Convergence across countries and regions: theory and empirics

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November 2002

Abstract

This paper surveys the recent literature on convergence across countries and regions. I discuss the main convergence and divergence mechanisms identified in the literature and develop a simple model that illustrates their implications for income dynamics. I then review the existing empirical evidence and discuss its theoretical implications. Early optimism concerning the ability of a human capital-augmented neoclassical model to explain productivity differences across economies has been questioned on the basis of more recent contributions that make use of panel data techniques and obtain theoretically implausible results. Some recent research in this area tries to reconcile these findings with sensible theoretical models by exploring the role of alternative convergence mechanisms and the possible shortcomings of panel data techniques for convergence analysis.

Keywords: convergence, growth
JEL Classification: O40

* This paper was prepared for a conference on "Growth, capital and new technologies" organized by the Instituto Valenciano de Investigaciones Económicas. A previous version was published in *EIB Papers/BEI Cahiers* 5(2), 2000, pp. 25-46. I would like to thank this journal for permission to reprint this work with some changes. Financial support from the European Fund for Regional Development, Fundación Caixa Galicia and the Spanish Ministry of Science and Technology (under grant SEC2002-01612) is gratefully acknowledged.

1. Introduction

In the last decade or so, growth has come to occupy an increasingly important place among the interests of macroeconomists, displacing to some extent their previous preoccupation with the business cycle. This change is largely due to two factors. The first one is the realization that, in terms of medium and long-term welfare, the trend is more important than the cycle -- provided the volatility of income remains as low as it has been during the last few decades.[1] The second factor is the increasing dissatisfaction with the traditional neoclassical models that summarized the preexisting consensus on the determinants of growth -- essentially because of their perceived inability to account for such key features of the data as the observed increase in international inequality or the absence of capital flows toward less developed countries.

Dissatisfaction with the received theory has motivated the search for alternatives to the traditional neoclassical model that has driven the recent literature on *endogenous growth*. At the theoretical level, numerous authors have developed a series of models in which departures from traditional assumptions about the properties of the production technology or the determinants of technical progress generate predictions about the evolution of the international income distribution that stand in sharp contrast with those of neoclassical theory. Some of these models emphasize the role of growth factors that were ignored by previous theories and generate policy implications that are considerably more activist than those derived from the traditional models. At the empirical level, there is also a rich literature that attempts to test the validity of the different theoretical models that have been proposed, and to quantify the impact of various factors of interest on growth and on the evolution of international or interregional income disparities.

This paper provides an introduction to the theoretical and empirical literature on growth and convergence across countries and regions. It is organized as follows. Section 2 contains some general considerations on the convergence and divergence mechanisms identified in the growth literature. In Section 3 I develop a simple descriptive model that attempts to capture the main immediate determinants of the growth of output and illustrates how some key properties of technology determine the evolution of the international or interregional income distribution. Section 4 focuses on the empirical implementation of growth models through convergence equations. Finally, sections 5 and 6 contain a brief survey of the main empirical results on convergence and a discussion of their theoretical implications. Section 7 concludes with a brief summary and some tentative conclusions.

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[1] See Lucas (1987).

2. Convergence and divergence in growth theory

As the reader will soon discover, the concept of *convergence* plays a crucial role in the literature we will survey. Although I will eventually provide a more precise defintion of this term, we can provisionally interpret it as short-hand for the possible existence of a tendency towards the reduction over time of income disparities across countries or regions. Hence, we will say that there is convergence in a given sample when the poorer economies in it tend to grow faster than their richer neighbours, thereby reducing the income differential between them. When we observe the opposite pattern (i.e. when the rich grow faster and increase their lead) we will say that there is divergence in the sample.

Economic theory does not provide unambiguous predictions about the convergence or divergence of per capita income levels across countries or regions. It does, however, identify a series of factors or mechanisms that are capable in principle of generating either convergence or divergence. Theoretical models based on different assumptions about the existence or relative importance of such mechanisms can generate very different predictions about the evolution of income disparities across territories.

At some risk of oversimplifying, we can classify growth models into two families according to their convergence predictions. According to those in the first group, being poor is, to some extent, an advantage. In these models the technology is such that, other things equal, poor countries grow faster than rich ones. This does not necessarily imply the eventual elimination of inequality (other things may not be equal), but it does mean that the distribution of relative income per capita across territories will tend to stabilize in the long run, provided some key "structural" characteristics of the different economies remain unchanged over time. In the second set of models, in contrast, rich countries grow faster and inequality increases without any bound.

The source of these contrasting predictions must be sought in very basic assumptions about the properties of the production technology at a given point in time and about the dynamics of technological progress. A first necessary condition for convergence is the existence of decreasing returns to scale in capital (or, more generally, in the various types of capital considered in the model). This assumption means that output grows less than proportionally with the stock of capital. This implies that the marginal productivity of this factor will decrease with its accumulation, reducing both the incentive to save and the contribution to growth of a given volume of investment and creating a tendency for growth to slow down over time. The same mechanism generates a convergence prediction in the cross-section: poor countries (in which capital is scarcer) will grow faster than rich ones because they have a greater incentive to save and a enjoy faster growth with the same rate of investment. This result will be reinforced by open-economy considerations, as the flows of mobile factors, together with international trade, will contribute to the equalization of factor prices and domestic products per worker. Under the opposite assumption (of increasing returns in capital), the preceeding neoclassical logic is inverted and we obtain a divergence prediction. In this case, the return on investment increases with the stock of capital per worker, favouring rich countries that tend to grow faster than poor ones, thereby increasing inequality further.

The second factor to consider in relation with the convergence or divergence of income per capita or productivity has to do with the determinants of technological progress. If countries differ in the intensity of their efforts to generate or adopt new technologies, their long-term growth rates will be different. One possible objection is that the persistence of such differences is not plausible. For instance, it may be argued that the return on technological capital should decrease with its accumulation, just as we would expect to find for other assets. In this case, large differences across countries in rates of technological investment would not be sustainable, and there would be a tendency towards the gradual equalization of technical efficiency levels. It is far from clear, however, that the accumulation of knowledge should be subject to the law of diminishing returns. If the cost of additional innovations falls with scientific or production experience, for instance, the return on technological investment may not be a decreasing function of the stock of accumulated knowledge, and cross-country differences in levels of technological effort could persist indefinitely.

Hence, technical progress could be an important divergence factor. But there are also forces that push in the opposite direction. As Abramovitz (1979, 1986) and other authors have pointed out, the public good properties of technical knowledge have an international dimension that tends to favour less advanced countries, provided they have the capability to absorb foreign technologies and adapt them to their own needs. The idea is simple: not having to reinvent each wheel, followers will be in a better position to grow quickly than the technological leader, who will have to assume the costs and lags associated with the development of new leading-edge technologies.[2] The resulting process of technological catch up could contribute significantly to convergence, particularly within the group of industrialized countries that are in a position to exploit the advantages derived from technological imitation.

In addition to decreasing returns and technological diffusion, the literature identifies a third convergence mechanism that, although featured less prominently in theoretical models, is likely to be of great practical importance. This mechanism works through structural change, or the reallocation of productive factors across sectors. Poorer countries and regions tend to have relatively large agricultural sectors. Given that output per worker is typically much lower in agriculture than in manufacturing or in the service sector, the flow of resources out of agriculture and into these other activities tends to increase average productivity. Since this process, moreover, has generally been more intense in poor economies than in rich ones in the last few decades, it may have contributed significantly to the observed reduction in productivity differentials across territories.

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[2] The idea seems to be due originally to Gerschenkron (1952) and has been developed among others by Abramovitz (1979, 1986), Baumol (1986), Dowrick and Nguyen (1989), Nelson and Wright (1992) and Wolff (1991).

In conclusion, economic theory identifies forces with contrasting implications for income dynamics. Convergence mechanisms feature prrominently in the neoclassical and catch-up models that dominated the literature until recently. The perceived failure of the optimistic convergence predictions of these models, however, has motivated the search for alternatives and contributed to the development of new theories that incorporate various divergence factors.[3] Some of the pioneers of the "endogenous growth" literature (especially Romer (1986 and 1987a and b) focused on the possibility of non-decreasing returns to scale in capital alone, while other authors, such as Lucas (1988), Romer (1990) and Grossman and Helpman (1991), developed models in which the rate of technical progress was determined endogenously and could differ permanently across countries, reflecting differences in structural characteristics. In both cases, the theory allows for the possibility of a sustained increase in the level of international or interregional inequality.

3. A formal model

In this section I will develop a simple model that summarizes the key ingredients of the two families of growth theories we have identified in the previous section. The model can generate very different predictions about the behaviour of the international or interregional income distribution depending on the values of certain parameters that capture assumptions about the properties of the production technology and the determinants of the rate of technical progress. In this model, taken from de la Fuente (1995), the evolution of the relative income of two countries or regions (a "leader" and a "follower"), appears as the result of two processes --the accumulation of capital and technological progress-- whose rhythm depends on the rates of investment on physical and knowledge capital and on the speed of technological diffusion. The analysis identifies two possible sources of divergence or rising inequality: the existence of increasing returns in reproducible factors, and the persistence of different rates of R&D investment in the absence of technological diffusion. Under the alternative assumptions of decreasing returns and technological catch-up, the model predicts that the level of international or interregional inequality will tend to stabilize with the passage of time, generating a stationary or long-term equilibrium distribution of income in which the relative position of each territory is determined by its investment effort.

a. Immediate determinants of the rate of growth

Economists have generally approached the study of growth with something like an aggregate production function in mind -- that is, starting from the hypothesis that there is a stable relationship between aggregate output on one hand and the stocks of physical inputs and technical knowledge on the other. From this perspective, the growth of output depends on the rate of accumulation of various productive factors and the speed of technical progress and, ultimately, on the determinants of these

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[3] See Romer (1986) and Lucas (1988 and 1990) among others.

variables, that is, on the underlying preference and technology parameters, on economic policies and political, social and demographic factors.

For the sake of concreteness, let us consider a world in which there are only two factors of production and one final good. Capital *(K)* and labour *(L)* are combined to produce a homogeneous output *(Y)* that can be consumed directly or used as capital in the production process. We will assume that the production technology can be adequately described by an aggregate production function of the form

$$(1)\ Y = \Phi K^{a}(AL)^{1-a} = \Phi ALZ^{a}$$

where A is an index of labour-augmenting technical efficiency and K denotes a broad capital aggregate that includes both human and physical capital. The variable $Z = K/AL$ denotes the capital/labour ratio in efficiency units and the coefficients a and $1-a$ measure the elasticity of output with respect to factor stocks.

To allow the possibility of increasing returns in the simplest possible way, I will assume that the term Φ, although perceived as an exogenous constant by individual agents, is in fact a function of the form $\Phi = Z^{b}$ that captures the external effects associated with investment.[4] Under these assumptions, output per worker, Q, is given by

$$(2)\ Q = AZ^{\alpha}$$

where $\alpha = a + b$ measures the degree of returns to scale in capital taking into account this factor's indirect contribution to productivity through possible externalities.

