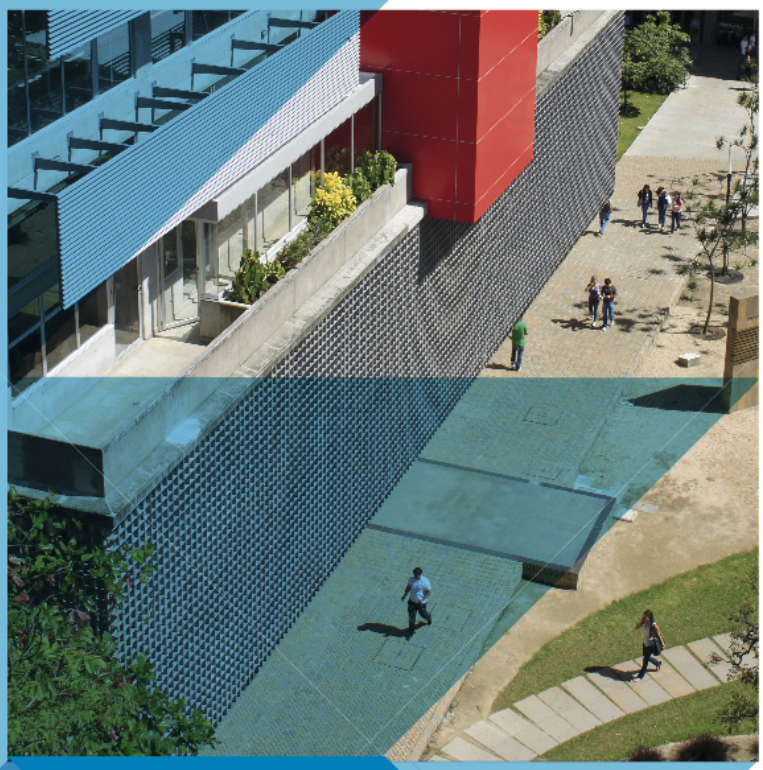

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## Schooling and Economic Growth: What Have We Learned?

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# Schooling and Economic Growth: What Have We Learned?

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## Abstract

*This paper explains why different studies present widely-varying estimates of the effect of increased schooling on national income. It shows that when correctly-interpreted, these studies support the hypothesis that a one-year increase in average schooling attainment raises national income directly by about 10% and indirectly by about 19%. The increases in national income are larger than the aggregate effect of higher workers' salaries, because schooling has external effects on national income. Due to the rising cost of additional years of schooling, the national return on investment in schooling is much lower in more-educated countries. The estimated real national return on investment in schooling in 2005 ranged from over 40% in the least educated countries to 8.5% in the most educated countries. Average levels of schooling and average test scores at ages 9 to 15 generally rise together, so either measure of human capital can explain differences in national income or growth rates across countries. Since the productivity of physical capital depends on the level of human capital, in a global financial market, the growth in human capital largely determines the growth in physical capital and in national income.*

Key Words: Schooling; Human Capital; Test Scores; Economic Growth

JEL Codes: O41; I25

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In several recent articles Eric Hanushek and Ludger Woessmann [2008, 2012a, and 2012b] present statistical results showing that differences in students' scores on international tests of science and mathematics explain three times the variation in GDP/capita growth rates explained by differences in adults' average schooling attainment. They also show that when the effect of average test scores and average attainment are examined together, differences in test scores explain most of the variation in growth rates and differences in schooling do not explain any of this variation. They conclude that more schooling does not reliably raise students' cognitive skills and that increases in cognitive skills at ages 9 to 15, not increases in schooling, cause economic growth [Hanushek and Woessmann, 2008].

But other studies of the effect of schooling on national income come to completely different conclusions. Gennaioli, La Porta, Lopez-de-Silanes, and Shleifer [2013] examine the relationship between average income/adult and average schooling attainment in 1569 world regions that account for 97 percent of world GDP. They find that differences in schooling can explain 58 percent of the differences in income/capita across these regions, far more than any other single factor. When they estimate the effect of multiple factors on income, they find that the level of schooling is by far the most important factor. Each additional year of schooling is associated with a 26% increase in income/capita.

