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The Convergence Hypothesis: History, Theory, and Evidence

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Abstract

The hypothesis that per capita output converges across economies over time represents one of the oldest controversies in economics. This essay surveys the history and development of the hypothesis, focusing particularly on its vast literature since the mid-1980s. A summary of empirical analyses, econometric issues, and various tests of the convergence hypothesis are also presented. Moreover, the essay analyzes the implications of the hypothesis for economic growth, especially as it relates to underdeveloped economies.

> "It was never surely the intention of Providence, that any one nation should be monopolizer of wealth"
>
> David Hume (1758)

Should we expect income disparity across economies to narrow over time? Is there an inherent tendency for low-income economies to grow faster than high-income economies? Will economic growth eventually slow down in high-income economies? Could answers to the foregoing questions be in the affirmative even in the absence of international trade ? Does growth in a high-income economy cause a higher growth rate (than otherwise would be possible) in a low-income economy? In other words, is there an international externality in economic growth? The foregoing questions, which sum up what is known as the convergence hypothesis, have attracted the attention of many economists, producing a massive literature, especially since the mid-1980s. The idea, however, represents one of the oldest controversies in economics.

The present essay surveys the historical background, theoritical development, and empirical analysis of the convergence hypothesis. Part 1 delineates the difference between micro and macro concepts of convergence; Part 2 describes three main sources of economic convergence; Part 3 analyzes

econometric issues surrounding the convergence tests; Part 4 focuses on the implications of the convergence hypothesis; and Part 5 offers some additional thoughts on economic convergence.

1. Micro convergence and macro convergence

Economic convergence may be divided into two categories. First, *micro convergence* refers to a tendency towards the equalization of income of identical factors across economies[1]. The factor-price equalization theorem (FPE) (see Heckscher, 1991; Samuelson, 1948) provides a rigorous theoretical framework for micro convergence. FPE predicts that under the conditions of the standard Heckscher-Ohlin-Samuelson model, returns to similar factors in the trading economies converge as trade barriers fall. Micro convergence has been the object of considerable attention since the early 1980s.[2]

Second, *macro convergence* focuses on aggregate variables such as per capita income or output per worker. Here the theory explains how per capita incomes across economies may converge or diverge. Since per capita income is a weighted average of factor prices, the notions of micro and macro convergence are related. The relationship, however, is not well developed in the literature[3]. More on this point in Section 2.3.

The present essay focuses on macro convergence.

2. The sources of convergence

Abramovitz and David (1996: 21) provide a succinct definition of the convergence hypothesis, "Under certain conditions, being behind gives a productivity laggard the ability to grow faster than the early leader. This is the main contention of the 'convergence hypothesis'." This section describes three main sources of the macro convergence hypothesis and traces their historical roots.

2.1. Diffusion of technology

Economic historians have found the origin of the convergence hypothesis in the scholarly writings of David Hume and Josiah Tucker in the mid-18th century (Elmslie, 1995).[4] Hume believed in a natural tendency towards convergence across economies during the course of economic growth, while Tucker held that international economic disparity can persist indefinitely. Their exchange of views, known as the "rich country-poor country" debate between Hume and Tucker, promoted a *laissez-faire* approach in international trade, thereby contributing to the adoption of the free trade policy in England in the 19th century.

Hume argued that transfer of technology and low wages would provide poor economies with an impetus to grow faster than rich economies. He also envisioned manufacturers who would "shift their places, leaving those countries

and provinces which they have already enriched, and flying to others, whether they are allured by the cheapness of provisions and labor; till they have enriched these also, and are again banished by the same causes" (Hume, 1758: 43). Although the foregoing passage presents an economic argument in favor of convergence, invoking some form of diminishing returns to manufacturing activities in an advancing economy, Hume's belief in convergence rests also on non-economic grounds. He was bothered by international income disparity and considered it to be a temporary phenomenon. Elmslie (1995: 213) notes that Hume's reasoning was driven by hope for his poor home Scotland to catch up with rich England. Whatever his motive, Hume launched, at the peak of the enlightenment era, a serious debate which has recently been greatly expanded and explored.

Although Veblen (1915) is often cited as the chief proponent of the theory that the transfer of technology from a more advanced to a less advanced economy contributes to convergence, Gerschenkron (1952) popularized and elaborated on the idea that there is an advantage in being technologically backward. The thrust of Gerschenkron's "theory of relative backwardness" is that "the opportunities inherent in industrialization may be said to vary directly with backwardness of the country" (p. 6). Gerschenkron's theory rests on historical and circumstantial evidence in Europe. The necessary conditions for taking advantage of backwardness include "adequate endowments of usable resources" and the absence of "great blocks to industrialization" (p. 6). McCloskey (1990: 71) calls Gerschenkron's theory of relative backwardness his "main scientific contribution." Gerschenkron further developed the theory in later publications, culminating in his book in 1962.

The publication of Angus Maddison's book in 1982, in which long-term macroeconomic data of advanced economies are presented, made it possible to test Gerschenkron's theory[5]. For example, Abramovitz (1986) applies Maddison's data to the idea that being technologically backward carries an opportunity for faster growth. Abramovitz hypothesizes that:

> When a leader discards old stock and replaces it, the accompanying productivity increase is governed and limited by the advance of knowledge between the time when old capital was installed and the time it was replaced. Those who are behind, however, have the potential to make a larger leap. New capital can embody the frontier of knowledge but the capital it replaces was technologically superannuated. So the larger the technological and, therefore, the productivity gap between leader and follower, the stronger the follower's potential for growth in productivity; and, other things being equal, the faster one expects the follower's growth rate to be. Followers tend to catch up faster if they are initially more backward. (p. 386)

Abramovitz notes that a necessary condition for catch-up is "social capability" in a backward economy. Social capability refers to adequate entrepreneurial

ability, managerial and technical staff, and ancillary institutions (banks, insurance companies, effective and impartial judiciary, etc.). Moreover, social capability entails cultural traits and attitudes towards work and wealth, class mobility within a social structure, and the ability to form a corporation beyond family business. Without social capability technological backwardness will not be advantageous[6].