Given equation (2), the growth of output per worker must be the result of the accumulation of productive factors or the outcome of technical progress. Taking logarithms of (2) and differentiating with respect to time, we see that the rate of growth of output per capita $\dot{Q}/Q = g_Q$,[5] can be written as the sum of two terms that reflect, respectively, the rate of technical progress and the accumulation of productive factors:

$$(3)\ g_Q = g_a + \alpha g_z.$$

In the rest of this section we will explore the immediate determinants of g_a and g_z. Let us start with the second factor. Denoting by s the share of investment in GDP and by δ the rate of depreciation, the increase in the aggregate capital stock is given by the difference between investment and depreciation, that is,

$$(4)\ \dot{K} = sY - \delta K = sLQ - \delta K$$

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4 This specification is basically the one proposed by Romer (1986) building on Arrow (1962) to capture the possibility that capital accumulation may generate positive spillovers. A possible justification is provided in Romer (1987b). If there are fixed entry costs, a larger capital stock will allow an increase in the number of firms and a finer division of labour. Increased specialization, particularly by producers of intermediate goods, could then improve overall efficiency.

5 I will use the notation $\dot{x} = dx/dt$ for the derivative of x with respect to time, that is, the increase in its value over an infinitesimally short period. I will denote the instantaneous growth rate of x by $g_x = \dot{x}/x = d\ln x/dt$, and make use of the following fact: if $x = y/z$, then $g_x = g_y - g_z$; similarly, if $x = yz$, then $g_x = g_y + g_z$.

where $\dot{K} = dK/dt$ is the instantaneous increase in the capital stock. Since $Z = K/AL$, the growth rate of the stock of capital per efficiency unit of labour, g_Z, is the difference between $g_k = \dot{K} / K$ and the sum of the rates of technical progress (g_a) and labour force growth (n). Using (2) and (4), it is easy to see that

$$(5)\ g_Z = g_k - g_a - n = sZ^{\alpha-1} - (n+g_a+\delta),$$

where the term $Z^{\alpha-1}$ ($= Q/(K/L)$) is the average product of capital. Substituting this expression into (3), we have

$$(6)\ g_Q = (1-\alpha)g_a + \alpha sZ^{\alpha-1} - \alpha(n+\delta).$$

Finally, we have to specify the determinants of the rate of technical progress, g_a. I will assume that g_a is an increasing function of the fraction of GDP invested in R&D (θ) and of the opportunities for technological catch-up, measured by the log difference ($b = \ln X - \ln A$) between a "technological frontier" denoted by X and the country's own technological index, A:

$$(7)\ g_a = \gamma\theta + \varepsilon b.$$

The parameters ε and γ measure, respectively, the speed of diffusion of new technologies across countries and the productivity of R&D. We will also assume that best-practice technology improves at a rate g_x which we will take as exogenous from the perspective of each given country and assume constant for simplicity.

Substituting (7) into (6) we finally arrive at an expression,

$$(8)\ g_Q = (1-\alpha)(\gamma\theta + \varepsilon b) + \alpha sZ^{\alpha-1} - \alpha(n+\delta),$$

that gives the rate of growth of output per worker, g_Q, as a weighted sum of two terms that capture the immediate determinants of the rates of technical progress and capital accumulation.

b.- Dynamics

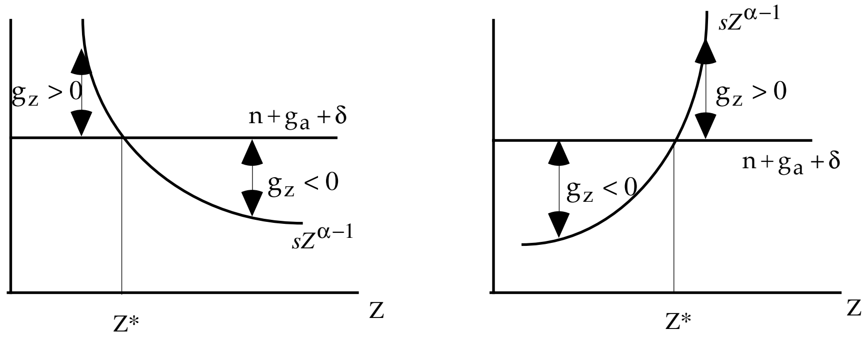
We will now explore the implications of equation (8) for the evolution of output per worker. To study the dynamics of the system, it will be convenient to organize the analysis in terms of the impact of two separate processes, capital accumulation and technical progress, on the evolution of the relative income of two countries, a "leader" and a "follower." I will show that each of these processes, by itself, can generate either convergence or divergence in output per worker. If the technology displays increasing returns in capital ($\alpha > 1$), the rate of return on investment increases with the stock of capital, and the system displays "explosive" behaviour. Over time, growth accelerates in each given country, and income differences across nations increase without bound. On the other hand, when $\alpha < 1$ the return on investment falls with accumulation and this implies that stocks of capital per worker (and hence per worker income levels) tend to converge across countries, provided they all share the same technology and other structural parameters. Similarly, the evolution of relative technical efficiency may adopt two quite different patterns. If there is no international technological diffusion ($\varepsilon=0$), the country that invests more in R&D will always have a higher rate of productivity growth. If there is a catch-up effect, however, the technological distance between the two countries will tend to stabilize at a point at which the advantage derived from the possibility of imitation is just sufficient to offset the lower R&D investment of the follower.

To analyze in detail the dynamics induced by capital accumulation, let us recall that the growth rate of the stock of capital per efficiency unit of labour is given by

$$(5)\ g_Z = sZ^{\alpha-1} - (n+g_a+\delta).$$

Assuming for now that the rate of technical progress, g_a, is an exogenous constant, we can draw both terms on the right-hand side of (5) as functions of Z. As shown in Figure 1, the rate of factor accumulation, g_Z, is the difference between the product of the investment rate and the average product of capital, $sZ^{\alpha-1}$, and the constant $(n+g_a+\delta)$ -- and corresponds, therefore, to the vertical distance between the two lines, as shown in the figure.[6]

Figure 1: Dynamics of capital accumulation



a. Decreasing returns in capital ($\alpha < 1$) b. Increasing returns ($\alpha > 1$)

The two panels of Figure 1 show that the behaviour of the dynamical system described by (5) depends crucially on the value of α. When $\alpha < 1$, that is, when the neoclassical assumption of decreasing returns holds, the return on investment decreases with the stock of capital. Hence, the term $Z^{\alpha-1}$, is a decreasing function of Z and cuts the horizontal line given by the constant $(n+g_a+\delta)$ at the point Z^* characterized by

$$g_Z = 0 \quad \Rightarrow \quad (9)\ Z^* = \left(\frac{s}{n+g_a+\delta}\right)^{1/(1-\alpha)}.$$

From a dynamic point of view, the key finding is that under the assumption of decreasing returns the curve $sZ^{\alpha-1}$ cuts the horizontal line from above, making the growth rate of Z a decreasing function of its level. This implies that the steady state or long-term equilibrium described by Z^* is stable. Notice that g_Z is positive (that is, Z increases over time) when the stock of capital per worker is small (and therefore the return on investment is high), and negative (Z decreases over time) when Z is "large" (larger than Z^*), for in this case the volume of investment is not enough to cover depreciation and

[6] The figure ignores the fact that the rate of technical progress, g_a will be changing over time, causing a vertical displacement of the horizontal line. It can be shown, however, that the "whole system" is stable. Asymptotically, the horizontal line stops shifting as g_a converges to the constante value g_x and Z converges to Z^* as shown in the figure.

equip newborn workers with the average stock of capital. Hence, we can interpret the steady-state value of the stock of capital per unit of labour, Z^*, as the one corresponding to a long-term equilibrium to which the economy gradually converges for any given initial value of Z .

In summary, when $\alpha < 1$ the system is stable and the stock of capital per efficiency unit of labour converges to its stationary value, Z^*. When the external effects associated with the accumulation of capital are sufficiently strong that $\alpha > 1$, the situation is very different, as shown in panel b of Figure 1. Since the return on investment, measured by $Z^{\alpha-1}$, is now an increasing function of the stock of capital per efficiency unit of labour, the rate of accumulation increases with Z instead of falling. Hence, Z grows when it is larger than Z^* and falls when it is smaller, moving farther and farther away from the steady state, which must now be interpreted as a threshold for growth rather than as a long-run equilibrium.

The implications of these results for convergence are clear. Given two countries identical except in their initial capital stocks (i.e. with access to the same technology and similar rates of investment and population growth), the evolution of their stocks of capital and therefore of their relative incomes depends crucially on the existence or inexistence of increasing returns to scale in capital. Under the assumption of decreasing returns, the stock of capital per worker (and hence average productivity) will converge to a common value. With increasing returns, on the other hand, the advantage of the initially richer country will increase over time.

To analyze the impact of technical progress on growth and convergence it will be convenient to work explicitly with two countries, f and l, (follower and leader). Let us define the technological distance between leader and follower by

$$b_{lf} = a_l - a_f = (a_l - x) - (a_f - x) = b_f - b_l$$

where b_l and b_f denote the technological distance between each of these countries and the best-practice frontier. Observe that the evolution of the technological gap between leader and follower, b_{lf}, satisfies the following equation: $\dot{b}_{lf}$

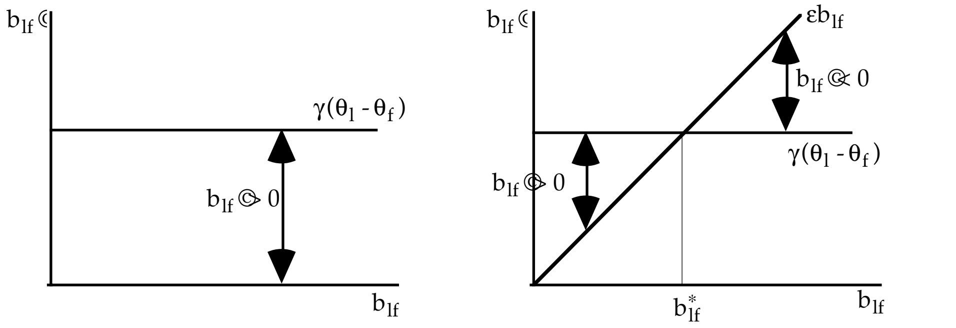
$$(10)\quad \dot{b}_{lf} = \dot{a}_l - \dot{a}_f = \gamma(\theta_l - \theta_f) + \varepsilon(b_l - b_f) = \gamma(\theta_l - \theta_f) - \varepsilon b_{lf}$$

Figure 2 displays the dynamics of this equation under two assumptions on the value of ε. When there is no technological diffusion $(\varepsilon = 0)$, the leading country (which by assumption invests more in R&D) always has a higher rate of productivity growth. As a result, $\dot{b}_{lf}$ is always positive and the technological distance between leader and follower, b_{lf}, grows without bound as shown in Figure 2a.

When $\varepsilon > 0$, on the other hand, the line εb_{lf} is positively-sloped and cuts the horizontal line $\gamma(\theta_l - \theta_f)$ at a finite value of b_{lf} we will denote by b_{lf}^*. Under this assumption, the model is stable: $\dot{b}_{lf}$ is positive (that is, the technological gap increases over time) when b_{lf} is below its stationary value, b_{lf}^*, and negative (b_{lf} decreases) otherwise (see Figure 2b). Hence, the technological gap converges to a finite value, b_{lf}^*, defined by

$$\dot{b}_{lf} = 0 \quad \Rightarrow \quad (11)\ b_{lf}^* = \frac{\gamma(\theta_l - \theta_f)}{\varepsilon}\,.$$

Figure 2: Evolution of the technological distance between leader and follower



a. No technological diffusion *(ε = 0)* b. Catch-up with technological diffusion *(ε > 0)*

In the long run, the (logarithm of the) ratio of the technical efficiency indices of the two countries converges to a constant value that is directly proportional to the difference between their rates of investment in R&D, and inversely proportional to the speed of technological diffusion.

