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Productivity Growth, Convergence, and Welfare: Reply

By WILLIAM J. BAUMOL AND EDWARD N. WOLFF*

Preamble: Mea Culpa. Bradford De Long has succeeded in showing the error of my ways. I must agree with almost everything he says in his paper—except for his conclusion. This remark is meant neither to denigrate his results nor to exonerate my work, but to show (as I believe, from correspondence, De Long now concurs) that his and our findings are compatible, and yield richer insights than were available before. An extensive study by Edward Wolff and myself indicates that there has indeed been convergence among productivity levels and per capita income levels of the richest industrialized countries, but the story is more complex than I had recognized.

First, let me agree that the sample of countries in my earlier article was inadvertently biased toward a showing of convergence. By using readily accessible data that dealt only with countries that afterward turned out to be successful I loaded the dice toward an appearance of convergence. It is no excuse (indeed perhaps the reverse) that I had recognized the problem in advance (under Paul Romer's prodding) and had said so in a footnote. De Long has found estimates of early GNP per capita for a wider spectrum of countries (Paul Bairoch, 1976, and Angus Maddison, 1969) and uses them to show masterfully that a less biased sample exhibits little sign of convergence.¹

How can this be consistent with a convergence story? Wolff and I set out to study every pertinent datum we could find and to subject the data to every relevant convergence test (virtuous data mining?). The results indicate that smaller groups of countries began to converge as early as, perhaps, 1860; that the size of the convergence club has since risen; but that for groups as large as De Long's, for the period he studies, there was, as he concludes, probably no convergence. The following is a small representative sample of our many tests, with their (rather consistent) results. The full study will appear in our book, *Productivity Performance: The Long View*, forthcoming 1989 [W.J.B.].

Estimates for Earlier Periods and Their Implications. We used Bairoch's (1976) estimates of GNP per capita for 19 European countries, essentially by decade, from 1830 to 1913 to rank his countries in descending order of GNP per capita in 1870 (the starting point in our earlier study²), we constructed a sample of countries consisting of the set of eight countries at the top of the list. Then we successively constructed samples of the top 9, the top 10, and so on, until we got to the top 14 (beyond that number of countries too many data points were missing). For each sample size we calculated a time-series of the coefficients of variation (i.e., standard deviation divided by the mean)

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¹At least one methodological problem does beset De Long's calculations—its mixing of historical statistical estimates from different sources. As Summers has emphasized to us, and as our own calculations with

more recent figures dramatically confirmed, two good time-series somewhat differently constructed can yield mutually consistent stories and yet produce a garbled tale when mixed together. However, neither this nor other possible criticisms on details undermines the basic validity of De Long's central argument.

²We also used 1830, Bairoch's initial year. However, it is not obvious that an *ex ante* sample, with its bias in the other direction is what is wanted, either. Perhaps a proper test of convergence requires some intermediate starting date.

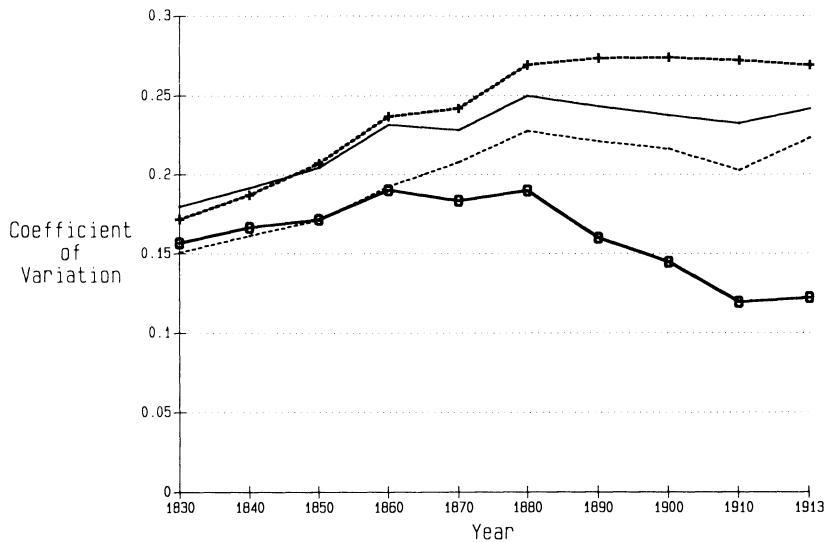


FIGURE 1. COEFFICIENT OF VARIATION GNP PER CAPITA, 1830-1913. BAIROCH COUNTRIES, 1870 RANKING. ○ TOP 8 COUNTRIES; --- TOP 9 COUNTRIES; — TOP 10 COUNTRIES; + TOP 11 COUNTRIES

for each year for which estimates were provided.