Although it can be argued that social capability may emerge or be strengthened in an expanding economy, historical evidence shows that it is primarily exogenous and usually precedes the convergence process. In an analysis of economic development in virtually every region of the world, Maddison (1995: 52) points out that Japan paved the way for rapid economic growth in the 20th century by reforming her institutions in the 19th century. Countries in South America and India that did not reform their institutions, Maddison notes, were unable to take advantage of their backwardness.

Baumol (1986) uses Maddison's data in an analysis of long-run growth and convergence among 16 advanced economies. After establishing convergence, he suggests, in the same vein as Abramovitz, that technology is a public good and its diffusion leads to catch-up and convergence. Growth spills over to the economies that are socially capable of applying new technology. In a later publication, Baumol (1994) calls this approach "contagion", suggesting that advancement of technology creates an external benefit across economies.

Although multinational corporations (MNCs) provide a most effective vehicle for the transfer of technology, not every host economy to the MNCs experiences higher growth. Blomström, Lipsey, and Zejan (1996) find that only the wealthiest 50% of developing economies, judged by per capita income, enjoy a higher economic growth due to inflows of foreign direct investment. Poor economies deprived of adequate resources are unable to absorb the technology brought in by the MNCs. Blomström and Lipsey (1996) present a summary of a number of their papers on the effect of technology diffusion, noting that globalization of production generally contributes to host countries' growth rates.

A follower-economy can experience a faster rate of growth because imitation of technology is less costly than innovation. In developing a new technique, a leader-economy commits errors that an imitator can avoid. A number of studies provide estimates of imitation cost and the time required for a successful imitation. Mansfield, Schwartz, and Wagner (1981) find that in products such as chemicals, electronics, machinery, and drugs in the United States, the imitation cost averages 65% of the innovation cost. Teece (1977) finds that for multinational corporations the cost of technology transfer amounts to 19% of overall cost of operation. The time it takes for imitators to learn about new products is roughly about one year. Mansfield (1985) finds a one year lag for 70% of product innovations. Caballero and Jaffe (1993) estimate that the time it takes for new ideas to influence other researchers is from one to two years.

2.2. The neoclassical growth model

Classical economists, such as Adam Smith and John Stuart Mill, envisioned the possibility of limits to growth. In *The Wealth of Nations* (1776) Smith predicts a maximum per capita income for every economy. In his words,

> In a country which had acquired that full complement of riches which the nature of its soil and climate, and its situation with respect to other countries, allowed it to acquire; which could, therefore, advance no further, and which was not going backwards, both the wages of labor and the profits of stock would probably be very low .... (pp. 94–95)

Smith, however, does not draw any conclusion regarding convergence. On the contrary, he disagrees with Hume (noted in the previous section) on the role of technology transfer and low wages in poor economies. Smith points out that higher productivity (due to division of labor) in rich economies helps them retain their lead and advantages over poor economies despite higher wages.

In his *Principles of Political Economy* (1848: 334) Mill notes that every economy is "always at the verge of" the stationary state and that it is postponed only due to technological advancement. Unlike Smith, Mill predicts convergence would come about by richer economies focusing on the distribution of wealth rather than on increasing it. This shift of focus would allow poor economies to catch-up.

In the neoclassical growth model developed by Solow (1956) and others[7], every economy approaches its own steady-state income level determined by that economy's aggregate parameters such as the discount rate, intertemporal elasticity of factor substitution, depreciation rate, capital share, and population growth rate. Once at the steady-state, the economy grows at a constant rate, including the zero rate. To the extent that the determinants of steady-state income are similar across economies, convergence is expected.

In this model, convergence can occur in autarky. An economy grows faster than others if its capital-labor ratio is low (and as a result the marginal productivity of capital is high) at the beginning of a period relative to the capital-labor ratio in the steady-state. A lower initial level of reproducible capital results in a faster accumulation of capital and higher growth. International mobility of capital and labor expedites the convergence process by moving resources from factor-abundant to factor-scarce areas. Two economies thus would have equal per capita income if they were identical in every respect or if one were a scale-up of the other at the steady-state. Moreover, the growth rate is inversely correlated with the distance from the steady-state value.

For a mathematical exposition of the convergence hypothesis in the neoclassical model, consider the following production function:

$$Y_t = F(K_t, H_t, A_t L_t, \varepsilon_t), \tag{1}$$

where Y denotes output, K and H depict physical and human capital, respectively, A represents technology, L denotes labor, and ε is a random error term. AL represents effective units of labor and t indexes time.

Equation (1) exhibits constant returns to scale; K, H, and AL all have positive marginal products and are subject diminishing returns; K and H depreciate at rates δ_K and δ_H; the economy invests the fractions s_K and s_H of output in K and H; A and L grow exogenously at constant rates x and n, respectively. Thus, AL grows at the rate $(x + n)$. Finally, the Inada conditions (Inada, 1963) apply.

