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Modalità di rappresentazione grafica dei dati contabili: funzionamento where μ_t is the sample mean of the $\log(y_{it})$. If there are a large number N of observations, the sample variance is close to the population variance, and we can use equation (1.31) to derive the evolution of D_t over time:

$$D_t \approx (1-b)^2 \cdot D_{t-1} + \sigma_u^2$$

This first-order difference equation for dispersion has a steady state given by

$$D^* = \sigma_u^2/[1-(1-b)^2]$$

Hence, the steady-state dispersion falls with b (the strength of the convergence effect) but rises with the variance σ_u^2 of the disturbance term. In particular, $D^* > 0$ even if $b > 0$, as long as $\sigma_u^2 > 0$.

The evolution of D_t can be expressed as

$$D_t = D^* + (1-b)^2 \cdot (D_{t-1} - D^*) = D^* + (1-b)^{2t} \cdot (D_0 - D^*) \tag{1.32}$$

where D_0 is the dispersion at time 0. Since $0 < b < 1$, D_t monotonically approaches its steady-state value, D^*, over time. Equation (1.32) implies that D_t rises or falls over time depending on whether D_0 begins below or above the steady-state value.[24] Note especially that a rising dispersion is consistent with absolute convergence ($b > 0$).

These results about convergence and dispersion are analogous to Galton's fallacy about the distribution of heights in a population (see Quah, 1993, and Hart, 1995, for discussions). The observation that heights in a family tend to regress toward the mean across generations (a property analogous to our convergence concept for per capita income) does not imply that the dispersion of heights across the full population (a measure that parallels the dispersion of per capita income across economies) tends to narrow over time.

1.2.12 Technological Progress

Classification of Inventions We have assumed thus far that the level of technology is constant over time. As a result, we found that all per capita variables were constant in the long run. This feature of the model is clearly unrealistic; in the United States, for example, the average per capita growth rate has been positive for over two centuries. In the absence of technological progress, diminishing returns would have made it impossible to maintain per capita growth for so long just by accumulating more capital per worker. The neoclassical economists of the 1950s and 1960s recognized this problem and amended the basic model

24. We could extend the model by allowing for temporary shocks to σ_u^2 or for major disturbances like wars or oil shocks that affect large subgroups of economies in a common way. In this extended model, the dispersion could depart from the deterministic path that we derived; for example, D_t could rise in some periods even if D_0 began above its steady-state value.

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Introduction

I.1 The Importance of Growth

To think about the importance of economic growth, we begin by assessing the long-term performance of the U.S. economy. The real per capita gross domestic product (GDP) in the United States grew by a factor of 10 from $3340 in 1870 to $33,330 in 2000, all measured in 1996 dollars. This increase in per capita GDP corresponds to a growth rate of 1.8 percent per year. This performance gave the United States the second-highest level of per capita GDP in the world in 2000 (after Luxembourg, a country with a population of only about 400,000).[1]

To appreciate the consequences of apparently small differentials in growth rates when compounded over long periods of time, we can calculate where the United States would have been in 2000 if it had grown since 1870 at 0.8 percent per year, one percentage point per year below its actual rate. A growth rate of 0.8 percent per year is close to the rate experienced in the long run—from 1900 to 1987—by India (0.64 percent per year), Pakistan (0.88 percent per year), and the Philippines (0.86 percent per year). If the United States had begun in 1870 at a real per capita GDP of $3340 and had then grown at 0.8 percent per year over the next 130 years, its per capita GDP in 2000 would have been $9450, only 2.8 times the value in 1870 and 28 percent of the actual value in 2000 of $33,330. Then, instead of ranking second in the world in 2000, the United States would have ranked 45th out of 150 countries with data. To put it another way, if the growth rate had been lower by just 1 percentage point per year, the U.S. per capita GDP in 2000 would have been close to that in Mexico and Poland.

Suppose, alternatively, that the U.S. real per capita GDP had grown since 1870 at 2.8 percent per year, 1 percentage point per year greater than the actual value. This higher growth rate is close to those experienced in the long run by Japan (2.95 percent per year from 1890 to 1990) and Taiwan (2.75 percent per year from 1900 to 1987). If the United States had still begun in 1870 at a per capita GDP of $3340 and had then grown at 2.8 percent per year over the next 130 years, its per capita GDP in 2000 would have been $127,000—38 times the value in 1870 and 3.8 times the actual value in 2000 of $33,330. A per capita GDP of $127,000 is well outside the historical experience of any country and may, in fact, be infeasible (although people in 1870 probably would have thought the same about $33,330). We can say, however, that a continuation of the long-term U.S. growth rate of 1.8 percent per year implies that the United States will not attain a per capita GDP of $127,000 until 2074.

