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The Neoclassical Revival in Growth Economics: Has It Gone Too Far?

1. *Introduction*

Theories endogenizing a country's technology, such as Romer (1990) and Grossman and Helpman (1991), arose from the desire to explain the enormous disparity of levels and growth rates of per capita output across countries. The belief was that differences in physical and human capital intensity were not up to the quantitative task. This belief has been shaken by a series of recent empirical studies. Mankiw, Romer, and Weil (1992) estimate that the Solow model augmented to include human capital can explain 78% of the cross-country variance of output per capita in 1985. Alwyn Young (1994, 1995) finds that the East Asian growth miracles were fueled more by growth in labor and capital than by rising productivity. And Barro and Sala-i-Martin (1995) show that the augmented Solow model is consistent with the speed of convergence they estimate across countries as well as across regions within the United States, Japan, and a number of European countries.[1]

In our view these studies constitute a *neoclassical revival*.[2] They suggest

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1 Mankiw, Romer, and Weil, and Barro and Sala-i-Martin do not explain the source of country differences in investment rates. Chari, Kehoe, and McGrattan (1996) argue that distortions such as tax rates, bribes, risk of expropriation, and corruption contribute to an effective tax rate which, if it varies in the right (stochastic) way across countries, can explain the levels and growth rates of income observed in the Summers-Heston (1991) panel.

2 We are indebted to Alwyn Young for this phrase.

that the level and growth rate of productivity is roughly the same across countries, so that differences in output levels and growth rates are largely due to differences in physical and human capital Romer (1993), in contrast, argues that "idea gaps" are much more important than "object gaps." In terms of a simplified production function $Y = AX$, where A is productivity and X encompasses physical and human capital, this debate is over the relative importance of A and X.

This debate matters because the positive and normative implications of the A view can differ dramatically from those of the X view. Technology-based models of A exhibit scale effects because of the nonrival nature of technology creation and adoption. And they suggest that openness, perhaps though its effect on technology diffusion, can have first-order effects on living standards and growth rates (without requiring big differences in rates of return to capital). These implications of openness could be positive in all countries, as in Rodríguez-Clare (1997), or positive in some and negative in others, as in Stokey (1991) and Young (1991). These implications are not shared by the basic neoclassical growth model, which has the same technology everywhere.

In this paper we offer new evidence relevant to this debate on the importance of productivity vs. physical and human capital in explaining international differences in levels and growth rates of output In Section 2 we reexamine Mankiw, Romer, and Weil's (hereafter MRW) methodology for estimating human capital. We update their data and add data on primary and tertiary schooling which have become available since their study. Because primary school attainment varies much less across countries than secondary school attainment does, the resulting estimates of human capital vary much less across countries than the MRW estimates. We also incorporate evidence suggesting that the production of human capital is more labor-intensive and less physical capital-intensive than is the production of other goods. This further narrows country differences in estimated human capital stocks.

In Section 3 we incorporate evidence that pins down the human capital intensity of production and the relative importance of primary vs. secondary schooling. We exploit information contained in Mincer regressions, commonly run in the labor literature, on the amount of human capital gained from each year of schooling. For a cross section of workers, Mincer (1974) ran a regression of worker log wages on worker years of schooling and experience. Such regressions have since been run for many countries (see Bils and Klenow, 1996, for citations for 48 countries) We combine this evidence with data on schooling attainment and estimates of school quality to produce measures of human capital for 98 countries. Using these Mincer-based estimates of human capital, we find

that productivity differences account for half or more of level differences in 1985 GDP per worker [3]

In Section 4 we carry out the same analysis as in Section 3, but here the objective is to produce 1960–1985 growth rates rather than 1985 levels. We find that differences in productivity growth explain the overwhelming majority of growth rate differences. These results seem at odds with Young (1994, 1995), so in Section 5 we compare and contrast our findings for 98 countries with his careful findings for four East Asian countries.

Hall and Jones (1996) also follow Bils and Klenow (1996) in using Mincer regression evidence to construct human capital stocks. As we do, they find that productivity differences are important in explaining international income variation.[4] Their main objective is different from ours, however, in that they are interested in finding correlates (such as language and climate) with productivity differences. In contrast, we focus on examining how human capital should be measured and how international productivity differences depend on how human capital is measured. We want to know, for instance, whether our measure of human capital is more appropriate than the one used by MRW, and we want to know how adding experience and correcting for schooling quality affects the results on productivity. Our paper also differs from Hall and Jones (1996) in that we study growth-rate differences as well as level differences, whereas they concentrate on level differences.[5]

3 OLS Mincer-equation estimates of the wage gain from each additional year of schooling might be too generous because of oft-cited ability bias (more able people acquire more education). In the NLSY over 1979–1993, we ran a Mincer regression of log (deflated wage) on schooling, experience, and experience squared and found a schooling coefficient of 9.3% (s.e. 0.1%). When we included the AFQT score as a proxy for ability, the estimated wage gain from each year of schooling fell to 6.8% (s.e. 0.2%). We stick with the standard estimates such as 9.3% for two reasons: first, since we will find that the role of human capital is smaller than MRW found, we prefer to err on the side of overstating variation in human capital across countries; second, the AFQT score could be a function of human capital investments in the home, and the overstated return may crudely capture how these investments tend to be higher when attainment is higher.

4 Hall and Jones reach quantitatively similar conclusions to ours because of two offsetting differences. First, as we will describe in Section 2 below, we take into account the natural effect of higher TFP on the capital–labor ratio (which increases to keep the return on capital at its steady-state equilibrium level) and therefore attribute the whole effect (i.e., higher TFP plus resulting higher capital–labor ratio) to higher productivity. Hall and Jones attribute only the direct effect to TFP, ignoring the indirect effect on the capital–labor ratio. Second, we estimate country differences in the quality of schooling that reinforce differences in the quantity of schooling attainment across countries. Hall and Jones look only at the quantity of schooling.

5 Bosworth, Collins, and Chen (1995) also estimate TFP growth rates with human capital stocks constructed using a methodology that is at some points close to ours. Instead of exploring the importance of differences in TFP growth rates in explaining international growth variation, these authors use such estimates of TFP growth to run cross-country TFP growth regressions.

2. *Reexamining MRW*

In this section we first describe and comment on MRW's methodology for attributing differences in output to differences in productivity vs. differences in capital intensity. We then update MRW's estimates and make a series of modifications, such as incorporating primary school data and a more labor-intensive technology for producing human capital.

MRW specify the production technology

$$Y = C + I_K + I_H = K^{\alpha}H^{\beta}(AL)^{1-\alpha-\beta}, \tag{1}$$

where Y is output, K and H are stocks of physical and human capital, A is a productivity index, and L is the number of workers. $H = hL$, where h is human capital per worker. Implicit is an infinite-lived representative agent whose time enters production through dual components, human capital H and raw labor L.[6] As shown in (1), MRW specify the same technology for producing human and physical capital. Time subscripts are suppressed, as are the standard accumulation equations for K and H. MRW assume that both stocks depreciate geometrically at a rate of 3% per year.

If one adds competitive output and input markets and constant relative risk aversion utility, then it is well known that higher A will induce proportionate increases in K and H. Given this fact, rather than the usual accounting exercise that assigns output or its growth rate to contributions from K, H, L, and A, we think MRW rightly rearrange (1) to yield

$$\frac{Y}{L} = A\left(\frac{K}{Y}\right)^{\alpha/(1-\alpha-\beta)}\left(\frac{H}{Y}\right)^{\beta/(1-\alpha-\beta)} = AX, \tag{2}$$

where X is a composite of the two capital intensities. We concur with MRW's adoption of (2) for two reasons. First, Y/L is the object of interest rather than Y, since we want to understand why output per worker varies across countries, leaving aside how a country's number of workers L is determined.[7] The A-vs.-X debate really has nothing to do with the determination of L. Second, (2) gives A "credit" for variations in K and H generated by differences in A The contributions of K and H

6 Formally, the efficiency units contributed by a worker with human capital h are $e = h^{\beta(1-\alpha)}A^{(1-\alpha-\beta)/(1-\alpha)}$, and the production function is $Y = K^{\alpha}E^{1-\alpha}$, where $E = eL$

7 Parente, Rogerson, and Wright (1996) argue that hours worked *in the market* (as opposed to home production) by the average worker varies a lot across countries, making the number of workers a poor measure of market labor input If, as these authors argue, market hours per worker are much higher in richer countries, it should contribute to higher A in richer countries

variations that are not induced by A are captured by variations in capital *intensity* X. This decomposition was also adopted by King and Levine (1994), albeit for a setting with physical capital but not human capital.

We offer two caveats to the decomposition in (2), both related to A being endogenous, say resulting from technology adoption decisions.[8] First, one would expect that many country policies affect both A and X. Weak enforcement of property rights in a country, for example, is likely to decrease both A and X. We think the decomposition in (2) is still useful, however, because there are some policies that could affect one factor much more than the other (e.g., education policies). Thus, finding that high levels of output per worker are explained mostly by high levels of H/Y would suggest that differences in education policies are an important element in explaining international differences in output per worker. Similarly, finding that differences in K/Y are important in accounting for the international variation in output per worker would point towards capital taxation or policies that affect the relative price of investment goods.

