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# COGNITIVE SKILLS, SCHOOLING ATTAINMENT, AND SCHOOLING RESOURCES: WHAT DRIVES ECONOMIC GROWTH?

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# Cognitive Skills, Schooling Attainment, and Schooling Resources:

# What Drives Economic Growth?

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**Abstract**

*This paper presents evidence that students' test scores at ages 9 to 15 are not a good proxy for a nation's stock of human capital. Across countries test scores rise with increases in human capital up to $40,000/adult (2000$), but then decline as human capital increases up to $125,000/adult. Schooling attainment is a better proxy for the human capital stock than test scores, but it is not very useful for statistical analysis because it is not a precise measure. The nation's stock of human capital, calculated from cumulative investment in schooling, is the schooling measure most correlated with national income.*

JEL Codes: F43, I21, O11, O15

Key Words: Cognitive Skills, Human Capital, Education, Schooling, Economic Growth

Hanushek and Woessmann [2008] review the empirical literature examining the relationship between students' cognitive skills and economic development. They also present new estimates of the effect of students' average scores on international tests and of average schooling attainment on national rates of economic growth. They interpret their statistical results to indicate that schools only contribute to economic development if they raise students' cognitive skills.

They then examine the level and distribution of test scores in low-income countries and interpret these scores to mean that many students completing early secondary schooling in these countries are functionally illiterate in math and science. They conclude that the quality of education in most developing countries is "truly dismal".

Hanushek and Woessmann raise the question whether programs, such as Education for All, or the Millenium Development Goals, may be misguided because they focus on the quantity rather than the quality of schooling. They argue that the focus of educational policies must shift from raising years of schooling to raising students' cognitive skills. Unfortunately, they also report that in low-income countries most policy initiatives to improve student achievement have not been effective.

One interpretation of Hanushek and Woessmann's findings is that a simple expansion of existing schools in low-income countries is not a promising strategy for economic development. But is this really true? Or are low-quality schools in these countries contributing effectively to economic development?

This paper reviews the statistical analysis of the effect of test scores and average schooling attainment on economic growth in Hanushek and Woessmann [2008]. It also examines the relationships between schooling resources, test scores, schooling attainment, and national income across countries using a new cross-country data base on the net human capital stock.

This paper argues that the growth model used by Hanushek and Woessmenn to compare the effectiveness of schooling attainment and test scores is not the most appropriate model for this comparison. It shows that when an alternative model is used for this comparison, years of schooling explain a larger share of the variation in national income across countries than test scores.

The new data on the human capital stock permit a comparison of the relationship between students' international test scores and a nation's human capital stock across countries. This comparison reveals that test scores and a nation's investment in schooling are positively correlated in countries with a human capital stock (from schooling) below $40,000/adult, but that between $40,000/adult and $125,000/adult, test scores decline with increases in the human capital stock. Even as test scores decline, national income continues to rise as the human capital stock rises. These patterns may indicate that schools contribute to human capital and economic growth in ways that are not measured by scores on tests of students' math and science skills at ages 9 to 15. One interpretation of these patterns is that test scores in elementary school are not a good measure of human capital across countries because in high-income countries most of the investment in schooling occurs at higher grade levels.

A surprising finding is that test scores are more highly correlated with a nation's physical capital stock than with its human capital stock. The countries with the highest test scores, countries like Japan, South Korea, Switzerland, and Singapore, also have the highest stocks of physical capital/adult. A possible explanation is that governments in these countries have national development policies that promote student excellence in science and math and investment in physical capital. These relationships in the macro data raise the possibility that

Hanushek and Woessmann have misinterpreted the meaning of the estimated coefficients in their growth model.

The analysis presented in this paper indicates that across countries cumulative investment in schooling is the schooling measure most correlated with national income. These results indicate that policies to increase financial resources for schools in low-income countries are likely to be a good development strategy. Incremental years of schooling appear to contribute to economic development because total investment in schooling rises with increases in the average years of schooling attainment. Simply increasing the time students are in school without increasing the total investment in schools is not associated with increases in national income. The analysis also indicates that test scores explain less of the variation in national income than the other schooling measures.

This paper is organized as follows. Section I reviews Hanushek and Woessmann's statistical analysis of the correlations between test scores and years of schooling and economic growth. Section II analyzes the correlations and the patterns between financial resources for schools, years of schooling attainment, test scores, and national income across countries in 2000. Section III concludes.

## I. Review of Hanushek and Woessmann's Methodology

Hanushek and Woessmann's [2008] conclusion that schooling quality is what matters is based in part on the statistical results from their economic growth model. They find that when average schooling attainment and student test scores are both in the model, that *all* of the effect on growth is associated with student test scores. They conclude that schooling contributes to economic growth, but only if it is raising students' cognitive skills. This interpretation of their statistical results is plausible, but only if their methodology is appropriate for evaluating the effect of these two measures of human capital on the rate of economic growth.

Hanushek and Woessmann estimate two models of economic growth. In their simple model, a nation's rate of economic growth over the period 1960 to 2000 is a function of its level of schooling attainment in 1960 (S), the cognitive skills of its work force over the 1960-2000 period (CS), and its level of income in 1960:

(1) $\ln(Y/L_{2000}) - \ln(Y/L_{1960}) = f(S_{1960}, CS_{1960\text{-}2000}) - \varphi \ln(Y/L_{1960})$

In this model Y/L is income/capita and CS is represented by the average of students' scores on international tests over the period 1964 to 2003. Their more complex model includes other explanatory variables, but their conclusions come from the simple model.