This enormous inconsistency in the estimated effect of increased schooling on national income across studies is not a new phenomenon. Krueger and Lindahl [2001] investigated the causes of this inconsistency in their comprehensive review of the earlier empirical literature. They found that the estimated effect of schooling depends on the structure of the income model used in each analysis. They showed that the estimates are very different if the physical capital stock is included or excluded from the model, or if

the effect of changes in schooling are examined prior to or during the growth period. They also found that the estimated effect of schooling is minimal if it is examined using poorly-measured schooling data over short periods, or if the mathematical relationship between the measures of income and schooling is not correctly specified.

The more recent literature continues to provide widely-varying estimates of the effect of additional schooling on national income. But I show in this article that these differences actually are consistent because they are entirely explained by differences in the structure of the growth model used to estimate the effect of schooling in the different studies. As a consequence, there is now strong evidence that increases in schooling are a reliable strategy for raising national income, even though some studies, such as Hanushek and Woessmann [2008], reach a different conclusion.

This article reviews the recent literature on the effect of increases in schooling on national income.

- Section I explains the two prominent models of the effect of schooling on growth, compares the results from the two models, and shows that the empirical evidence now clearly supports one over the other.
- Section II explains the mechanisms through which increases in schooling raise national income in the best-supported model.
- Section III presents the results from the literature on the magnitude of the various effects of schooling on national income.
- Section IV examines the relationship between a country's average level of schooling and its level of cognitive skills, as measured by international test scores, and explains why increases in either measure can explain economic growth.

- Section V examines whether the share of national investment expended in post-secondary schooling affects national income.
- Section VI explains why in a global financial market a country's level of human capital/adult determines its level of physical capital/adult and its national income/adult.
- Section VII summarizes what we have learned.

## I. Exogenous and Endogenous Growth Models

Economists agree that increases in a nation's level of capital, both physical capital (e.g., machinery) and human capital (i.e., acquired skills), cause economic growth, but until recently they have not agreed on the dynamics of this process or on the magnitude of the effects of increased human capital on growth. Analysis at the micro level (i.e., at the level of the firm) clearly indicates that an increase in the level of capital raises output. If an individual attends school and raises her level of human capital through the schooling process, she generally can obtain a higher salary in the work place. Studies of why this occurs provide pretty strong evidence that more educated workers are paid higher salaries because they are more productive on the job. Similarly, if a factory owner invests in additional physical capital that improves the factory's productive capacity, the factory becomes more productive.

The physical connection between capital and output is not observable for the economy as a whole, but logically the aggregate increases in physical capital and human capital at the micro level raise the nation's stocks of these two kinds of capital, which in the aggregate raises the economy's productive capacity. If there is sufficient demand to make use of this additional capacity, then national output should rise.

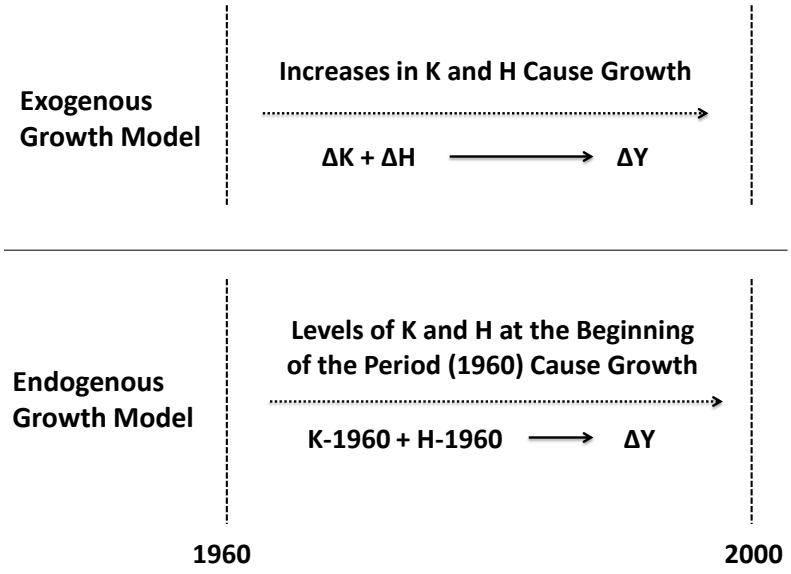
Economists have defined the macro relationship between increased capital and increased output over a period as "exogenous" growth. The process is denoted "exogenous" because the increases in capital that raise national output occur outside the growth model. The model simply quantifies the relationship between the increases in capital (when they occur) and the resulting increases in output.

