solow model without technological progress may be summarised as follows: first, there is an equilibrium of per capita income defined by $y^* = f(k^*)$ and towards which the economy must converge irrespective of the initial volume of per capita capital from which it historically originates. Once this level of equilibrium is reached, income stabilises so that the rate of economic growth per capita as of that moment is zero.

Second, unlike what happened in the Harrod-Domar model, in the Solow model the savings rate has no effect on long-term economic growth (which is zero) but on the level of steady per capita income. When there is an increase in the savings rate, the curve sy in Figure (2.7) moves up, generating, on the one hand, a temporary increase in the economic growth rate (Barro and Sala-i-Martin L999) and, on the other, an increase in steady per capita income.

Finally, the Solow model predicts an international convergence among nations in terms of their average income levels. Consider two countries A and B with similar rates of saving, capital depreciation and population growth: this means that both countries have equal equilibrium values y^* and k^*. Suppose, however, that country A has a level of k that is lower than in country B for historical reasons; for example, country A participated in a war and, consequently, a large part of its capital stock has been destroyed. As can be deduced

from the Solow model, the poorest economy (country A) will have a higher y and k growth rate, so that in the long term both countries will achieve similar levels of economic development. In the next section, we present a review of the most influential empirical studies that have tested the implications of the Solow model and, above all, this latter assumption.

Before contrasting the Solow hypothesis with the data, let's analyse the version of the Solow model that includes technological progress. The examination that has so far been considered of the Solow theory rested on the assumption that the technological change in the economy was null. Hence the conclusion that, in the presence of diminishing capital returns, a country cannot sustain indefinite per capita growth. The data on average income growth that we have seen previously suggest, however, that very rich countries such as the United States have managed to maintain a positive variation of per capita production for decades and yet still continue to grow at not insignificant rates. By introducing technological advancement into the model, it will be possible to reconcile the data with the theory, since, as we shall see, it is feasible that even in the long term the economy continues to grow in per capita terms.

One way of understanding technological progress is to consider that it encourages labour efficiency or productivity, which means that the number of workers needed to obtain a given production quantity is lower, or that a higher amount of productive quantity is available in the production process[10]. Formally, this can be expressed in the following manner. Let's suppose that

$$L(t) = E(t)N(t), \tag{2.7}$$

10 The degree of efficiency of the production process refers to the total product that is extracted given a precise number of inputs or production factors. Technological change supposes advances in this efficiency. These improvements in the production process can strictly affect different elements of the production function represented previously in equation (2.4), $Y = F(K, N)$. More specifically, technological changes can influence the individual productivity of each of the factors (labour or capital) and/or the overall production efficiency if production increases proportionally, regardless of the composition of the inputs used. The Solow model introduces technological progress into the analysis affecting labour productivity and, consequently, increasing the number of effective workers in the economy. However, none of its conclusions vary considering that advances in the technology used in the production of a country also include those that increase capital productivity and improve the overall efficiency of the production process.

where $N(t)$ indicates, as before, the population and $E(t)$ the productivity of an individual in year t. Consequently, $L(t)$, which is usually called the *effective population*, represents the amount of *effective* labour in the economy. Note that $L(t)$ increases as the productivity $E(t)$ is higher. The assumption introduced in this version of the Solow model is that $E(t)$ is not constant but advances at a fixed rate that we will call π, so that $E(t + 1) = (1 + \pi)E(t)$. Given that the population also expands in a proportion n, then the growth rate of the effective population $L(t)$ is equal to $n + \pi$.

In order to see what implications technological progress has on the basic Solow model, we will rewrite all the previous equations, substituting the population $N(t)$ for the effective population $L(t)$. In this way, the two core expressions of the model, (2.5) and (2.6), would look as follows

$$\hat{y} = f(\hat{k}), \tag{2.8}$$

where $\hat{y}$ is equal to the production per effective worker, *Y/EN,* and $\hat{k}$ the capital stock per effective worker, *K/EN*. The capital per efficient unit of labour generates the production per efficient unit of labour. This new production function satisfies the property of diminishing capital returns but referred now to effective units of labour.