Columns 1 and 2 in Table 1 replicate their analysis for the model in equation (1), from which they conclude 1) that cognitive skills can explain three times the variation in economic growth that is explained by average schooling attainment and 2) that schooling attainment does not explain any of the income growth once cognitive skills are included. The difference in the variation in income explained between the models in columns 1 and 2 is not three times because the analysis is based on data for 39 countries rather than the 50 countries used in their regression, but the pattern in the results is similar.[1]

Two aspects of their methodology are troubling. The first is their selection of the dates for average schooling attainment and for the cognitive skills of the work force in the model. Their schooling attainment variable is the average attainment for the population age 15 to 64 in 1960 from Cohen and Soto [2007]. This variable is a measure of the human capital of the work force in 1960. Their measure of cognitive skills is a simple average of the scores on tests of math and science skills given to students aged 9 to 15 between 1964 and 2003, but with scores for relatively few countries prior to 1990. Given the lag between when the tests were given and when the students are likely to have entered the work force, the test scores are a measure of the

[1] The data set is limited to 39 countries for consistency with the analysis in the next section.

human capital of the work force in 2010 or later, not a measure for the period 1960-2000. As a result, the difference in time between the two measures of the nation's human capital is at least 50 years.

**Table 1**
**Regression of Human Capital on Income Growth over the Period 1960-2000**
(Dependent variable is log(national income/adult)

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Schooling Attainment in 1960 | 0.11*<br>(.04) | 0.02<br>(.04) | | |
| $\text{Log}(Y/L_{1960})$ | -0.57*<br>(.19) | -0.54*<br>(.12) | -0.56*<br>(.09) | -0.49*<br>(.06) |
| Average Test Score/100 | | 0.63*<br>(.08) | | 0.66*<br>(.12) |
| Schooling Attainment in 2000 | | | 0.13*<br>(.02) | 0.00<br>(.04) |
| $R^2$ | .31 | .71 | .40 | .70 |

Note: White-adjusted standard errors in parentheses
*Significant at one percent level

Hanushek and Woessmann state in the appendix to their article that students' test scores over the 1964-2003 period are assumed to represent the skills of the work force over the 1960-2000 period on the assumption that test scores were constant over this period. There are two problems with this assumption. First, they acknowledge that test scores were not constant over this period. But even if the scores were constant, they would not measure the capabilities of the work force during the 1960-2000 period because the workers during this time period were schooled between 1915 and 1995.

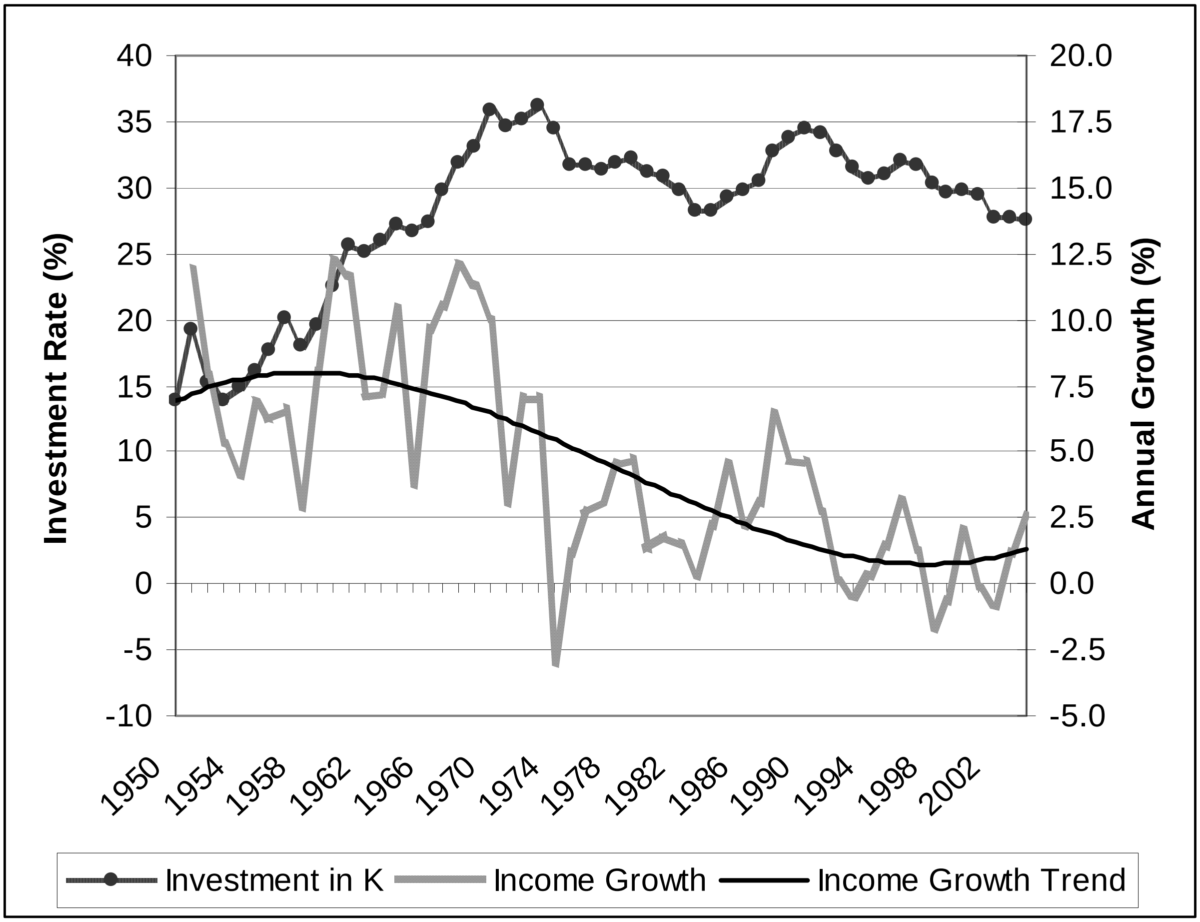
Columns 3 and 4 replicate their analysis using the schooling attainment of the work force in 2000 rather than in 1960, which provides a comparison of the effect of the two measures using dates that are more similar. The basic model with only schooling attainment in 2000 explains 40 percent of the variation in national income, which reduces the incremental explanatory power provided by the test score measure. Nevertheless, the pattern of the estimated coefficients in the two models is similar to the pattern using schooling attainment in 1960. When both schooling attainment and test scores are included in the model, only test scores is statistically significant.

But even if the comparison of these two measures of the human capital stock is made at a similar point in time, this comparison is still problematic. Logically, the human capital stock in 2000 or 2010 cannot affect economic growth over the 1960-2000 period. Implicitly, the validity of these statistical results depends on the unlikely assumption that students' cognitive skills have not changed since 1915.