The second related caveat concerning the decomposition in (2) is that, just as K and H are affected by A, A itself may be affected by capital intensity X. If A is determined by technology adoption, for instance,

8 We do not list the embodiment of technology in physical capital as problematic for the decomposition in (2). Suppose that productivity entirely reflects the quality of physical capital, and that all countries invest in the highest quality capital goods available in the world in the period of investment. Then differences in country productivity levels could be due to differences in the vintage or age of a country's capital stock, i.e. unmeasured differences in the quality of a country's capital stock. In this situation, one might think (2) would attribute to productivity differences what in reality should be attributed to differences in physical capital intensity, say because countries with high investment rates and high capital intensity are using younger and therefore better equipment. If so, our results would understate the role of capital intensity in explaining international output differences. This concern turns out to be unfounded along a steady-state growth path. To see why, suppose the true, quality-adjusted capital stock evolves according to $\Delta K_t = B_t I_t - \delta K_t$, where Δ is the first-difference operator and B is an exogenous capital-embodied technology index which grows at the constant rate g and (recall) is the same for all countries. Imagine also that the *measured* capital stock evolves according to $\Delta K_{Mt} = I_t - \delta K_{Mt}$ so that it does not reflect improvements in quality coming from embodied technology. In this case one can show that if $Y = K^{\alpha}L^{1-\alpha}$, then along a steady state growth path with constant I/Y and K_M/Y one has $Y_t/L_t = (cB_t)^{1-\alpha}(K_M/Y)^{\alpha/(1-\alpha)}$ with c a constant which depends on g, α, and δ, and with $K_M/Y = (I/Y)/(g+n+\delta)$, where n is the exogenous growth rate of L. Thus, along a steady-state growth path, a country's TFP is independent of its investment rate in physical capital. That is, the investment rate does not affect the TFP residual, which in this case is equal to $\ln(Y_t/L_t) - \alpha/(1-\alpha)\ln(K_m/Y)$, which in turn is equal to $[1/(1-\alpha)]\ln(cB_t)$. The intuition for this result is that a higher investment rate reduces the average age of the capital only temporarily, along the transition path. When the new steady-state path is reached with higher capital intensity, the age distribution of the capital stock—which is synonymous with the quality distribution—is the same as the distribution with a lower capital intensity. Thus a country with a permanently higher I/Y than another country will have no younger or better capital and therefore no higher TFP.

then it is likely that higher schooling (i.e., higher H/Y) leads to a higher level of A. Once we obtain estimates of A and X, below we will actually use the decomposition of equation (2) to study this issue by looking at the correlation between A and the capital-intensity variables K/Y and H/Y. A hypothetical example will illustrate the usefulness of this approach. Imagine that, using this decomposition, we find that almost all of the international variation in levels of Y/L is accounted for by international differences in A. But imagine that we also find a strong positive correlation between A and H/Y. This would be consistent with—but not necessarily proof for—the view that human capital explains differences in Y/L, albeit indirectly through its effect on A (say through economywide technology adoption as in the model of Ciccone, 1994). On the other hand, finding no correlation between A and H/Y would suggest that differences in schooling are not important in explaining international output differences.

With these preliminaries out of the way, we now proceed to updating and modifying MRW's estimates. For Y/L MRW use the Summers–Heston GDP per capita in 1985 For K/Y for each country they use

$$\frac{K}{Y} = \frac{I_K/Y}{g + \delta + n}, \tag{3}$$

where I_K/Y is the average Summers–Heston investment rate in physical capital over 1960–1985, g is 0.02 (an estimate of the world average growth rate of Y/L), δ is 0.03 (a rather low depreciation rate, but none of the results in their paper or ours are sensitive to using 0.06 instead), and n is the country's average rate of growth of its working-age population (15- to 64-year-olds) over 1960–1985 (UNESCO yearbook). Expression (3) is derived as the constant (or steady-state) K/Y implied by the capital accumulation equation given a constant I/Y and constant growth rates of Y/L and L.[9] For H/Y MRW use the average 1960–1985 investment rate in human capital divided by the same sum.

$$\frac{H}{Y} = \frac{I_H/Y}{g + \delta + n}. \tag{4}$$

9 In Section 3 below we relax this assumption that in 1985 K/Y is at its steady-state value We make varying assumptions about 1960 K/Y levels for each country, then use the accumulation equation and data on I/Y and Y over 1960–1985 to calculate the 1985 K/Y We find that the results vary little depending on the assumed 1960 value of K/Y As for the H/Y levels, in Section 3 we use data on schooling attainment in 1960 and 1985

MRW use the average 1960–1985 ratio of secondary-school students to the working-age population (UNESCO yearbook) as an estimate of the average investment rate in human capital:

$$\frac{I_H}{Y} = (\text{secondary enrollment rate}) \cdot \left[\frac{\text{population 12–17}}{\text{population 15–64}} \right]$$

Ignoring nonsecondary schooling (which we will find matters), the ratio is L_H/L, the fraction of worker time spent in the human-capital sector.[10] Since in (1) the production technology for human capital is the same as that for other goods, equating the ratios of marginal products of labor and physical capital across sectors entails $L_H/L = K_H/K$, *where* $L = L_H + L_Y$ and $K = K_H + K_Y$.[11]

With their 1985 levels of Y/L, K/Y, and H/Y for 98 countries, MRW regress $\ln(Y/L)$ on $\ln(K/Y)$ and $\ln(H/Y)$. They obtain an R^2 of 0.78, and their estimated coefficients are consistent with production elasticities of $\alpha = 0.30$ for physical capital and $\beta = 0.28$ for human capital (their Table II, restricted regression). The high R^2 is the basis of Mankiw's (1995, p. 295) conclusion that "Put simply, most international differences in living standards can be explained by differences in accumulation of both human and physical capital."

Even assuming H/Y is measured properly, we are deeply uncomfortable with estimating α and β from an OLS regression of $\ln(Y/L)$ on $\ln(K/Y)$ and $\ln(H/Y)$. Consistency of such estimates requires that $\ln(X)$ be orthogonal to $\ln(A)$. Yet countries with policies discouraging capital accumulation may also tend to have policies discouraging activites (such as technology adoption) which contribute to higher A. In Rodríguez-Clare (1997), one of us develops a quality ladder model wherein higher tariffs on imported capital goods result in both lower X (by reducing the investment rate) and lower A (by increasing the average distance between the quality of goods imported and the highest quality of goods available in the world).

Given the possibility that true X and true A are correlated, our preference is to use independent evidence to determine appropriate values of α and β, and then use them to construct X and A. This being said, $\alpha = 0.30$ is actually in the ballpark of estimates obtained using national income accounts (see Gollin, 1996, for evidence on 31 countries with care-

10 The implicit infinite-lived representative agent is simultaneously teacher (H) and student (L)!

11 $H_H/H = L_H/L$, because the representative worker's human capital and labor components are supplied jointly.

ful treatment of proprietors' income). But we have no cause for comfort with $\beta = 0.28$. Studies such as Jorgenson (1995) and Young (1995) look at compensation of workers in different education and experience categories, thereby bypassing the need to choose a single share going to human capital. In other words, the share going to labor input is $1 - \alpha$, and workers with more education and experience receive larger subshares of this $1 - \alpha$. We will do something similar in Section 3 below by looking at Mincerian estimates of wage differences across workers with different education and experience levels. For the rest of this section we keep $\beta = 0.28$, but we discuss at the end how the results are affected by considering higher values.

We now show how the MRW results are sensitive to several modifications that we deem necessary. We keep $\alpha = 0.30$ and $\beta = 0.28$ for comparison purposes. Given that our modified estimates of X and A will be correlated, there will not be a unique decomposition of the variance of $\ln(Y/L)$ into the variance of $\ln(X)$ and the variance of $\ln(A)$.[12] We think an informative way of characterizing the data is to split the covariance term, giving half to $\ln(X)$ and half to $\ln(A)$. This means we decompose the variance of $\ln(Y/L)$ as follows:

$$\frac{\text{var } \ln(Y/L)}{\text{var } \ln(Y/L)} = \frac{\text{cov}(\ln(Y/L),\ln(Y/L))}{\text{var } \ln(Y/L)} = \frac{\text{cov}(\ln(Y/L),\ln(X)) + \text{cov}(\ln(Y/L),\ln(A))}{\text{var } \ln(Y/L),}$$

or

$$1 = \frac{\text{cov}(\ln(Y/L),\ln(X))}{\text{var } \ln(Y/L)} + \frac{\text{cov}(\ln(Y/L),\ln(A))}{\text{var } \ln(Y/L)}.$$

This decomposition is equivalent to looking at the coefficients from independently regressing $\ln(X)$ and $\ln(A)$, respectively, on $\ln(Y/L)$. Since $\ln(X) + \ln(A) = \ln(Y/L)$ and OLS is a linear operator, the coefficients sum to one. So our decomposition amounts to asking, "When we see 1% higher Y/L in one country relative to the mean of 98 countries, how much higher is our conditional expectation of X and how much higher is our conditional expectation of A?" The first row of Table 1 gives the answer for MRW0, the original MRW measure. Since the covariance term is zero by construction for MRW0, the breakdown is precisely their 78% $\ln(X)$ and 22% $\ln(A)$.