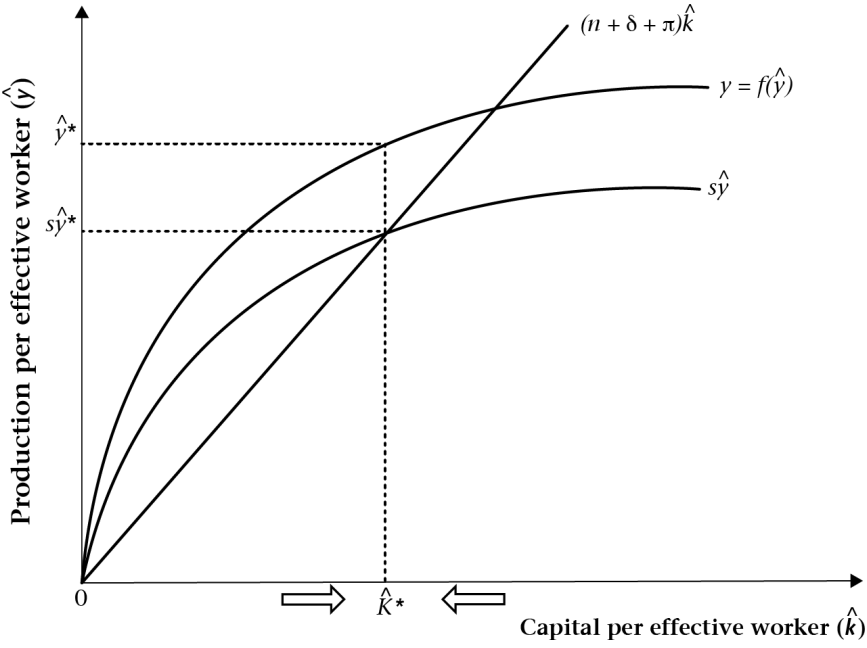
As regards the fundamental equation of capital accumulation, we have to

$$\Delta\hat{k} = s\hat{y}(t) - (\delta + n + \pi)\hat{k}(t). \tag{2.9}$$

Note that the rate at which π technology changes appears with a negative sign on the right side of equation (2.9). Intuitively, so that $\hat{k}$ does not change, which is equal to *K/EN*, it is essential that the investment increases the capital stock K in such a way that the capital depreciation and the effective population growth $n + \pi$ are compensated.

Equipped with these new equations, we reproduce in Figure (2.8) the relationships of Figure (2.7) but expressed in efficient units of labour. The dynamics of capital and production, explained previously, are applied in the same way in this new context with technological progress. Thus, the economy is directed towards long-term balance levels $\hat{y}^*$ and $\hat{k}^*$. However, the interpretation of what happens in the balance is different. Although the level of capital and income *per effective worker* remain constant over the long term, the stock of capital per capita (k) and income per person (y) continue

Figure 2.8 Evolution of capital and production with technological progress



to rise. In addition, the long-term growth of these two per capita variables, y and k, is equal to the rate of technological advance, π.

The logic behind this proposition is as follows. We know that the capital stock K depreciates in a proportion δ and that the population and technology grow at a rate n and π, respectively. In addition, we know that these three phenomena reduce the level of capital per effective worker $\hat{k} = K/EN$. Since, if the value of $\hat{k}$ is the same over time, then the investment must be high enough to counteract these three negative effects. First, a certain fraction of the total investment must replace the depreciated capital so that the capital stock K is equal to that of the previous period. Second, another proportion of investment must be translated into an increase of K just to compensate for the population growth; consequently, per capita capital k remains constant. And, third, the rest of the investment must raise even more K in order to contain the consequences of the technological progress so that the level of capital per efficient unit of labour $\hat{k}$ is the same. Therefore, all the investment destined to compensate for this latter effect necessarily induces an increase in per capita capital k and, by extension, the average income of the

economy. In other words, so that $\hat{k}$ (capital per effective worker) remains constant, capital per worker k has to increase period on period, which produces constant increments in the level of per capita production.