The second troubling aspect of their methodology is the structure of the model they use to compare their two measures of the stock of human capital. The growth model in equation (1), with an independent variable for initial income, is a reduced form of a Solow model designed to estimate growth during a period when the economy is responding to an increase in the rate of investment in physical or human capital [Mankiw, Romer, and Weil, 1992]. This model estimates the rate of income growth over a period in which growth is temporarily above the steady-state rate but is declining toward the steady-state rate. Conceptually, the human capital variable in this model should be the average rate of investment in schooling over the 1960-2000 period, not a capital stock at the beginning and/or the end of the period.

The dynamic process this growth model is designed to measure is shown in Figure 1, which illustrates investment in physical capital and economic growth in Japan over the 1950-2004 period, using data from Penn World Table 6.2 [Heston, Summers, and Aten, 2006]. Between 1950 and 1968 Japan's rate of investment in physical capital increased from 13 to 32 percent of GDP, which temporarily drove Japan's rate of economic growth to 15 percent per year. Then between 1968 and 2004 the rate of investment in physical capital fluctuated, but remained at the higher rate of about 32 percent. Changes in the rate of investment in human capital from schooling, which also would have affected the rate of economic growth, are not shown in the figure, as Breton [2009a] shows that this rate was approximately constant over the period.

**Figure 1: Investment in Physical Capital and Economic Growth in Japan**




The Solow model predicts that after the rate of investment increases, economic growth rises above the steady-state rate for a long period of time. After the investment rate stabilizes, the transition to the steady-state rate begins, during which the rate of economic growth steadily declines and eventually converges on the steady-state rate. As shown in Figure 1, the behavior of Japan's rate of economic growth over the 1960-2000 period is consistent with this pattern.

The period of transition began in 1968 and ended in about 1998, when the rate of economic growth converged on a steady-state rate of about 1.0 percent/year.

Japan is one of the three countries with the highest average test scores in the sample of 39 countries. Over the period 1960-2000 it had a relatively high average annual growth rate of 4.1 percent, so this rate lends support to Hanushek and Woessmann's hypothesis that economic growth in the period 1960-2000 is correlated with average test scores over this period. But as discussed earlier, the Japanese students tested over the 1964-2003 time period were in the work force at the end of the period shown in Figure 1, not during the earlier period when Japan's growth rate was exceedingly high. At the end of the period, Japan's growth rate was so low that it does not support Hanushek and Woessmann's hypothesis that test scores are correlated with rates of economic growth.

Japan is only one country, and statistically it could be an anomaly, but the point is that the model in equation (1) is not the appropriate model for testing the effect of the human capital stock on national income across countries at a single point in time. The standard model for estimating this relationship is a production function.

The production function most widely used in the literature to evaluate the effect of the human capital stock is a Cobb-Douglas model that includes the stocks of physical capital and human capital:

(2) $(Y/L)_{it} = (K/L)_{it}^{\alpha} (Hs/L)_{it}^{\beta} A_{it}$

In this model Y is national income, K is the physical capital stock, Hs is the human capital stock from schooling, L is the number of workers, and A includes other national characteristics affecting productivity.

This model can be estimated in different ways. One way is to regress income/worker on capital stock data across countries in one year. Another way is to use data for two different years and examine the effect of the change in the capital stocks on the change in income between these two years. This is the model used by Cohen and Soto [2007] to show that changes in schooling attainment affect national income. Given that Hanushek and Woessmann's average test score data are a proxy for the human capital of each nation's work force in a single year around 2010 or later, ideally the comparison of the effect of test scores vs. schooling attainment should be estimated using the model in equation (2) and cross-country data for 2010.

## II. Comparison of the Various Measures of Human Capital

This section presents the statistical results for the national income model in equation (2) estimated in log form. The data set includes 39 countries for which data were available for three measures of the human capital stock. These measures are the log of the (net) human capital stock (Hs/L), the average test scores for the period 1964-2003[2], and average schooling attainment in the population 15 to 64 in 2000 from Cohen and Soto [2007]. The model is estimated for the year 2000. This is not the ideal year to evaluate the test score measure, but it is close enough to 2010 that the statistical results should provide a valid indication of the relative precision of the various measures of human capital.

The net human capital stock (Hs/L) in 2000 for 39 countries is calculated using the perpetual inventory method described in OECD [2001]. National data on investment in schooling for the period 1960-95 are used to estimate 40 years of investment, the approximate period of schooling investment for the work force in the year 2000. The total investment is calculated using investment rates as a share of national income and income data adjusted for purchasing power parity from Penn World Table 6.2. The investment in schooling includes public and private expenditures, foregone student earnings, and a carrying cost for interest on investment during the period students are in school. The gross human capital stock is reduced to

[2] Provided by Eric Hanushek via email.

account for financial depreciation over a worker's 40-year working life. The estimate for each country is a measure of the nation's actual human capital stock from schooling, rather than a proxy for it. The full documentation for the methodology used to estimate this stock is provided in Breton [2009b].

The test score and schooling attainment proxies for log(Hs/L) are used directly rather than in log form. Breton [2009b] shows that schooling attainment is linearly related to log(Hs/L). The relationship is log-linear because investment per year of schooling rises substantially with increases in a nation's average years of schooling attainment.[3] The mathematical relationship between log(Hs/L) and test scores is less evident, but the log-linear relationship seems to provide fit than a linear relationship (See Figure 2).

The proxy for the physical capital stock in 2000 is the cumulative gross investment in physical capital over the 15-year period 1985-99. As the income model is estimated in log form, this estimate is a reasonable proxy for K if it is proportional to the (net) physical capital stock. While ideally the stock of physical capital would be estimated using the perpetual inventory method, different components of physical capital have such a range of working lives that this stock cannot be estimated using this method without considerably more information than what is available.