Defining $y_t \equiv Y_t/A_tL_t$; $k_t \equiv K_t/A_tL_t$; $h_t \equiv H_t/A_tL_t$, the following "laws of motion" govern the accumulation of K and H:

$$\dot{k}_t = s_K y_t - (x + n + \delta_K)k_t, \tag{2}$$

$$\dot{h}_t = s_H y_t - (x + n + \delta_H)h_t. \tag{3}$$

In this model, the assumption of diminishing returns implies that the economy will eventually reach the steady-state values of k^* and h^* at which $\dot{k} = \dot{h} = 0$. As an example, suppose the production function of an economy has the form:

$$Y_t = K_t^{\alpha_1} H_t^{\alpha_2} (A_t L_t)^{(1-\alpha_1-\alpha_2)}. \tag{4}$$

Given the assumptions of the model and Eq. (4),

$$k^* = \left[\left(s_K^{(1-\alpha_2)} s_H^{\alpha_2}\right) \Big/ (x + n + \delta_K)\right]^{1/(1-\alpha_1-\alpha_2)}, \tag{5}$$

and

$$h^* = \left[\left(s_K^{\alpha_1} s_H^{(1-\alpha_1)}\right) \Big/ (x + n + \delta_H)\right]^{1/(1-\alpha_1-\alpha_2)}. \tag{6}$$

If all the parameters in (5) and (6) for two economies i and j are identical, then $k_i^* = k_j^*$, $h_i^* = h_j^*$, and thus $y_i^* = y_j^*$, i.e., the output per worker in economies i and j converge to the same value. This is the essence of convergence in the neoclassical model. Note that these final values grow at a constant rate (including the zero rate). Before reaching the steady-state, however, the two economies necessarily grow at different rates. The farther the actual values of k and h (thus y) are from k^* and h^* (thus y^*) the faster an economy will grow. In other words, the speed of convergence is inversely correlated with the distance between the actual and final values.

The speed of convergence β can be expressed as follows:

$$d \ln y_t / d_t = \beta(\ln y^* - \ln y_t). \tag{7}$$

Since the actual value y_t is a weighted average of y_0 (a value at some initial date)[8] and y^* (the final value), the following equation holds:

$$\ln y_t = e^{-\beta t} \ln y_o + (1 - e^{-\beta t}) \ln y^*. \tag{8}$$

Subtracting $\ln y_o$ from both sides of (8) and adding a stochastic term η yields:

$$\ln y_t - \ln y_o = -(1 - e^{-\beta t}) \ln y_o + (1 - e^{-\beta t}) \ln y^* + \eta. \quad (9)$$

Alternatively,

$$\hat{y}_{0\sim t} = \gamma_0 \tilde{y}_0 - \gamma_0 \tilde{y}^* + \eta, \quad (10)$$

where:

$\hat{y}_{0\sim t}$ = growth rate of an economy over the period 0 to t,
$\gamma_0 = -(1 - e^{-\beta t})$,
$\tilde{y}_0 =$ logarithm of initial value of output per worker,
$\tilde{y}^* =$ logarithm of variables that proxy (determine) the steady-state value y^*.

The list of variables that proxy y^* can be quite long. Sala-i-Martin (1997) finds 22 out of 59 variables to have a significant effect on economic growth. His list includes: regional variables (e.g., location; distance from the equator); political variables (e.g., civil liberties; number of revolutions); religious variables (e.g., Buddhist; Catholic); market distortion; types of investment; primary sector production; openness to world markets; type of economic system; and former Spanish colonies.

According to Eq. (10), if a group of economies share the same steady-state values, those with lower initial income will grow faster. To test this implication, a popular approach involves estimating Eq. (10) in a cross section of economies. If $\hat{y}_{0\sim t}$ is regressed only on $\tilde{y}_0$, then a negative γ_0 suggests that output per worker in the low-income economies has grown faster than in the high-income economies over the sample period. Such an outcome is called *absolute* or *gross convergence* indicating the sample economies have more or less the same steady-state values.

A non-negative coefficient γ_0, however, does not necessarily invalidate the convergence implication of the neoclassical model. Rather, it would suggest that sample economies may be converging to different steady-state values. A negative γ_0 in the presence of variables that determine the steady-state value y^* would signify a *conditional convergence*. Barro and Sala-i-Martin, in a number of publications (e.g., 1995: 387), call this approach β-convergence[9]. Baumol (1994) refers to it as the "common forces" approach, meaning that the same forces (i.e., the determinants of y^*) drive the economic convergence.

In Eq. (7), the speed of convergence β equals $(x + n + \delta)(1 - \alpha_1 - \alpha_2)$. Thus, if $(x + n + \delta) = 0.06$ and $\alpha_1 = \alpha_2 = 1/3$, then $\beta = 0.02$, implying that an economy closes half the gap with its steady-state value in 35 years. Mankiw, Romer, and Weil (1992) argue that the neoclassical growth model (*a la* Solow) augmented with human capital (as in Eq. (4)) adequately explains variations in output per worker across economies. They suggest that setting $\alpha_1 = \alpha_2 = 1/3$ provides a reasonable approximation of the real world[10].

In a recent paper, Sala-i-Martin (1996) presents evidence of absolute β-convergence within the following economies: 48 states in the United States (1880–1990); 47 prefectures in Japan (1955–1990); and 90 regions in Europe (1950–1990). The following regions also exhibit absolute convergence: 11 regions in Germany (1950–1990); 11 regions in UK (1950–1990); 21 regions in France (1950–1990); 20 regions in Italy (1950–1990); 17 regions in Spain (1955–1987); and 10 provinces in Canada (1961–1991). Remarkably, Sals-i-Martin reports a speed of convergence of about 2% across these regions. Barro and Sala-i-Martin (1995, Ch. 11) and Mankiw, Romer, and Weil (1992) estimate the speed of conditional convergence for various regions and groups of economies. They also find the speed of convergence to be around 2%. Quah (1996), however, conducting Monte Carlo simulations, finds that, for moderate-sized samples, a 2% convergence rate is not at all uncommon. He suggests that the 2% convergence speed is due to "finite-sample bias" (p. 1360).