1. The long-term data on GDP come from Maddison (1991) and are discussed in chapter 12. Recent data are from Heston, Summers, and Aten (2002) and are also discussed in chapter 12.

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Conversione di un documento da word in pdf: motivazione e procedure ratios; the data for the other seven countries show a clear increase in these ratios over time. In particular, the ratios for 1950–89 are, in all cases, substantially greater than those from before World War II. The long-term data therefore suggest that the ratios to GDP of gross domestic investment and gross national saving tend to rise as an economy develops, at least over some range. The assumption of a constant gross saving ratio, which appears in chapter 1 in the Solow–Swan model, misses this regularity in the data.

The cross-country data also reveal some regularities with respect to fertility rates and, hence, rates of population growth. For most countries, the fertility rate tends to decline with increases in per capita GDP. For the poorest countries, however, the fertility rate may rise with per capita GDP, as Malthus (1798) predicted. Even stronger relations exist between educational attainment and fertility. Except for the most advanced countries, female schooling is negatively related with the fertility rate, whereas male schooling is positively related with the fertility rate. The net effect of these forces is that the fertility rate—and the rate of population growth—tend to fall over some range as an economy develops. The assumption of an exogenous, constant rate of population growth—another element of the Solow–Swan model—conflicts with this empirical pattern.

I.4 A Brief History of Modern Growth Theory

Classical economists, such as Adam Smith (1776), David Ricardo (1817), and Thomas Malthus (1798), and, much later, Frank Ramsey (1928), Allyn Young (1928), Frank Knight (1944), and Joseph Schumpeter (1934), provided many of the basic ingredients that appear in modern theories of economic growth. These ideas include the basic approaches of competitive behavior and equilibrium dynamics, the role of diminishing returns and its relation to the accumulation of physical and human capital, the interplay between per capita income and the growth rate of population, the effects of technological progress in the forms of increased specialization of labor and discoveries of new goods and methods of production, and the role of monopoly power as an incentive for technological advance.

Our main study begins with these building blocks already in place and focuses on the contributions in the neoclassical tradition since the late 1950s. We use the neoclassical methodology and language and rely on concepts such as aggregate capital stocks, aggregate production functions, and utility functions for representative consumers (who often have infinite horizons). We also use modern mathematical methods of dynamic optimization and differential equations. These tools, which are described in the appendix at the end of this book, are familiar today to most first-year graduate students in economics.

From a chronological viewpoint, the starting point for modern growth theory is the classic article of Ramsey (1928), a work that was several decades ahead of its time. Ramsey's

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where s_k is an exogenous constant. Similarly, for human capital, the growth rate is

$$\dot{\hat{h}} = s_h \tilde{A} \hat{k}^{\alpha} \hat{h}^{\eta-1} - (\delta + n + x) = s_h \tilde{A} \cdot e^{\alpha \ln \hat{k}} \cdot e^{-(1-\eta) \ln \hat{h}} - (\delta + n + x) \tag{1.56}$$

where s_h is another exogenous constant. A shortcoming of this approach is that the rates of return to physical and human capital are not equated.

The growth rate of $\hat{y}$ is a weighted average of the growth rates of the two inputs:

$$\dot{\hat{y}}/\hat{y} = \alpha \cdot (\dot{\hat{k}}/\hat{k}) + \eta \cdot (\dot{\hat{h}}/\hat{h})$$

If we use equations (1.55) and (1.56) and take a two-dimensional first-order Taylor-series expansion, we get

$$\begin{aligned}
\dot{\hat{y}}/\hat{y} = {} & \big[\alpha s_k \tilde{A} \cdot e^{-(1-\alpha)\ln \hat{k}^*} \cdot e^{\eta \ln \hat{h}^*} \cdot [-(1-\alpha)] \\
& + \eta s_h \tilde{A} \cdot e^{\alpha \ln \hat{k}^*} \cdot e^{-(1-\eta)\ln \hat{h}^*} \cdot \alpha\big] \cdot (\ln \hat{k} - \ln \hat{k}^*) \\
& + \big[\alpha s_k \tilde{A} \cdot e^{-(1-\alpha)\ln k^*} \cdot e^{\hat{\eta} \ln h^*} \cdot \eta \\
& + \eta s_h \tilde{A} \cdot e^{\alpha \ln \hat{k}} \cdot e^{-(1-\eta)\ln \hat{h}^*} \cdot [-(1-\eta)]\big] \cdot (\ln \hat{h} - \ln \hat{h}^*)
\end{aligned}$$