The dependent variable in all the models is log(Y/L) where Y/L is national income/adult. Income/adult is used, rather than the income/capita variable used by Hanushek and Woessmann, because adults are more representative of the work force than the total population. Y/L and K/L are calculated from data in Penn World Table 6.2. The data used in the analysis is presented in the Appendix.

[3] This increase in investment per year of schooling can also be observed in Figure 4.

The statistical results from the estimation of the model in equation (2) are shown in Table 2. The results from the various regressions show how well each measure of the log of human capital per adult can explain variations in the log of national income per adult, with and without a variable for the stock of physical capital in the model. All of the models are estimated using OLS.

**Table 2**
**Regression of Human Capital on National Income in 2000**
(Dependent variable is log(national income/adult)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Log(K/L) | 0.36*<br>(.07) | 0.52*<br>(.13) | 0.60*<br>(.06) | 0.29*<br>(.07) | | | | |
| Log(Hs/L) | 0.36*<br>(.06) | | | 0.38*<br>(.06) | 0.68*<br>(.03) | | | 0.58*<br>(.07) |
| Average Test Scores/100 | | | 0.17<br>(.09) | 0.17*<br>(.06) | | 1.03*<br>(.12) | | 0.36*<br>(.09) |
| Schooling Attainment in 2000 | | 0.05<br>(.03) | | -0.02<br>(.02) | | | 0.23*<br>(.02) | -0.02<br>(.03) |
| $R^2$ | .96 | .92 | .91 | .96 | .91 | .70 | .70 | .94 |

Note: White-adjusted standard errors in parentheses
*Significant at one percent level

As in Hanushek and Woessmann's [2008] analysis, no effort is made to control for simultaneity bias. They argue that since the test scores occur many years before national income is estimated, simultaneity bias is not an issue.[4] This same argument can be used for average schooling attainment, the human capital stock, and the physical capital stock, all of which are predetermined variables. Arguably, even if the estimated coefficients do exhibit some simultaneity bias in a cross-country analysis, conclusions drawn from a comparison of the statistical results for the various measures of human capital are still valid.

[4] This argument seems to conflict with their assumption that test scores do not change over time.

The results in column 1 show that the simple Cobb-Douglas income model in equation (2) with the human capital stock variable (Hs/L) can explain 96 percent of the variation in log(Y/L) across 39 countries. The coefficient on physical capital (α) is 0.36, which is similar to physical capital's share of national income, a requirement for a valid Cobb-Douglas income model. Bernanke and Gurkaynak [2001] have estimated that physical capital receives about 35 percent of national income across countries.

Column 2 presents the estimate of the income model using the average schooling attainment proxy for human capital. The estimated coefficient on schooling attainment is significant at the five percent level, but most of the income variation is explained by the variation in physical capital. Krueger and Lindahl [2001] have previously shown that this result is due to the measurement error in the schooling attainment proxy for human capital combined with the high correlation between the stocks of human capital and physical capital.

Column 3 presents the estimate of the income model using test scores as a proxy for human capital. The estimated coefficient is not significant at the five percent level, and most of the variation in national income is explained by differences in the physical capital stock. The test score variable explains less of the variation in national income than the schooling attainment variable, as more of the variation in this model is explained by the physical capital variable than in the other two models.

Column 4 presents the estimates of the income model with all of the human capital measures included. In this model the estimated coefficient on the human capital stock remains relatively unchanged compared to its estimate when is the only measure of human capital in the income model. The overall share of the variation in national income explained by the model is the same as in the model with the human capital stock alone. Some of the variation that previously was explained by the variation in physical capital -- that independent estimates of the physical capital share of national income indicate should by explained by physical capital -- is now explained by the variation in the test score data. This result indicates that test scores are more correlated with log(K/L) than with log(Hs/L). An analysis of the correlation coefficients reveals that test scores have a correlation coefficient of 0.83 with log(K/L) and of 0.76 with log(H/L). The surprising implication is that test scores are a better proxy for physical capital than for human capital.

Columns 5-8 present the results for the same models, excluding the physical capital variable. This model has some conceptual validity, as Breton [2009c] has shown that in a global capital market, with investment in physical capital determined by its marginal product, the stock of physical capital is a function of the stock of human capital. In these regressions the net human capital variable continues to explain much more of the variation in national income than either the schooling attainment or the test scores proxies for human capital (91 percent vs. 70 percent). Schooling attainment and test scores are similar in the amount of variation in national income they explain.

These results lead to a different conclusion about the relative validity of average schooling attainment and test scores as measures of human capital than the one reached by Hanushek and Woessmann [2008]. Schooling attainment is found to be a better proxy for a nation's level of human capital than test scores. The high correlation between test scores and national income is found to be due to the high correlation of test scores with the stock of physical capital, not to the correlation of test scores with the nation's stock of human capital.

Table 3 presents the results of a direct test of whether test scores or schooling attainment is a better proxy for the net human capital stock. These results from a regression of log(Hs/L) on either or both of the other two measures of human capital indicate that schooling attainment is a much better proxy for log(Hs/L) than test scores. When the human capital stock is regressed on both proxies, the coefficient on average test scores is not statistically significant. When log(Hs/L) is regressed on each measure alone, average schooling attainment explains considerably more of the variation in log(Hs/L) than test scores.

**Table 3**
**Regression of Human Capital on Test Scores and Schooling Attainment in 2000**
(Dependent variable is log(human capital/adult)

| | 1 | 2 | 3 |
|---|---|---|---|
| Avg Test Scores/100 | 0.36<br>(.20) | | 1.31*<br>(.19) |
| Schooling Attainment in 2000 | 0.26*<br>(.05) | 0.32<br>(.04) | |
| $R^2$ | .77 | .74 | .57 |

Note: White-adjusted standard errors in parentheses
*Significant at one percent level

Figure 2 shows the relationship between human capital from (investment in) schooling and test scores across the 39 countries. Test scores rise substantially as human capital per adult increases from $3000/adult to $40,000/adult, but between $40,000/adult and $125,000/adult test scores decline with increases in the human capital stock (r = -0.40). In countries with a human capital stock above $40,000/adult much of the investment in schooling occurs in levels of schooling that are above the level where the students were tested for math and science skills. It appears that test scores are a poor measure of the human capital stock in these countries.