The most important conclusion of Solow's theory is that the technological advancement of the economy constitutes the fundamental source of long-term per capita growth and not the accumulation of production factors or inputs. The accumulation of physical capital can generate significant increases in the average

Table 2.1 Solow model hypotheses

Hypothesis	Basic model	Model with progress technological
Levels and long-term growth	The economy tends towards balance levels of per capita income y^* and per capita capital k^*. In balance, per capita income growth is null.	The economy tends towards the balance levels of income per effective worker $\hat{y}^*$ and of capital per effective worker $\hat{k}^*$. In equilibrium, $\hat{y}^*$ and $\hat{k}^*$ are constant, while the per capita income and grows at the rate of technological progress π.
Savings rate	No effect on long-term growth but it increases the balance level of average income y^*.	No effect on long-term growth but increases the equilibrium level of income per effective worker $\hat{y}^*$ and the average income y.
Economic convergence	If the rates of savings s, capital depreciation δ and growth of population n are equal among countries, then they converge towards the same level of per capita income y^*.	If the rates of savings s, capital depreciation δ, population growth n and technological progress π are equal between countries, then these converge towards the same level of income per effective worker $\hat{y}^*$. If, in addition, they share the same technology (E), they converge towards the same level of per capita income y.

wealth of a country, but only when the economy has few capital resources per worker. As the physical capital increases for a given size of the labour force, the additional returns produced by the subsequent increases in capital are increasingly smaller until reaching a point at which these added returns are non-existent. On the other hand, by increasing the efficiency of the production process — that is, by obtaining a higher level of production given a specific quantity of production factors, such as labour and physical capital — technological progress is an inexhaustible force capable of sustaining the growth of per capita income indefinitely. Lastly, the Solow model with technological progress does not introduce any change as regards predictions about the effect of the savings rate and the convergence between countries. Table (2.1) presents the hypotheses of both versions of the Solow theory.

4. Empirical evidence

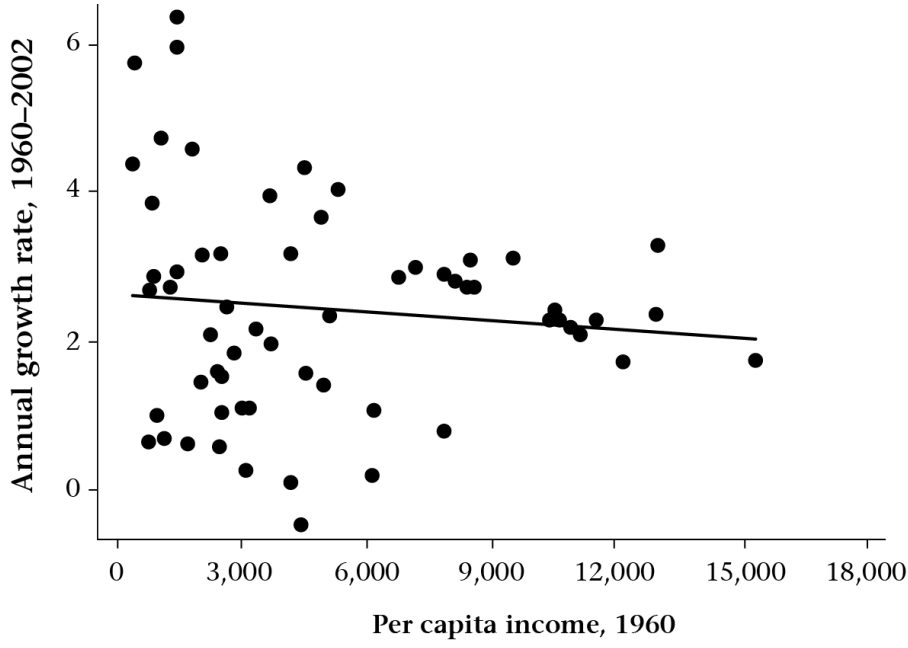
In this section, the most important empirical studies of the debate on international convergence are discussed. This hypothesis is the one that has received the most attention from growth theorists and empiricists among those that are shown in Table (2.1). The notion of convergence is defined in two different ways in this debate. First, there is the *absolute convergence* hypothesis, according to which income per effective worker converges in all countries toward the same balance value $\hat{y}^*$ regardless of the initial level of wealth from which the countries historically start. If technology E is identical in all economies, then per capita income is also going to lead to the same level in the long term. Consequently, poor economies should show a higher growth trend than do richer ones. This prediction rests, as Table (2.1) indicates, on the assumption that the parameters determining economic evolution, namely the rates of technological progress, savings, population growth and capital depreciation, are common to all countries.

