Fundamental Sources of Long-Run Growth

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During the past decade, there has been a tremendous advance in our understanding of economic development. On the one hand, the theoretical understanding of economic growth has progressed on various fronts, including among other topics of concern the investigation of endogenous technical innovation and increasing returns to scale (Paul Romer, 1986); the interaction of population, fertility, human capital, and growth; international spillovers in technology and capital accumulation; and the role of institutions. On the other hand, the increasing availability and use of standardized data sets, notably the important Penn World Tables data set (Robert Summers and Alan Heston, 1991), has led to a burgeoning empirical literature on cross-country growth, especially following the path-breaking work of Robert Barro (1991).

The conflicting claims in this large and growing literature are yet to be sorted out, which is understandable given the rapid increase in studies in recent years. This brief note cannot, of course, offer a real synthesis of the existing materials, but it can serve to highlight some of the key emerging themes in the literature and to put them in a new light. Therefore, we describe our own view of the recent literature on cross-country growth, present some of our own new empirical findings, and discuss the main directions for future research as we see them.

I. A Theoretical Framework

Here we sketch a theoretical framework for empirical growth analysis. Suppose output is a constant-returns-to-scale function of physical capital, human capital, and labor. As in the original Solow growth model, assume that labor is subject to labor-force growth (n) plus labor-augmenting technical change (λ), so that the *effective* supply of labor grows at the rate $n + \lambda$. As in standard analyses, we can rescale the production function in terms of effective labor and then approximate output (in logs) around the steady state as a function of physical capital and human capital per effective labor supply: $q = \theta + \alpha k + \sigma h$. In steady-state growth, GDP per effective labor supply reaches a long-term constant level. GDP per actual labor supply grows in the steady state at the rate λ, and GDP itself grows in the steady state at the rate $n + \lambda$.

Following the Solow growth model, we use the steady-state condition that national saving is equal to capital widening, $s \exp(q) = (n + \delta)\exp(k)$ where s is the saving rate with respect to physical capital, and δ is the rate of depreciation on physical capital. Combining this equation with the production function and linearizing the result, we can derive the result that the steady-state capital stock is a function of any variable that affects the national saving rate, s, or total factor productivity, θ.

Let k^* and h^* stand for the steady-state levels of physical and human capital. We do not have space here to specify fully the dynamics of capital accumulation, but as a fairly general matter, models with stable growth dynamics will allow a linearization of the dynamics around the steady state, with dk/dt written as a function of $k^* - k$ and $h^* - h$.

In a standard growth decomposition, we can write the growth of q as a weighted sum of the growth of k and h: $dq/dt = \alpha\, dk/dt + \sigma\, dh/dt$. Thus, dq/dt can be written as a function of $k^* - k$, $h^* - h$, and dh/dt. Since we can also write $q - q^*$ as a function of $k^* - k$ and $h^* - h$, it is straightforward to substitute for dk/dt and $k^* - k$ and thereby write the growth dynamics as follows:

$$(1) \quad dq/dt = \beta(q^* - q) - \rho(h^* - h) + \sigma\, dh/dt.$$

The link between growth and human capital in equation (1) is a bit subtle. We would ex-

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pect that dq/dt is a positive function of dh/dt, and a negative function of $h^* - h$. A country with a low *level* of human capital will tend to have a lower rate of physical-capital accumulation (i.e., $d[dk/dt]/dh$), since physical and human capital tend to be complements in production. Moreover, at a given level of q, a lower h will be associated with a higher level of k. This too will tend to reduce physical-capital accumulation, since dk/dt is a function of the gap between actual k and long-term k^*. At the same time, a country with a rapid *increase* in human capital, (i.e., dh/dt large) will have rapid transitional growth. Thus, $\sigma > 0$.

Steady-state output, q^*, is a positive function of both the national saving rate and total factor productivity. In the empirical work below, these in turn are assumed to vary across countries as the result of a set of exogenous variables Z. We also assume that h^*, the long-run level of human capital per effective worker, is the same across countries. That is, we assume that all countries are converging on similar levels of literacy, life expectancy, and education levels, though they may be at very different levels today. This assumption is probably adequate for certain dimensions of human capital (e.g., literacy, life expectancy, primary schooling) but not for others. It is made mainly for convenience: we still lack good models of multidimensional human-capital accumulation, as well as adequate cross-country data to test those models. In any event, the upshot of the two assumptions is that (1) is rewritten as

$$(2) \qquad dq/dt = -\beta q + \boldsymbol{\phi}\mathbf{Z} + \rho h + \sigma\, dh/dt + \text{constant}$$

$\mathbf{Z}$ is a vector of determinants of long-term total factor productivity and national saving rates, and terms involving h^* are impounded in the constant term.

