Human Capital and Growth

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Since the late 1980's, much of the attention of macroeconomists has focused on the determinants of long-term economic growth. This paper emphasizes the role of education. The analysis distinguishes the quantity of education, measured by years of school attainment, from the quality, as gauged by scores on internationally comparable examinations.

I. Basic Empirical Results on Growth

The empirical framework, derived from an extended version of the neoclassical growth model and summarized in Barro (1997), can be described by

$$\text{(1)} \qquad \mathrm{D}y = F(y, y^*)$$

where y is per capita product, y^* is the long-run level of y, and Dy is the growth rate. In the neoclassical model, Dy is inversely related to y and positively related to y^*. The value y^* depends on government policies and institutions and on the character of the national population. For example, better enforcement of property rights, fewer market distortions, and a greater willingness to save tend to raise y^*. In a setting that includes human capital, y would be generalized to encompass the levels of physical and human capital. In some theories, Dy rises with the ratio of human to physical capital.

The empirical analysis applies to roughly 100 countries and therefore includes countries at very different levels of economic development. Table 1 shows panel regression estimates for the determination of the growth rate of real per capita GDP.[1] (Henceforth, the designation GDP refers to real per capita GDP.) The growth rate is measured over three ten-year periods, 1965–1975, 1975–1985, and 1985–1995. Estimation is by three-stage least squares, using lags of the independent variables as instruments (see the notes to Table 1). The effects of the variable y show up in the level and square of log(GDP) at the start of each period. The other regressors are measures of government consumption, rule of law, international openness, the inflation rate, the fertility rate, the ratio of investment to GDP, the terms of trade, and the quantity and quality of schooling. Before focusing on education, I summarize the results for the other variables.

The Level of GDP.—As is well known, the simple relation between growth rates and initial levels of GDP is virtually nil. However, when the other independent variables shown in Table 1 are held constant, there is a strong relation between growth rate and level. The estimated coefficients are significantly positive for log(GDP) and negative for the square of log(GDP). These coefficients imply the partial relation between growth rate and level as shown in Figure 1. For the poorest countries (with GDP below \$580 in 1985 prices), the marginal effect of log(GDP) on the growth rate is small and may be positive. For the richest countries, the marginal effect is strongly negative. For example, for the United States, which in 1995 had the second-largest GDP (\$18,951 in 1985 prices),

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[1] The GDP figures in 1985 prices are the purchasing-power-parity-adjusted, chain-weighted values from the Penn World Table of Robert Summers and Alan Heston, version 5.6. These data are available on the Internet from the National Bureau of Economic Research ⟨nber.org⟩.

TABLE 1—PANEL REGRESSION FOR GROWTH RATE

Independent variable	Coefficient
Log(per capita GDP)	0.107 (0.025)
Log(per capita GDP) squared	−0.0084 (0.0016)
Male secondary and higher schooling	0.0044 (0.0018)
Govt. consumption/GDP	−0.157 (0.022)
Rule-of-law index	0.0138 (0.0056)
Openness ratio	0.133 (0.041)
(Openness ratio) × log(GDP)	−0.0142 (0.0048)
Inflation rate	−0.0137 (0.0090)
Log(total fertility rate)	−0.0275 (0.0050)
Investment/GDP	0.033 (0.026)
Growth rate of terms of trade	0.110 (0.030)
Numbers of observations:	81, 84, 81
R^2:	0.62, 0.50, 0.47

Notes: The dependent variable is the growth rate of real per capita GDP for each of the periods 1965–1975, 1975–1985, and 1985–1995. Individual constants are included in each panel for each period. The log of real per capita GDP and the average years of school attainment are measured at the beginning of each period. Government consumption is measured exclusively of spending on education and defense. The openness ratio is the ratio of exports plus imports to GDP, filtered for the estimated relation of this ratio to country size, as measured by the logs of land area and population. The government consumption ratio, the openness ratio, the ratio of investment (private plus public) to GDP, the inflation rate (for consumer prices), the total fertility rate, and the growth rate of the terms of trade (export over import prices) are period averages. (For the last period, the government and investment ratios are for 1985–1992.) The variable openness ratio × log(GDP) is the openness ratio multiplied by the log of per capita GDP at the start of the period. The rule-of-law index is the earliest value available (for 1982 or 1985) in the first two equations and the period average for the third equation.

Estimation is by three-stage least squares. Instruments are the actual values of the schooling, openness, and terms-of-trade variables, and lagged values of the other variables. The earliest value available for the rule-of-law index (for 1982 or 1985) is included as an instrument for the first two equations, and the 1985 value is included for the third equation. Standard errors are shown in parentheses. The R^2 values apply to each period separately.