**Figure 2: Test Scores vs. Human Capital from Schooling per Adult in 2000**

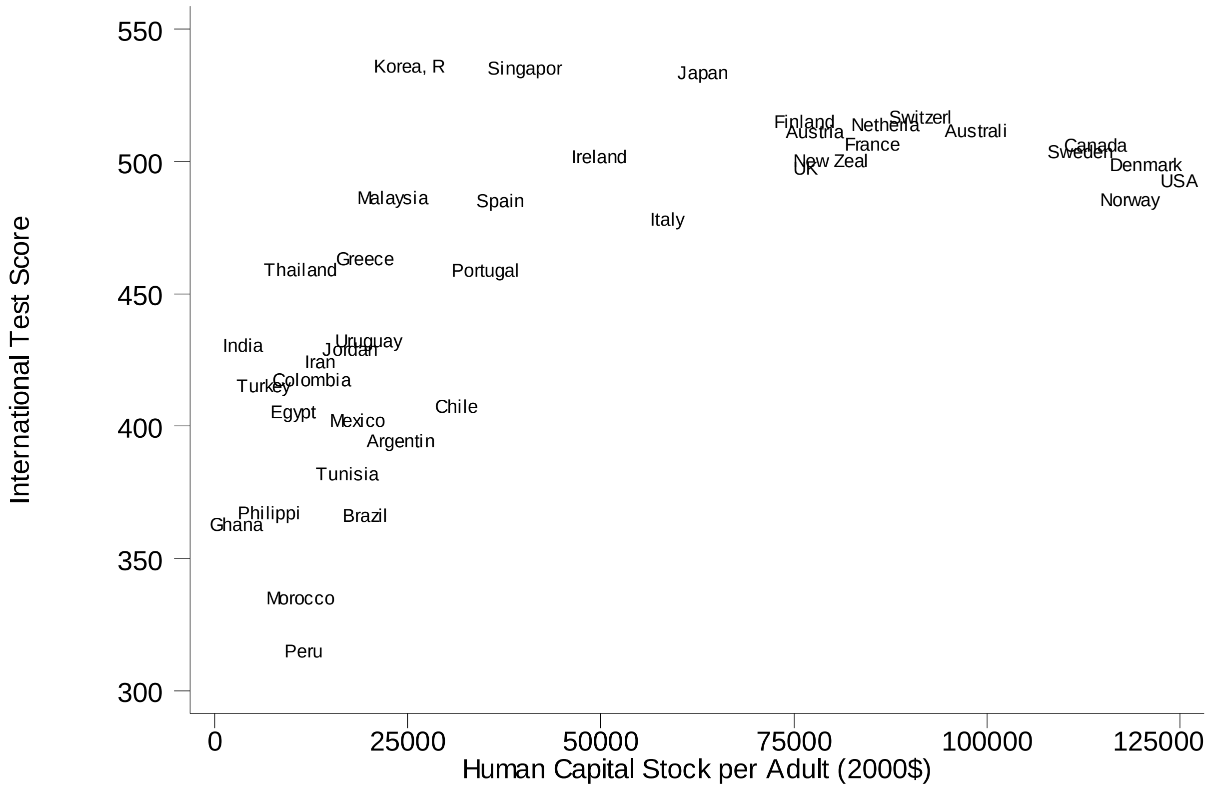



Figure 3 shows the relationship between national income/adult and human capital/adult across the 39 countries. Income/adult rises strongly up to the human capital stock of $40,000/adult. Above this level income/adult continues to rise as human capital levels rise, but at a slower pace due to diminishing returns. The patterns in Figures 2 and 3 and the statistical results in Tables 2 and 3 suggest that income growth is tied primarily to increases in national investment in schools, not to increases in student test scores at ages 9 to 15. It is quite possible that the increase in income is due to an improvement in the cognitive skills of the work force, but this hypothesis cannot be evaluated with tests of students' capabilities that are given long before the students complete their schooling.