Absolute convergence for samples that include developed as well as developing economies is invariably rejected. Mankiw, Romer, and Weil (1992) show that while absolute convergence holds for a sample of OECD economies over the years 1960–1985 ($\gamma_0 = -0.341$, t statistic $= 4.31$), it gets rejected in a broader sample of 75 economies ($\gamma_0 = -0.004, t = 0.08$). For a sample of 98 economies they discover absolute *divergence* ($\gamma_0 = 0.094, t = 1.90$). They find, however, strong conditional convergence for all three samples.

The absence of global (absolute) convergnce has motivated some economists to develop growth models in which income disparity among economies can persist indefinitely. These models, known as endogenous growth models, are characterized by non-decreasing returns to capital. For example, if in Eq. (4) we set $\alpha_1 + \alpha_2 = 1$, then capital (broadly defined to include K and H) will no longer be subject to diminishing returns, and an economy with a higher level of capital (and therefore a higher level of output per worker) will maintain its lead forever because its ability to save and invest will never diminish. The pioneering works of Romer (1986) and Lucas (1988) gave birth to the endogenous growth models in which investment (for Romer in physical capital and for Lucas in human capital) embodies spillover effects, thus offsetting the tendency towards diminishing returns. Convergence disappears when the assumption of diminishing returns is dropped because an economy can now grow without limits.

The proponents of endogenous growth insist that the neoclassical growth model makes implausible assumptions (e.g., technological opportunities are equally available everywhere), thereby reaching untenable conclusions (e.g., convergence). The advocates of the neoclassical growth model (e.g., Mankiw, Romer, and Weil, 1992), however, point out that the convergence underlying the model is *conditional*, not absolute. Nevertheless, one would expect at some point that diminishing returns would set in and global convergence would emerge. Yet, *divergence* rather than convergence has characterized the world economy (at least in the past 200 years) and some empirical studies suggest that the current income disparity between the rich economies and poor economies

will persist and even widen in the future. For example, Quah (1993: 435) in a sample of 118 countries finds "the very richest remain so with probability at least 98 percent; the very poorest with probability at least 95 percent." The middle-income economies, he suggests, are vanishing. More on this point in Section 4.

2.3. The role of globalization

Although convergence can occur in the absence of trade across economies (e.g., as in the neoclassical model), international trade quite likely influences the convergence (or divergence) process. Economists generally maintain that the real output of trading partners rises as a result of more trade[11]. However, whether trade leads to convergence of economies is a separate issue and remains controversial.

Adam Smith (Elmslie, 1994) envisioned a situation in which trade between a rich economy and a poor economy will lead to income divergence, although trade benefits them both. In Smith's model, productivity in the manufacturing sector rises faster than in the agriculture sector. Export of manufacturing goods by the rich economy would drive the manufacturing sector in the poor economy out of business, eliminating a source of productivity improvement. Hence trade could widen the income gap.

In the 1950s a number of development economists echoed Smith's contention regarding the role of international trade in the development process in poor economies[12]. Prebisch (1950) and Singer (1950) independently argued that the terms of trade moves against the under-developed economies. Their influential writings led to the protectionist policies in much of the underdeveloped world. The Prebisch-Singer hypothesis was readily accepted because of the huge income gap between the industrial and non-industrial regions and the belief that the gap is widening[13]. In his Cairo lecture, Myrdal (1956) captures the prevalent view on this point:

> If international trade did not stimulate manufacturing industry in the underdeveloped countries but instead robbed them of what they had of old-established crafts, it did promote the production of primary products, and such production, employing mostly unskilled labor, came to constitute the basis for the bulk of their exports ... because of inelastic demands the result will often not even be a very large enlargement of the markets and of production and employment. In any case, the wages and the export returns per unit of product will tend to remain low as the supply of unskilled labor is almost unlimited (p. 48).

Myrdal further states that "trade ... tends to have backsetting effects and to strengthen the forces maintaining stagnation or regression" (p. 49). Finally, he asserts "under these circumstances the forces in the markets will in a cumulative way tend to cause ever greater international inequalities between countries

as to their level of economic development and average national income per capita" (p. 51).[14]

Myrdal's hypothesis, however, does not survive empirical scrutiny. Protectionist policies, especially those in Central and South America (under the influence of Prebisch), after nearly four decades produced a dismal record. Maddison (1995: 228) reports that average per capita GDP (1990 Geary-Khamis Dollars) across 44 Latin American economies *fell* by 8% between 1980 and 1990; 56 African economies also experienced an 8% decline in real per capita GDP during roughly the same period.

Some Asian economies, notably South Korea and Singapore, have narrowed the income gap with rich economies by promoting exports while protecting some domestic industries. For the outward-orientated economies, international markets and not the government ultimately determine the success or failure of domestic producers.

Edwards (1993a) studies the effects of trade orientation on productivity improvements in a sample of 54 countries over the peroid 1971–82. In all versions of his model the variables that proxy trade distortion and protectionism adversely affect total factor productivity. He also finds a positive correlation between trade liberalization programs and faster productivity growth in Latin America[15].