12 Since MRW construct $\ln(X)$ by regressing $\ln(Y/L)$ on $\ln(H/Y)$ and $\ln(K/Y)$ with $\ln(A)$ as the residual, their $\ln(X)$ and $\ln(A)$ are orthogonal by construction, and the unique variance decomposition is R^2, $1 - R^2$

Table 1 THE ROLES OF A AND X IN 1985 PROSPERITY[a]

	$cov[\ln(Y/L), \ln(Z)]/var \ln(Y/L)$			
Source[a]	$Z = \left(\frac{K_Y}{Y}\right)^{\frac{\alpha}{1-\alpha-\beta}}$	$Z = \left(\frac{H_Y}{Y}\right)^{\frac{\beta}{1-\alpha-\beta}}$	$Z = X$	$Z = A$
MRW0	29	49	78	22
MRW1	.27	49	76	.24
MRW2	31	47	78	.22
MRW3	.29	11	40	60
MRW4	29	04	33	67

[a]MRW0 from MRW (uses their data appendix) MRW1 MRW0 but with K_Y/Y instead of K/Y MRW2 MRW1 but with L = worker instead of working-age population, 14 countries in/out MRW3 MRW2 but with all enrollment rather than just secondary enrollment MRW4 MRW3 but with (K, H, L) shares of (0 1, 0 4, 0 5), not (0 20, 0 28, 0 42), in H production

Our first modification of MRW's methodology is to recognize that, contrary to (1), national income accounting measures of output do not include the value of student time—an important component of human capital investment.[13] To see how important this might be, we consider the extreme case in which none of the human capital investment is measured as part of total output. To do this we replace K/Y and H/Y in equation (2) with K_Y/Y and H_Y/Y, since only K_Y and H_Y are used in the production of Y when Y does not include human capital investment. It turns out that the MRW measure of I_H/Y, namely L_H/L, is also appropriate for H_Y/Y when all human capital investment goes unmeasured. The same is not true for physical capital intensity, for which we must use $K_Y/Y = (K/Y)(L_Y/L)$ As shown by the MRW1 row of Table 1, this modification results in a 76% $\ln(X)$ vs 24% $\ln(A)$ breakdown, so this distinction does not appear to be quantitatively important

The MRW2 row of Table 1 reproduces the MRW1 row, only with updated data and a set of countries for which we have all the necessary schooling attainment data for the remainder of this paper Like MRW,

13 MRW contend that this slippage between model and data is not quantitatively important Parente and Prescott (1996) disagree, contending that unmeasured human capital investment must be implausibly large for the combined share of capital to be about two-thirds Parente, Rogerson, and Wright (1996) illustrate that unmeasured investment would have to be 25–76% of GDP We are in closer agreement with MRW, since, according to Kendrick (1976), about half of schooling investment consists of education expenditures (teachers, facilities) which *are* included in measured output According to the *1996 Digest of Education Statistics* published by the U S Department of Education (1996), education expenditures averaged 7% of GDP over 1960–1990 Back-of-the-envelope calculations suggest unmeasured investment might therefore be only 13% of GDP

we have a sample of 98 countries.[14] We use the latest Summers–Heston data (Mark 5.6) and use output per worker, whereas MRW used output per capita. The measure we use for H_Y/Y here is the same as that used by MRW, except we use Barro and Lee's (1993) data on secondary enrollment rates in 1960, 1965, . . . , 1985 and United Nations (1994) population data by age groups to compute the value of

$$\frac{I_H}{Y} = \text{secondary enrollment rate} \cdot \left[\frac{\text{population 15–19}}{\text{population 15–64}} \right]$$

for each country's investment rate in human capital in 1960, 1965, . . . , 1985. MRW used population aged 12–17 in the numerator of the fraction in brackets, due to data availability. As shown in the MRW2 row of Table 1, if we see 1% higher Y/L, we expect 0.78% higher X and 0.22% higher A. Since the results are very similar to MRW1, we can now incorporate data on primary schooling enrollment, etc., for our sample of 98 countries without fear that the change in sample obscures the comparison.

Using data from Barro and Lee (1993), the MRW3 row of Table 1 uses H_Y/Y calculated with all three enrollment rates The results are striking. Conditional on 1% higher Y/L in a country, we now expect only 0.40% higher X and fully 0.60% higher A. As suggested by these results, primary enrollment rates do not vary as much across countries as secondary enrollment rates do. The MRW3 measure of $\ln(H_Y/Y)$ has only about one-fourth the variance of the MRW0 measure of $\ln(H_Y/Y)$.[15] Moreover, the correlation of the MRW3 measure of $\ln(H_Y/Y)$ with $\ln(Y/L)$ is only .52, as opposed to .84 for the MRW0 measure. This is *not* to say that primary-schooling investments are unproductive compared to other schooling investments, for our methodology assumes that they are productive.[16] It

14 In our sample but not in MRW's Gambia, Guinea-Bissau, Lesotho, Swaziland, Barbados, Guyana, Iran, Iraq, Taiwan, Cyprus, Iceland, Malta, Yugoslavia, and Fiji In MRW's sample but not in ours Angola, Burkina Faso, Burundi, Chad, Egypt, Ethiopia, Ivory Coast, Madagascar, Mauritania, Morocco, Nigeria, Sierra Leone, Somalia, and Sudan

15 One might think that adding primary schooling enrollment rates to secondary enrollment rates will not lower the variance, since adding a constant does not affect the variance of a random variable But since we are looking at the *percentage* variance, adding the relatively stable primary school enrollment indeed lowers the variance

16 In the next section we discuss Mincer regression evidence consistent with primary schooling indeed being productive Specifically, each additional year of primary schooling in poor countries is associated with roughly 10% higher wages, suggesting important human capital investment is going on in primary schools that should not be ignored There remains the issue of whether a year of enrollment in secondary school involves more investment in human capital than a year in primary school, so that the two enrollment rates should not simply be added together as we have done in the current section The Mincer evidence that each additional year of schooling raises wages about 10% suggests that more *absolute* investment in human capital is occurring in secondary school than in primary school

says, rather, that primary schooling does not vary anywhere near as much with Y/L across countries as secondary schooling does. By focusing only on secondary schooling, one overstates the percentage variation in human capital across countries and its covariance with output per worker.

A further objection we have to the MRW measure of the human capital stock is that, as shown in (1), its construction assumes the same technology for producing human capital as for producing consumption and physical capital. Kendrick (1976) presents evidence that the technology for producing human capital is more intensive in labor than is the technology for producing other goods. He estimates that about 50% of investment in human capital in the United States represents the opportunity cost of student time. The remaining 50% is composed of expenditures on teachers (human capital) and facilities (physical capital). According to the *1996 Digest of Education Statistics*, expenditures on teachers represent about 80% of all expenditures. These figures suggest factor shares of 10%, 40%, and 50% for physical capital, human capital, and raw labor in the production of human capital, as opposed to the 30%, 28%, and 42% shares MRW use for the production of consumption goods and new physical capital. If we let

$$\dot{H}_H = K_H^{1-\phi-\lambda} H_H^{\phi} (AL_H)^{\lambda}, \tag{5}$$

this evidence suggests $\phi = 0.4$ and $\lambda = 0.5$. Combining (2), (4), and (5) yields[17]

$$\frac{H_Y}{Y} = \left(\frac{L_H/L}{n+g+\delta}\right)^{[1-\phi+\lambda\beta/(1-\alpha-\beta)]} \left(\frac{K_Y}{Y}\right)^{[1-\phi-\lambda(1-\beta)/(1-\alpha-\beta)]/[1-\phi+\lambda\beta/(1-\alpha-\beta)]} \tag{6}$$

When the two sectors have the same factor intensity ($\phi = \beta$ and $\lambda = 1 - \alpha - \beta$), this reduces to $H_Y/Y = (L_H/L)/(n+g+\delta)$, which MRW used and we used above. But with $\phi = 0.40$ and $\lambda = 0.50$ the powers in (6) are 1.07 on the first fraction and -0.28 on the second. Because human capital production is more human capital-intensive than is the production of Y ($\phi > \beta$), a large share of labor devoted to human capital accumulation has a more than proportionate effect on H_Y/Y. And because human capital production is less physical capital-intensive than is the production of Y ($1 - \phi - \lambda < \alpha$), a high rate of investment in physical capital raises Y more

17 $H_Y/Y = (L_Y/L)\,(H/Y) = (L_Y/L)\,(\dot{H}_H/Y)/(n+g+\delta) = [(L_H/L)/(n+g+\delta)]\,(K_H/Y)^{1-\phi-\lambda}(H_H/Y)^{\phi}(AL_H/Y)^{\lambda}$. The expression in the text can be obtained by substituting for A using (2) with H_Y/Y and K_Y/Y and by using $K_H/Y = (L_H/L_Y)\,(K_Y/Y)$ and $H_H/Y = (L_H/L_Y)\,(H_Y/Y)$ (ignoring multiplicative constants).

than H, thereby reducing H_Y/Y. As shown in the MRW4 row of Table 1, using $\phi = 0\ 40$ and $\lambda = 0.50$ results in a split of 33% ln(X) vs. 67% ln(A). Comparing MRW4 with MRW3, we see that lowering the capital intensity of human capital production modestly lowers the variation of H_Y/Y across countries.

As shown by comparing MRW0 with MRW4 in Table 1, the cumulative effect of these modifications is to remove the linchpin of the neoclassical revival: MRW's original (78%, 22%) decomposition has given way to a (33%, 67%) decomposition. Can one restore MRW's results with a higher β? Doubling β from 0.28 to 0.56 yields a (51%, 49%) division. As β rises toward ⅔, the decomposition approaches 60% vs. 40%. Thus a sufficiently high β does generate results that, although not as dramatic as those of MRW, still have the major part of international income variation explained by differences in levels of physical and human capital per worker. But what is the right value for β? Unfortunately, we know of no independent estimates of "the" share of human capital. Fortunately, in the next section we are able to exploit wage regressions to measure human-capital stocks in a way that does not depend on the value of β. This regression evidence also appropriately weights primary schooling attainment relative to secondary schooling attainment, rather than lumping them together with equal weight as we have done in the preceding.