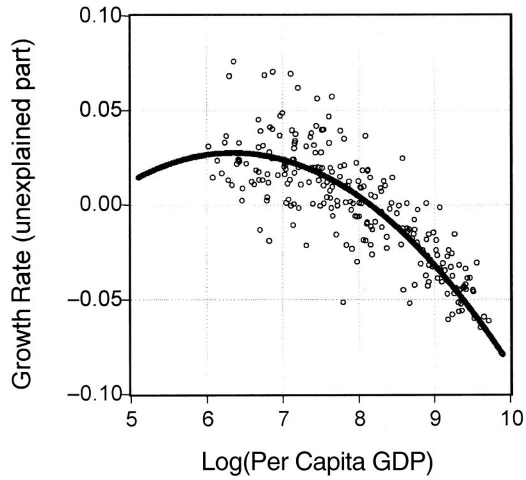

FIGURE 1. GROWTH RATE VERSUS LOG(GDP)

Notes: The variable on the vertical axis is the growth rate net of the estimated effect of all explanatory variables aside from log(GDP) and its square. The value plotted was normalized to make its mean value zero.

the estimated marginal effect is −0.058. This convergence coefficient implies that an increase in GDP by 10 percent lowers the growth rate on impact by 0.6 percent per year.

Government Consumption.—The ratio of government consumption to GDP, G/Y, is intended to measure public outlays that do not directly enhance productivity. The estimated effect on growth is significantly negative: an increase in G/Y by 10 percentage points is estimated to reduce the growth rate on impact by 1.6 percent per year.

Rule of Law.—Many analysts believe that secure property rights and a strong legal system are central for economic growth.[2] These factors have been assessed subjectively by a number of international consulting companies, including Political Risk Services in its publication *International*

[2] In previous analyses, I also looked for effects of democracy, measured by political rights or civil liberties. Results using subjective data from Freedom House (see Raymond D. Gastil, 1982–1983) indicate that these measures have little explanatory power for growth, once the explanatory variables shown in Table 1 are held constant.

Country Risk Guide.[3] The variable used in Table 1 is an index for overall maintenance of the rule of law. This index is measured on a 0–1 scale, with 0 indicating the poorest maintenance of the rule of law and 1 the best. The results indicate that an increase in the rule of law has a positive and statistically significant effect on growth. An improvement by one category among the seven used by Political Risk Services (i.e., an increase by 0.17) is estimated to raise the growth rate on impact by 0.2 percent per year.

International Openness.—The measure of openness is the ratio of exports plus imports to GDP, filtered for the estimated relation of this ratio to country size (as gauged by population and area). This openness variable has a significantly positive effect on growth. However, the negative effect of the interaction term with log(GDP) means that the effect of openness diminishes as a country gets richer. The estimates imply that the effect of openness on growth would reach zero at a GDP of $11,700 (1985 U.S. dollars), a value below the GDP's of the richest countries, such as the United States.

Inflation Rate.—Table 1 shows a marginally significant, negative effect of inflation on economic growth. The estimated coefficient implies that an increase in the average rate of inflation by 10 percent per year would lower the growth rate on impact by 0.14 percent per year.

Fertility Rate.—The estimates indicate that economic growth is significantly negatively related to the total fertility rate. Thus, the choice to have more children per adult (and, hence, in the long run, to have a higher rate of population growth) comes at the expense of growth in output per person.

Investment Ratio.—The results show that the growth rate depends positively and marginally significantly on the investment ratio. Since the instrument lists include lagged values of the investment ratio, but not values that are contemporaneous with the growth rate, there is some reason to believe that the estimated relation reflects effects of greater investment on the growth rate, rather than the reverse.

Terms of Trade.—The estimates indicate that improvements in the terms of trade (a higher growth rate of the ratio of export prices to import prices) enhance economic growth.

II. Effects of Education

Given the level of GDP, a higher initial stock of human capital signifies a higher ratio of human to physical capital. This higher ratio tends to generate higher growth through at least two channels. First, more human capital facilitates the absorption of superior technologies from leading countries. This channel is likely to be especially important for schooling at the secondary and higher levels. Second, human capital tends to be more difficult to adjust than physical capital. Therefore, a country that starts with a high ratio of human to physical capital (such as in the aftermath of a war that destroys primarily physical capital) tends to grow rapidly by adjusting upward the quantity of physical capital.

The first set of empirical results measures human capital by the quantity of education, in the sense of the value at the start of each period of the years of school attainment of a population group aged 25 and older. (Results are similar for persons aged 15 and older.) The school-attainment data are discussed in Barro and Jong-Wha Lee (2001).

In Table 1, the school-attainment variable refers to males at the secondary and higher levels. The estimated coefficient is positive and statistically significant, and Figure 2 depicts the partial relationship with growth. The estimates imply that an additional year of schooling (roughly a one-standard-deviation change) raises the growth rate on impact by 0.44 percent per year. (This estimate can be shown to imply a social rate of return to male secondary and higher education of around 7 percent per year.)