Numerous empirical studies have provided evidence contradicting the existence of a process of economic convergence that has allowed the poorest countries to get close to the well-being levels of the most developed nations (Barro 1991, Mankiw, Romer and Weil 1992; Sala-i- Martin 1996; Barro and Sala-i-Martin 1995). According to the results of their analyses, the association between economic growth and the initial average income level is not negative, as one might expect. The regression coefficients suggest a positive, albeit

very weak, correlation. By way of example, Figure (2.9) shows how average growth of per capita income during the period 1960–2002 changes depending on the countries' initial level of wealth in 1960[11]. In line with the results of previous studies, the data do not seem to indicate then that there is a clear tendency for poor countries to grow faster than relatively more advanced nations.

An alternative way to verify whether there has been a degree of economic convergence between nations is to analyse the time evolution of dispersion of the countries' per capita income distribution. If the economies are getting close to a similar level

Figure 2.9 Economic convergence, 1960–2002



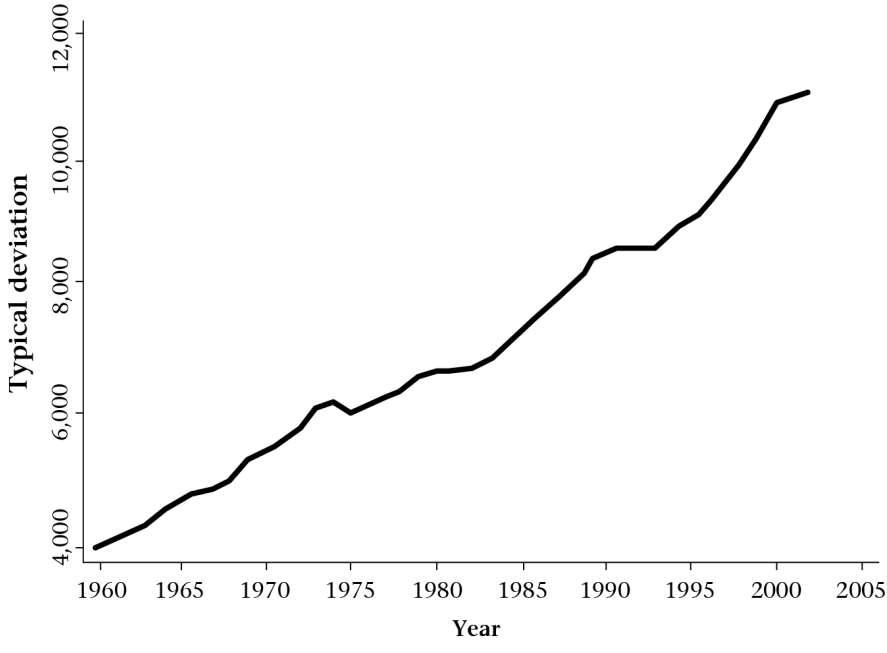
SOURCE: Penn World Table 6.2.