The results showed a straightforward pattern (Figure 1). Up to about 1860, for all samples, we found growing *divergence* in GDP per capita (rising coefficient of variation). But in the top group (8 countries) convergence appears to begin as early as 1860, and certainly by 1880. Slower and later convergence is shown for the top 9 and 10 country groups. However, if the remaining countries in Bairoch's table are added to the sample, divergence among this larger group continues all the way to the end of Bairoch's period.

These calculations, then, suggest that much of the nineteenth century was a period of divergence in standards of living of the leading European economies. Then, sometime toward the end of the century, this process began to erode, and was replaced by convergence among increasingly large sets of the initially (or later) more affluent of the countries. Moses Abramovitz has suggested to us that this is precisely what should have been expected. Before the Industrial Revolution the countries of Europe (with, perhaps, the

exception of the Dutch Republic) were relatively homogeneous in their general poverty. Then Great Britain pulled ahead, inaugurating a growth in heterogeneity which was intensified as a small set of European leaders, including Belgium, Switzerland, the Netherlands, France, and Germany, also jumped ahead of the others. Only toward the end of the century was the leaders' example learned by others, so that convergence could extend to a group of any considerable size.

The Postwar Summers-Heston Data. Because Bairoch's figures stop in 1913, and his sample of countries is still far too small, they are insufficient to permit any conclusive *ex ante* classification test of the reality and prevalence of convergence. Fortunately, for 1950-80 Robert Summers and Alan Heston (1984) provide excellent data on real GDP (RGDP) per capita (in 1975 "international dollars") for 72 countries. We used these figures to test the hypothesis of our earlier study that among wealthier countries homogenization had occurred, but not among poorer countries. We tested this by calculating whether initially poorer countries subsequently grew faster than initially richer ones,

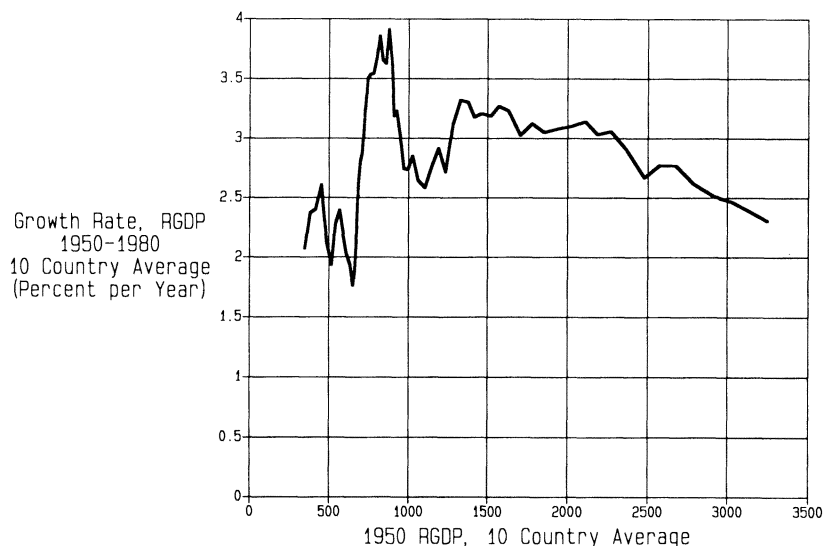


FIGURE 2. GROWTH RATE, RGDP (1950-80) vs. 1950 RGDP 10-COUNTRY MOVING AVERAGE, 72 COUNTRIES RANKED BY 1950 RGDP (SUMMERS-HESTON DATA)

as convergence requires. To reduce scatter and obtain a coherent pattern, we calculated moving averages for sets of 10 countries at a time. That is, the first set was made up of the 10 countries ranked lowest in terms of 1950 GDP per capita. The second set added the eleventh lowest and removed the (first) lowest, etc. For each group we graphed average 1950 RGDP on the horizontal axis, and the growth rate of RGDP, 1950 to 1980, on the vertical axis (Figure 2). The graph is an automatic *ex ante* stratification, since poorer countries in 1950 must lie to the left, while initially wealthier countries lie to the right. Our hypothesis amounts to the conjecture that the moving average graph would be roughly positively sloping toward the left (poorer countries growing more slowly), and distinctly negatively sloping toward the right, meaning that per capita incomes among LDCs, selected *ex ante*, had diverged, while the opposite had been true among initially "industrialized" countries.

This is, roughly, what Figure 2 shows. For nations with initial per-capita real GDPs below about \$700, the curve's slope is highly erratic, and can, perhaps, be interpreted to

be positive overall. Beginning possibly with a 700 dollar annual figure, and certainly above \$1,300, the slope is clearly negative. Of the 72 countries, something between 29 and 52 fall in that group in the downward-sloping portion of the curve, while between 20 and 43 fall in the more or less positively sloping segment. This suggests that somewhere near the median in our sample of countries "the advantages of backwardness" do indeed begin to overbalance the counteracting forces, sociological, educational, and other.

In a more formal regression analysis, both a nonlinear relationship and a piecewise-linear relation composed of two line segments were fitted to the RGDP data.