Although increases in capital over time are the mechanism most likely to raise national income, the level of capital also could affect the economy's growth rate. It is possible that with a certain *level* of physical and human capital, national output might increase over time without further increases in the amount of capital, and this increase might be greater in countries that started with a higher level of capital. Economists have designated this process "endogenous" growth because the economy itself increases output by raising the productivity of its existing capital over time. Implicitly the work force uses its existing ingenuity to increase the productivity of the installed capital, and this productivity increases more in countries that begin the time period with more human capital.

Figure 1 illustrates how growth in output occurs in the exogenous and endogenous growth models for an illustrative time period, 1960-2000. When the effect of increased schooling on national income is estimated in these two models, the results measure the magnitude of different relationships. In the *exogenous* growth model, they estimate how an increase in capital *over a period* (in this case 1960-2000) raises national income over this same period. In the *endogenous* growth model, they estimate how an increase in capital *at the beginning of the period* (in this case 1960) raises the amount of growth in output that occurs over the subsequent time period (in this case 1960-2000).

**Figure 1**

**Growth in Exogenous and Endogenous Growth Models**




Since historically national levels of physical and human capital have increased relatively steadily across countries, it is difficult to identify whether the observed growth in national income has been due to "exogenous" or "endogenous" growth, or to both types simultaneously. Researchers have attempted to determine which type of growth has occurred using statistical models, but they have not always correctly interpreted their results.

Breton [2011] points out that the endogenous growth model has an inherent inconsistency, which is so serious that the model is conceptually flawed. Since the model only considers the effect on growth of changes in the level of capital at the beginning of the period, it implicitly assumes that any increases in capital that occur later, even very soon thereafter, have no effect on growth during the period. In the illustration in Figure 1, which corresponds to Hanushek and Woessmann's analysis, the growth period is 40 years. Logically it makes no sense that an increase in capital in

1960 increases growth over 1960-2000, but that an additional increase in capital in 1965 has no effect on growth over this period. Yet this is what the model assumes. The structure of the endogenous growth model could be modified so that increases in capital after 1960 also affect growth, but then the growth in the endogenous model would no longer be entirely endogenous.

Importantly, if either of these growth models is not a valid model of how growth actually occurs, then when that model is estimated statistically, its results will show that an increase in schooling does not cause much, or any growth. This is why two studies, one estimating effects in the exogenous growth model and one estimating effects in the endogenous growth model, can reach entirely different conclusions about whether additional schooling causes growth. *A study finding no effect from an increase in schooling has implicitly rejected the type of growth model used in the analysis, but it has not shown that an increase in schooling in the other type of model has no effect*.

Researchers are not always clear about which growth model they have specified, and they almost never explain their results as confirmation or rejection of a specific growth model. As a result, they may misinterpret their findings and draw invalid conclusions about the implications of their findings for educational policy.