3. *Using Mincer Regression Evidence to Estimate Human Capital Stocks*

In this section we exploit evidence from the labor literature on the wage gains associated with more schooling and experience For a cross section of workers, Mincer (1974) ran a regression of worker log wages on worker years of schooling and experience. He chose this specification because it fit the data much better than, say, a regression of the *level* of wages on the years of schooling and experience. To incorporate this evidence into the technology for producing human capital, we abandon the infinite-life construct in favor of a life cycle in which people first go to school full time and then work full time We specify the following technology for human capital:

$$h_s = (K_H/L_H)^{1-\phi-\lambda}(h_T)^{\phi}(Ae^{(\gamma/\lambda)s})^{\lambda}, \tag{7}$$

where h_s is the human capital of somebody with s years of schooling, K_H is the capital stock used in the education sector, L_H is the number of

students, and h_T is the human capital of each teacher. Manipulating (7) leads to[18]

$$\frac{H_Y}{Y} = \left(e^{\gamma s}\right)^{1/[1-\phi+\lambda\beta/(1-\alpha-\beta)]} \left(\frac{K_Y}{Y}\right)^{[1-\phi-\lambda(1-\beta)/(1-\alpha-\beta)]/[1-\phi+\lambda\beta/(1-\alpha-\beta)]} \tag{8}$$

Bils and Klenow (1996) look at Mincer regression studies covering 48 countries and find that the wage gain associated with an additional year of education averages 9.5% across the 48 countries and ranges from 5% to 15% for 36 of the 48 countries. Based on technologies (1) and (7), the percentage wage gain to a representative agent from one more year of schooling is $\beta\gamma/(1-\alpha)$. Therefore, to match an estimated wage gain of 9.5% we set $\gamma = 0.095(1-\alpha)/\beta$.

Table 2 presents results based on (7). The rows are labeled BK*n* because (7) is from Bils and Klenow (1996). As with MRW4 above, we use $\alpha = 0.30$, $\beta = 0.28$, $\phi = 0.4$, and $\lambda = 0.5$. For years of schooling s, row BK1 uses the level implied by the enrollment rates used in MRW3 and MRW4: $s = 8 \cdot \text{primary} + 4 \cdot \text{secondary} + 4 \cdot \text{tertiary}$. As the BK1 row shows, conditional on 1% higher Y/L we expect 0.60% higher X and 0.40% higher A. So switching from (6) used for MRW4 to (8) used for BK1 dramatically shifts the breakdown from (33%, 67%) to (60%, 40%). The exponential form of (7) implies that the higher the level of schooling, the bigger is the absolute amount of human capital obtained from the next year of schooling. The exponential form therefore puts more weight on secondary school enrollment than on primary school enrollment, moving us back toward MRW's 78%-vs -22% breakdown.

One concern we have about BK1, as well as all of Table 1, is the assumption that in 1985 K/Y and H/Y are at steady-state levels. The data show lots of movement in country growth rates of Y, L, and Y/L and in country investment rates in physical and human capital, suggesting that country K/Y and H/Y levels change over time. To estimate an off-steady-state 1985 K/Y, we use the accumulation equation and data on I/Y and Y

18 In steady state $h_s = h_T = h$, so that the human capital of each student entering the workforce is the same as that of each teacher or worker. Using this fact, $h = H_H/L_H$, so that $H = hL = L(K_H/L_H)^{1-\phi-\lambda}(H_H/L_H)^{\phi}(Ae^{(\gamma/\lambda)s})^{\lambda}$, where H_H is the total human capital of teachers. Expression (8) can then be obtained much as expression (6) was above. There are two (offsetting?) shortcomings in our treatment. First, we are assuming the student–teacher ratio is the same in each country (we fix it at one, but the level does not affect cross-country variance analysis). This ratio is presumably lower in richer countries. Second, our setup assumes that teacher education varies as much across countries as average worker education does ($h_s = h$). In reality teacher schooling may vary less than average worker schooling, say if in every country high-school teachers must have at least a high-school diploma.

Table 2 THE ROLES OF A AND X IN 1985 PROSPERITY

	$cov[\ln(Y/L), \ln(Z)]/var \ln(Y/L)$			
Source[a]	$Z = \left(\frac{K_Y}{Y}\right)^{\frac{\alpha}{1-\alpha-\beta}}$	$Z = \left(\frac{H_Y}{Y}\right)^{\frac{\beta}{1-\alpha-\beta}}$	$Z = X$	$Z = A$
BK1	.29	31	.60	40
BK2	23	.33	56	44
BK3	23	.31	.53	.47
BK4	.23	11	.34	66

[a]BK1 uses (7), i e Mincer evidence BK2 calculates years of schooling s from Barro–Lee 1985 stocks instead of 1960–1985 flows BK3 adds average years of experience BK4 BK3 but with (K, H, L) shares of (0, 0, 1) instead of (0 1, 0 4, 0 5) in H production

over 1960–1985. Unfortunately, direct estimates of the 1960 K/Y are not available for most countries. We therefore set, for each country,

$$\left(\frac{K}{Y}\right)_{1960} = \frac{I_K/Y}{g + \delta + n}$$

with the investment rate I_K/Y, the growth rate of Y/L (g), and the population growth rate (n) equal to the country's averages over either 1960–1965, 1960–1970, or 1960–1985, and δ either 0.03, 0.05, or 0.07. We also followed a procedure akin to King and Levine (1994) where we set g in the denominator equal to a weighted average of own-country and world growth. The results were not at all sensitive to which way we calculated the 1960 K/Y, so we report the results with 1960 K/Y calculated using $\delta = 0.03$ (as in Table 1) and the country's own averages over 1960–1970 for g and n. To construct the 1985 H/Y, we use Barro and Lee's (1993) data on average years of schooling attained by the 25–64-year-old population in each country in 1985. We report the results of using this approach to obtain 1985 levels of K/Y and H/Y in the BK2 row of Table 2. Conditional on 1% higher Y/L in one country in 1985, we expect 0.56% higher X and 0.44% higher A in that country. These results are not far from the (60%, 40%) breakdown in BK1 with the steady-state assumption for K/Y and H/Y.[19]

We now modify (7) to incorporate human capital acquired through experience:

$$h_s = (K_H/L_H)^{1-\phi-\lambda}(h_T)^{\phi}(Ae^{(\gamma_1 s + \gamma_2 \exp + \gamma_3 \exp^2)/\lambda})^{\lambda}, \tag{9}$$

19 The close similarity between H/Y calculated in BK1 and in BK2, i e. between school attainment implied by enrollments and measures of years of schooling attained, suggests that differences in the duration of primary, secondary, and higher education from our assumed 8, 4, and 4 years are not quantitatively meaningful

where exp = (age − s − 6). The average experience level among workers was estimated using United Nations (1994) data in combination with Barro and Lee's schooling attainment data. For each country experience was calculated as the population-weighted average of (age − s − 6) at ages 27, 32, . . . , 62 for the groups 25–29, 30–34, . . , 60–64 in 1985. Surprisingly, we find that the correlation between average years of experience of 25–64-year-olds and ln(*Y*/*L*) in 1985 is −0.67. Richer countries have older workforces, but slightly less experienced ones because they spend more years in school As above, $\gamma_1 = 0.095(1-\alpha)/\beta$. Bils and Klenow (1996) report average estimated coefficients on exp and exp^2 across 48 countries of 0.0495 and −0.0007. Based on these, we set $\gamma_2 = 0.0495(1-\alpha)/\beta$ and $\gamma_3 = 0.0007(1-\alpha)/\beta$ The consequence of adding experience can be seen in the BK3 row of Table 2. As compared to the (56%, 44%) split in BK2, the split in BK3 is (53%, 47%).

Underlying this breakdown of 53% ln(*X*) vs. 47% ln(*A*) is the supposition that the *quality* of schooling is much higher in richer countries. In richer countries, students enjoy better facilities (higher K_H/L_H) and better teachers (higher H_H/L_H). From (9), the quality of schooling is

$$\text{quality of schooling} = (K_H/L_H)^{1-\phi-\lambda} h_T^{\phi} A^{\lambda}$$

Using this formula, for BK3 the elasticity of quality with respect to a country's *Y*/*L* is 0.95%.[20] This means a country with 1% higher *Y*/*L* has 0.95% higher quality education Note that higher quality of this type does *not* raise the percentage wage premium from education, but instead raises the base (log) wage for anyone in the country receiving *some* education. It should affect the intercept of the Mincer regression for a country, but not the coefficient on schooling

Is an educational quality elasticity of 0.95% reasonable? Is it plausible that, like GDP per worker, the quality of education varies by a factor of about 34 across countries in 1985? An independent estimate of the quality elasticity can be gleaned from the wages of U.S. immigrants [21] Using 1970 and 1980 census data on the U S earnings of immigrants from 41 countries, Borjas (1987) estimates country of-origin-specific intercepts in a Mincer regression of log wages on immigrant years of education and experience He finds that immigrants with 1% higher per capita income in their country of origin exhibit a 0.116% higher wage intercept (stan-

20 Calculated as *cov*[ln(quality), ln(*Y*/*L*)]/*var* ln(*Y*/*L*)

21 Incidentally, the enormous pressure for migration from poor to rich countries is itself consistent with substantial differences in productivity across countries However, this pressure could be entirely explained by higher physical capital–output ratios and greater nonpecuniary benefits of living in richer countries

dard error 0.025). This implies a quality elasticity of only 0.12%, suggesting that the elasticity embedded in BK3 is very aggressive.[22,23]

Borjas's evidence suggests an alternative, namely that teachers and class facilities affect school quality through the schooling coefficient γ. In this event we would expect to see higher Mincer schooling coefficients in richer countries. Bils and Klenow (1996) find the opposite: each additional year of schooling brings roughly 10% higher wages in a country where the average worker has 5 years of schooling, compared to only about 5% higher wages in a country where the average worker has 10 years of schooling. Perhaps γ's *are* higher in richer countries, but the effect on the education premium is more than offset by a lower relative marginal product of human capital in richer countries. This could arise because of imperfect substitutability of workers with different education levels combined with abundance of human capital in richer countries. Indeed, the Cobb–Douglas technology in (1) implies unit elasticity of substitution between human capital and raw labor and therefore a falling education premium with a country's H/Y, holding γ constant.