A linkage between trade liberalization and economic convergence is suggested in an empirical study by Sachs and Warner (1995) who examine the role of international trade and the protection of property rights in a sample of 117 economies over the years 1970–1985. The overwhelming majority of economies that grew more than 2% over the sample period pursued policies that increased international trade and enforced property rights protection. Sachs and Warner conclude that poor economies need to reduce trade barriers in order to catch-up with rich economies. Several other studies have also found a link between trade and convergence. These studies include Rassekh (1992), Williamson (1996, 1997), and Ben-David (1996).[16]

In a study unrelated to economic convergence, Magee, Brock, and Young (1989: 253) discover a U-shaped pattern between tariff rates and GDP per capita in a sample of 47 economies. They point out that "young and old countries get greater protection than middle-age countries." Political rent-seeking emerges more easily in old (i.e., wealthy) economies than in middle-age (i.e., less wealthy) economies. To the extent that these activities slow down growth, the income gap between the two groups of economies narrows. Moreover, activities that redistribute rather than create wealth lower economic growth. Magee, Brock, and Young (p. 119) also finds a negative correlation between the growth rate in per capita GDP and the ratio of lawyers to physicians in a sample of 34 countries. Economies that have relatively few lawyers (who represent a redistributive group) experience higher growth rates.

These findings corroborate Olson's thesis (Olson, 1982) which states that in advanced, stable, and secure societies that enjoy freedom of association, distributional coalitions (interest groups) lobby and receive concessions that

benefit them but retard economic growth. These groups include labor unions, guilds, trade associations, professional associations, etc. According to this view, one would expect economic growth to slow down in high-income economies.

Although globalizaion is shown to be correlated with convergence, it is not clear how globalizaion leads to convergence. A possible channel involves homogenization of the determinants of income at the steady-state across economies. Ben-David and Loewy (1996) show that trade liberalization can generate such an outcome. Free trade, however, potentially presents a problem in the process of macro convergence. The problem lies in the prediction of the factor-price equalization theorem (FPE): free trade would lead to the equality of factor income across economies. There are circumstances in which the FPE process actually leads to a *divergence* of per capita incomes. For example, Krueger (1968) points out that if economy i on a per capita basis is endowed with more of every factor than economy j, then the FPE outcome would ensure that free trade would keep per capita income in i always higher than in j. In other words, free trade in such a setting may *prevent* the equalizaion of per capita incomes because it promotes the equalizaion of factor incomes. For a theoretical elaboration of this point see Slaughter (1997) and Rassekh and Thompson (1998). For a related empirical work, see Bernard and Jones (1997). Further research in this area would enrich the convergence literature.

3. Econometric issues

A substantial literature has been developed which addresses the statistical and econometric issues and pitfalls of various convergence tests. This section reviews major contributions to the empirics of the convergence hypothesis.

3.1. Criticisms of β-convergence

Baumol (1986) shows, inter alia, that output per work-hour among 16 advanced economies converged over the years 1870–1979. This seminal study played a key role in renewing interest in the convergence hypothesis[17]. Baumol's work, however, has been criticized on two grounds. First, De Long (1988) shows that if one adds to Baumol's sample six economies that were rich in 1870, the convergence will disappear. This criticism is known as the "selection bias", implying that Baumol's sample included economies that had converged ex post. In a subsequent book, Baumol, Blackman, and Wolff (1989) carried out the calculations in which the criticism was dealt with. De Long's contribution, however, lies in, not faulting Baumol with selection bias, but rather analyzing why the convergence disappears when one expands Baumol's sample. De Long finds that religious establishment carries a significant weight in predicting who would join the "convergence club" over the period 1870–1979. Protestant nations, by and large, gained membership while Catholic nations did not. The enormous empirical analyses of convergence since Baumol's publication shows

very clearly that convergence results are sensitive to sample economies and sample periods.

The second criticism is concerned with β-convergence. The application of this approach by numerous economists, most prominently by Barro and Sala-i-Martin, has been the subject of many critiques and has led to the development of other tests of the convergence hypothesis.

Friedman (1992) and Quah (1993) point out that β-convergence suffers from Galton's classical fallacy[18]. Francis Galton noticed that the sons of tall fathers are shorter than their fathers, while the sons of short fathers are taller than their fathers. This observation, he concluded, suggests a regression towards the mean. The conclusion, however, conflicts with the fact that the deviation from the mean height does not diminish over time. (Galton was unable to resolve this dilemma.) Similarly, low-income economies may grow faster than the high-income economies, producing a negative γ_0 in Eq. (10), but the dispersion in income data may not diminish over time due to shocks to the economies. Quah shows that a negative coefficient on initial income is consistent with non-decreasing income dispersion.

Bernard and Durlauf (1996) criticize the β-convergence approach on the grounds that a negative γ_0 can be estimated in Eq. (10) even if only *some* economies converge. They show that the ordinary least squares (OLS) estimator of γ_0 is a "weighted average of the ratio of differences of growth rates from the sample means to differences of initial incomes from the sample means" (p. 167). Thus, if income differences between *some* pairs of economies diminish, the OLS estimation of Eq. (10) will produce a negative γ_0. Consequently, in a cross-section of economies, the β-convergence approach may provide a misleading impression that the whole sample is converging. In a companion paper, Bernard and Durlauf (1995) point out that in the β-convergence approach, the null hypothesis is that no economies are converging versus the alternative that *all* economies are. This approach, as a result, is not suited for cases in which only some economies converge.

Durlauf and Johnson (1995) question the validity of the β-convergence approach on the grounds that Eq. (10) assumes all the sample economies obey the same linear model. Using regression tree analysis they find that production functions differ substantially across economies according to their initial conditions. In addition to income and literacy, they suggest initial conditions that include 'social capital' in order to capture cultural norms and values concerning work and property rights. To the extent that sample economies differ in their underlying model, the β-convergence approach will produce biased results.