The steady-state conditions derived from equations (1.55) and (1.56) can be used to get

$$\begin{aligned}
\dot{\hat{y}}/\hat{y} &= -(1-\alpha-\eta) \cdot (\delta + n + x) \cdot [\alpha \cdot (\ln \hat{k} - \ln \hat{k}^*) + \eta \cdot (\ln \hat{h} - \ln \hat{h}^*)] \\
&= -\beta^* \cdot (\ln \hat{y} - \ln \hat{y}^*)
\end{aligned} \tag{1.57}$$

Therefore, in the neighborhood of the steady state, the convergence coefficient is $\beta^* = (1-\alpha-\eta) \cdot (\delta + n + x)$, just as in equation (1.54).

1.3 Models of Endogenous Growth

1.3.1 Theoretical Dissatisfaction with Neoclassical Theory

In the mid-1980s it became increasingly clear that the standard neoclassical growth model was theoretically unsatisfactory as a tool to explore the determinants of long-run growth. We have seen that the model without technological change predicts that the economy will eventually converge to a steady state with zero per capita growth. The fundamental reason is the diminishing returns to capital. One way out of this problem was to broaden the concept of capital, notably to include human components, and then assume that diminishing returns did not apply to this broader class of capital. This approach is the one outlined in the next section and explored in detail in chapters 4 and 5. However, another view was that technological progress in the form of the generation of new ideas was the only way that an economy could escape from diminishing returns in the long run. Thus it became a priority to go beyond the treatment of technological progress as exogenous and, instead, to explain this

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We know now that there are several implausible assumptions in the arguments of Harrod and Domar. First, the Solow–Swan model showed that Harrod and Domar's parameter A—the average product of capital—would typically depend on k, and k would adjust to satisfy the equality $s \cdot f(k)/k = n + \delta$ in the steady state. Second, the saving rate could adjust to satisfy this condition. In particular, if agents maximize utility (as we assume in the next chapter), they would not find it optimal to continue to save at the constant rate s when the marginal product of capital was zero. This adjustment of the saving rate would rule out an equilibrium with permanently idle machinery.

1.4.2 Growth Models with Poverty Traps

One theme in the literature of economic development concerns *poverty traps*.[37] We can think of a poverty trap as a stable steady state with low levels of per capita output and capital stock. This outcome is a trap because, if agents attempt to break out of it, the economy has a tendency to return to the low-level, stable steady state.

We observed that the average product of capital, $f(k)/k$, declines with k in the neoclassical model. We also noted, however, that this average product may rise with k in some models that feature increasing returns, for example, in formulations that involve learning by doing and spillovers. One way for a poverty trap to arise is for the economy to have an interval of diminishing average product of capital followed by a range of rising average product. (Poverty traps also arise in some models with nonconstant saving rates; see Galor and Ryder, 1989.)

We can get a range of increasing returns by imagining that a country has access to a traditional, as well as a modern, technology.[38] Imagine that producers can use a primitive production function, which takes the usual Cobb–Douglas form,

$$Y_A = AK^{\alpha}L^{1-\alpha} \tag{1.69}$$

The country also has access to a modern, higher productivity technology,[39]

$$Y_B = BK^{\alpha}L^{1-\alpha} \tag{1.70}$$

where $B > A$. However, in order to exploit this better technology, the country as a whole is assumed to have to pay a setup cost at every moment in time, perhaps to cover the necessary public infrastructure or legal system. We assume that this cost is proportional to

37. See especially the *big-push* model of Lewis (1954). A more modern formulation of this idea appears in Murphy, Shleifer, and Vishny (1989).

38. This section is an adaptation of Galor and Zeira (1993), who use two technologies in the context of education.

39. More generally, the capital intensity for the advanced technology would differ from that for the primitive technology. However, this extension complicates the algebra without making any substantive differences.