It is interesting to explore the possibility that the Mincer coefficients already capture the effect of education quality combined with imperfect substitutability. This would correspond to the extreme case when teachers and class buildings affect only the γ's, so that $\phi = 0$ and $\lambda = 1$. It would be ideal to do this exercise using Mincer coefficients for each country, but unfortunately we do not have such data for all countries. Here we use the average Mincer coefficient of 9.5% instead. (The reader should note that, since the Mincer coefficient is actually declining with income per worker, this biases the results against a large role for A.) As we report in the BK4 row of Table 2, without Mincer-intercept-type variations in school quality, human capital contributes much less to Y/L variation. The (ln(X), ln(A)) division shifts from (53%, 47%) in BK3 to (34%, 66%) in BK4.

How do we choose between BK3 and BK4? Recall that the school

22 Immigrants may be more able than the average person in their country of origin Borjas's regression controls for observable differences in immigrants' ability such as age, years of schooling, and English proficiency With regard to unobservables, the estimate of education quality differences would be biased downward if positive selection (in Borjas's terminology) were greater the poorer the country of origin As Borjas notes, the opposite may be true, since income inequality tends to be greater in poorer countries

23 Further cause for concern is the difficulty researchers such as Hanushek (1986) and Heckman, Layne-Farrar, and Todd (1996) have encountered in correlating schooling outcomes with teacher inputs A (virtually controlled) experiment in Tennessee, however, found that the group of students placed in smaller K–3 classes performed significantly better on standardized tests (Mosteller, 1995)

quality elasticity implied by BK3 is 0.95%, whereas BK4 implies no variation in school quality (of the intercept type) across countries. The evidence from Borjas (1987) suggests that BK3's elasticity is much higher than the truth; the zero elasticity in BK4 seems closer. But if BK3 comes from data on the shares of capital and teachers in the U S education sector, why might it deliver wrong results? There are three possibilities. First is the reason we just gave, namely that these inputs affect the γ's. Second, it could be that human capital varies much less across education sectors than across other sectors, i.e., international differences in human capital may be smaller for teachers than for other workers. Finally, it could be that productivity A is not as significant in the education sector as it is in other sectors. In the extreme case when A does not enter the education sector at all, we find that the parameter values $\phi = 0.19$ and $\lambda = 0.81$ generate a quality elasticity matching Borjas's 0 12. In this case we find a (42%, 58%) breakdown, in between BK3 and BK4 but a little closer to the latter

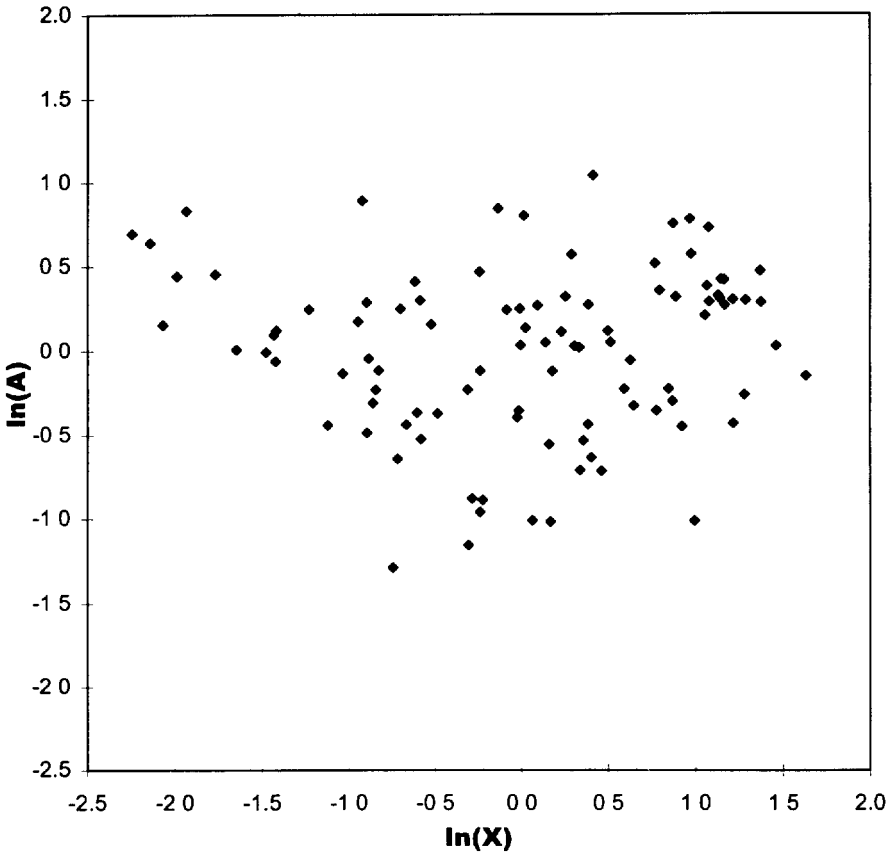
We conclude that richer countries tend to have higher K/Y, higher H/Y, and higher A, with a dominant role for A, a large role for K/Y, and a modest-to-large role for H/Y. To us this says that theorizing about international output differences should center at least as much on differences in productivity as on differences in physical or human capital intensity. Figures 1 and 2 display $\ln(A)$ and $\ln(X)$ using MRW0 and BK4, respectively.[24] In the MRW0 world, research should focus on explaining why $\ln(X)$ varies so much, in the BK4 world a greater priority is to understand differences in $\ln(A)$.

In contrasting MRW0 and BK4, it is instructive to look at the correlations among output per worker (Y/L), capital intensity (K/Y and H/Y), and productivity (A) Table 3a shows the correlation matrix for the case where H/Y is measured according to MRW0; Table 3b does the same for the case where H/Y is measured according to BK4. In both cases Y/L, K/Y, and H/Y are highly positively correlated with each other. The difference arises in the correlation between these variables and A. In particular, Table 3a shows no correlation between A and K/Y or between A and H/Y (both by MRW construction), whereas the corresponding correlations are quite positive in Table 3b. In thinking about a theory of endogenous A, it is hard to imagine that policies discouraging K/Y and H/Y—such as high tax rates—would not also discourge A The positive BK4 correlations seem much easier to generate theoretically

A possible reason for the 0.57 correlation between $\ln(A)$ and $\ln(H/Y)$ is

24 These figures display visually what we try to convey by splitting the covariance terms in Tables 1 and 2

Figure 1 1985 LEVELS MRW0



that high H/Y, say due to generous education subsidies, facilitates technology adoption. Ciccone (1994) presents a model with this feature: the larger the economy's stock of human capital, the more profitable it is for a firm to spend the fixed costs of adopting a given technology, and therefore the higher the economy's A relative to the world frontier. Note that this story links an economy's A to an economy's H/Y, not an individual worker's A to an individual worker's h. We stress that the Mincer evidence deployed in this section should capture any link between the schooling of an individual worker and the level of technology (e.g. equipment quality) that worker can use. This is because technology adoption that is linked to the individual should show up in the private wage gain to more education.

Figure 2 1985 LEVELS BK4

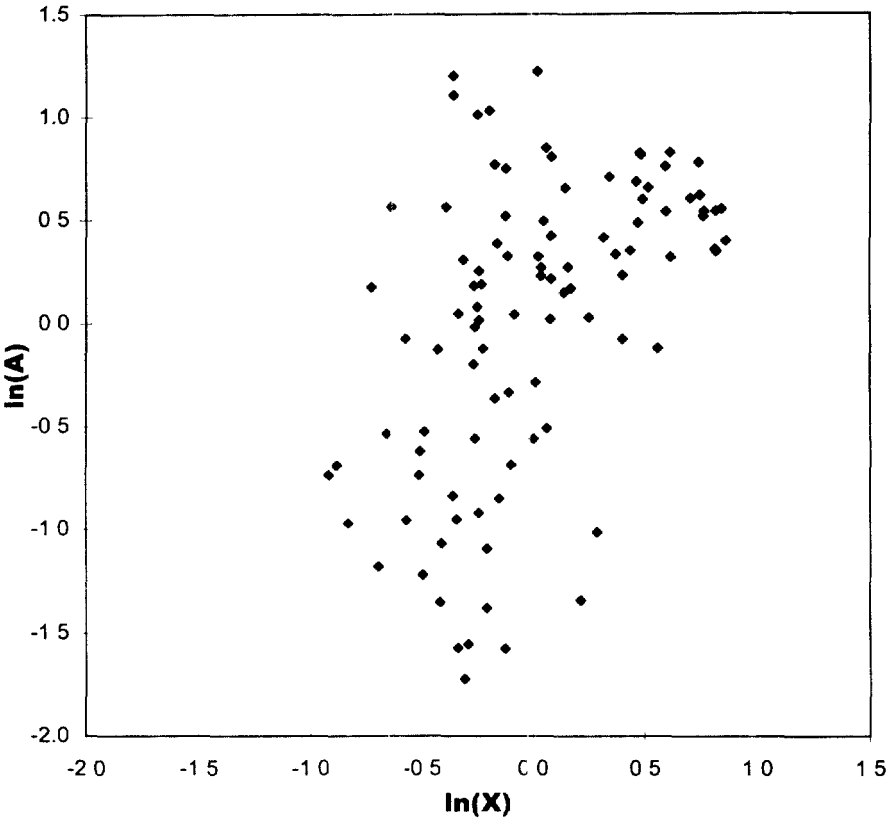


Table 3 CORRELATION MATRICES

a With MRW0 methodology	ln(*Y*/*L*)	ln(*K*/*Y*)	ln(*H*/*Y*)
ln(*K*/*Y*)	77		
ln(*H*/*Y*)	84	67	
ln(*A*)	47	00	00

b With BK4 Methodology	ln(*Y*/*L*)	ln(*K*/*Y*)	ln(*H*/*Y*)
ln(*K*/*Y*)	.59		
ln(*H*/*Y*)	60	02	
ln(*A*)	93	28	57