11 Figures (2.9) and (2.10) include all countries with available information on their per capita income levels and growth for every year of the 1960–2002 period. This source of the data is Penn World Tables, version PWT6.2. For a definition of the variables, see footnote No. 3.

of average income, as the convergence hypothesis suggests, we should observe that the variance in the international distribution of income decreases over time. Against this argument, we have seen in the introduction to this chapter that the economic gap between the richest countries of the OECD and the remaining countries has widened with the passage of time. Figure (2.10), which shows the standard deviation of countries' average income distribution between 1960 and 2002, offers additional evidence that points to the fact that economic differences between nations have progressively increased. Far from reducing the distances that separated the different economies of the world in 1960, it seems that international inequality of wealth has increased over the subsequent decades. In conclusion, the idea of *absolute convergence*, according to which countries trailing behind economically should grow faster than those with higher levels of development, is outright rejected by the observed data.

One of the reasons why no convergent trend is seen in the degree of material well-being of countries is that the parameters

Figure 2.10 Dispersion of per capita income, 1960–2002



SOURCE: Penn World Table 6.2.

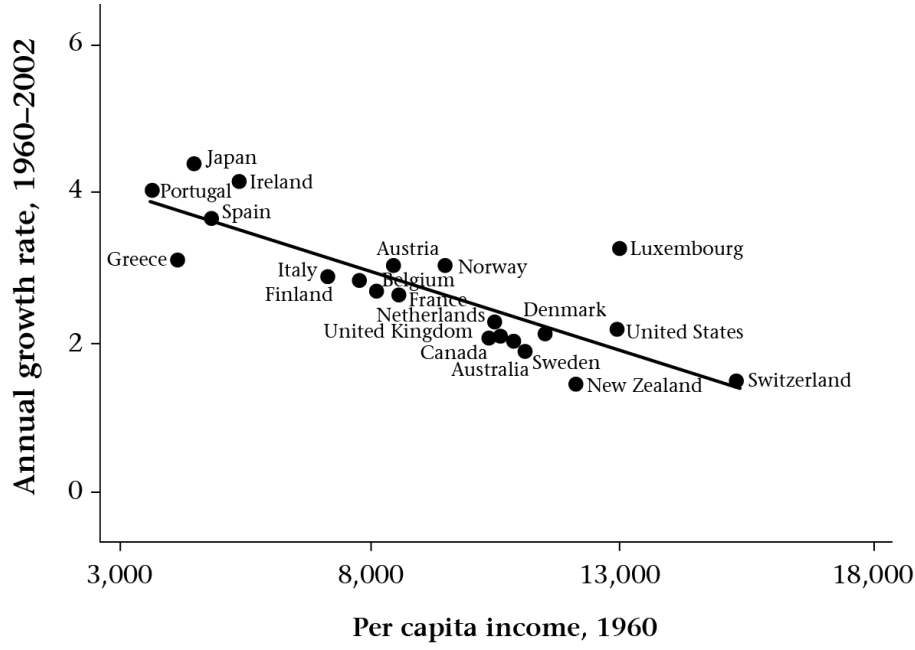
determining the evolution of the economy are not identical in all countries, as the assumption on which the absolute convergence hypothesis was based. On the contrary, it seems more sensible to consider that economies have different rates of saving, population growth and technological progress. Although this does not affect Solow's theory that, in the long term, economies approach their balance levels, these balance values may vary between societies, so it cannot always be assumed that any two nations will achieve a similar level of economic development. This argument leads us to the notion of *conditional convergence*, according to which the inequalities between certain countries will disappear in the long term as long as the economic positions that define their steady states — savings rate, state of technology and rate of technological change— are equivalent.