Combining the results of the partial analyses undertaken so far, we can distinguish between two cases. When the technology exhibits increasing returns in capital $(\alpha > 1)$ or there is no technological diffusion $(\varepsilon = 0)$, the model is unstable and the growth paths of the two countries diverge. If there are decreasing returns and technological diffusion ($\alpha < 1$ and $\varepsilon > 0$), however, the model is stable. In the long run, the rates of growth of the two countries converge to the world rate of technical progress, g_x, and the ratio of their per capita incomes

$$\frac{Q_l}{Q_f} = \frac{A_l Z_l^{\alpha}}{A_f Z_f^{\alpha}},$$

approaches a strictly positive constant value whose logarithm is given by:

$$(12)\ (q_l - q_f)^* = b_{lf}^* + \alpha(z_l^* - z_f^*) = \frac{\gamma(\theta_l - \theta_f)}{\varepsilon} + \frac{\alpha}{1-\alpha}\, ln\left(\frac{s_l(n_f + g_x + \delta)}{s_f(n_l + g_x + \delta)}\right),$$

where $z = ln\ Z$ and $q = ln\ Q$. Hence, there is convergence in the sense that each country approaches a long-run equilibrium in which its income per capita, expressed as a fraction of the sample average, remains constant over time at a level determined by its fundamentals.

This expression shows that long-run income disparities can be attributed to differences in levels of investment in physical and technological capital and in rates of population growth. Notice, however, that the extent to which such differences in "fundamentals" translate into long-term productivity differentials depends on the strength of the two convergence mechanisms present in the model. For given values of θ, s and n, the income differential across countries will be a decreasing function of the rate of technological diffusion (ε) and the degree of returns to scale in capital (α). Hence, both convergence mechanisms tend to mitigate the level of international inequality induced by cross-country differences in fundamentals, but do not eliminate it.

4. From theory to empirics: a framework for empirical analysis and some convergence concepts

In the previous sections we have identified two groups of theories of growth with contrasting implications for the evolution of the international or interregional distribution of income. While traditional neoclassical models and those that incorporate the assumption of technological catch-up have relatively optimistic convergence implications, some endogenous growth models based on the assumption of increasing returns and those that emphasize the endogeneity of the rate of technical progress can generate a tendency towards the increase of income disparities across economies.

When it comes to trying to distinguish empirically between these two families of models, the natural starting point is probably the observation that the main testable difference between them has to do with the sign of the partial correlation between the growth rate and the initial level of income per capita. While this correlation should be negative according to standard neoclassical models (that is, other things equal poorer countries should grow faster), in some models of endogenous growth the expected sign would be the opposite one. This suggests that a natural way to try to determine which group of models provides a better explanation of the growth experience involves estimating a *convergence equation,* that is, a regression model in which the dependent variable is the growth rate of income per capita or output per worker and the explanatory variable is the initial value of the same income indicator. The sign of the estimated coefficient of this last variable allows us in principle to discriminate between the two sets of alternative models.

The correct formulation of the empirical model, however, requires that we control for other variables that may affect the growth rate of the economies in the sample. As we have seen in a previous section, neoclassical and catch-up models predict that poor countries will grow faster than rich ones only under certain conditions. In Solow's (1956) neoclassical model, for instance, the long-term level of income is a function of the rates of investment and population growth and can, therefore, differ across countries. In a similar vein, Abramovitz (1979, 1986) emphasizes that the process of technological catch-up is far from automatic. Although relative backwardness carries with it the potential for rapid growth, the degree to which this potential will be realized in a given country depends on its "social capability" to adopt advanced foreign technologies (i.e. on factors such as the level of schooling of its population and the availability of qualified scientific and technical personnel) and on the existence of a political and macroeconomic environment conducive to investment and structural change.

In short, even in models where convergence forces prevail, long-term income levels can vary across territories, reflecting underlying differences in "fundamentals." If we do not control for such differences, the estimated relationship between growth and initial income could be very misleading. Imagine, for instance, that the Solow model (with decreasing returns and access by all economies to a common technology) is the correct one, and that richer countries display on average higher rates of investment and lower rates of population growth than poorer countries (which is why they are richer in the first place). According to the model, these two factors would have a positive effect on the growth rate (during the transition to the long-run equilibrium) that could conceivably dominate the convergence effect that makes growth a decreasing function of income with other things constant. It is clear that if we do not include the rates of investment and population growth in the equation, we could find that the estimated coefficient of initial income is positive and conclude, erroneously, from this fact that the predictions of the Solow model fail to hold. To put it in a slightly different way, the problem would be that when we do not control for the determinants of the steady state, we are actually testing the hypothesis that all economies converge to the same long-run equilibrium. The rejection of this hypothesis, however, has no implications for the validity of the Solow model, since this model makes no such prediction except when the economies in the sample are exactly alike.

On the basis of the preceding discussion, we can conclude that a "minimal" model for the empirical analysis of convergence would be an equation of the form

$$(13)\ \Delta y_{it} = \gamma x_{it} - \beta y_{it} + \varepsilon_{it}\ ,$$

where y_{it} is income per capita or per worker in territory i at the beginning of period t, Δy_{it} the growth rate of the same variable over the period, ε_{it} a random disturbance and x_{it} a variable or set of variables that captures the "fundamentals" of economy i, that is, all those characteristics of this territory that have a permanent effect on its growth rate.

a. Structural convergence equations

Many empirical studies of growth and convergence have proceeded by estimating some variant of equation (13). In early studies the empirical specification was frequently ad hoc and only loosely tied with the theory.[7] In recent years, however, researchers have increasingly focused on the estimation of "structural" convergence equations derived explicitly from formal models. One of the most popular specifications in the literature is the one derived by Mankiw, Romer and Weil (MRW 1992) from an extended neoclassical model à la Solow (1956) that would be equivalent to the one developed in Section 3 under the assumption that the rate of technical progress is an exogenous constant common to all countries.[8] Working with a log-linear approximation to the model around its steady state, MRW show that the growth rate of output per worker in territory i during the period that starts at t is given approximately by the following equation:[9]

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[7] See for instance Kormendi and McGuire (1985), Grier and Tullock (1989) and Barro (1991).

[8] That is, the specification of the rate of technical progress as a function of R&D expenditure and the technological gap is abandoned, being replaced by the simple assumption that the rate of technological progress is an exogenous constant, g, equal for all countries. The part of the model that describes capital accumulation, on the other hand, would be exactly as developed in Section 3.

[9] Barro and Sala i Martin (1990, 1992) derive a similar expression from a variant of the optimal growth model of Cass (1965) and Koopmans (1965) with exogenous technical progress. The resulting equation is similar to (14) except that the investment rate (which is now endogenous) is replaced by the rate of time discount among the determinants of the steady state. The convergence coefficient, β, is now a more complicated function of the parameters of the model, but it still depends on the degree of decreasing returns to capital and on the rates of population growth, depreciation and technical progress. A second difference between the two models is that, whereas the MRW model can be easily extended to incorporate investment in human capital, Barro and Sala i Martin do not include this factor as an argument of the production function, although they do bring it into their empirical specification, in an ad hoc way, as a determinant of the steady state.

$$(14)\ \Delta y_{it} = g + \beta(a_{io} + gt) + \beta \frac{\alpha}{1-\alpha} ln \frac{s_{it}}{\delta+g+n_{it}} - \beta y_{it}$$

where

$$(15)\ \beta = (1-\alpha)\,(\delta+g+n),$$

g is the rate of technical progress, δ the depreciation rate, α the coefficient of capital in the aggregate production function, t the time elapsed since the beginning of the sample period, a_{io} the logarithm of the index of technical efficiency at time zero, s the share of investment in GDP and n the rate of growth of the labour force.

It is important to understand that the estimation of equation (14) does not imply that we are literally accepting the assumptions of the underlying Solow-type model (i.e. we do not need to assume that the investment rate is exogenous or constant over time). What we are doing is simply assigning to some of the parameters of the Solow model (in particular, to s and n) the observed average values of their empirical counterparts during a given period. During this period, the economy will behave approximately as if it were approaching the steady state of the Solow model that corresponds to the contemporaneous parameter values. In the next period, of course, we are likely to observe different values of the investment and population growth rates and therefore, a different steady state, but this poses no real difficulty. In essence, all we are doing is constructing a convenient approximation to the production function that allows us to recover its parameters using data on investment flows rather than factor stocks. This is very convenient because such data are easier to come by and can be expected to be both more reliable and more comparable over time and across countries than most existing estimates of factor stocks. It must be kept in mind, however, that the only information we can extract from the estimation of a convergence equation of the form (14) concerns the properties of the production technology. As Cohen (1992) emphasizes, the estimated equation does not, in particular, tell us anything about the actual dynamics of the economy or the position of a hypothetical long-run equilibrium -- although it does allow us to make predictions about long-term income levels conditional on assumptions about the future behaviour of investment and population growth rates.

The empirical implementation of equation (13) or (14) does not, in principle, raise special problems. Given time series data on income, population and investment for a sample of countries or regions, we can use (14) to recover estimates of the rate of convergence and the parameters of the production function. The convergence equation can be estimated using either cross-section or pooled data. Most of the earlier convergence studies took the first route, averaging the variables over the entire sample period and working with a single observation for each country or region. The second possibility, which has become increasingly popular, involves averaging over shorter subperiods in order to obtain several observations per country.

In either case, one difficulty which immediately becomes apparent is that three of the variables on the right-hand side of the equation (g, δ and a_{io}) are not directly observable. In the first two cases, the problem is probably not very important. Although these coefficients can be estimated inside the equation (and this has been done occasionally), the usual procedure in the literature is to impose "reasonable" values of these parameters prior to estimation. The standard assumption is that $g = 0.02$ and $\delta = 0.03$, but researchers report that estimation results are not very sensitive to changes in these values.

The possibility that initial levels of technical efficiency (a_{io}) may differ across countries does raise a more difficult problem. Although some authors have argued that it may be reasonable to assume a common value of a_{io} because most technical knowlege is in principle accessible from everywhere, casual observation suggests that levels of technological development differ widely across countries. If this is so, failure to control for such differences (or for any other omitted variables) will bias the estimates of the remaining parameters whenever the other regressors in the equation are correlated with the missing ones. In other words, we can only legitimately subsume technological differences across countries in the error term if they are uncorrelated with investment rates and population growth. This seems unlikely, however, as the level of total factor productivity is one of the key determinants of the rate of return on investment.

The standard solution for this problem is to turn to panel data techniques in order to control for unobserved national or regional fixed effects. The simplest procedure involves introducing country or regional dummies in order to estimate a different regression constant for each territory. It should be noted, however, that this is equivalent to estimating the equation with the dependent and independent variables measured in deviations from their average values (computed over time for each country or region in the sample). Hence, this procedure (as most panel techniques designed for removing fixed effects), ignores the information contained in observed cross-country differences and produces parameter estimates which are based only on the time variation of the data within each territory over relatively short periods. Since what we are trying to do is characterizing the long-term dynamics of a sample of economies, this may be rather dangerous, particularly when the data contain an important cyclical component or other short-term noise.

The structural convergence equation methodology has some important advantages and limitations, both of which are derived from the close linkage between theory and empirics that charaterizes this approach. Its most attractive feature is that it allows us to use the relevant theory to explicitly guide the formulation of the empirical model -- that is, the formal model is used to determine what variables must be included in the regression and how they must enter in order to obtain direct estimates of the structural parameters of the model. It is clear, however, that such guidance comes at a price, as our estimates will be, at best, only as good as the underlying theoretical model. Hence, an inadequate specification of this model can yield very misleading conclusions.