Evans and Karras (1996a) argue that the β-convergence approach would produce valid inferences under only "incredible assumptions". To understand the essence of their argument, consider Eq. (10) (presented here as Eq. (11)) for economy n:

$$\hat{Y}_{n,0\sim t} = \gamma_0 \tilde{y}_{n,0} - \gamma \tilde{y}_n^* + \eta_n. \tag{11}$$

Convergence is absolute when $\gamma_0 < 0$ and $\gamma = 0$; conditional when $\gamma \neq 0$. Evans and Karras describe convergence as follows:

$$\lim_{i \to \infty} E_t(\tilde{y}_{n,t+i} - \bar{\tilde{y}}_{t+1}) = a_n, \tag{12}$$

where:

$\tilde{y}_{n,t+i} =$ logarithm of output per worker of economy n at time $t+i$,
$\bar{\tilde{y}}_{t+1} =$ mean of $\tilde{y}_{t+i}$ across economies, and
$a_n =$ a constant value.

In this formulation convergence requires that $\tilde{y}_{n,t}$ be nonstationary and $(\tilde{y}_{n,t} - \bar{\tilde{y}}_t)$ be stationary for every economy[19].

For Eq. (11) to produce valid inferences, η_n and $\tilde{y}_{n,0}$ need to be uncorrelated. But this condition would hold if and only if $(\tilde{y}_{n,t} - \bar{\tilde{y}}_t)$ is generated by the process

$$\tilde{y}_{n,t} - \bar{\tilde{y}}_t = a + b(\tilde{y}_{n,t-1} - \bar{\tilde{y}}_{t-1}) + u_{n,t}, \tag{13}$$

where $u_{n,t}$ is a serially uncorrelated stochastic term. It is the necessary and sufficient conditions underlying the data generating process (13) that render β-convergence virtually useless. These conditions require that "the dynamical structures of the economies have identical first-order autoregressive representation; every economy affects every other economy completely symmetrically; and the vector of variables control for all permanent cross-economy differences" (Evans and Karras, 1996b). They call these conditions "incredible" and state that, in the absence of good luck and happenstance, Eq. (11) will produce invalid inferences. Evans and Karras indeed deal a deadly blow to the β-convergence approach.

3.2. Alternative tests of convergence

Largely, if not solely, due to the problems concerning β-convergence, other tests of convergence have been proposed in the literature. Friedman (1992: 2131) favors a measure of dispersion such as the standard deviation (σ) or the coefficient of variation (CV). A declining σ or CV of output per worker across economies over time signifies convergence. Barro and Sala-i-Martin (1995: 392) call this approach σ-convergence, which has been applied in numerous studies. Quah (1996: 1365), however, points out that, due to shocks to economies, σ or CV, at best, approach a constant, not zero. As a result, this approach represents only average behavior, revealing nothing about the entire distribution. In fact, Rassekh, Panik, and Kolluri (1997) calculate the CV of output per worker across 24 OECD economies over the period 1950–1990. The CV declines from 1950 until 1978. But an examination of each economy's performance relative to the

OECD average reveals that only 11 economies contribute to the declining CV. There are non-convergers as well as divergers during the period when the CV suggests that the OECD economies as a whole are converging.

Bernard and Durlauf (1996: 170) distinguish between cross-section tests and time-series tests. β-convergence is an example of a cross-section test in which convergence requires the following to hold:

$$\text{If } y_{i,o} - y_{j,o} > 0, \quad \text{then } E(\hat{y}_{i,t} - \hat{y}_{j,t}) < 0.$$

That is, economy i, which has initially a higher output per worker, must grow more slowly than economy j. Under time-series tests, convergence requires that $E(\hat{y}_{i,t} - \hat{y}_{j,t})$ equal zero regardless of the value of $(y_{i,o} - y_{j,o})$. Bernard and Durlauf point out that an investigator may find convergence under one test but no convergence under the other. The cross-section tests place weaker restrictions on the growth process, leading to spuriously rejecting the "no convergence null hypothesis for data generated by economies with different long run steady states" (p. 172).

Although the time-series tests do not suffer from any such inadequacy, they are beset by the requirement that the economies be near their long-run equilibrium. Neither test yields unambiguous results. Bernard and Durlauf suggest that a reliable test should integrate the two types of tests by estimating a general Markov transition function and inferring the limiting distribution of the cross-section. In their companion paper, Bernard and Durlauf (1995) develop two convergence tests based on recent advancements in econometrics[20]. The tests do not reject the null hypothesis of no convergence among 15 OECD economies over the years 1900–1987.

Evans and Karras (1996a) devise a covergence test to avoid the problem with β-convergence. From a certain data generating process they postulate the following equation for economy n at time t:

$$\Delta(\tilde{y}_{nt} - \bar{\tilde{y}}_t) = a_n + b_n(\tilde{y}_{n,t-1} - \bar{\tilde{y}}_{t-1}) + \sum_{i=1}^{p} c_{ni}\Delta(\tilde{y}_{n,t-1} - \bar{\tilde{y}}_{t-1}) + u_{nt}, \tag{14}$$

where a, b, and c are parameters; u denotes an error term; p represents the number of lags; and $\tilde{y}_n$ and $\bar{\tilde{y}}$ are, respectively, the logarithm of per capita output for economy n and the mean of $\tilde{y}_n$ across the sample economies.

OLS is applied to Eq. (14) to obtain the standard error of estimate (σ), which in turn is used to calculate the normalized values $Z_{nt} \equiv (\tilde{y}_{nt} - \bar{\tilde{y}}_t)/\sigma$ for each economy. All the variables and parameters (and the error term) are transformed accordingly. The normalized version of Eq. (14) is estimated to test for convergence

$$\Delta Z_{nt} = \hat{a}_n + \hat{b}_n Z_{n,t-1} + \sum_{i=1}^{p} \hat{c}_{ni}\Delta Z_{n,t-1} + \hat{u}_{nt}, \tag{15}$$

where "ˆ" denotes the transformed parameters and error term. If $\hat{b} < 0$, the economies converge; if $\hat{b} = 0$, they diverge. Evans and Karras apply Eq. (15) to 48 US states over the years 1929–1991 and to 54 countries over the period 1950–1990. They establish only conditional convergence for both groups. Their rejection of absolute convergence for US states contradicts the finding of Sala-i-Martin (1996), reviewed earlier.