The methodological implication of this proposition is that, in order to examine the convergence between countries, it is necessary to keep the characteristics that sustain the long-term balance constant. This can be done in two different ways (Sala-i-Martin 1996). One is by introducing the variables of rates of savings, population growth, capital depreciation and technological progress in the regression analysis as control factors. Another is by restricting the study of absolute convergence to a set of homogeneous economies for which it is reasonable to assume that these parameters are equal. In line with this latter strategy, Figure (2.11) reproduces the relationship between growth and per capita income in Figure (2.9) but for OECD countries only. The data in the chart reveal that initially poorer nations did later manage to sustain higher average annual per capita growth rates. In the case of a more restricted sample of currently developed societies (OECD), it therefore seems that there has indeed been a significant trend towards convergence[12].

The evidence provided by other studies (Mankiw, Romer and Weil 1992; Sala-i-Martin 1996; Barro and Sala-i-Martin 1995) also supports the idea of conditional convergence for a series of economic characteristics such as savings rates, population growth or technological advancement. Although this hypothesis of Solow's model is confirmed in several empirical analyses, one of the strongest criticisms of the model is that it does not explain why countries demonstrate so much variability in those economic aspects that determine their economic trajectories. As we have

12 Similar results were obtained in studies examining the economic convergence between regions or between states within a country.

Figure 2.11 Economic convergence among OECD countries, 1960–2002



SOURCE: Penn World Table 6.2.

studied in the Solow model, the proportion of income dedicated to savings, the population growth, the rate at which technology advances or the rate of capital depreciation are all exogenous parameters, that is to say that they are not explained by the model. Why do individuals in some societies save more than in others? On what does population growth depend? What are the factors determining technological change? Why do some countries introduce better techniques in their production process than others? The Solow model, in both of its versions, does not respond to these questions that are so crucial to understanding, in essence, the ultimate sources of economic development. In addition, what factors influence investment in physical and human capital? Is it true that savings are automatically transformed into investment, as is posited by both Solow's theory and the Harrod-Domar model? Given certain economic opportunities, defined by the potential benefit that could be extracted from certain investment plans, it is reasonable to think that other causes of a political nature, such as the degree of protection of property rights, are involved in the decisions made by economic

Table 2.3 Human capital and growth

Labour is a production factor the quantity of which, according to the Harrod-Domar and Solow models, is determined by population growth and/or technological progress. Since both variables are exogenous in these models, the quantity of labour is a parameter outside the control of politicians or of economic players. However, some recent growth theories (Lucas 1988; Barro 1991; Mankiw et al. 1992) have abandoned this assumption by arguing that governments, as has been demonstrated in more advanced countries, can increase the said production factor by investing in education. Rather than simply considering labour, the relevant variable for production is human capital, which often refers to the skill level of the labour force. Moreover, it is considered that, like physical capital, human capital is subject to a deliberate process of accumulation, resulting from individual investment decisions, for example. Now the economic players can give their savings over to investing not only in physical capital but also in human capital.

In the most simplified version of this theory, production depends solely on physical and human capital stock. It is assumed that although both production factors have decreasing returns separately, the combination of physical and human capital generates constant returns. That is, when the two factors increase simultaneously, production grows steadily regardless of the initial level of capital stock of each variable. The implications of this theory for long-term growth and convergence between countries are very different from those of the Solow model. First, the long-term growth of per capita income is not zero — as in the version of the Solow model without technological progress — but will be a positive and constant amount determined, moreover, by the savings rate and the proportion of savings that are given over to the accumulation of human capital. Thus, as in the Harrod-Domar theory, savings have consequences for the balance rate of economic growth.

Second, it is not clear that economic inequalities between countries will disappear progressively in the long term. Even if they have similar rates of savings and technological progress, their essential differences may remain. Even if at the balance point they grow at the same rate, those countries with a higher initial stock of physical and human capital, and thus a higher per capita income, will continue to be relatively richer on balance.

players regarding the realisation of their business projects. In the next chapter we examine the effects of political institutions on economic growth. Political-institutional explanations of development generally seek to answer precisely the above questions. The usefulness of deepening the mechanics of growth, thanks to the study of economic growth models, is that it allows us to establish an analysis framework to better understand how variables of a more political and social nature influence the economic well-being of a country.