Although this problem arises to some extent whenever we run a regression, there are reasons to think that it may be particularly important in the present context. In most of the recent empirical work on growth and convergence, the theoretical model of reference is some version of the one-sector neoclassical model with exogenous technical progress that underlies equation (14). Since the only convergence force present in this model is what we may call the neoclassical mechanism, the usual finding of a negative partial correlation between growth and initial income must be interpreted in this framework as evidence that the aggregate production function displays decreasing returns to scale in reproducible factors. In fact, this assumption is precisely what allows us to draw inferences about the degree of returns to scale from the estimated value of the convergence coefficient. The problem, of course, is that if there are any other operative convergence mechanisms, the inference will not be valid, as the estimated value of the convergence parameter will also capture their effects.

As we have seen, the literature identifies at least two factors other than decreasing returns that can generate a negative partial correlation between income levels and growth rates holding investment and population growth constant: technological diffusion and structural change. Although none of these convergence mechanisms is incompatible with the neoclassical story, the observation that this is not the only possible source of convergence suggests that it may be dangerous to accept without question an interpretation of the convergence coefficient based too literally on the preceding model. For instance, if income per capita is highly correlated with the level of technological development, the coefficient of initial income in a convergence regression could capture, at least in part, a technological catch-up effect. To avoid the danger of drawing the wrong conclusions about the properties of the technology, it may be preferable to interpret existing estimates of the convergence parameter, β, (particularly in the case of unconditional convergence equations) as summary measures of the joint effect of several possible convergence mechanisms. The value of this parameter (i.e. the partial correlation betwen the growth rate and initial income) will depend on the coefficient of capital in the production function, the speed of technological diffusion, the impact of sectoral change and on the response of investment rates to rising income), and will be positive (i.e. growth will be negatively correlated with initial income) whenever the forces making for convergence dominate those working in the opposite direction.

b. Some convergence concepts

Before we review the empirical evidence, it is convenient to introduce some concepts of convergence that will feature prominently in the discussion below. Perhaps the first question that arises concerning the evolution of the distribution of income per capita is whether the dispersion of this variable (measured for instance by the standard deviation of its logarithm) tends to decrease over time. The concept of convergence implicit in this question, called *σ-convergence* by Barro and Sala i Martin (1990, 1992), is probably the one closest to the intuitive notion of convergence. It is not, however, the only possible one. We may also ask, for instance, whether poorer countries tend to catch up with richer ones, or whether the relative position of each country within the income distribution tends to stabilize over time. The concepts of *absolute* and *conditional β-convergence* proposed by Barro and Sala i Martin (B&S) correspond roughly to these two questions.

To make more precise these two notions of convergence, we can use a variant of equation (13) in which we assume that each economy's fundamentals remain constant over time (that is, that $x_{it} = x_i$ for all t) and we interpret the variable y_{it} as relative income per capita, that is, income per capita normalized by the contemporaneous sample average. Omitting the disturbance term, the evolution of relative income in territory i is described by

$$(13') \; \Delta y_{it} = \gamma x_i - \beta y_{it}.$$

Setting Δy_{it} equal to zero in this expression, we can solve for the steady-state value of relative income,

$$(16) \; y_i^* = \frac{\gamma x_i}{\beta}.$$

It is easy to check that if β lies between zero and one, the system described by equation (13') is stable. This implies that the relative income of territory i converges in the long run to the equilibrium value given by y_i^*. Notice that the equilibrium can differ across countries as a function of the "fundamentals" described by x_i.

In terms of this simple model, we will say that there is conditional β-convergence when β lies between zero and one, and absolute β-convergence when this is true and, in addition, x_i is the same for all economies -- i.e. when all countries or regions in the sample converge to the same income per capita.

Even though they are closely related, the three concepts of convergence are far from being equivalent. Some type of β-convergence is a necessary condition for sustained σ-convergence, for the level of inequality will grow without bound when β is negative (i.e. when the rich grow faster than the poor). It is not sufficient, however, because a positive value of β is compatible with a transitory increase of income dispersion due either to random shocks or to the fact that the initial level of inequality is below its steady-state value (as determined by the dispersion of fundamentals and the variance of the disturbance). The two types of β-convergence, moreover, have very different implications. Absolute β convergence implies a tendency towards the equalization of per capita incomes within the sample. Initially poor economies tend to grow faster until they catch up with the richer ones. In the long run, expected per capita income is the same for all members of the group, independently of its initial value. As we know, this does not mean that inequality will disappear completely, for there will be random shocks with uneven effects on the different territories. Such disturbances, however, will have only transitory effects, implying that, in the long run, we should observe a fluid distribution in which the relative positions of the different regions change rapidly. With conditional β-convergence, on the other hand, each territory converges only to its own steady state but these can be very different from each other. Hence, a high degree of inequality could persist, even in the long run, and we would also observe high persistence in the relative positions of the different economies. In other words, rich economies will generally remain rich while the poor continue to lag behind.

It is important to observe that, although the difference between absolute and conditional convergence is very sharp in principle, things are often much less clear in practice. In empirical studies we generally find that a number of variables other than initial income enter significantly in convergence equations. This finding suggests that steady states differ across countries or regions and, therefore, that convergence is only conditional. It is typically the case, however, that these conditioning variables change over time and often tend to converge themselves across countries or regions. Hence, income may still converge unconditionally in the long run, and this convergence may reflect in part the gradual equalization of the underlying fundamentals. In this situation, a conditional and an unconditional convergence equation will yield different estimates of the convergence rate. There is, however, no contradiction between these estimates once we recognize that they are measuring different things: while the unconditional parameter measures the overall intensity of a process of income convergence which may work in part through changes over time in various structural characteristics, the conditional parameter captures the speed at which the economy would be approaching a "pseudo steady state" whose location is determined by the current values of the conditioning variables.

5. Convergence across countries and regions: empirical evidence and theoretical implications

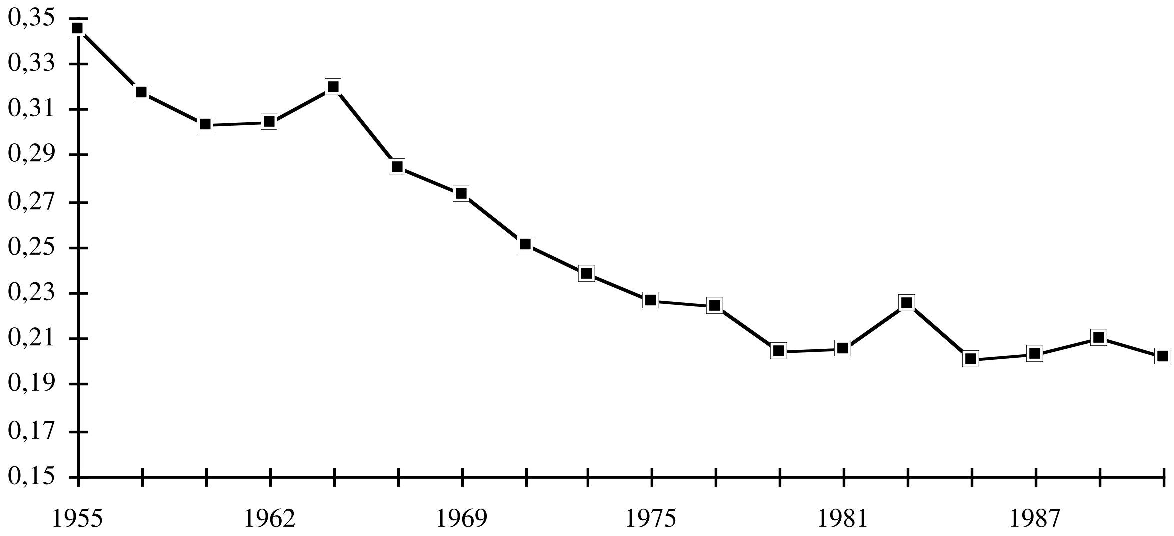
Having reviewed the theoretical and empirical framework used in the convergence literature, we are now in a position to examine the available empirical evidence an discuss its implications. I will begin this section with a review of some of the more significant empirical results in this literature. Although I will pay special attention to the case of Spain, the evolution of the regional income distribution follows a similar pattern in most samples. In most industrial countries we observe a significant reduction of the level of regional inequality over the medium and long run, although this process of convergence seems to cease or at least slow down in recent years. There is also clear evidence of β convergence: the correlation between initial income and subsequent growth is generally negative in regional samples even without conditioning on additional variables. At the national level, the situation is quite different. In broad country samples, the level of inequality increases over time and beta convergence emerges only when we condition on variables like human capital indicators and investment rates. On the other hand, the convergence rate estimated after controlling for these variables is quite similar to the one obtained with regional samples.

In addition to their descriptive interest, these results have interesting theoretical implications. The consensus view in the literature (at least until recently) seems to be that the apparent slowness of the process of convergence can be taken as an indication that the production technology displays almost constant returns to scale in capital -- a conclusion that only seems plausible if we extend the traditional concept of capital to incorporate educational investment. Hence, the empirical results seem to point towards an extended version of the neoclassical model built around a richer concept of capital than the one we find in the traditional theory. Some recent studies, however, suggest that it is probably premature to conclude that such a simple model provides a satisfactory description of the growth process and of the determinants of income levels.

a.-Some "classical" results on convergence

In this section I will review some representative results of a series of studies that follow what Sala i Martin (1996a) has called the "classical approach" to convergence analysis. To summarize the key features of the convergence pattern within a given sample, I will make use of two techniques that have been frequently used in the literature. The first one, designed for the study of sigma convergence, involves plotting the time path of some measure of dispersion of income per capita, typically the standard deviation of its logarithm. To analyze the pattern of beta convergence, I will estimate an unconditional convergence equation -- i.e. a version of equation (13) without conditioning variables in which I impose the assumption of a common intercept-- and plot the estimated regression line together with the corresponding scatter plot, identifying each of the observations. This procedure allows us to visualize the initial position of each economy and its performance relative to a hypothetical average region whose behaviour is described by the fitted regression line.

Figure 3: σ convergence in the Spanish regions, 1955-91



- *Note:* the original income variable is regional gross value added per capita in 1990 ptas., taken from Banco Bilbao Vizcaya (various years).

The case of Spain provides a representative illustration of what we find in most available regional samples. Figure 3 shows the time path of the standard deviation of relative regional income per capita (defined as log income per capita measured in deviations from its interregional average) during the period 1955-91. The pattern of sigma convergence is clear: over the period as a whole, the standard deviation of relative income per capita falls by approximately 40%. The level of inequality, however, stabilizes after the second half of the 70s. Although this may be an indication that the regional income distribution is close to its steady state, it may still be too soon to rule out the possibility that the interruption of the convergence process may be a transitory phenomenon due to the oil shocks and other macroeconomic turbulences of the last decades.