**Figure 3: National Income/Adult vs. Human Capital from Schooling per Adult in 2000**

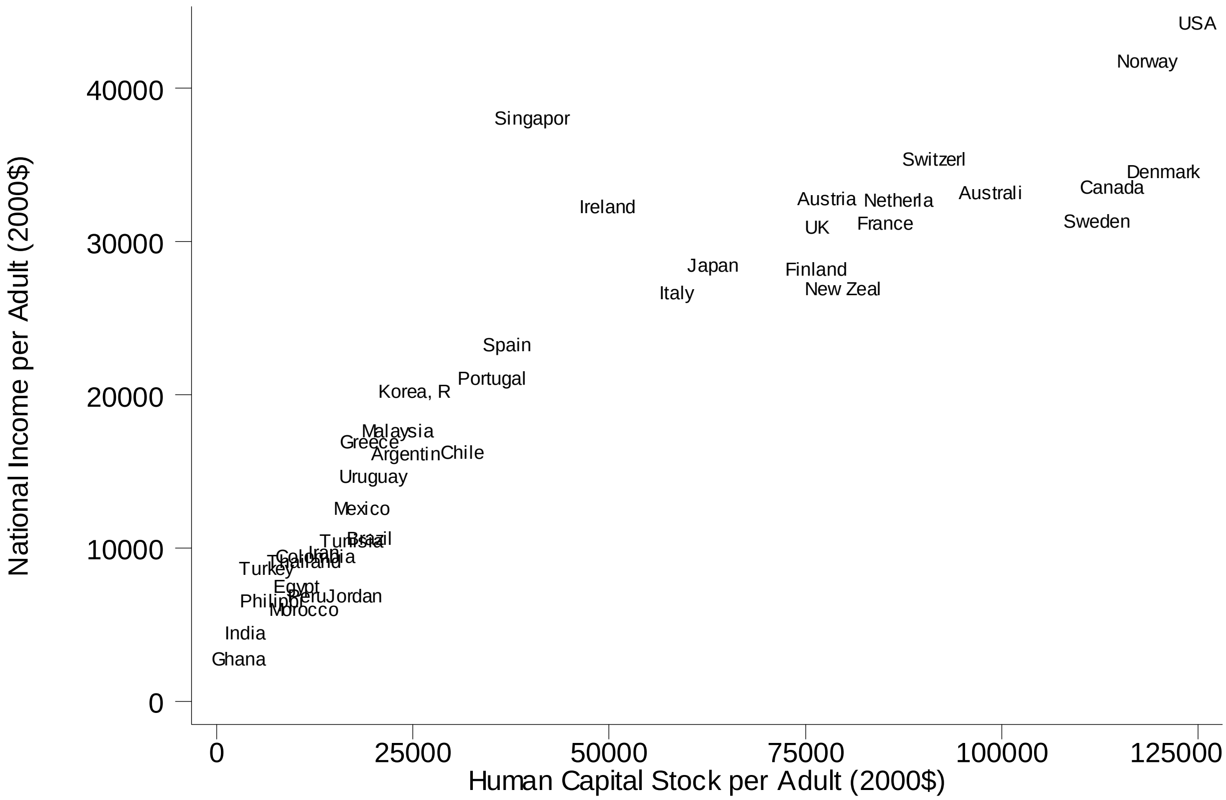



Figure 4 shows the relationship between test scores and the proxy for the physical capital stock/adult. In contrast to the relationship of test scores with the human capital stock, the relationship between test scores and the physical capital stock is positive throughout. The countries with the highest physical capital stock also have the highest test scores. The plots of the data in Figures 2 and 4 provide further confirmation that the high correlation of test scores with national income is due to the correlation of test scores with the physical capital stock. The issue that arises is whether this correlation is causal or spurious. It seems quite possible that this relationship is due to the effect of government policies that simultaneously promote student achievement in math and science and investment in physical capital. At a minimum the discovery of this correlation calls into question the validity of scores on international math and science tests as a proxy for the cognitive skills of the work force.

**Figure 4: Test Scores vs. Physical Capital per Adult in 2000**

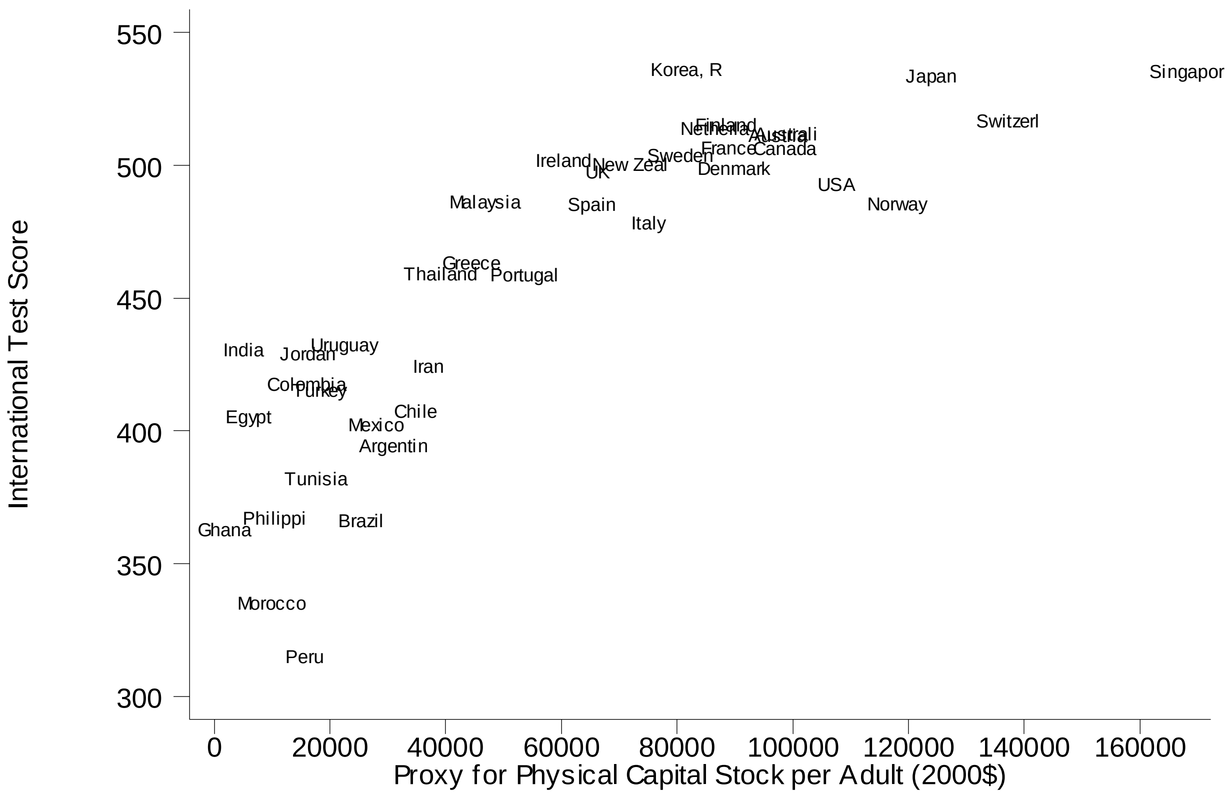



Table 4 presents the results from an additional test of whether test scores or average schooling attainment are valid proxies for a nation's human capital stock. It shows the results of a regression of these measures on log(K/L) and log(H/L). The results in column 1 confirm that in a national production function, test scores are a proxy for the log of the physical capital stock, not the log of the human capital stock. In contrast, the results in column 2 shows that average schooling attainment is a statistically-significant proxy for the log of the nation's human capital stock.