5. Appendix

5.1. The Harrod-Domar model

In this section, the equations of the Harrod-Domar model are derived step by step. In order to facilitate analysis of this model, it is necessary to start with some basic concepts of macroeconomic balance. Any introductory manual to macroeconomics tells us that when the market is balanced, it must satisfy the condition according to which the supply or production of goods *(Y)* must be equal to demand, that is[13]

$$Y(t) = C(t) + I(t),$$

where Y refers to total production, C to total consumption, I to investment or aggregate demand for capital goods and t to temporal space that is divided into annual periods $t = 0, 1, 2, 3...$ As we can see, total production is composed of consumer goods and capital goods — which are goods destined for the production of other goods. In general, families are those that buy consumer goods, while companies buy capital goods. Simultaneously, all production is translated into income in the form of wages, benefits, rents, dividends, etc., received by families, who dedicate part of this income to consumption C, and the rest to savings S, so that

$$Y(t) = C(t) + S(t).$$

Families, through their savings, make available to companies a fund of resources that, in turn, enables companies to meet their investments (or to purchase capital goods). Without savings there is no investment.

13 We will assume that the economy is closed — there is no commercial or financial opening — and we also leave aside taxes and government spending.

In balance, companies' investment must be equal to the families' savings:

$$I(t) = S(t).\ 2 \qquad (2.A.1)$$

We will now look at the steps taken to arrive at the Harrod-Domar equation (2.2) in the main text, which determines the growth of income or aggregate production. First, we introduce into equation (2.1) of the text about the process of accumulation of physical capital the previous balance condition (2.A.1), so that

$$K(t + 1) = (1 - \theta)K(t) + S(t).$$

From the definitions of the savings rate and the capital-production ratio, we see that $S(t) = sY(t)$ and $K(t) = \theta Y(t)$ for all periods t. If we substitute these equalities into the previous expression, then

$$\theta Y(t + 1) = (1 - \delta)\theta Y(t) + sY(t), \qquad (2.A.2)$$

so that

$$\frac{Y(t + 1) - Y(t)}{Y(t)} = \frac{s}{\theta} - \delta.$$

Since the left term of this equation is the growth rate g, the derivation of the equation (2.2) ends here.

To arrive at (2.3), which determines per capita income growth, we first divide both sides of (2.A.2) by $N(t)$, multiply and divide by $N(t + 1)$ the left side of the equation to get

$$\frac{\theta Y(t + 1)}{N(t + 1)} \frac{\mathrm{N}(t + 1)}{N(t)} = (1 - \delta)\theta \frac{Y(t)}{N(t)} + s \frac{Y(t)}{N(t)},$$

which is equal to

$$\theta y(t + 1) \frac{N(t + 1)}{N(t)} = (1 - \delta)\theta y(t) + sy(t),$$

where $y(t)$ is the income per person in period t, that is, $y(t) \equiv (Y(t))/(N(t))$. If we divide everything by $y(t)\theta$, we see that

$$\frac{y(t + 1)}{y(t)} \frac{\mathrm{N}(t + 1)}{N(t)} = (1 - \delta) + \frac{s}{\theta}.$$