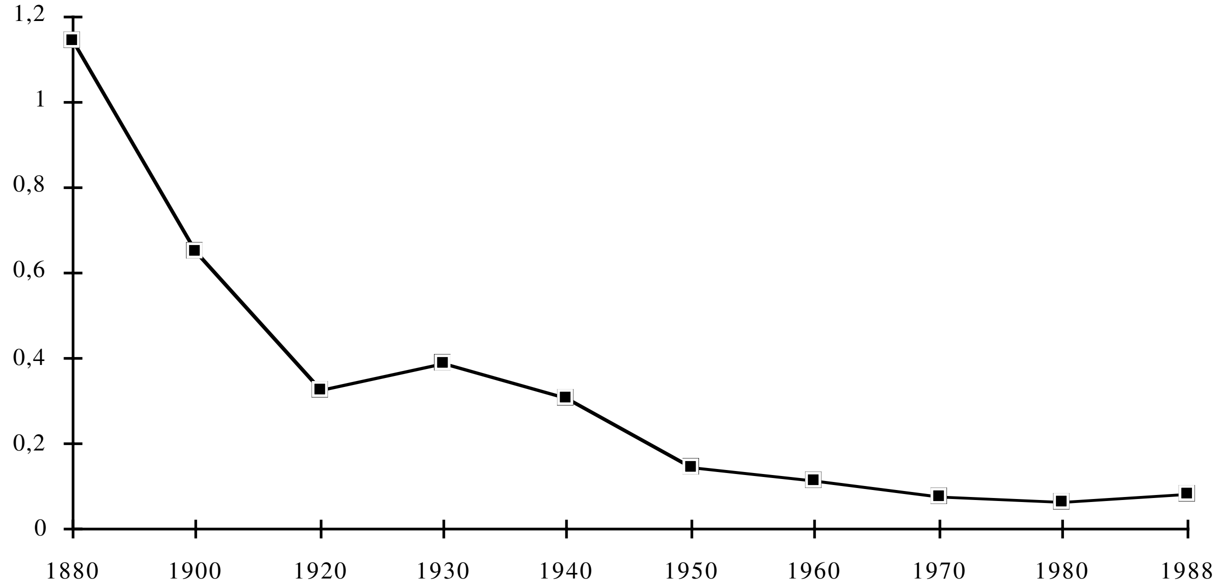
Figure 4: β convergence in the Spanish regions, 1955-91

- *Note:* The estimated equation is
$\Delta y_i = -0.01506 * y_{io}$ $t = 5.72$ $R^2 = 0.6859$.

Figure 4 summarizes the results of an unconditional convergence regression in which the dependent variable is the average growth rate of relative income during the whole sample period. The negative slope of the fitted regression line indicates that, on average, growth has been faster in the initially poorer regions. The fit of the regression is fairly good but the rate of convergence (i.e. the slope of the regression line) suggests that the process of convergence is very slow. The value of this coefficient (0.015) indicates that, in the case of a "typical region," only 1.5% of the income differential with respect to the national average is eliminated each year.

Moving on to other countries, the pattern of σ convergence at the regional level is very similar in most industrial economies. The States of the US, the Japanese prefectures and the regions of the European Union all display a gradual reduction of the level of inequality, although this process is sometimes interrupted by shocks such as WWII, the Great Depression or the oil shocks. In the last two decades, moreover, the pace of convergence slows down. The level of inequality stabilizes and even displays a slight increase in some cases. As an illustration, Figure 5 shows the evolution of the dispersion of personal income per capita in the states of the US during the last century.

Figure 5: σ convergence across the US states



- *Note:* coefficient of variation of the logarithm of personal income per capita.
- *Source:* Barro and Sala i Martin (1991).

We also find a similar pattern of beta convergence in most regional samples. Table 1 summarizes the results of the estimation of a standard convergence equation with regional data for a number of different countries.[10] In the European case, the data for the different countries are pooled and a common value of β is imposed with income measured in deviations from national means. Hence, the results refer to the speed of regional convergence within each country, just as in the individual regressions for the five largest EU members also reported in the table.

Two alternative estimates of β are reported for most samples. The first one comes from a cross-section regression of the average growth rate of income per capita over the entire sample period on the initial level of income. The second equation is estimated with pooled data for shorter subperiods, imposing a constant value of β but including fixed time effects. Most of the equations include as regressors indices of the sectoral composition of output (typically the share of agriculture) in order to control for aggregate shocks that may be correlated with initial income. In all cases, the estimated value of the convergence parameter is positive, indicating that poorer regions tend to grow faster than richer ones. A second empirical regularity (to which we will return in the next section) is that the estimated value of β is very small (around 2% per year) and rather stable across samples.

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10 This table is taken from a recent paper by Sala i Martin (1996b) that summarizes the results of various studies on regional convergence (in particular, Barro and Sala i Martin (1990) and (1991) for the US and several European countries, Coulombe and Lee (1993) for Canada and Shioji (1996) for Japan. Similar results are also reported by Dolado et al (1994) for Spain and by Persson (1997) for Sweden.

It is interesting to note that results obtained with national data are slightly different. When no additional variables are included to control for possible differences across national steady states, divergence (i.e. a negative value of β) is the norm in large samples. When we control for educational levels and other variables that may be considered reasonable proxies for the steady state, the hypothesis of (conditional) convergence is accepted in all samples and the estimated convergence rate approaches again the ubiquitous 2% figure.

Table 1: Regional convergence in different samples

	a single long period		*panel*
	β	R^2	β
sample and period:	[s.e.]		[s.e.]
48 US states 1880-1990	0.017 [0.002]	0.89	0.022 [0.002]
47 japanese prefectures 1955-1990	0.019 [0.004]	0.59	0.031 [0.004]
90 EU regions 1950-1990	0.015 [0.002]		0.018 [0.003]
11 German regions 1950-1990	0.014 [0.005]	0.55	0.016 [0.006]
11 UK regions 1950-1990	0.03 [0.007]	0.61	0.029 [0.009]
21 French regions 1950-1990	0.016 [0.004]	0.55	0.015 [0.003]
20 Italian regions 1950-1990	0.010 [0.003]	0.46	0.016 [0.003]
17 Spanish regions 1955-1987	0.023 [0.007]	0.63	0.019 [0.005]
10 Canadian provinces 1961-1991	0.024 [0.008]	0.29	

- *Note:* standard errors in brackets below each coefficient.
- *Source:* Sala i Martin (1996b)

Table 2, taken from B&S (1992a) summarizes the results of the estimation of a convergence equation with cross-section data for three different samples over roughly the same period: a broad sample of 98 countries, a smaller one formed by the 20 original OECD members, and a third one which comprises the 48 continental states of the US. As can be seen in the table, the results are very different in the three cases. When we do not control for other variables, the estimated value of the convergence parameter (β) is negative in the largest sample (equation [1]), indicating a tendency for rich countries to grow faster than poor ones. The coefficient is positive in the other two samples (equations [3] and [5]), but the estimated speed of convergence is twice as large for the US states than for the OECD countries.

Table 2: Convergence among countries and regions

Sample and period	*BETA [s.e.]*	R^2	*Other variables*
[1] 98 countries 1960-85	-0.0037 [0.0018]	0.04	no
[2] 98 countries 1960-85	0.0184 [0.0045]	0.52	yes
[3] OECD 1960-85	0.0095 [0.0028]	0.45	no
[4] OECD 1960-85	0.0203 [0.0068]	0.69	yes
[5] 48 US states 1963-1986	0.0218 [0.0053]	0.38	no
[6] 48 US states 1963-1986	0.0236 [0.0013]	0.61	yes

- *Source:* Barro and Sala i Martin (1992).
- The "other variables" included in regressions [2] and [4] are the primary and secondary enrollment rates in 1960, public consumption (excluding defense and education) as a fraction of GDP, the average annual number of political murders, the average number of revolutions and coups, and an index of the relative price of capital goods (constructed by Summers and Heston, 1991) in 1967.
  In addition to the initial level of income, equation [6] includes as regressors a set of regional dummies, a sectoral composition variable and the fraction of the labour force with some university enducation in 1960.
- Standard errors in brackets below each coefficient.

Barro and Sala i Martin interpret these results as an indication of the relative importance of the within-sample differences in steady states. As the sample becomes more and more homogeneous, the bias induced in the estimation of β by the omission of the relevant control variables will decrease. The results of equations [2], [4] and [6], where additional control variables are included, are consistent with this interpretation. Regressions [2] and [4] include as explanatory variables a proxy for the initial level of human capital, two indices of political stability, the share of non-productive public expenditure in GDP, and a measure of the distortions that affect the relative price of capital goods. Controlling for these variables, the estimated value of β is positive in both samples and very close to the value of 2% estimated in equation [5] for the continental US states. On the other hand, the inclusion of additional control variables (regional dummies, an index of education and a sectoral composition variable) in the last equation increases only slightly the estimated rate of convergence among the US states.

b. Theoretical implications: a revised neoclassical consensus?

The papers we have just reviewed highlight three interesting empirical regularities. i) First, evidence of some sort of beta convergence is found in practically all available samples. While convergence is only conditional at the national level, a negative correlation between initial income and subsequent growth emerges without controlling for other variables in regional samples. This second result is consistent with the existence of absolute convergence at the regional level -- but most of the studies we have reviewed do not explicitly test this hypothesis.[11] ii) Second, we have seen that the process of convergence seems to be extremely slow. Many of the existing estimates of the convergence parameter cluster around a value of 2% per year which implies that it takes around 35 years for a typical region to reduce its income gap with the national average by one half. Hence, the expected duration of the convergence process must be measured in decades. iii) Finally, it is interesting to oberve that the estimated convergence coefficient is remarkably stable across samples. This stability suggests that the mechanisms that drive convergence in income per capita across different economies seem to operate in a regular fashion. Hence, we can at least hope to provide a unified structural explanation of the convergence process in terms of a "general" theoretical model.

Perhaps the dominant view in the literature is that a good candidate for this "general" model is a simple extension of the one-sector neoclassical model with exogenous technical progress. Just about the only departure from the traditional assumptions required in order to explain the empirical evidence is a broadening of the relevant concept of capital in order to include investment in intangibles such as human and technological capital. This conclusion is reached essentially by interpreting the results we have just reviewed within the framework of the growth model underlying the conditional convergence equation given in (14). According to our previous discussion, the finding of (at least conditional) beta convergence in most national or regional samples can be interpreted as evidence in favour of the neoclassical assumption of decreasing returns to capital, as this result would not be consistent with increasing returns models that predict an explosive behaviour of income and its distribution. On the other hand, the apparent slowness of the convergence process does suggest that we are not that far from having constant returns in reproducible factors -- a result that seems considerably more plausible if we think in terms of a broad capital aggregate, rather than the rather restrictive concept of capital we find in old-fashioned neoclassical models.

Since this broader concept of capital is probably one of the most significant contributions of the recent literature to our understanding of the mechanics of growth, the issue probably deserves a fairly

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[11] Those that do test it by including different sets of conditioning variables generally reject it, as the significance of many of these variables implies important cross-regional differences in steady states. (See for instance Dolado et al (1994) and Mas et al (1995) for the Spanish provinces, Herz and Röger (1996) for the German Raumordnungsregionen, Grahl and Simms (1993), Neven and Gouyette (1995) and Faberberg and Verspagen (1996) for various samples of European regions, Holtz-Eakin (1993) for the states of the US and Paci and Pigliaru (1995), Fabiani and Pellegrini (1996) and Cellini and Scorcu (1996) for the regions of Italy.) As we have noted in Section 4b, however, this evidence does not conclusively reject the hypothesis of absolute convergence, as conditioning variables (and hence steady states) may themselves be converging over time.

detailed discussion. The reader will recall that within the framework of the Solow model the convergence coefficient *(β)* depends on the degree of returns to scale, measured by α (with $\alpha = a + b$, where a is the coefficient of capital in the "private" production function and b captures the possible externalities), and on the rates of technical progress *(g)*, population growth *(n)* and depreciation *(δ)*. More specifically, we have seen that the relationship among these variables is given by

(15′) $\beta = (1-a-b)(\delta+g+n)$.