**Table 4**
**Validity of Test Scores as a Proxy for a Nation's Stock of Human Capital**
(Dependent variable is log(human capital/adult))

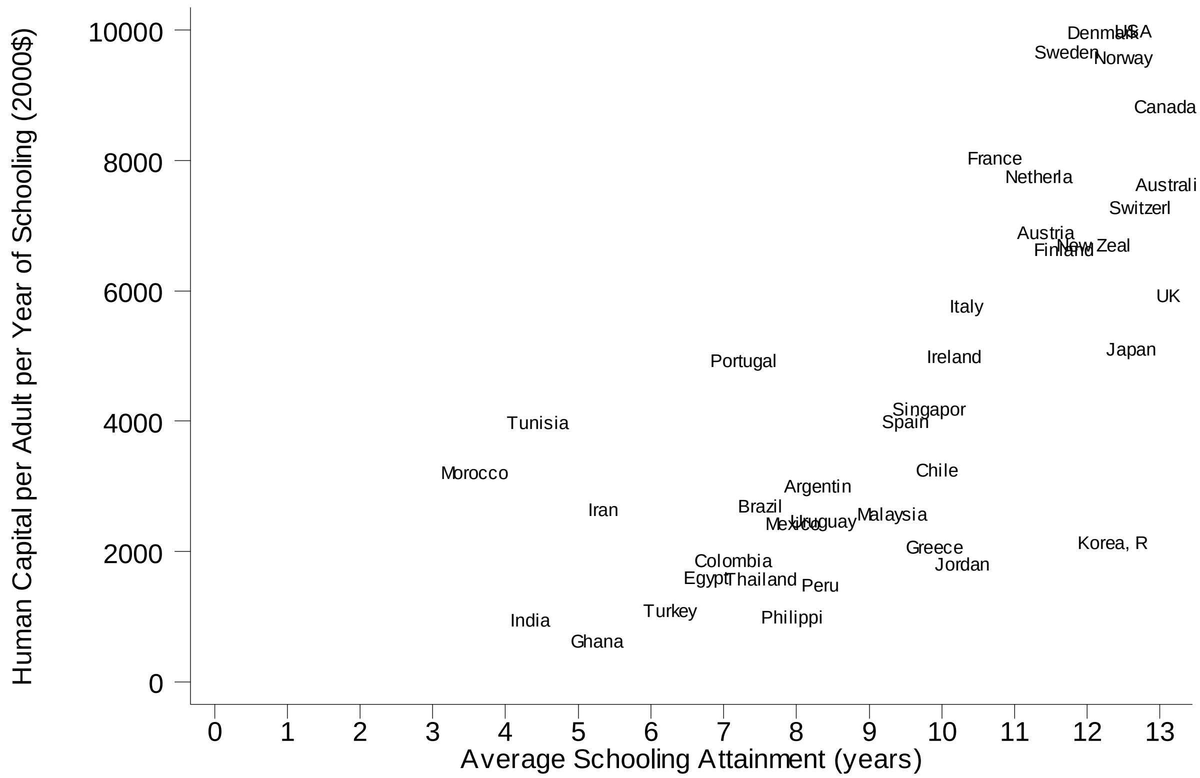
| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Dependent Variable | Test Scores/100 | Attainment | Test Scores/100 | Attainment |
| Sample | 39 | 39 | 22 < $40,000 | 22 < $40,000 |
| Log (K/L) | 0.45*<br>(.12) | 0.47<br>(.59) | 0.55*<br>(.17) | 0.91<br>(.88) |
| Log (Hs/L) | 0.04<br>(.09) | 1.87*<br>(.50) | -0.31<br>(.20) | 0.89<br>(1.00) |
| $R^2$ | .69 | .75 | .44 | .41 |

Note: White-adjusted standard errors in parentheses
*Significant at one percent level

Columns 3 and 4 in Table 4 present the results for the same regressions for countries with a human capital stock below $40,000/adult, which in Figure 1 seemed to be a group of countries in which test scores and the human capital stock were positively correlated. The statistical results for this subgroup of 22 countries are similar to the results in the larger group of 39 countries; test scores continue to be a proxy for the physical capital stock rather than the human capital stock. In this group of countries, however, average schooling attainment is not a good proxy for the human capital stock.

Figure 5 illustrates the problem with the use of the average schooling attainment measure as a proxy for the nation's human capital stock. The data show each country's net human capital per adult per year of schooling compared to its average years of schooling attainment. The data show that there is a tremendous variation across countries in the amount of financial resources invested per year of schooling, even in countries with the same average years of schooling attainment. This illustration highlights the lack of precision of a year of schooling as a measure of human capital and reveals why statistical estimates of the effect of schooling attainment on national income often find little or no relationship.

**Figure 5: Human Capital/Adult per Year of Schooling vs. Years of Schooling in 2000**




In contrast, a nation's cumulative investment in schooling is a well-defined measure of a nation's human capital that is comparable across countries and over time. The superior capability of the human capital stock indicator to measure quality differences in the level of education of the work force is the likely explanation of why it explains more of the differences in national income across countries than the other measures of schooling.

As an example, the data in Figure 5 show that South Korea has the same level of average schooling attainment as other countries that have invested much more per year of schooling. Figure 3 shows that South Korea's level of national income is in line with its cumulative investment in schooling, which implies that national income is not tied to South Korea's average years of schooling attainment. This does not mean that additional years of schooling do not provide economic benefits in South Korea; rather it means that the benefit of an additional year of schooling is a result of the incremental investment normally associated with an additional year of schooling, not to the extra time that students are spending in school.

**III. Conclusions**

This paper reviews the statistical analysis performed by Hanushek and Woessmann [2008] that supports their conclusion that increases in the quality rather than the quantity of schooling are what contribute to economic growth. This paper argues that they did not use the most appropriate model for analyzing the relationship between a stock of human capital and income growth. It shows that a more appropriate model provides different empirical results. In this alternative model increased resources for schooling are highly correlated with income growth across countries. Increases in schooling attainment are also correlated with income growth but not as strongly.

Perhaps the most surprising finding in this paper is that the test scores of students age 9 to 15 are not a good proxy for the human capital in a country's work force. An analysis of the relationship between the stock of human capital and test scores shows that increases in human capital from $40,000/adult to $125,000/adult are associated with increases in national income but with declines in test scores.

Students' test scores are shown to be more correlated with a country's stock of physical capital/adult than with its stock of human capital/adult. As a result, while higher test scores are correlated with higher levels of national income, this correlation does not provide convincing evidence that students' cognitive skills are more important than years of schooling or greater school resources in promoting economic development.