Since $[y(t+1)]/[y(t)] = 1 + \hat{g}$ y $[N(t+1)]/[N(t)] = 1 + n$, by substituting these expressions in the above equation, we obtain

$$s/\theta = (1 + \hat{g})(1 + n) - (1 - \delta).$$

Now we expand the right side of this equation so that $s/\theta = \hat{g} + n + \delta - \hat{g}n$. The sum of the growth rates $\hat{g}$ and n could be eliminated since it is a very small number in relation to the other terms. In this way, this equation can be approximated by equation (2.3) of the text according to which

$$\hat{g} = \frac{s}{\theta} - \delta - n.$$

5.2. The Solow model

A. Production function

To derive the per capita production function (2.5) from the text, we first define the property of constant returns to scale that satisfies the aggregate production function (2.4) in the text. According to this property, when we increase the number of workers and the amount of capital by a positive factor, $x > 0$, production increases in the same proportion x:

$$xY = F(xK, xP). \qquad (2.A.3)$$

For example, if we double the quantity of both factors, then the aggregate production will also double.

$$2Y = F(2K, xP).$$

Note that this property is applied to changes in production when both capital and labour increase in the same proportion. By contrast, the property of diminishing returns of the individual production factors refers to how the production varies when one of the factors changes while keeping the rest of the variables constant. If x equals $1/N$ in equation (2.A.3), then

$$Y/N = F(K/N, 1). \qquad (2.A.4)$$

This equation tells us that the per capita production Y/N is a function that depends only on the K/N ratio, the per capita capital, and not on the two factors separately. If $y = Y/N$ and $k = K/N$; in such a case, the function (2.A.4) can be simplified as follows: $y = f(k)$.

B. Capital variation (dynamics of the economy)[14]

Starting from equations (2.1) and (2.A.1) and assuming that the total savings $S(t)$ constitute a proportion of the national product, $S = sY(t)$, we obtain the following expression that describes the evolution of the capital stock in the economy:

$$K(t + 1) = (1 - \delta)K(t) + sY(t). \qquad (2.A.5)$$

The variation of the capital stock, $\Delta K = K(t + 1) - K(t)$, is given then by $\Delta K = sY(t) - \delta K(t)$. If we divide this equation by the population $N(t)$, we obtain the change of the capital stock in per capita magnitudes

$$\frac{\Delta K}{N(t)} = sy(t) - \delta k(t). \qquad (2.A.6)$$

Suppose as before that the population grows at a constant rate of way that $\Delta N/N(t) = n$; then, the growth rate of per capita capital defined as $k(t) = K(t)/N(t)$ is

$$\frac{\Delta K}{k(t)} = \frac{\Delta K}{K(t)} - \frac{\Delta N}{N(t)} = \frac{\Delta K}{K(t)} - n. \qquad (2.A.7)$$

In words, the percentage increase in per capita capital is equal to the rate of total capital growth in the economy minus the growth of the population. If we rearrange the terms of (2.A.7) so that $\Delta K = [\Delta k/k(t)]K(t) + nK(t)$ and we divide this result by the population $N(t)$, we have

$$\frac{\Delta K}{N(t)} = \Delta k + nk(t). \qquad (2.A.8)$$

14 The following formal derivations have been extracted from the explanation developed by Joaquín Ledesma on the Solow model in chapter 13 of his manual *Economía, teoría y política*, Buenos Aires: Pearson-Prentice Hall, 2004.

By matching the expressions (2.A.6) and (2.A.8), we obtain the fundamental equation on the dynamics of the economy of the Solow model, equation (2.6) of the text: $\Delta k = sy(t) - (n + \delta)k(t)$.

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7. Questions

2.1 Per capita income is the most commonly used indicator to measure the level of economic development of a country. There are wide differences between countries in terms of their per capita income levels. Explain how the economic differences between the OECD group of countries and the least developed countries have evolved up to the year 2000. Also describe the different development trajectories that have taken place in less developed countries since 1960.

2.2 Why is the long-term economic growth rate null according to the basic version of the Solow model? How does this prediction change when technological progress is introduced into the model? Why?

2.3 What are the theoretical reasons that support the hypothesis of convergence in the level of economic development among countries in the Solow basic model?

2.4 Discuss the existing empirical evidence on convergence among countries with respect to their per capita income levels. How does *absolute* and *conditional* convergence differ?