Ben-David (1995a) has applied the following test in a number of papers. The test involves the estimaton of ϕ in the equation

$$\tilde{y}_{n,t} - \bar{\tilde{y}}_t = \phi(\tilde{y}_{n,t-1} - \bar{\tilde{y}}_{t-1}).$$

The notations are as before. If the estimate of $\phi < 0$, then economy n's output per worker approaches the sample mean, indicating convergence. The advantage of this approach lies in clarity, simplicity, and applicability to each economy in the sample. Moreover, one can identify the convergers as well as non-covergers.

4. Implications of the convergence hypothesis

The convergence hypothesis has gained popularity and credibility due to the enormous intellectual energy devoted to its analysis and refinement since the mid-1980s. Economic growth is, once again, a thriving field of study. This is due, in part, to the controversy over the convergence hypothesis[21]. Scholars who puzzled over the mediocre economic growth of the USA and Australia in the post-war era, as compared with other advanced economies, are now satisfied that the answer, to some extent, lies in the convergence hypothesis. Dowrick and Nguyen (1987: 37) argue that "Australia's post-war growth has been very close to that which we would expect of a typical OECD country which started with a relatively high level of income." Similarly, Olson (1982: 88) says "... because Switzerland for some time has had a higher per capita income than most other European countries [it] has enjoyed less 'catch up' growth." In other words, economies with high incomes, through no fault of their own, will eventually grow more slowly than others. In fact, Gruen (1986: 84) estimates that "on average, each $1,000 more initial per capita income was associated with a reduction in the growth rate of 1 percentage point". Baumol (1986: 1081) concludes "The convergence of productivity levels in industrialized countries inevitably condemned those with high 1870 productivity levels to relatively slow growth since then."

The foregoing analysis, as Baumol points out in his paper, applies only to the industrialized economies. A close look at the world income distribution since 1820 shows significant inocme *divergence*. Figure 1, reproduced from Maddison (1995), groups economies based on geographical proximity while designating the USA, Canada, New Zealand, and Australia as western offshoots (WO). It is striking that over the period of 172 years (1820–1992) the income ranking of these seven groups (comprising 199 countries) stayed the same[22].

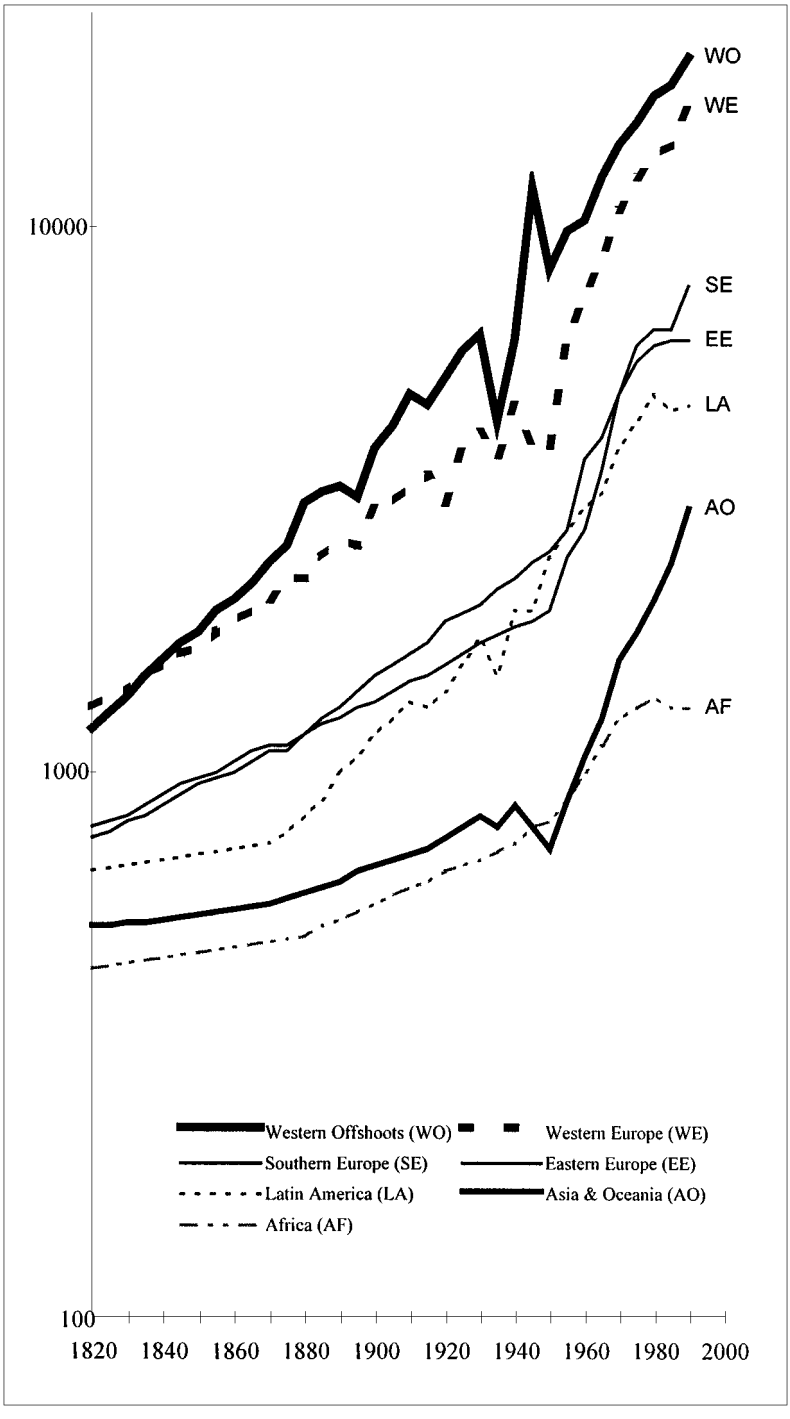

Figure 1. Levels of GDP per capita by region, 199 countries, 1820–1992 (1990 Geary-Khamis Dollars). (Madison, 1995, p. 21).