It remains to specify some dynamics for human-capital accumulation. The simplest model would write dh/dt as a linear function of the gap between h^* (assumed to be the same across countries) and current h. Countries with low initial levels of human capital would have the fastest rates of increase in human capital. Formally, the assumption would be $dh/dt = \mu(h^* - h)$. This linear assumption is probably not adequate, however. Considerable microeconomic and macroeconomic evidence suggests that human-capital development, especially in children, is partly the result of positive externalities within the family and community. Literate parents (especially literate mothers) raise healthier and more literate children. A literate community will also produce more literate children for any given level of formal expenditure on education. Thus, within a range, dh/dt is likely to be *positively* related to the existing stock of human capital. As is well known, this gives rise to the possibility of low-level poverty traps, in which a low-human-capital generation is succeeded by another low-human-capital generation, while an initially high-human-capital generation would give rise to another high-human-capital generation.

In our empirical work, we examine a logistic specification, $dh/dt = \nu h(1 - h/h^*)$, which makes dh/dt a quadratic function of h. When initial human capital is low, so too is human-capital accumulation. When human capital is at an intermediate level (precisely $h^*/2$ in this simple specification), then the increase in human capital is the fastest. When h is already very high, and therefore close to the long-run level h^*, then once again dh/dt is low. This kind of nonlinear dynamic for human capital is borne out by cross-country equations on several different dimensions of human capital, including average literacy, life expectancy at birth, and average years of schooling among the adult population (see Table 1). The upshot is that we substitute for dh/dt in (2) with a quadratic expression in h; dq/dt is then a function of both initial h and h^2. We expect, and later find, that dq/dt is a positive function of h and a negative function of h^2. This means that, other things equal, growth tends to be higher in countries with an intermediate level of human capital than in countries with very low or very high levels of human capital.

There is a final bit of cleaning up to attend to. Production theory explains output per worker, but most studies examine output per capita. During demographic transition (and for other reasons) there may be a transitional gap between the growth of the population and the

TABLE 1—ESTIMATES OF LOGISTIC GROWTH PROCESS FOR SEVERAL MEASURES OF HUMAN-CAPITAL ACCUMULATION

Measure of human capital	λ_1	λ_2	R^2	N
Life expectancy	0.92 (6.2)	−0.008 (−6.6)	0.33	145
Adult literacy rate	0.27 (3.1)	−0.003 (−4.6)	0.64	63
Years of secondary schooling	0.37 (4.8)	−0.076 (3.0)	0.34	98

Notes: Numbers in parentheses are t ratios. For each of the three human-capital measures, h_{it}, the estimated equation is

$$\sum \Delta h_i/T = \lambda_1 \left(\sum h_i/\mathrm{T}\right) + \lambda_2\left(\sum h_i^2/T\right)$$

where the terms in parentheses are the means over time of the human-capital variable and the square of the human-capital variable.

growth of the labor force, as the age structure of the population changes. Let dy/dt be the rate of growth of GDP per capita. Let π be the rate of population growth, and let n be the rate of labor-force growth. Then, $dy/dt = dq/dt + (n + \lambda - \pi)$.

We finally arrive at a form for estimation. Substituting in (2) for dh/dt, and changing dq/dt to dy/dt, we have

$$(3)\quad (dy/dt)_i = \beta_0 + \beta_1 q_i + \boldsymbol{\beta}_2'\mathbf{Z}_i + \beta_3 h_i + \beta_4 h_i^2 + (n - \pi)_i + \varepsilon_i$$

The subscript i refers to country i, and the error term is independently and identically distributed. We expect $\beta_4 < 0$. Note that we have impounded terms related to λ and h^* in the constant term. An additional issue is that, for estimation, we integrate (3) over a time interval from 0 to T and rearrange so that the dependent variable matches the way average growth is measured, namely, $(100/T)[y(T) - y(0)]$. This shows that the estimated regression coefficients are not the same as the β's (e.g., the coefficient on initial income is an estimate of $[100/T][e^{\beta_1 T} - 1]$ rather than $100\beta_1$). For calculations that require the β's, we solve for consistent estimates of the β's from the estimated regression coefficients. In our regressions, the implied β's are about 33-percent larger (in absolute value) than the estimated regression coefficients.

II. Empirical Growth Equations

An important step in estimating (2) is to include a reasonably comprehensive set of exogenous variables in $\mathbf{Z}$. Many empirical studies of growth suffer from the fact that the authors include just a small subset of appropriate variables. For example, if the author is studying the effects of income inequality on growth, then only a measure of income inequality is included in (2). Without a comprehensive set of $\mathbf{Z}$ variables, cross-country growth studies are plagued by left-out-variable errors of great importance. In our own work, and in our reading of the literature, we find that the $\mathbf{Z}$ vector should include: measures of geography (e.g., whether the country is landlocked, or in the tropics); measures of resource endowments (e.g., whether the country is labor-abundant or natural-resource-abundant); and measures of economic policy (e.g., whether the country is open to trade; whether the rule of law prevails; whether the government is a net saver or dissaver).