Other measures of school attainment were added one at a time to the system shown in Table 1. Female attainment at the secondary and higher levels of education lacks significant explanatory power: the estimated coefficient is -0.0011 (SE $= 0.0040$). One possible interpre-

[3] These data were introduced to economists by Stephen Knack and Philip Keefer (1995).

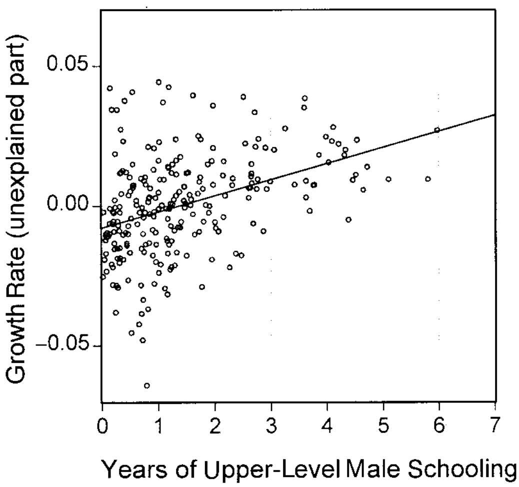

FIGURE 2. GROWTH RATE VERSUS SCHOOLING

tation is that many countries follow discriminatory practices that prevent the efficient exploitation of well-educated females in the formal labor market. Male primary schooling is also insignificant for growth: the estimated coefficient is 0.0011 (SE = 0.0013). (Primary schooling is, however, critical as a prerequisite for secondary education.) Female primary schooling is positive (coefficient = 0.0019; SE = 0.0013) but statistically insignificant. Note, however, that the estimation holds fixed the fertility rate. If fertility is not held constant, then the estimated coefficient on female primary schooling becomes significantly positive: 0.0039 (SE = 0.0013). Hence, female primary education likely promotes growth indirectly by encouraging lower fertility.

Many researchers argue that the quality of schooling is more important than the quantity. For example, Erik Hanushek and Dennis Kimko (2000) find that scores on international examinations (indicators of the quality of schooling capital) matter more than years of attainment for subsequent economic growth. Information on student test scores in science, mathematics, and reading is available for 43 of the countries in my sample. Unfortunately, the data apply to different years and are most plentiful in the 1990's. The available data, discussed in Barro and Lee (1997), were used to construct a single cross section of test scores in the three subject areas. These variables were entered into the system from Table 1. One shortcoming with this approach is that later values of test scores are allowed to influence earlier values of economic growth. However, the results turn out to be similar if the instrument lists omit the test-score variables and include instead only prior values of variables that have predictive content for test scores. These variables, suggested by Barro and Lee (1997), are the total years of schooling of the adult population (a proxy for the education of parents), pupil–teacher ratios, and school dropout rates.

The results for the growth effects of test scores are in Table 2. Note that sample sizes are less than half of those from Table 1 because of the limited availability of the data on examinations. Science scores have a statistically significantly positive effect on growth, as shown in column (i) of Table 2. With this score variable included, the estimated coefficient of male upper-level attainment is still positive, but only marginally significant. The estimated coefficient on the science scores, 0.13 (SE = 0.02), implies that a one-standard-deviation increase in scores (by 0.08) would raise the growth rate on impact by 1.0 percent per year. In contrast, the estimated coefficient for the school attainment variable, 0.002 (SE = 0.001), implies that a one-standard-deviation rise in attainment would increase the growth rate on impact by only 0.2 percent per year. Thus, the results suggest that the quality and quantity of schooling both matter for growth but that quality is much more important.

Mathematics scores are also significantly positive in column (ii), but less significant than the science scores. Column (iv) includes the two scores together, and the results indicate that the science scores are somewhat more predictive of economic growth. Reading scores are puzzlingly negative in column (iii). However, the reading coefficient becomes positive when this variable is entered with the science or mathematics scores in columns (v)–(vii).