This does not mean that schooling's effect on students' cognitive skills is not the key factor determining whether additional schooling leads to economic development. It just means that a different measure of workers' cognitive skills is required to test this hypothesis. It appears that tests of student capabilities at the ages of 9 to 15 cannot reliably measure the capability of workers who continued in school until age 21 or longer.

Across countries average schooling attainment appears to be a much better proxy for human capital than average test scores, but since a year of schooling is not a precise measure of educational achievement, the average attainment data are of limited use for statistical analysis. Average attainment is highly correlated with the human capital stock in the overall sample of countries (0.86), but the level of correlation is much lower (0.61) in countries with a human capital stock below $40,000/adult. This low correlation between a country's investment in schooling and its years of schooling in low-income countries may explain why increases in schooling attainment are not reliably associated with rates of economic growth in these countries.

The evidence presented in this paper does not change Hanushek and Woessmann's findings that cognitive skills related to math and science are very low in low-income countries, but it puts a different perspective on these findings. This paper shows that at the macro level increases in financial resources for schools are highly correlated with increases in national income. This relationship holds for both low-income and high-income countries. Schools in low-income countries may not educate students to a high level, but these schools do appear to contribute strongly to economic growth.

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# Appendix

**Table A-1**
**Data Used in Analysis**

| Country | Income/Adult | | School Attainment | | Test Score | Hs/Adult | Pxy K/Adult |
|---|---|---|---|---|---|---|---|
| **Year** | **1960** | **2000** | **1960** | **2000** | | **2000** | **2000** |
| **Units** | **2000 $** | **2000 $** | **Years** | **Years** | | **2000 $** | **2000 $** |
| Argentina | 11327 | 15739 | 6.1 | 8.3 | 392.0 | 24107 | 31017 |
| Australia | 15472 | 32785 | 9.8 | 13.1 | 509.4 | 98626 | 98822 |
| Austria | 10840 | 32374 | 8.3 | 11.4 | 508.9 | 77674 | 97416 |
| Brazil | 4662 | 10218 | 3.1 | 7.5 | 363.8 | 19499 | 25355 |
| Canada | 15903 | 33153 | 9.1 | 13.1 | 503.8 | 114090 | 98645 |
| Chile | 8407 | 15831 | 6.2 | 9.9 | 404.9 | 31301 | 34834 |
| Colombia | 5249 | 9047 | 3.7 | 7.1 | 415.2 | 12563 | 15947 |
| Denmark | 15292 | 34144 | 9.1 | 12.2 | 496.2 | 120423 | 89591 |
| Egypt | 2555 | 7076 | 1.0 | 6.8 | 403.0 | 10154 | 5904 |
| Finland | 11185 | 27766 | 6.9 | 11.7 | 512.6 | 76368 | 88510 |
| France | 11591 | 30767 | 6.7 | 10.7 | 504.0 | 85173 | 88900 |
| Ghana | 743 | 2368 | 1.9 | 5.3 | 360.3 | 2753 | 1750 |
| Greece | 5683 | 16489 | 5.9 | 9.9 | 460.8 | 19511 | 44454 |
| India | 1481 | 4012 | 1.2 | 4.3 | 428.1 | 3673 | 5050 |
| Iran | 5892 | 9330 | 0.7 | 5.3 | 421.9 | 13613 | 36958 |
| Ireland | 7683 | 31862 | 7.3 | 10.2 | 499.5 | 49800 | 60366 |
| Italy | 9531 | 26239 | 5.8 | 10.3 | 475.8 | 58527 | 74917 |
| Japan | 6459 | 28069 | 9.5 | 12.6 | 531.0 | 63198 | 123912 |
| Jordan | 7466 | 6428 | 2.6 | 10.3 | 426.4 | 17557 | 16226 |
| Korea, Rep | 2510 | 19826 | 5.0 | 12.3 | 533.8 | 25207 | 81530 |
| Malaysia | 3292 | 17203 | 3.2 | 9.3 | 483.8 | 23008 | 46761 |
| Mexico | 6762 | 12190 | 4.0 | 8.0 | 399.8 | 18528 | 27982 |
| Morocco | 2353 | 5586 | 0.6 | 3.6 | 332.7 | 11146 | 10008 |
| Netherlands | 14946 | 32261 | 8.3 | 11.3 | 511.5 | 86861 | 86527 |
| New Zealand | 17977 | 26489 | 9.0 | 12.1 | 497.8 | 79850 | 71976 |
| Norway | 12784 | 41365 | 9.1 | 12.5 | 483.0 | 118403 | 118001 |
| Peru | 5519 | 6419 | 4.3 | 8.3 | 312.5 | 11540 | 15597 |
| Philippines | 3768 | 6121 | 4.5 | 7.9 | 364.7 | 7093 | 10392 |
| Portugal | 5211 | 20672 | 3.2 | 7.3 | 456.4 | 35150 | 53701 |
| Singapore | 7428 | 37639 | 4.2 | 9.8 | 533.0 | 40113 | 168038 |
| Spain | 6723 | 22876 | 5.8 | 9.5 | 482.9 | 37035 | 65280 |
| Sweden | 14186 | 30921 | 8.7 | 11.7 | 501.3 | 112108 | 80580 |
| Switzerland | 19965 | 34947 | 11.0 | 12.7 | 514.2 | 91410 | 137202 |
| Thailand | 1905 | 8701 | 2.6 | 7.5 | 456.5 | 11152 | 39124 |
| Tunisia | 3753 | 10019 | 0.8 | 4.4 | 379.5 | 17226 | 17580 |
| Turkey | 3907 | 8246 | 2.1 | 6.3 | 412.8 | 6224 | 18093 |
| UK | 13459 | 30490 | 9.1 | 13.1 | 495.0 | 76539 | 66328 |
| Uruguay | 8519 | 14282 | 5.3 | 8.4 | 430.0 | 19827 | 22344 |
| USA | 18630 | 43832 | 10.2 | 12.6 | 490.3 | 124883 | 107617 |