At this point several robustness checks are in order. We first look at the potential importance of imperfect substitutability. For 45 countries in Bils and Klenow's (1996) sample, Barro and Lee (1996) report percentages of the 25–64-year-old population in seven educational attainment categories: none, some primary, completed primary only, some secondary, completed secondary only, some tertiary, and completed tertiary. We treat "some" as half-completed, and assume the durations are 8, 4, and 4 years for primary, secondary, and tertiary schooling. We assume the first three categories are perfectly substitutable "primary equivalents," and that the last four are perfectly substitutable "secondary equivalents":

$$Y = K^{\alpha}(H_{\text{prim}}^{1-1/t} + H_{\text{sec}}^{1-1/\sigma})^{(1-\alpha)/(1-1/\sigma)}$$

with

$$H_{\text{prim}} = \sum_{s=0,4,8} AL_s e^{\gamma s}, \qquad H_{\text{sec}} = \sum_{s=10,12,14,16} AL_s e^{\gamma s},$$

where L_s is the number of working-age people in schooling group s. Note that this specification follows BK4 in eschewing Mincer-intercept-affecting school quality differences. We use nonlinear least squares to estimate σ and $\gamma\beta/(1-\alpha)$ using Barro and Lee's L_s data and Bils and Klenow's data on the estimated education premium for the 45 countries. The resulting estimates are $\gamma = 0.09(1-\alpha)/\beta$ and $\sigma = 65$.[25] We then use these estimates to construct H aggregates for the 84 of our 98 countries for which Barro and Lee (1996) have the necessary schooling attainment data. The resulting breakdown is (40%, 60%), tilted a little toward ln(X) relative to the BK4 row, which uses $\gamma = 0.095(1-\alpha)/\beta$ and $\sigma = 1$ (albeit with human capital vs. raw labor rather than primary equivalents vs. secondary equivalents). We conclude from this exercise that allowing for imperfect substitutability (and incorporating heterogeneity in schooling attainment within each country) does not significantly affect the results.

Our next robustness check concerns the size of β. In the previous section we found that raising the value of this parameter boosted the role of human capital in explaining international income variation. This does not happen here. Here we choose the coefficients γ in (7) and (9) so that the implied wage gain for each additional year of education, which is

25 This degree of substitutability is very high compared to the 1.5 estimated by Katz and Murphy (1992) for high-school vs. college equivalents in the United States. We have imposed a common γ, however, so our high estimated substitutability may be capturing the combination of less substitutability and higher γ's in richer countries.

given by $\beta\gamma/(1-\alpha)$, matches the Mincer evidence discussed in Bils and Klenow (1996). Thus changing β results in an offsetting adjustment in γ to preserve the equality $\beta\gamma/(1-\alpha) = 9.5\%$. In other words, there is no doubling of the importance of human capital from doubling β to 0.56, since the coefficient γ must be halved at the same time. Indeed, there is zero effect. The intuition is that the Mincer estimates pin down the combined effect of translating schooling into human capital and translating human capital into output. Thus a larger elasticity of output with respect to human capital requires a smaller elasticity of human capital with respect to schooling in order to maintain consistency with the Mincer regression evidence.

An objection to the Mincer evidence is that the coefficient on schooling captures only *private* gains from schooling. Productive benefits of *economywide* human capital, as proposed by Lucas (1988), would be absorbed in the Mincer intercept. Lucas (1990) argues that human capital externalities can explain the large differences in TFP that Krueger (1968) found across 28 countries even after adjusting for human capital per worker (measured much as in BK4). Leaving aside the nature of these externalities, it is illuminating to ask how big they have to be in order to restore MRW's 78%-vs.-22% breakdown. For BK3, with its substantial variation in education quality, we find that the social Mincer coefficient on schooling would have to be 15.6%, as opposed to the 9.5% or so typically found. For BK4, the social education premium would have to be 29%. Since the evidence on school quality favors BK4, it appears that external benefits of schooling would need to be larger than the private benefits! In any case, entertaining externalities leads to questions about their exact nature and transmission. To us, this supports our call for more research into the source of productivity differences across countries.

4. *From Development Accounting to Growth Accounting*

Whereas Tables 1 and 2 were concerned with development accounting (King and Levine's felicitous 1994 phrase), Table 4 is about growth accounting. For Table 4 we constructed K/Y and H/Y for each country in 1960 so that we could compute 1960–1985 growth rates. We did this for BK2 through BK4 (one cannot do it under the steady-state assumptions used for MRWs and for BK1). For H/Y we used Barro and Lee's (1993) schooling stocks in 1960 and, when necessary to construct experience levels, the United Nations (1994) population data for 1960. We estimated the 1960 K/Y's as described in the previous section, and the results here are not at all sensitive to the various ways we tried to estimate 1960 K/Y's.

Table 4 presents the results of 1960–1985 growth accounting. When a

Table 4 THE ROLES OF A AND X IN 1960–1985 GROWTH

	$cov[\Delta \ln(Y/L), \Delta \ln(Z)]/var\, \Delta \ln(Y/L)$			
Source[a]	$Z=\left(\frac{K_Y}{Y}\right)^{\frac{\alpha}{1-\alpha-\beta}}$	$Z=\left(\frac{H_Y}{Y}\right)^{\frac{\beta}{1-\alpha-\beta}}$	$Z = X$	$Z = A$
BK2	.03	12	.15	.85
BK3	03	12	.14	.86
BK4	.03	.06	.09	91

[a]BK2 calculates years of schooling s from Barro–Lee 1985 stocks instead of 1960–1985 flows BK3 adds average years of experience BK4 BK3 but with (K, H, L) shares of (0, 0, 1) instead of (0 1, 0 4, 0 5) in H production

country's 1960–1985 growth rate of output per worker is 1% faster than average, growth in physical capital intensity typically contributes about 0.03%. For BK2, which includes only the schooling contribution to human capital, H/Y growth contributes 0.12% more, the share owing to A being 0.85%. Adding experience (BK3) does not change the calculus. Letting education quality enter through the Mincer coefficients, as in BK4, boosts the contribution of A to 91%.

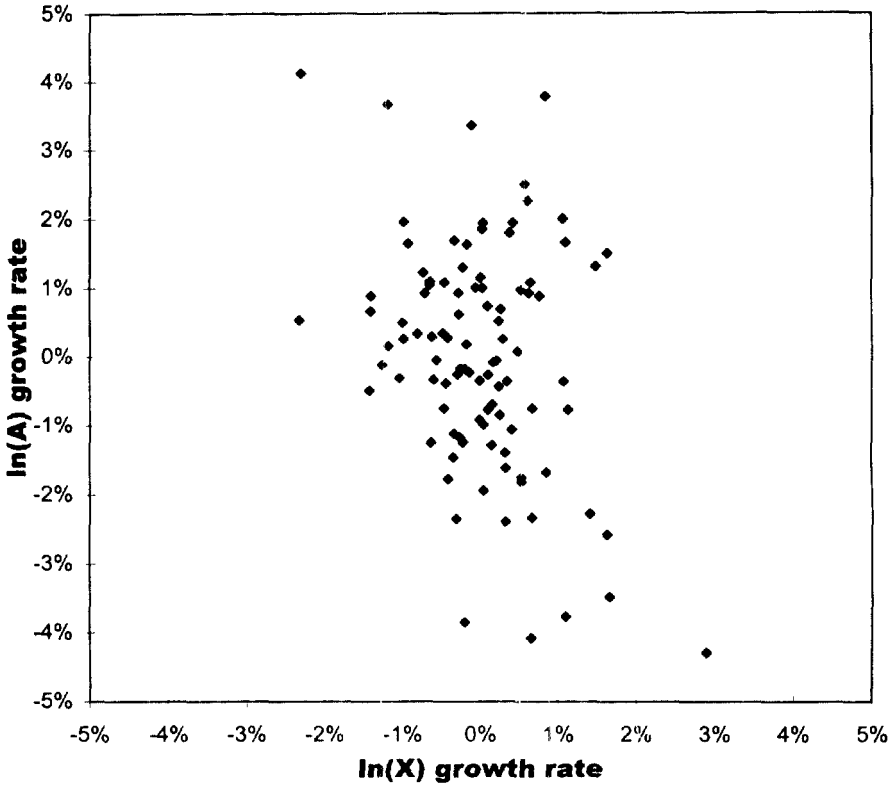
The consistent outcome in Table 4 is that differences in growth rates of Y/L derive overwhelmingly from differences in growth rates of A.[26] Figure 3 plots A growth against X growth (based on BK4) to demonstrate this visually. The small role we find for growth in the human-capital stock is not new Benhabib and Spiegel (1994) and Pritchett (1995) report that the growth rate of schooling attainment is virtually uncorrelated with growth in output per worker across countries over 1960–1985. Barro and Sala-i-Martin find the same thing (1995, Chapter 12), but mark it down to measurement error.