Using this expression and making reasonable guesses about the values of some of the parameters, we can extract information about key properties of the production technology from empirical estimates of the convergence rate. For a start, let us consider the expected value of β under conventional assumptions about the values of the remaining parameters. Within the framework of a traditional neoclassical model (with constant returns to scale in capital and labour, perfect competition and no externalities) we would have $b = 0$ and a would be equal to capital's share of national income, which is around one third. The average rate of population growth in the industrial countries during the post-WWII period is approximately 1%. Available estimates of the rate of technical progress are around 2% per year. Finally, estimates of the rate of depreciation vary considerably. In the convergence literature it is commonly assumed that $\delta = 0.03$, but a higher value (around 5 or 6% per year) may be more reasonable. Given these assumptions, the expected value of β lies between 0.04 and 0.06.

As we have seen, the empirical results of Barro and Sala i Martin (1990, 1992), Mankiw, Romer and Weil (1992) and other authors point towards a much lower convergence rate. Since the estimated value of the parameter is still positive, the evidence is consistent with decreasing returns to capital (i.e. $a + b < 1$). The low value of β, however, suggests that we are relatively close to having constant returns to capital. Maintaining our previous assumptions about the values of the remaining parameters, a convergence coefficient of 0.02 would imply a value of a+b between 0.67 and 0.78 -- more than twice the share of capital in national income.

One possible explanation (Romer, 1987b) is that this result may reflect the existence of important externalities associated with the accumulation of physical capital (that is, a large positive value of b). While these external effects would not be sufficiently strong to generate increasing returns in capital alone, they might still account for the apparent slowness of convergence. Other authors, however, argue that a more plausible explanation is that the omission of variables which are positively correlated with investment in physical capital may bias upward the coefficient of this variable. Barro and Sala i Martin (1990, 1992) argue that a value of capital's coefficient around 0.7 only makes sense if we count accumulated educational investment as part of the stock of capital.

Mankiw, Romer and Weil (1992) advance the same hypothesis and test it explicitly by estimating a structural convergence equation similar to equation (14) above that explicitly incorporates a proxy for the rate of investment in human capital as a regressor. Their results, and those obtained by other authors who estimate similar specifications,[12] tend to confirm the hypothesis that investment in human (and technological) capital plays an important role in the growth process.[13] As Mankiw (1995) points out, once human capital is included as an input in the production function, the resulting model is consistent with some of the key features of the data. Countries that invest more in physical capital and education tend to grow faster and therefore eventually attain high levels of relative income. Cross-country differences in rates of accumulation, moreover, are sufficiently high to explain the bulk of the observed dispersion of income levels and growth rates.

6. Loose ends and recent developments

We have seen in the previous section that the main theoretical conclusion drawn from the earlier studies of convergence is that a modified version of the aggregate neoclassical model provides a satisfactory description of the process of growth and of the evolution of the regional (or national) income distribution. The main change relative to the more traditional models is the broadening of the relevant concept of capital in order to include human and possibly technological capital. Other than this, the model is essentially Solow's (1956) model with exogenous technological progress and does not incorporate any convergence mechanisms other than the one derived from the existence of decreasing returns to capital.

It is probably fair to say that just a few years ago this extended neoclassical model summarized a consensus view on the mechanics of growth that was shared (possibly with some reservations) by most researchers working in the field. In recent years, however, this emerging consensus has been challanged by a series of papers that, relying on panel data techniques, obtain results that are difficult to reconcile with the prevailing theoretical framework. In this section I will review some of the key findings of these studies, discuss the theoretical difficulties they raise, and summarize some recent research that may provide at least partial answers to some difficult questions. The reader should be warned that the second half of this section draws much more on my own work than the remainder of the paper, and that the views I will present there are not uncontroversial.

a. Convergence and panel data

One of the key findings of the "classical" convergence studies is that convergence to the steady state is an extremely slow process. It has recently been argued, however, that this result may be due to a bias arising from the use of econometric specifications that do not adequately allow for unobserved differences across countries or regions. To get around this problem, a number of authors have proposed the use of panel techniques that allow for unobserved fixed effects. As we will see in this section, their results raise some puzzling questions.

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[12] See for instance Lichtenberg (1992), Holtz-Eakin (1993), Nonneman and Vanhoudt (1996), Vasudeva and Chien (1997) and de la Fuente, (1998a).

[13] See de la Fuente (1997) for a more detailed review of this literature.

Marcet (1994), Raymond and García (1994), Canova and Marcet (1995), de la Fuente (1996), Tondl (1997) and Gorostiaga (1998), among others, estimate fixed-effects convergence models using panel data for a variety of regional samples. Their results suggest a view of the regional convergence process that stands in sharp contrast with the one advanced in earlier studies by B&S and other authors: instead of slow convergence to a common income level, regional economies within a given country seem to be converging extremely fast (at rates of up to 20% per year) but to very different steady states.[14] Cross-national studies provide a roughly similar picture: Knight et al (1993), Canova and Marcet (1995), Islam (1995) and Caselli et al (1996) among others, find evidence of rapid convergence across countries (at rates of up to 12% per annum) toward very different steady states whose dispersion can be explained only in part by observed cross-national differences in rates of population growth and investment ratios. In both cases, many of the standard conditioning variables (and in particular human capital indicators) lose their statistical significance, the estimated coefficient of physical capital adopts rather low values, and the size and significance of the regional or national fixed effects suggests that persistent differences in levels of total factor productivity (TFP) play a crucial role in explaining the dispersion of income levels.

I will illustrate the sharp contrast between fixed-effects and pooled data or cross-section estimates of the convergence coefficient using data for two samples of (European and Spanish) regions. For each sample I estimate two versions of the following convergence equation

(17) $\Delta y_{rt} = \alpha_r - \beta y_{rt} + \varepsilon_{rt}$

where Δy_{rt} is the average annual growth rate of relative income over the subperiod starting at time t and α_r a region-specific constant that can be used to recover an estimate of the steady-state income level $(y_r^* = \alpha_r/\beta)$. First, I estimate a restricted or unconditional version of equation (17) with the pooled data after imposing the assumption of a common intercept (and therefore a common steady state) for all regions. Next, I estimate an unrestricted or conditional version of the same equation using ordinary least squares with dummy variables (LSDV) to estimate regional fixed effects. Finally, I will repeat the exercise using Arellano's (1988) orthogonal deviations (OD) procedure in order to try to avoid the short sample bias that may affect LSDV estimates.

Table 3 summarizes the results of the exercise. In the Spanish case, the estimated rate of unconditional convergence is 2.2% and the standard deviation of the implied asymptotic distribution of relative income per capita (which reflects only the variance of the shocks ε_{rt}) is 0.10 (column [1] of Table 3). With the LSDV specification, the (now conditional) convergence rate increases almost four-fold to 8% per year[15] and more than half of the regional dummies are highly significant. The implied steady states look a lot like the end-of-sample incomes and the standard deviation of the implied stationary distribution (taking into account the estimated variance of the shocks) is $\bar{\sigma}_y = 0.21$, which is

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[14] Similar results are also reported by Evans and Karras (1996) for a sample of US states using time series techniques.

[15] This figure is significantly higher when we work with output per employed worker rather than income per capita.

quite close to the observed dispersion in the final year of the sample ($\sigma_y(1993) = 0.20$). Finally, the OD procedure yields an estimate of the convergence parameter which is only slightly smaller than the previous one and leaves unaltered the dispersion of the estimated regional steady states (see equation [3]).

Table 3: Estimated regional convergence rates and long-term dispersion of income per capita with various specifications

	[1]	*[2]*	*[3]*	*[4]*	*[5]*	*[6]*
β	0.022	0.080	0.076	0.0085	0.2591	0.3912
(t)	(4.76)	(5.63)	(3.91)	(3.24)	(14.64)	(8.83)
std dev iation y_r^*	[0.000]	0.2057	0.2056	[0.000]	0.2322	0.2328
$\bar{\sigma}_y$	0.0995	0.2120				
$\sigma_y(1993)$	0.1980	0.1980	0.1980	0.2340	0.2340	0.2340
fixed effects	no	yes	yes	no	yes	yes
specification	OLS	LSDV	OD	OLS	LSDV	OD
sample	Spain	Spain	Spain	EU	EU	EU
period	1955-91	1955-91	1955-91	1980-94	1980-94	1980-94

- *Notes:* Data from Eurostat for 99 regions from the five largest EU countries (Germany, France, UK, Italy and Spain) and from FUNDACIóN BBV for the 17 Spanish regions. The Spanish data are available at intervals of generally two (and sometimes three) years and are not corrected for cross-regional price differences, while the Eurostat data are annual figures and corrected for differences in purchasing power. In both cases I work with relative income per capita, that is, income is normalized by its contemporaneous sample average.

As in previous studies, the conditional and unconditional versions of equation (17) tell very different stories. In the first case, the conclusion is that we have pretty much reached the steady state. Hence, the substantial degree of inequality we observe today is likely to persist indefinitely in the absence of "structural change." If we believe the restricted equation, however, we can still hope that regional inequality in Spain will eventually fall to about one half its current level.

The pattern is similar and even more extreme for the sample of European regions (equations [4]-[6] in Table 3). The unconditional specification of equation (17) yields an estimate of the convergence rate of less than 1%. The value of this parameter, however, rises to over 25% when we introduce fixed effects and, surprisingly, increases even further when we use the OD procedure. As in the case of Spain, moreover, both fixed effects specifications predict that the long-term dispersion of relative income per capita will be very close to its observed end-of-sample value.

b. Full circle back to Solow?

The panel results I have just reviewed are rather problematic if we try to interpret them within the standard neoclassical framework. The first difficulty has to do with the interpretation of the convergence rate. Solving for the coefficient of capital, α, in the expression that relates the convergence rate with the parameters of the production function (equation (15)), we have

$$(18)\ \alpha = 1 - \frac{\beta}{g+n+\delta}\,.$$

Maintaining our previous assumptions about the rest of the parameters on the right-hand side of equation (18) (and assuming that the regional dummies adequately capture differences in investment shares and rates of population growth), the convergence rate I have estimated for the EU regions (see Table 3) implies a negative value of α, while the estimate for the Spanish sample would leave us, under the most "favourable" assumption about the value of δ, with a value of α around 0.20. Hence, these estimates of the convergence rate take us back, in the best of cases, to the old-fashioned Solow model with narrowly defined capital, and often lead to non-sensical results, such as a negative capital share.

A second problem with similar implications is that panel estimates of the neoclassical model tend to attribute most of the observed variation in productivity across economies to the country or regional dummies (i.e. to unknown factors that affect technical efficiency, rather than to differences in factor stocks) -- a result that says very little in favour of the model's explanatory power. As I will show below, the estimates of the production function parameters obtained by Islam (1995) and Caselli et al (1996) imply that factor stocks account only for a small fraction (between one tenth and one third) of observed productivity differentials in a sample of OECD countries.

In a very real sense, these results -- together with the loss of significance of human capital indicators in panel growth equations-- take us back to 1957, right after the discovery of the Solow residual, and negate much of what we thought we had learned since then. While it now arises in a cross-section rather than in a time-series setting, the problem is essentially the same one: we cannot explain why output varies across time or space in terms of the things we think are important and know how to measure.