As examination of the two studies described earlier reveals that Hanushek and Woessmann and Gennaioli, La Porta, Lopez-de-Silanes, and Shleifer did not estimate the same growth model. Gennaioli, et. al. estimated the effect of additional schooling across countries in the same year, which is an application of the *exogenous* growth

model. So a correct characterization of their results is that they found that an increase in schooling across regions is highly correlated with an increase in national income.[1]

Hanushek and Woessmann estimated the effects of increased schooling in 1960 and of higher test scores over the 1960-2000 period on growth over this period, which is a mix of endogenous and exogenous components [Breton, 2011]. As a result, their estimates are difficult to interpret, but implicitly what they found is that an increase in initial schooling in the *endogenous* growth model has no effect on national income, and instead growth is explained entirely by the increase in test scores in the *exogenous* growth model.[2]

So Hanushek and Woessmann's and Gennaioli, et. al.'s results are consistent. Both sets of researchers found that an increase in schooling or in test scores during a period substantially increased national income over that period, as specified in the *exogenous* growth model. But in addition, Hanushek and Woessmann found that the *endogenous* growth model does not explain growth over this same period. So they found no support for the model that seems to have a conceptual flaw. Unfortunately, Hanushek and Woessmann drew the wrong conclusions from their results. They concluded that increases in schooling do not cause growth, when what they actually found is that the *endogenous* growth model does not explain growth.

Breton [2011] notes the inconsistent treatment of increases in schooling and increases in test scores in Hanushek and Woessmann's growth model, and he concludes that their results cannot be used to determine whether increases in schooling or in test scores have a larger effect. He then examines the effect of both increased schooling and

[1] Conceptually, a cross-sectional comparison is equivalent to looking at the effect of raising schooling in a single country over a very long period of time.

[2] Hanushek and Woessmann's model includes the variables from the dynamic form of the exogenous growth model, which are the flow of human capital during the growth period and the initial level of GDP/capita [Mankiw, Romer, and Weil, 1992].

higher test scores in the same *exogenous* growth model, and he finds that either an increase in schooling or an increase in test scores raises national income and that the variation in national income explained by the two measures are relatively similar. So he also finds that increases in human capital have a large effect in the *exogenous* growth model.

Hanushek and Woessmann's [2008, 2012a, and 2012b] finding that increases in the initial levels of schooling (and physical capital), i.e., the effects examined in *endogenous* growth models, do not increase national income is consistent with the results from other studies. Sunde and Vischer [2011] carry out an extensive analysis to determine whether increases in schooling raise national income in either model over the 1970-2000 period. They find that estimates of the effect of changes in schooling and in initial schooling are both statistically significant, but the effect of changes in schooling (the *exogenous* model) is large and the effect of changes in initial schooling (the *endogenous* model) is very small (about $1/20^{th}$ of the effect of changes in schooling).

Other empirical studies also provide consistent results. Cohen and Soto [2007] and Breton [2013a] estimate *exogenous* growth models, and they both present evidence that increases in physical capital and in schooling attainment raise national income in this model. Jones [1995] and Liu [2005] test the consistency of historic changes in physical and human capital with the predictions of the *endogenous* growth model, and both studies reject the validity of this model.

## II. The Dynamics of the Exogenous Growth Model

Given that the existing empirical evidence strongly and consistently supports the validity of the *exogenous* growth model, it is useful to examine the model's dynamics in detail. The standard exogenous, or neoclassical, model in the empirical literature is the

Solow growth model, augmented with human capital. It behaves much like the basic Solow growth model, but with some additional complexity. An important feature of this model is that it exhibits diminishing returns to investment in capital. Increases in physical or human capital, or both together, raise national income, but at a decreasing rate as capital/worker rises.