Table 4 suggests that Chapters 1 to 4 in Barro and Sala-i-Martin (1995) and studies such as Chari, Kehoe, and McGrattan (1996) that emphasize transition dynamics of the neoclassical growth model ignore the major source of differences in country growth rates. Our results call for greater emphasis on models of technology diffusion and policies that directly affect productivity.[27]

26 For the 98-country sample, the unweighted average Y/L growth across the 98 countries is 2 24% Using (2), this can be broken down into 0 77% from K/Y growth, 0 44% from H/Y growth, and 1 03% from A growth This *average-world-growth accounting* is distinct from the *country-variation-in-growth-rates accounting* that we focus on above. Unlike the country-variation-in-growth rates, which are dominated by variation in the growth rate of A, the trend growth in Y/L in the world (2 24%) owes more to X growth (1 21%) than to A growth (1 03%)

27 Some of the examples offered by Chari, Kehoe, and McGrattan (1996) as contributors to their effective tax rate may affect productivity A directly Regulations and corruption would be expected to hinder firms' ability to translate K and H into Y

Figure 3 1960–1985 GROWTH RATES BK4



The Appendix contains 1985 levels and 1960–1985 growth rates of *Y/L*, *K/Y*, *H/Y*, and *A* (the latter two for BK4). For ease of interpretation the 1985 level variables are given relative to the United States. Many countries surprisingly come out higher than the United States in our estimates for *A*. Perhaps we have been aggressive in our estimates of the return to human capital (e.g. making no attempt to adjust for ability bias), but we prefer to err on this side, given our conclusion that human capital's importance has been seriously overstated in previous research.

As we mentioned at the beginning of Section 2, the fact that *A* is not exogenous implies that the growth rate of *A* could be affected by the growth rate of *K/Y* and *H/Y*. Increasing levels of capital intensity and schooling could thus be responsible for high growth rates indirectly, by allowing for a faster growth of *A*. To examine this possibility Table 5 shows the correlation matrix for the 1960-1985 growth rates of *Y/L*, *K/Y*,

Table 5 CORRELATION MATRIX (BK4 GROWTH RATES)

	$\Delta \ln(Y/L)$	$\Delta \ln(K/Y)$	$\Delta \ln(H/Y)$
$\Delta \ln(K/Y)$	04		
$\Delta \ln(H/Y)$	28	−.50	
$\Delta \ln(A)$	.87	− 42	.34

H/Y, and A according to BK4. The 0.34 correlation between the growth rates of A and H/Y suggests that countries with high growth in A have had unusually high growth rates of schooling. Thus it could be that high growth in economywide schooling attainment powerfully boosts growth through its effect on technology adoption. In contrast, the negative correlations between the growth rate of K/Y and the growth rates of, respectively, H/Y and A are puzzling [28]

An alternative way to think about the role of factor accumulation and total productivity factor (TFP) growth in explaining differences in economic performance across countries is to look at what has happened to the standard deviations of Y/L, K/Y, H/Y, X, and A (as logarithms) across time. Table 6 compares the standard deviations of these variables in 1960 and 1985 As is well known, the standard deviation of the logarithm of output per worker increased somewhat during this period (i.e., σ-divergence). We find that σ-convergence occurred for K/Y, but not for H/Y, X, and A. Thus the lack of σ-convergence in Y/L does not stem from, say, A-convergence combined with X-divergence [29]

5. *Do Young's Findings Contradict Ours?*

The debate over whether fast rates of growth in some countries stem from accumulation of capital or from technology catch-up has been heavily influenced by the East Asian miracles. It was initially thought that these countries had very high TFP growth rates, pointing to technology catch-up as the heart of the story. Then came the careful work of Alwyn Young showing that these countries grew mostly through input accumulation (Young, 1995), and that their TFP growth rates were not extraordinarily high (Young, 1994). Singapore, for instance, was shown to have

28 The negative correlation between the growth rates of A and K/Y could indicate an overstatement of the contribution of K/Y to output per worker One reason for this may be that public investment (which is part of the data on investment that we used to generate K/Y) is less efficient than private investment in generating efficiency units of capital If this is true, then the role of A is even larger than shown in our results

29 We also did our variance decomposition on the 1960 numbers and obtained exactly the same breakdown (34% $\ln(X)$ vs 66% $\ln(A)$) for BK4 that we did for 1985 in Table 2

Table 6 STANDARD DEVIATIONS (BK4 LEVELS)

Quantity	*1960*	*1985*
$\ln(Y/L)$	0 95	1 01
$\ln(K/Y)$	0 73	0 55
$\ln(H/Y)$	0 28	0 28
$\ln(X)$	0 46	0 44
$\ln(A)$	0.71	0 72

virtually no productivity growth over the last decades. As a result of this work, many people have concluded that the East Asian episodes illustrate the importance of neoclassical transition dynamics rather than technology catch-up

We do not think this interpretation of Young's results is correct. First, as we argued above, we think the debate is over whether capital accumulation or technology catch-up explains growth in output *per worker*, not growth in output Neither hypothesis tries to explain the growth rate of employment Second, as we also argued above, growth in physical capital induced by rising productivity should be attributed to productivity [Barro and Sala-i-Martin also make this point (1995, p. 352)]. A higher level of productivity raises the marginal point of capital, thereby stimulating investment and capital accumulation that would not have occurred without the higher level of productivity. The role of capital accumulation over and above that stimulated by productivity growth can be measured by the growth rate of the capital–output ratio Table 7a reports a few calculations from Young's (1995) tables to illustrate the quantitative importance of these considerations. The annual growth rates of output and TFP, respectively, were 7.3% and 2 3% in Hong Kong, 8.7% and 0.2% in Singapore, 10.3% and 1.7% in South Korea, and 9 4% and 2 6% in Taiwan. So growth in output clearly came primarily from input accumulation But the growth rates of output per *worker* and *adjusted TFP*—TFP raised to 1/(1 − capital's share) because of its effect on capital accumulation—were as follows: 4 7% and 3.7% in Hong Kong, 4.2% and 0.3% in Singapore, 4.9% and 2.5% in South Korea, and 4.8% and 3.5% in Taiwan. So in three of the four East Asian miracles growth in output per worker came mostly from productivity gains.

In any case, the debate should not focus entirely on the miracle countries of East Asia. Although our data is much less detailed than the data Young compiled for each of the four Asian tigers, our hope is that by covering 98 countries we get a sense of whether Young's results are typical of the sources of growth differences in the world as a whole We are particularly interested, therefore, in whether our results for the Asian

Table 7

a. Alwyn Young's results

Country	*Y* Growth	*TFP Growth*
Hong Kong	7 3	2.3
Korea	10.3	1.7
Singapore	8 7	0.2
Taiwan	9.4	2 6
Country	*Y/L* Growth	*A* Growth
Hong Kong	4.7	3 7
Korea	4.9	2.5
Singapore	4 2	0 3
Taiwan	4 8	3.5

b. Young's A growth vs. ours

	A growth		
Country	*Young's*	*Ours*	*Why different?*
Hong Kong	3 7	4.4	*L* data
Korea	2.5	2 5	O.K.
Singapore	0.3	3.3	*L* data, *K* share
Taiwan	3.5	3 0	O.K

tigers are not too far off from Young's numbers. Table 7b reports our BK4 1960–1985 *A* growth rates for the Asian tigers alongside Young's estimates. Our estimate for South Korea matches Young's (2.5%), and our estimate for Taiwan actually falls below Young's (3.0% vs. his 3.5%). For Hong Kong our estimate is higher (4.4% vs. 3.7%), and for Singapore our estimate is much higher (3.3% vs. 0.3%). Young uses census data for *L* rather than Summers–Heston data, and the census data show faster growth of *L* for Hong Kong and Singapore.[30] Faster growth of L translates into slower growth of *Y/L* and *A* (with growth in *H/Y* and *K/Y* unaffected). This explains the entire difference in our estimates for Hong Kong. For Singapore Young used a physical-capital share of 0.49, as opposed to the 0.30 we used. Combined with the difference in *L* growth, Young's higher capital share explains almost all of the gap in our Singapore estimates, since *K/Y* grew sharply there.

We close by stressing that our results share two important features

30 For 1966–1990, Young's worker/population ratios rose from 0 38 to 0 49 for Hong Kong and from 0 27 to 0 51 for Singapore The comparable Summers–Heston figures were 0 54 to 0 65 and 0 34 to 0 48

with those of Young (1994, 1995) First, we find a very modest role for growth in human capital per worker in explaining growth (Young's adjustments for labor quality are a few tenths of a percent per year). Second, we find that TFP growth accounts for most of the growth of output per worker in Hong Kong, South Korea, and Taiwan. And we stress that this relative importance of TFP growth for three of the four Asian tigers generalizes to our sample of 98 countries: we find that roughly 90% of country differences in Y/L growth are attributable to differences in A growth Combining these growth results with our findings on levels, we call for returning productivity differences to the center of theorizing about international differences in output per worker

Appendix. Data

Y/L = 1985 RGDPW in Summers–Heston PWT 5 6
K/Y = 1985 physical-capital-to-output ratio (see Section 4 for K/Y used for BK2–BK4)
H/Y = 1985 human-capital-to-output ratio (see Section 4 for H/Y used for BK4).
A = 1985 level of productivity [see equation (2)] Note Levels are relative to the United States
$g(Z)$ = 1960–1985 annual growth rate of series Z