The literature and our own recent investigations lead us to the following baseline set of variables. With respect to geography, we include the share of land in a country subject to a tropical climate (which is generally associated with poorer soils and higher infectious-disease endemicity) and whether the country is landlocked (since landlocked countries will find it harder to benefit from international trade). With respect to resource endowments, we include the share of natural-resource exports in GDP in 1970, as per our earlier work (Sachs and Warner, 1995b). With respect to economic policies, we include the difference between current revenues and current expenditures of the central government over the period 1970–1990 and an index of institutional quality taken as the average of the subindexes for rule of law, bureaucratic quality, corruption, and the like, available from data in the *International Country Risk Guide,* and an index of openness to international trade based on our earlier research (Sachs and Warner, 1995a). In addition, in line with equation (3), we also control for initial GDP and the level and the square of human capital (in this case measured by life expectancy).

Now we discuss briefly the regression estimates. The estimated parameter of −1.5 on initial income implies that it takes 37 years for a country to close half the gap between its current income and its steady-state income. Countries with tropical climates and landlocked countries have lower steady-state incomes and, therefore, lower growth from any initial level of GDP per capita. Higher government saving, increased global integration, and better institutional quality all raise steady-state income and, therefore, bolster transitional growth. Countries that are abundant in natural resources have lower growth, for reasons discussed in Sachs and Warner (1995b).

We now turn to the relation between convergence and factor mobility. Though we have described a model of a closed economy, economic theory suggests that open economies might enjoy faster income convergence than closed economies, since international mobility of capital and technology can speed the transition to steady-state income. Is there evidence in cross-country regressions that openness facilitates convergence? To address this, we have reestimated the regression with the openness index interacted with the initial income term. The estimated coefficient on this interaction term is −1.1 (t ratio = −3.0), suggesting that open economies do indeed converge faster than closed economies. The point estimates imply that, while it takes closed economies 37 years to close half of the gap between current income and steady-state income, open economies do so in 17 years.

Next we turn to evidence in our regression results concerning poverty traps. The first question is whether there is any regression evidence suggesting a nonlinear relation between initial income and growth. For example, a poverty trap would be implied if the estimate of $dg/d\ln(y)$ was positive over some range of income corresponding to poorer countries. In general however, we do not find evidence for nonlinear terms on the initial-income variable.

TABLE 2—CROSS-COUNTRY GROWTH REGRESSION (DEPENDENT VARIABLE = GROWTH PER CAPITA, 1965–1990; 83-COUNTRY MEAN = 0.33 PERCENT)

Independent variable	Estimated regression coefficient
lnGDP per economically active person in 1965	−1.5 (−6.5)
Share of years open, 1965–1990	10.9 (3.7)
GDP in 1965 times share of years open	−1.1 (−3.0)
Growth of economically active population − population growth	0.7 (1.9)
Central government budget balance, 1970–1990	0.11 (5.2)
Institutional quality index (1980)	0.32 (3.8)
Tropics	−0.8 (−3.0)
Landlocked	−0.6 (−2.3)
Share of natural-resource exports in GDP, 1970	−3.9 (−4.0)
Life expectancy	0.3 (2.8)
Life expectancy squared	−0.0026 (−2.3)
Adjusted R^2:	0.84
Number of countries:	83
Standard error:	0.77

Notes: Numbers in parentheses are t statistics. Botswana, Gabon, Guyana, Israel, and Madagascar are outlying observations in this regression. In a regression without these countries, all coefficients have the same sign and are statistically significant.

We next ask whether there is a nonlinear relationship between growth and human-capital accumulation. Using life expectancy (LE) as the human-capital proxy, the regression evidence shows $dg/d(\text{LE}) = 0.34 - 2(0.0026)(\text{LE})$, with all coefficients statistically significant. This implies that the function reaches a maximum at a life expectancy of about 65 years. Since this is near the highest life expectancy in the sample (LE for United States = 70, LE for Sweden = 74), this means that most countries are indeed on the positively sloping side of this curve. Therefore, higher life expectancy raises growth, except at very high levels of life expectancy, where the impact is essentially zero.

Our last point concerns robustness. We have found that our regression evidence is reasonably robust to the inclusion of several other variables suggested in the literature, and to the elimination of outlying observations; but we have not performed a full-fledged robustness study. In the regression in Table 2, we have tried to include variables from the broad dimensions of economic policy, geography, and resource endowments. We find that the results are reasonably robust at the level of broad concepts, but it is quite possible that future research will indicate less robustness with regard to the specific variables used to measure these concepts. For example, better measures of fiscal policy or openness might supplant the particular specifications of the variables that we have used in the regression estimates.

III. Some Directions for Further Research

Regarding future research, cross-country growth studies require much better measures of human-capital attainment and an improved theoretical framework concerning the dynamics of human-capital accumulation, especially for the poorer countries where the measurement problems are the greatest and where bottlenecks in human-capital accumulation appear to be crucial factors in the success or failure of economic development. We also think that much more work needs to be undertaken to understand the impact of geography, resource endowments, and climate on long-term growth. These are among the longest-standing topics in development (including important observations by Adam Smith on the role of geography in affecting trade and the division of labor) but have been insufficiently studied in the empirical growth literature of recent years.

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