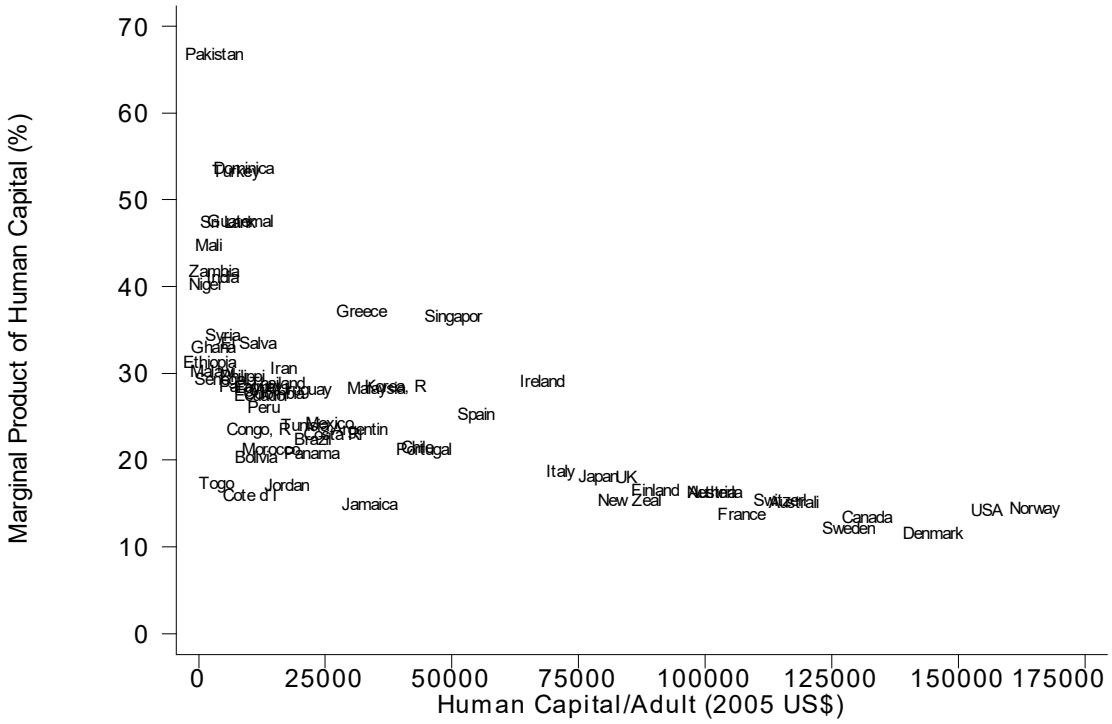
In a modern economy human capital is created primarily in schools, so the nation's cumulative investment in the schooling of the adult population, net of financial depreciation, is a measure of a country's stock of human capital. Figure 2 shows the estimated relationship between the marginal product of human capital and the stock of human capital/adult for 60 countries in 2005 [Breton, 2013c]. The marginal product measures how much national output increases when human capital increases ($\Delta GDP/\Delta H$). The pattern in the figure shows the large effect of incremental human capital on national income in countries with little human capital/adult and the diminishing effect that accompanies increases in human capital/adult. National output is equal to national income, so the marginal product of human capital relationship in Figure 2 also shows how national income increases as human capital/worker increases.

Importantly, this increase in national income does <u>not</u> accrue entirely to the worker who raises his human capital by obtaining additional schooling. As will be discussed later, some of this increased national income accrues to other factors of production in the economy due to the external, or spill-over, effect of the more educated workers on the productivity of the other factors of production. The spill-over effects of human capital and physical capital on worker productivity explain why workers earn more in countries with higher levels of capital/worker. When a worker migrates from a low-capital country to a high-capital country, she earns more because the larger spill-

over (or external) effects of the greater human and physical capital/worker in the high-capital country raise her productivity.