	Y/L	K/Y	H/Y	A	$g(Y/L)$ (%)	$g(K/Y)$ (%)	$g(H/Y)$ (%)	$g(A)$ (%)
Algeria	0 40	0 79	0 33	0 99	2.89	0 71	0.64	1 96
Benin	0 07	0 47	0 34	0 25	0 78	1 37	0.02	−0.21
Botswana	0 20	0 49	0 47	0 55	6 85	2 20	0 71	4.81
Cameroon	0 11	0 27	0 56	0 43	4 22	1 16	0 63	2 97
Central Afr R.	0 04	0 60	0 30	0 12	0 33	−0 79	0.53	0 54
Congo	0 20	0 29	0 48	0 81	4 06	−1 81	0.30	5 16
Gambia	0 05	0 39	0 38	0 18	1 37	4 32	−0 70	−1 25
Ghana	0 07	0 43	0 47	0 20	0 36	−0 60	1 51	−0 22
Guinea-Biss	0 04	1 23	0 22	0 10	1 52	−0 01	0 34	1 29
Kenya	0 06	0 63	0 40	0 15	1 31	−0 10	1 03	0 70
Lesotho	0 06	0 41	0 51	0 18	5 03	4 28	−0 55	2.34
Liberia	0 07	0 74	0 31	0 18	1 22	−0 82	0 92	1 19
Malawi	0 03	0 57	0 39	0 10	1 70	1 87	0.04	0.34
Mali	0 05	0 67	0 27	0 16	0 45	−2 28	0 77	1 57
Mauritius	0 22	0 42	0 57	0 59	0 90	−1 09	1.43	0 72
Mozambique	0 04	0 18	0 52	0 22	−1 18	2 98	−0 39	−3.05
Niger	0 03	0 79	0 25	0 10	0 79	1 82	−0 64	−0 09
Rwanda	0 05	0 18	0 55	0 23	1 89	1 70	−0.02	0 68
Senegal	0 08	0 38	0 45	0 27	0.87	−0 64	0 62	0 92
South Africa	0 29	0 84	0 45	0 57	1 82	1 23	0 12	0 86

	Y/L	*K/Y*	*H/Y*	*A*	*g(Y/L)* (%)	*g(K/Y)* (%)	*g(H/Y)* (%)	*g(A)* (%)
Swaziland	0.15	0 53	0 47	0 41	2 96	2 87	0.35	0.67
Tanzania	0 03	0.59	0 37	0 08	2.08	1 80	0.05	0.77
Togo	0.04	0 76	0.32	0 12	2.60	3 02	0 28	0 26
Tunisia	0.26	0.46	0 42	0 81	3.22	−0.94	1 35	2.99
Uganda	0.04	0.19	0.57	0.17	0 06	0.96	0 17	−0.74
Zaire	0 03	0.24	0.54	0 14	0 42	4 19	−0.19	−2 45
Zambia	0 07	1 31	0.34	0.12	−0 42	−0 07	1 43	−1.32
Zimbabwe	0 10	0 61	0 38	0 26	1 50	−0.96	0.74	1.70
Barbados	0 36	0 51	0.77	0.70	2.39	1.55	0.46	0.97
Canada	0.92	0.97	0 85	1 05	1.88	0.64	0 94	0.80
Costa Rica	0 27	0 50	0 58	0 64	1.17	1.68	0 50	−0.36
Dominican Rep.	0.21	0.48	0 51	0.55	2 16	2.33	0 33	0 28
El Salvador	0 16	0 42	0.51	0.48	0 95	1.94	0 53	−0.79
Guatemala	0.22	0.54	0.40	0 62	1 32	1 24	0.47	0.12
Haiti	0.06	0 42	0 39	0 22	0.96	2.23	−0.07	−0.58
Honduras	0.14	0.50	0 46	0 38	1.41	0 21	0.93	0.64
Jamaica	0 14	0 93	0 39	0.28	0 34	1.23	0.56	−0.91
Mexico	0.50	0 49	0 53	1.29	2.33	1 27	0 70	0.95
Nicaragua	0.17	0.51	0.47	0 47	0 56	2.35	0 28	−1 31
Panama	0.30	0 58	0 62	0.60	3 00	1 45	0 62	1 55
Trinidad & Tobago	0 76	0.54	0.66	1 55	1.65	1 57	0 52	0 18
United States	1 00	1 00	1 00	1 00	1 30	0 56	1.27	0 04
Argentina	0 44	1 11	0 51	0 64	1.11	1 38	0 57	−0.25
Bolivia	0 17	0 81	0 42	0 35	2 11	0.57	0 48	1.38
Brazil	0.32	0.70	0 40	0 77	2.73	0 32	0 36	2 26
Chile	0.29	0.91	0.53	0.47	0.44	0.73	0.52	−0 43
Colombia	0.27	0.53	0.51	0.68	2 10	0 33	0.84	1 31
Ecuador	0 28	0.67	0.53	0 58	3 07	0.78	1.12	1 77
Guyana	0 11	1 34	0 37	0.17	−1 80	1 58	−0.18	−2 82
Paraguay	0 18	0 42	0 58	0 50	2.23	2 10	0.09	0.67
Peru	0.24	0.70	0 54	0 47	1.02	1.45	1 05	−0.72
Uruguay	0.30	1 22	0 48	0.43	0 17	1.34	0 87	−1.36
Venezuela	0.54	0.74	0.49	1 07	−0.43	2.46	0 82	−2 74
Bangladesh	0.13	0.24	0.52	0.55	1 73	−1.11	0 90	1 92
Hong Kong	0.49	0 57	0.74	0 88	5.49	0 53	1.08	4 39
India	0 08	0 71	0.38	0.20	1 74	−0 70	1 07	1.53
Indonesia	0 13	0 59	0.45	0 32	3 89	1 88	0.95	1.91
Iran	0 41	0 73	0.39	0 97	1 29	3 35	0.68	−1.55
Iraq	0.47	0 58	0.41	1 26	0.85	5 70	0.05	−3.26
Israel	0.65	0.88	0 79	0.84	3 27	0.79	1 02	2 03
Japan	0.56	1.35	0.60	0 63	5.30	2 01	0 51	3 53
Jordan	0 46	0.34	0.61	1.39	5 00	2.34	0 95	2.69
Korea, Rep.	0.31	0 58	0.76	0 54	5 37	2.32	1.77	2 54

	Y/L	*K/Y*	*H/Y*	*A*	*g(Y/L)* (%)	*g(K/Y)* (%)	*g(H/Y)* (%)	*g(A)* (%)
Malaysia	0 31	0 68	0 51	0 63	3 74	1 30	1 21	2 00
Myanmar	0 04	0.39	0 42	0 14	2 64	0 36	0 46	2 08
Nepal	0.07	0.35	0 38	0 27	2.25	1 36	0 09	1 21
Pakistan	0 13	0 48	0 38	0 40	2 96	−0 31	0 76	2 68
Philippines	0 13	0 53	0.66	0 26	1.41	2 18	0 76	−0 65
Singapore	0.53	0 93	0.41	1 03	5 11	2 40	0 16	3 29
Sri Lanka	0.17	0 35	0 69	0 45	1.87	0 63	0.84	0 85
Syria	0 51	0 37	0 56	1 52	4 42	0 97	1 35	2 83
Taiwan	0 38	0 51	0 73	0 75	5 30	1 76	1.52	3 03
Thailand	0 14	0 53	0 55	0 33	3 70	0 87	0 62	2 66
Austria	0 71	1 53	0.45	0 88	3.20	0 74	1.42	1 72
Belgium	0 81	1 43	0 64	0 84	2 59	0 63	0 73	1 65
Cyprus	0 41	1.11	0 54	0 58	4 12	0 49	1 33	2 88
Denmark	0 71	1 49	0 73	0 66	1 91	0 58	0 26	1 32
Finland	0 70	1 80	0.60	0 65	2 87	0 15	0 97	2 11
France	0 80	1 47	0 45	1.04	2 79	1 16	1 02	1 29
Germany, W	0 81	1 85	0 53	0 79	2 69	0 51	0 30	2 12
Greece	0 48	1.25	0 50	0 65	4.60	1 41	0 94	2 97
Iceland	0 69	1.10	0 59	0 91	2 46	-0 42	1 20	1 95
Ireland	0 57	1 07	0 62	0 75	3.31	0 93	0 47	2 33
Italy	0 80	1 51	0 43	1 04	3 60	0 44	0 85	2 72
Malta	0 46	0.95	0 56	0 70	4 71	−1 08	1 18	4.69
Netherlands	0 85	1 28	0 61	0 98	2 05	0 68	1.45	0.59
Norway	0 85	1 49	0.73	0 79	2 80	0 18	2 35	1 10
Portugal	0 34	1 21	0 34	0 60	3 40	0 93	0.83	2 18
Spain	0 63	1 28	0 42	0 93	3 80	1 91	0 71	1.96
Sweden	0 78	1 54	0 65	0 77	1 69	0 57	0 77	0 77
Switzerland	0 88	2 03	0 55	0 80	1 57	1 03	0 86	0 26
Turkey	0.21	0 79	0.37	0 48	3 19	1 23	0 41	2 04
United Kingdom	0 68	1 23	0 64	0 79	1 77	0 21	0.38	1 37
Yugoslavia	0 34	1 52	0 48	0 41	3 97	1 44	1 25	2.11
Australia	0 86	1 33	0 74	0 85	1 63	0 46	0.48	0 98
Fiji	0 29	0 68	0 61	0 53	1 03	0 25	0.86	0.28
New Zealand	0 77	1 25	0 94	0 68	0 81	0 38	1 01	−0 14
Papua N Guinea	0 10	1 08	0 26	0 23	1 59	2 77	- 0.54	−0 03

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Comment

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Instructors of macroeconomics who teach their students about economic growth often use Solow's version of the neoclassical growth model as the starting point for discussion. This model shows very simply how an economy's production technology and its rates of capital accumulation determine its steady-state level of income per person. After presenting this elegant theory, the instructor is left with a nagging question: So what? Does this model really explain why some countries are rich and others are poor? Or does this model leave most of the action unexplained in a variable that has been called, at various times, total factor productivity, the Solow residual, and "a measure of our ignorance"?