In the light of figure 1, one could speculate that the convergence hypothesis may be valid among certain economies (e.g., very rich or very poor) but not between them. In fact, Ben-David (1995b) finds a convergence club among the very wealthy economies in which the less wealthy catch up with the more wealthy. But he also finds a convergence club among the very poor economies in which those with relatively higher income move downward towards the very poorest.

In a study of world income distribution over the years 1870–1985, Pritchett (1997) shows that income between the rich and poor economies is marked with significant divergence. Such evidence, combined with Quah's (1993) calculation that "the very richest remain so with probability at least 98 percent; the very poorest, with probability at lest 95 per cent," paint a gloomy picture for the future of the low-income economies. However, in the late 1980s and the early 1990s, a number of developing economies began introducing market-oriented economic policies that promise to generate high growth rates. Rowen (1996) argues that by the year 2020, the world will be more prosperous, democratic, and (perhaps) peaceful. In this process, he estimates, the developing economies converge towards rich economies, although the convergence will not include very poor regions, such as sub-Saharan Africa. The basis for optimism lies in the fact that many countries, disillusioned with protectionism, interventionism, and socialism, are reforming towards a market economy.

The convergence hypothesis implies that the low-income economies can experience a higher growth rate if they create the economic environment capable of absorbing the spillover effects of growth in high-income economies. This implication is supported by the empirical evidence that, in a cross-section of economies, if all the variables that influence growth are controlled for, lower-income economies tend to grow faster.

5. A final note

Several forces could result in the convergence of output per person (or per worker) across economies over time. To the extent that the less-advanced economies can employ the technology of more-advanced economies, convergence is expected. The neoclassical growth model implies conditional convergence by postulating diminishing returns to capital. Globalization is shown to be correlated with convergence, although the process is not clear.

Economic convergence is desirable because inordinate income disparity between rich and poor economies is offensive to human dignity, and it also continues to fuel the international tension that has existed since the colonial era. The recent flood of scholarship on economic convergence makes it abundantly clear that social capability is indispensable for growth and convergence. In the presence of social capability, investment (in both physical and human capital) in laggard economies will result in growth rates higher than those in leader economies. Moreover, the experience of several economies (e.g., South Korea, Taiwan, Singapore, Chili, etc.) shows that the release of entrepreneurial energy,

latent in every nation, holds the key to growth. Although we may not know exactly how to bring about social capability and release the energy, the accumulated evidence since World War II, and particularly since the mid-1980s, points to the market as a potent force.

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Notes

1. This essay uses the term *economy* (rather than country) to refer to any macro economic unit such as state, province, region, country, etc.
2. For a book on micro convergence, see Dollar and Wolff (1993); for a survey article, see Rassekh and Thompson (1993). See also O'Rouke, Taylor, and Williamson (1996).
3. See, however, Krueger (1968).
4. See also Irwin (1996: 154–161).
5. Since 1982, Maddison has published several articles and books presenting additional long-term data, e.g., see Maddison (1987, 1995).
6. For further elaboration, see Abramovitz and David (1996).
7. For a full set of references, see Barro and Sala-i-Martin (1995), chapter 1.
8. In empirical analysis, y_o would be the earliest value of output per worker (or per capita).
9. This approach has been criticized by numerous economists. See Section 3.
10. For a critical review of Mankiw, Romer, and Weil's paper, see Grossman and Helpman (1994).
11. For an intellectual history of free trade see Irwin (1996).
12. Meier (1995) surveys the theories exploring the effects of trade on income inequality across economies.
13. For an empirical scrutiny of the Prebisch-Singer hypothesis, see von Hagen (1989).
14. For theoretical models in which trade widens the income gap between rich and poor economies see Stockey (1991) and Young (1991).
15. For a survey of the effects of trade openness on economic growth in developing economies see Edwards (1993b).
16. See the references in Ben-David (1996) for several other papers of his on this point.
17. The pioneering work of Abramovitz was also published in the same year, 1986. Independently of both papers, Gruen (1986) (notice the year) offered almost the same analysis and arguments as in Baumol and Abramovitz. The essence of Abramovitz's argument, however, is presented in an earlier paper, see Abramovitz (1979).
18. β-covergence or the initial value approach is also known as "the Barro regression" (Quah, 1993), "the conventional approach" (Evans and Karras, 1996a), and "cross-section tests" (Bernard and Durlauf, 1996).
19. A stationary variable has a constant mean and variance.
20. These tests are econometrically too complicated and too lengthy to be presented here.
21. Romer (1994) notes that his work on endogenous growth was motivated by the lack of global convergence, a central implication of the neoclassical growth model.
22. A referee of this review pointed out that national borders have changed in the past 200 years. Moreover, some borders may have been altered to avoid sharing wealth with poor regions. For

example, in the last 100 years West Germany separated itself from less-developed East and West Prussia. Thus a self-selection bias may have contributed to the observed divergence.

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