**Figure 2**

**Marginal Product of Human Capital Across Countries in 2005**



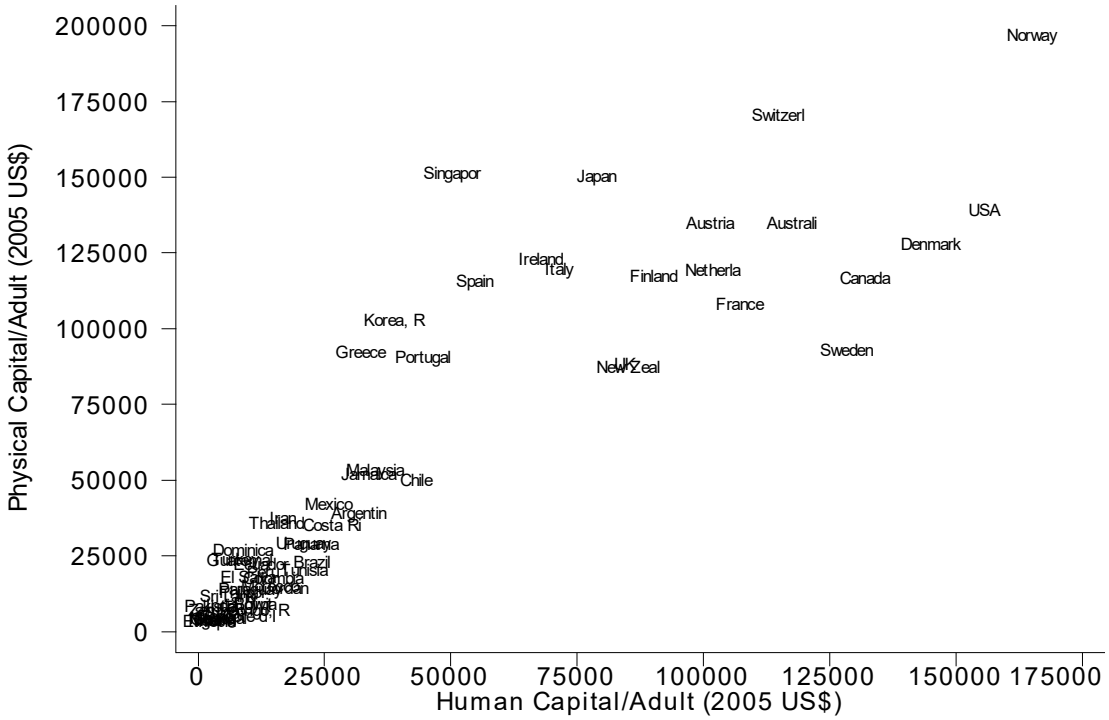

Source: Breton [2013c]

Since the two types of capital are complementary, an increase in either type raises the productivity of the other type. As an example, an increase in the capability of workers using computers makes the computers more productive. Similarly, an increase in the number of computers makes skilled workers more productive. As a consequence of this complementary relationship, countries have a lot or a little of *both* kinds of capital, because neither kind alone is very productive. The relationship between the stocks of these two kinds of capital is shown in Figure 3 for 2005. Japan has more

physical capital than human capital, and the U.S. has more human capital than physical capital, but both countries have considerable amounts of both types. Sub-Saharan African countries have very little of either type.