There have been some attempts in the literature to get us out of this corner, but most of them have not been particularly convincing. Islam (1995) tries to rescue human capital as a determinant of the level of technological development (which is presumably what is being captured by the country dummies) by observing that the fixed effects are highly correlated with standard measures of educational achievement. The argument, however, merely sidesteps the problem: we know that human capital variables work well with cross-section data, but if they really had an effect on the level of technical efficiency they should be significant when entered into the panel equation. Taking a different line, Caselli et al (1996) are quite willing to ditch human capital and would settle for the old fashioned Solow model, but their estimated convergence rate is too high for even that. To rationalize their results, they turn to some unspecified open-economy version of the standard neoclassical model. The problem is that, although such a model could indeed generate very fast unconditional convergence, this should work largely through factor flows. Hence, once we condition on investment and population growth rates, as Caselli et al do, the estimated convergence rate should reflect only the characteristics of the technology and would therefore imply an unreasonably low share of capital.

c. Some tentative answers

Growth economists have spent more than forty years slowing chipping away at the Solow residual, largely by attributing increasingly larger chunks of it to investment in human capital and in other intangible assets. A few years ago we were reasonably certain that this was the way to go. But an increasing number of studies seem to be telling us that the effect of these variables on productivity vanishes when we turn to what seem to be the appropriate econometric techniques for the purpose of estimating growth equations.

Should we take these results at face value? Before we do so and abandon the only workable models we have, it seems sensible to search for some way to reconcile recent empirical findings with some kind of plausible theory. In this section, I will argue that this can be done at least to some extent by combining three ingredients: better data on human capital, a further extension of the human capital-augmented neoclassical model that allows for cross-country TFP differentials and for technological diffusion, and a bit more care in the estimation of convergence equations so as to avoid mixing up short-term and long-term dynamics.

i. Making sense of fast convergence

As we have seen in the previous section, part of the puzzle raised by the panel data studies has to do with the extremely high estimates of the rate of conditional convergence they typically produce. In this section I will argue that a reasonable interpretation of these results is that, if we have correctly estimated the relevant parameter (and we may not), then convergence is much too fast to be simply the result of diminishing returns to scale. This observation points to two complementary lines of research. The first one proceeds by identifying plausible mechanisms that may help account for rapid convergence and incorporating them into theoretical and empirical models. The second asks whether panel specifications of growth equations do in fact yield estimates of the relevant parameter.

Starting with the second line of research, Shioji (1997a and b) and de la Fuente (1998b) provide some evidence that panel estimates of the convergence rate may tell us very little about the speed at which economies approach their steady states (and therefore about the degree of returns to scale in reproducible factors). The reason is that these estimates are likely to capture short-term adjustments around trend as well as the long-term growth dynamics we are really interested in. Both authors show that correcting for the resulting bias in various ways brings us back to convergence rates that are broadly compatible with a sensible production function.

On the first issue, allowing for technological diffusion can go a long way towards explaining fast conditional convergence without resorting to sharply diminishing returns to scale.[16] In a series of papers, some of them written in collaboration with R. Doménech, I have used a further extension of

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[16] There is also some evidence that a significant part of what appears to be TFP convergence at the aggregate level is in fact due to factor reallocation across sectors. See for instance Paci and Pigliaru (1995), de la Fuente (1996), Caselli and Coleman (1999) and de la Fuente and Freire (2000).

the neoclassical model that incorporates this convergence mechanism to analyze the pattern of growth in the OECD and in the Spanish regions with rather encouraging results.[17] Our specification combines a production function in first differences with a technical progress function that allows for technological catch-up. The estimated equation is of the form

$$(19)\ \Delta q_{it} = \Gamma_o + \gamma_i + \eta_t + \alpha\Delta k_{it} + \gamma\Delta h_{it} + \lambda b_{it} + \varepsilon_{it}$$

where Δ denotes annual growth rates (over the subperiod starting at time t), q_{it} is the log of output per employed worker in country or region i at time t, k the log of the stock of physical capital per employed worker, h a measure of the average stock of human capital and η_t and μ_i are fixed time and country or region effects. The only non-standard term, b_{it}, is a technological gap measure which enters the equation as a determinant of the rate of technical progress in order to allow for a catch-up effect. This term is the Hicks-neutral TFP gap between each country or region and the reference territory, r (the US for the OECD and an artificial average region for the Spanish case) at the beginning of each subperiod, which given by

$$(20)\ b_{it} = (q_{rt} - \alpha k_{rt} - \gamma h_{rt}) - (q_{it} - \alpha k_{it} - \gamma h_{it})$$

To estimate the model we substitute (20) into (19) and use non-linear least squares on the resulting equation with data on both factor stocks and on their growth rates. In this specification the parameter λ measures the rate of (conditional) technological convergence. Notice that if this parameter is positive, relative TFP levels eventually stabilize, signalling a common asymptotic rate of technical progress for all countries, and the territorial fixed effects μ_i capture permanent differences in relative total factor productivity that will presumably reflect differences across countries or regions in R&D investment and other omitted variables.

The results for both samples suggest that fast conditional convergence is consistent with a sensible production function. The estimated diffusion parameter, λ, (7.4% for the OECD countries and 20% for the Spanish regions) is sufficiently high to generate rapid conditional convergence in output per worker even though the sum of the output elasticities of physical and human capital is around 0.7.

ii. Reassessing the role of human capital

A second troublesome feature of the recent literature is that human capital indicators are often not significant or even display the "wrong" sign in panel analyses and other studies.[18] There is a widespread feeling in the profession that these results may be due at least in part to the poor quality of the available schooling data. Some recent work by R. Doménech and myself (D&D 2000, 2001 and 2002) helps support this conclusion. We find, in particular, that the amount of measurement error in the educational data sets that have been used in most growth studies is very considerable, and that

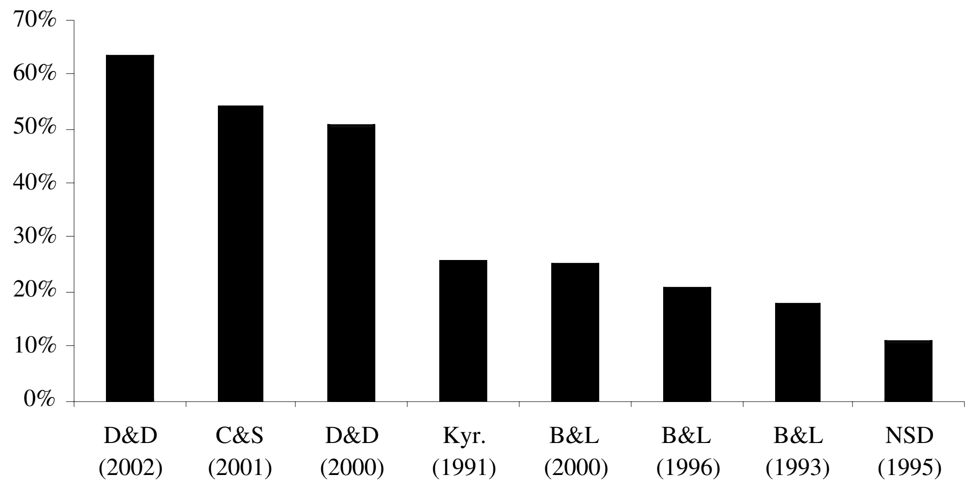
[17] See de la Fuente (1995, 2002a and 2002b) and de la Fuente and Doménech (2000, 2001 and 2002). Dowrick and Nguyen (1989) also investigate the quantitative importance of technological catch-up as a convergence factor, but their empirical specification makes it difficult to disentangle this effect from the neoclassical convergence mechanism. Helliwell (1992), Coe and Helpman (1995) and Engelbrecht (1997) provide additional evidence on technological diffusion.

[18] See among others Knight, Loayza and Villanueva (1993), Benhabib and Spiegel (1994), Islam (1995), Caselli et al (1996), Hamilton and Monteagudo (1998) and Pritchett (1999).

this induces a large downward bias in the estimated coefficient of human capital in the aggregate production function. When this bias is corrected, the contribution of educational investment to productivity growth turns out to be quite sizable.

In our latest paper on this issue (D&D, 2002) we investigate the quality of the schooling data sets that have been used in the recent growth literature (including some estimates of our own for the OECD countries). Following Krueger and Lindhal (2001), we construct estimates of reliability ratios that measure the information content of these series, restricting ourselves to a sample of OECD countries for which the available attainment information should presumably be of relatively high quality. The average value of this indicator (computed across different data transformations) for each of these data sets is shown in Figure 6. Our mean estimate of the reliability ratio of the schooling data is 0.335. Since this parameter must range between zero and one (with zero indicating that the data contains no information and one corresponding to perfect data without measurement error), our results suggest that the amount of noise in the data is quite high, and that, as a result, the average estimate of the coefficient of schooling in a growth equation is likely to suffer from a substantial downward bias, as predicted by the classical errors-in-variables model.

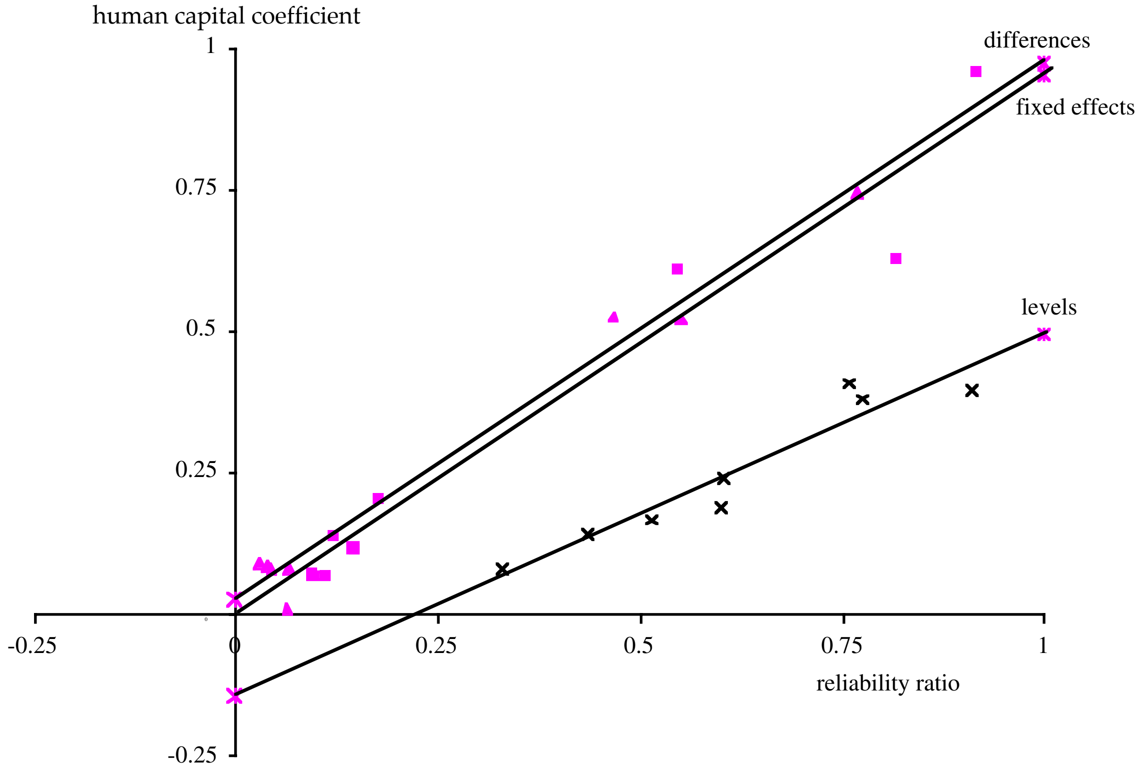
Figure 6: Average reliability ratios for different schooling data sets



- *Source:* de la Fuente and Doménech (2002), Table 8b.
- *Key: NSD* = Nehru et al (1995); *Kyr* = Kyriacou (1991); *B&L* = Barro and Lee (various years); *C&S* = Cohen and Soto (2001); *D&D* = de la Fuente and Doménech (various years).