To increase the sample size, I constructed a test-scores variable that was based on science scores, where available, and then filled in some missing observations by using the reading scores. (The mathematics scores turned out not to yield any additional observations.) The results, shown in column (viii), are similar to

TABLE 2—PANEL REGRESSIONS FOR GROWTH RATE: EFFECTS OF TEST SCORES

Independent variable	Regression (i)	(ii)	(iii)	(iv)
Science score	0.129 (0.022)	—	—	0.064 (0.037)
Mathematics score	—	0.076 (0.022)	—	0.036 (0.029)
Reading score	—	—	−0.025 (0.040)	—
Overall test score	—	—	—	—
Male secondary and higher schooling	0.0019 (0.0011)	0.0019 (0.0013)	0.0013 (0.0018)	0.0020 (0.0012)
Numbers of observations:	37, 37, 36	34, 34, 33	32, 32, 32	34, 34, 33
R^2:	0.72, 0.45, 0.28	0.68, 0.52, 0.55	0.72, 0.39, 0.53	0.69, 0.52, 0.51

Independent variable	Regression (v)	(vi)	(vii)	(viii)
Science score	0.060 (0.021)	—	0.034 (0.027)	—
Mathematics score	—	−0.001 (0.027)	−0.017 (0.029)	—
Reading score	0.034 (0.026)	0.074 (0.028)	0.067 (0.028)	—
Overall test score	—	—	—	0.125 (0.029)
Male secondary and higher schooling	0.0000 (0.0009)	0.0010 (0.0009)	0.0009 (0.0009)	0.0017 (0.0015)
Numbers of observations:	26, 26, 26	23, 23, 23	23, 23, 23	43, 43, 42
R^2:	0.82, 0.29, 0.53	0.74, 0.36, 0.55	0.76, 0.33, 0.54	0.65, 0.59, 0.37

Notes: Test scores from science, mathematics, and reading examinations are measured as percentage correct. The data used are a cross section, consisting of only one average score in each field per country. The overall test score, used in regression (viii), equals the science score, where available, and uses the reading score, adjusted for differences in average levels from the science scores, to fill in some additional observations. The test-score variables were entered into the system described in Table 1. The test-score variables are included in the instrument lists for each equation. For the other explanatory variables in the system, the estimated coefficient of the variable for male secondary and higher school attainment is shown, but the other coefficients are not shown. See the notes to Table 1 for additional information.

those found in column (i). Figure 3 shows graphically the partial relation between growth and the overall test-score variable.

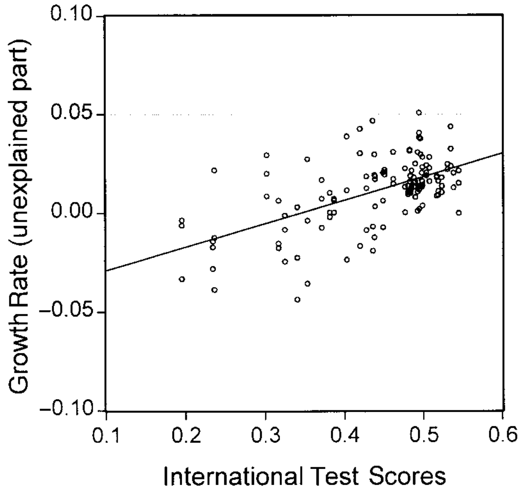

FIGURE 3. GROWTH RATE VERSUS TEST SCORES

III. Summary of Major Results

The growth effects of education were analyzed in a panel of around 100 countries observed from 1965 to 1995. Growth is positively related to the starting level of average years of school attainment of adult males at the secondary and higher levels. Since workers with this educational background would be complementary with new technologies, the results suggest an important role for the diffusion of technology. Growth is insignificantly related to years of school attainment of females at the secondary and higher levels. This result suggests that highly educated women are not well utilized in the labor markets of many countries. Growth is insignificantly related to male schooling at the primary level. However, this schooling is a prerequisite for secondary schooling and would therefore affect growth through this channel. Education of women at the primary level stimulates growth indirectly by inducing a lower fertility rate.

Data on students' scores on internationally comparable examinations in science, mathematics, and reading were used to measure the quality of schooling. Scores on science tests have a particularly strong positive relation with growth. Given the quality of education, as represented by the test scores, the quantity of schooling, measured by average years of attainment of adult males at the secondary and higher levels, is still positively related to subsequent growth. However, the effect of school quality is quantitatively much more important.

REFERENCES

Barro, Robert J. *Determinants of economic growth: A cross-country empirical study*. Cambridge, MA: MIT Press, 1997.

Barro, Robert J. and Lee, Jong-Wha. "Determinants of Schooling Quality." Unpublished manuscript, Harvard University, July 1997; *Economica* (forthcoming).

______ . "International Data on Educational Attainment—Updates and Implications." *Oxford Economic Papers*, 2001 (forthcoming).

Gastil, Raymond D. *Freedom in the world*. Westport, CT: Greenwood Press, various years. [Recent editions are published by Freedom House.]

Hanushek, Eric and Kimko, Dennis D. "Schooling, Labor-Force Quality, and the Growth of Nations." *American Economic Review*, December 2000, *90*(5), pp. 1184–1208.

Knack, Stephen and Keefer, Philip. "Institutions and Economic Performance: Cross-Country Tests Using Alternative Institutional Measures." *Economics and Politics*, November 1995, *7*(3), pp. 207–27.