The quadratic regression yielded the equation

$$\ln \text{RATIO} = 0.586 + 0.00038 \text{RGDP50} \quad [4.2] \quad [2.1]$$

$$- (9.9/10^7) \text{RGDP50}^2, \quad [2.2]$$

$$R^2 = 0.07, N = 72,$$

where RATIO = 1980 RGDP divided by

1950 RGDP and $RGDP50 = \text{per capita 1950 GDP}$. The maximum of the equation occurs at a 1950 RGDP value of about \$1900. Both variables are significant at the 5 percent level, with the predicted signs. The results again show divergence among the 1950 lower-income countries and convergence among the higher-income ones.

The piecewise-linear regression was designed to attain its maximum near that of the nonlinear one, putting 17 of the 72 countries into the *ex ante* upper-income category.

The resulting regression equation is

$$\ln \text{RATIO} = 0.658 + 0.00019 \text{RGDP50}$$

[5.8] [1.9]

$$- 0.00044 \quad \text{D1900,}$$

[2.2]

$$R^2 = 0.07, \quad N = 72,$$

where $\text{D1900} = \text{RGDP50}$ if $\text{RGDP50} \geq \$1,900$ and 0 if $\text{RGDP50} < \$1,900$. The first variable is significant at the 10 percent level, the second at the 5 percent level, and both have the predicted signs, confirming the quadratic-equation results. Finally, separate regressions were run for the upper-income sample and for the lower-income group.

For the upper-income group

$$\text{RATIO} = 3.3 - 0.00038 \text{RGDP50,}$$

[7.7] [12.5]

$$R^2 = 0.30, \quad N = 17,$$

and for the lower-income group

$$\text{RATIO} = 2.1 + 0.0005 \text{RGDP50,}$$

[5.5] [1.3]

$$R^2 = 0.03, \quad n = 55.$$

This provides strong evidence of convergence in the upper-income group but much weaker evidence of divergence among the lower-income countries.

The preceding tests can be criticized because they compare only 1950 and 1980, with no attention to intermediate year figures. It can be argued that RGDPs in 1950 were atypically diverse because of the great

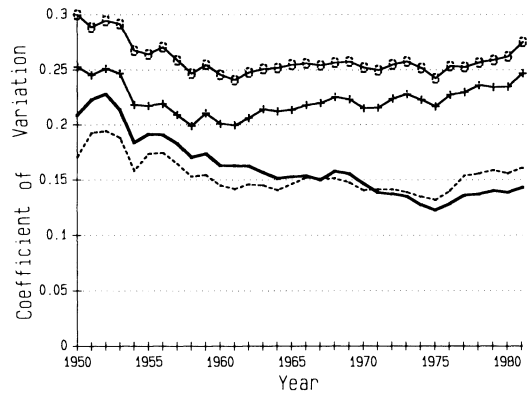


FIGURE 3. COEFFICIENT OF VARIATION, RGDP, 1950–1981, FOR SETS OF COUNTRIES BY 1950 RGDP RANK. --- TOP 10 COUNTRIES; — TOP 14 COUNTRIES; + TOP 20 COUNTRIES; o TOP 24 COUNTRIES

war damage to several industrialized economies. Their recovery naturally contributed abnormal convergence and thereby biased the calculation in the direction of our hypothesis.

To avoid such problems, we calculated for different *ex ante* country samples the time path of the coefficient of variation for each year in the period 1950–1981. The Summers–Heston countries were again ranked on a 1950 basis. The time-series of coefficient of variation was calculated for the top 10 countries and for the top 12, 14, 16, 18, 22, 24, 26, 28, 30, 35, 40, 45, 50, 55, and 60 countries.

There is a sharp break in pattern of behavior between the samples that include fewer than 16 countries and those that include 16 or more. In Figure 3, the curve for the sample of the top 14 countries is typical for the (smaller) sets, containing the countries with the highest RDGP values in 1950. The coefficient of variation fell steadily and sharply throughout the period, except at its very beginning and very end. Noteworthy is the fairly steady but fairly modest rise since 1975. For larger samples divergence (positive slope) begins much earlier and continues far longer. In Figure 3, the curve for the sample of the top 26 countries, with its steady rise in divergence since 1961, is not atypical (though

for larger samples patterns become more erratic). The coefficient of variation in 1981 was still about midway between its 1950 high and its 1961 low, so that about half of the initial homogenization has been lost.

These, then, are the facts, so far as they can be ascertained from the available data and many tests that lack of space prevents our reporting; indeed, from every test we could think of. They indicate that for perhaps the top 15 countries convergence has been marked and unambiguous, with a mild recent retreat. All countries together, excluding LDCs, have also shown some convergence. Yet, larger samples do not display convergence, in part because of the heterogeneous performance of the LDCs and failure of South American countries to live up to their growth promise.

This record offers no certain portents for the future, and it leaves open the most difficult and most crucial issue—just how countries achieve membership in the convergence club, and on what basis they are sometimes ejected.

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