Our results also indicate that the importance of measurement error varies significantly across data sets, although their precise ranking depends on the data transformation that is chosen. Two of the datasets most widely used in cross-country empirical work, those by Kyriacou (1991) and Barro and Lee (various years), perform relatively well when the data are used in levels but, as Krueger and Lindhal (2001) note, contain very little signal when the data are differenced. Recent efforts to increase the signal content of the schooling data seem to have been at least partially successful. Taking as a reference the average reliability ratio for the (1996) version of the Barro and Lee data set, the latest revision of these series by the same authors has increased their information content by 21%, while the estimates reported in Cohen and Soto (2001) and in de la Fuente and Doménech (2002) raise the estimated reliability ratio by 162% and 207% respectively.

Figure 7: Estimated human capital coefficient vs. reliability ratio



In the last part of the same paper, we systematically compare the performance of the different data sets in a number of growth specifications and find a clear positive correlation between estimated schooling coefficients and data quality measures. We then extrapolate this pattern to construct meta-estimates of the value of the coefficient that would be obtained with the correctly measured stock of human capital. Although there are technical complications that I will not discuss here, the intution of the exercise is well captured by Figure 7, where we plot the estimates of the elasticity of output with respect to the stock of human capital obtained with different data sets and econometric specifications against the relevant reliability ratios. The scatter shows a clear positive correlation between these two variables within each specification and suggests that the true value of the human capital parameter is at least 0.50, which is the prediction of the levels equation for a reliability ratio of one. This figure is significantly larger than Mankiw, Romer and Weil's (1992) estimate of 1/3, which could probably have been considered a consensus value for this parameter a few years ago and had lately come to be regarded as too optimistic in the light of recent negative results in the literature.

iii. How important are factor stocks?

Some of the results I have just discussed can be used to perform a simple accounting exercise that may give us some idea of the explanatory power of the augmented neoclassical model that underlies much of recent research into growth and convergence. The exercise provides a simple way to illustrate the extent to which the results discussed in the previous subsections help overcome the puzzles raised by the panel studies and tie in well with the theme of this conference.

I will, in particular, attempt to gauge the relative importance of factor endowments and of TFP in explaining productivity differentials in a sample of 21 OECD countries.[19] Using the production function given in equation (19) above, I will recover the Hicks-neutral technological gap between each country in the sample and a fictional average economy to which I will attribute the observed sample averages of log productivity *(q)* and log factor stocks per employed worker *(k* and *h)*. Thus, I will define relative TFP *(tfprel)* by

$$(21)\ tfprel_{it} = (q_{it} - \alpha k_{it} - \beta h_{it}) - (qav_{it} - \alpha kav_{it} - \beta hav_{it}) = qrel_{it} - (\alpha krel_{it} + \beta hrel_{it})$$

where *av* denotes sample averages and *rel* deviations from them. To obtain a summary measure of the importance of TFP as a source of productivity differentials, I will regress relative TFP on relative productivity. (Notice that the regression constant will vanish because both variables are measured in deviations from sample means). The estimated coefficient gives the fraction of the productivity differential with the sample average explained by the TFP gap in a typical OECD country.

Figure 8 summarizes the results of the exercise for 1990 using four alternative sets of parameter values. The first two are taken from Caselli et al (1996) and from Islam (1995). The other two come from de la Fuente and Doménech (2002). The first of these, labeled D&D1 in the figure, corresponds to uncorrected estimates using the latest version of our data set and the catch-up specification discussed in subsection c.i; the second one uses our lowest meta-estimate of the coefficient of human capital after correcting for measurement error. As noted above, the results of Caselli et al (1996) and Islam (1995) imply that TFP accounts for the bulk of observed productivity differentials, as factor stocks only explain between 10 and 30% of them. With our parameter estimates, by contrast, the contribution of factor stocks rougly doubles, leaving only about a 30% unexplained residual that we attribute to TFP.[20] On the other hand, our calculations also suggest that the share of TFP in relative productivity has been rising over time, while the impact of physical capital has decreased and that of human capital has remained roughly stable. This is illustrated in Figure 9, which shows the breakdown of the relative productivity of the typical OECD country into the contributions of these three factors in 1960 and 1990.

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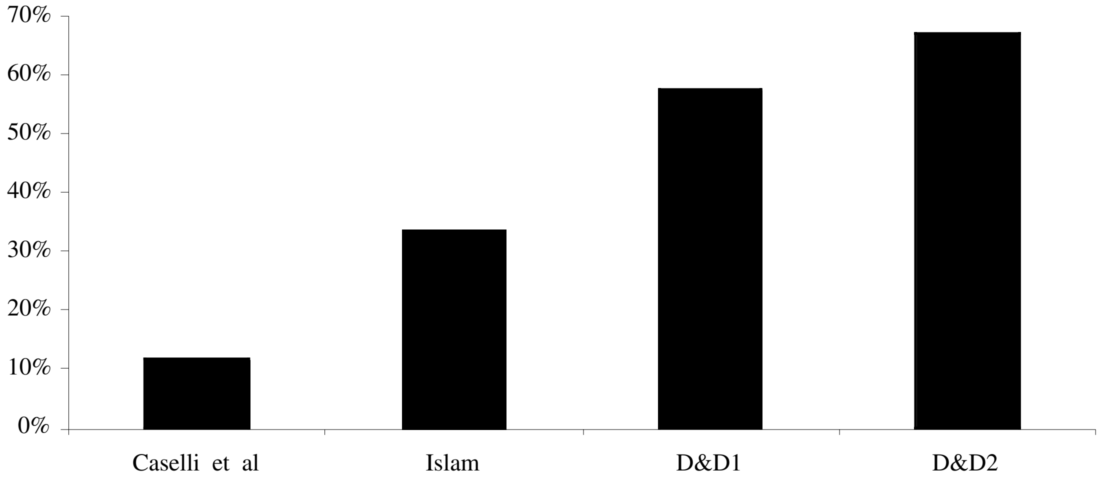
[19] This section updates the exercise in section III of de la Fuente and Doménech (2001) drawing on the results of de la Fuente and Doménech (2002).

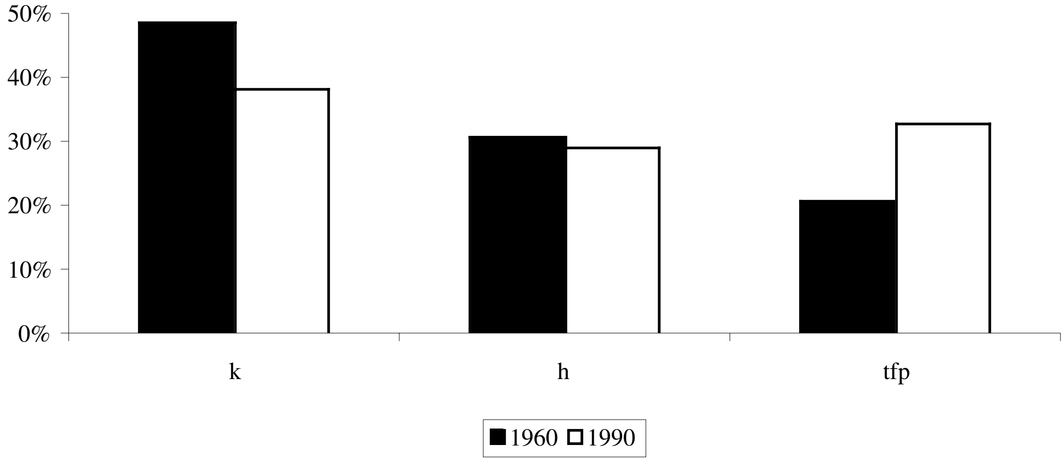
[20] This is considerably lower than our (2001) estimate, where the TFP contribution in 1990 was close to 50%. The difference comes mostly from the upward revision in the coefficient of human capital as a result of improvements in our data (in the estimate labeled D&D1) and the correction for remaining measurement error (D&D2).

Figure 8: Fraction of the productivity differential with the sample average explained by differences in per worker factor endowments in a typical OECD country in 1990



Notes:
- The data on factor stocks are taken from de la Fuente and Doménech (2002).
- The assumed coefficients of physical capital are 0.305 for Islam (for an OECD sample) and 0.107 for Caselli et al (for a sample of 97 countries). Both authors obtain negative coefficients for human capital when this variable is included, so I have taken their estimates for the standard Solow model without human capital and assumed a zero value for the schooling coefficient.
- The estimates labeled D&D1 andD&D2 are based on de la Fuente and Doménech (2002). The first estimate is based on the uncorrected results of our preferred specification, which yields values of 0.345 and 0.394 respectively for the coefficients of physical and human capital. In the second case, we use the same coefficient for physical capital and our lowest meta-estimate of the human capital coefficient after correcting for measurement error (which is 0.587).

Figure 9: Decomposition of the productivity differential with the sample average in a typical OECD country in 1960 and 1990



- *Note:* calculations based on the same parameter values as the estimate labeled D&D2 in Figure 8.

Hence, our results are more optimistic than those obtained by Klenow and Rodriguez-Clare (1997) is a similar exercise. They fall approximately half way between the conclusions of Mankiw (1995), who attributes the bulk of observed income differentials to factor endowments, and those of Islam (1996) and some other recent panel studies, where fixed effects that presumably capture TFP differences account for most of the observed cross-country income disparities. We view these findings as an indication that, while the augmented neoclassical model prevalent in the literature does indeed capture some of the key determinants of productivity, there is a clear need for additional work on the dynamics and determinants of the level of technical efficiency, which seems to be gaining importance over time as a source of productivity disparities.

7. Summary and conclusions

In this paper I have reviewed the recent literature on growth and convergence. The first part of the paper focused on theoretical issues. After discussing the main convergence and divergence mechanisms identified in growth theory, I have developed a descriptive model that incorporates the most important such mechanisms and illustrates their implications for the dynamic of the distribution of income across countries and regions.

In the rest of the paper I have developed a framework for the empirical analysis of growth, summarized some of the main results of the relevant literature and discussed their theoretical implications. In the current state of the literature the conclusions we can draw must necessarily remain rather tentative. Practically all existing studies on the subject find clear evidence of some sort of convergence both across countries and across regions. These findings allow us to reject with a fair degree of confidence a series of recent models in which the assumption of increasing returns generates an explosive behaviour of the distribution of income across economies that cannot be found in the data. Many of the results I have reviewed are consistent with an extended neoclassical model built around an aggregate production function that includes human capital as a productive input. Indeed, such findings seem to have motivated a sort of neoclassical revival that came close to becoming the conventional wisdom in the literature just a few years ago.

Recently, discussion has livened up again as a result of a number of studies that, using panel data techniques, turned up rather discouraging results that suggested, in particular, that educational investment was not productive and that the bulk of productivity differences across countries or regions has little to do with differences in stocks of productive factors. In my opinion, this has been largely a false alarm, but it has been useful in shaking up what was probably an exaggerated confidence in our ability to explain why some countries or regions are richer than others with an extremely simple model, and in directing researchers' attention to the determinants of technological progress and to some of the difficult econometric and data issues involved in the estimation of growth models.

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