**Figure 3**

**Stocks of Physical Capital and Human Capital Across Countries in 2005**



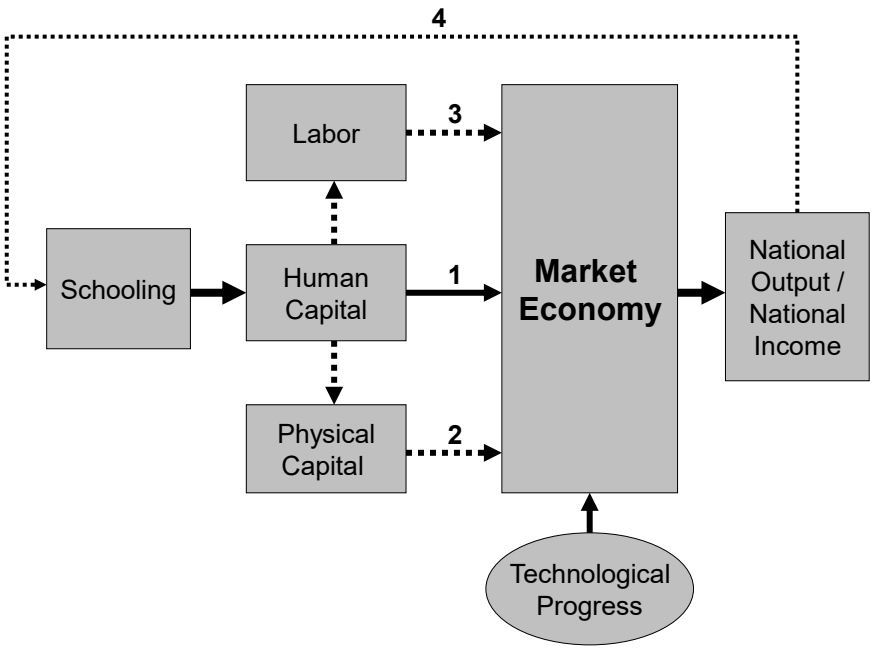

Source: Breton [2013c]

Figure 4 shows the dynamics of the economic growth process in the augmented Solow model when the level of schooling increases [Breton, 2013a]. An increase in schooling increases the nation's human capital, which then raises output both directly (the solid line) and via two indirect effects on the productivity of physical capital and (unschooled) labor, the other two factors of production (the dotted lines). The figure

also shows a third indirect effect (labeled "4") common in most countries today: the positive effect that rising income has on the society's demand for schooling.

**Figure 4**

**Effect of Schooling on National Production and Income**




The augmented Solow model simulates the physical investment process that follows an increase in the level of schooling. This investment does not occur immediately because an increase in schooling does not affect the economy until the schooled individuals enter the work force. The delay is longer with investment in primary schooling than with investment in secondary or post-secondary schooling. As a consequence, the poorest countries must wait the longest for investment in schooling to pay off, but eventually it yields a very high return, higher than the return in more educated countries.

The eventual increase in the human capital of the work force raises the marginal productivity of physical capital, which raises its expected return on investment. Private investors then increase their investment in physical capital, which has a direct effect on output and an indirect effect on the productivity of human capital and (unschooled) labor. As these various productivity effects work their way through the economy, economic output rises, and national income increases along with it.

Technological progress also increases the productivity of the three factors of production, which raises the return on investment in physical capital. Breton [2013b] estimates that on average world technological progress raised world total factor productivity by 0.3% per year during the twentieth century, so its cumulative effect is large over long periods of time, but quite small in the short term.

In the augmented Solow model, increases in human capital, labor, and world technological progress all make physical capital more productive. If none of these factors increase, incremental investment in physical capital is not financially viable. An increase in any of them causes growth, but in a market economy only the increase in human capital is under the direct control of the government through its support for schooling.

Human capital and physical capital are identical mathematically in the augmented Solow model. But the market dynamics of investment in these two types of capital are very different. In a market economy private investment responds immediately and automatically to an increase in the productivity of physical capital. In contrast, the private investment response to an increase in the productivity of human capital is much more limited.

In highly educated countries the dynamics of investment in human capital has some similarities to investment in physical capital. Many individuals have financial assets they can use to collateralize school loans, and high-level education is often of short duration, so it provides some financial return relatively quickly. As a consequence, educated individuals respond to rising financial returns for human capital by raising their investment in post-secondary schooling.

But in poor countries with low average levels of schooling, the dynamics of investment in human capital is completely different. Most of the population is poor and has no assets. Investment in schooling must begin at the primary level in children. The risk of the investment is high because there is no financial return for many years. Poor countries find themselves in a "low-education trap." Most individuals have no skills and no capability to finance acquisition of these skills. Cordoba and Ripoll [2013] present evidence that in poor countries the high fertility rates in poor families make it impossible for them to pay the costs of private schooling for their children.

Even in a country with a market economy and institutions capable of protecting private property, the financial capital market cannot solve the country's low human capital problem. The financial risk associated with long-term, uncollateralized loans to individuals with no financial assets is simply too high. Ben Mimoun [2008] shows that the high income inequality combined with underdeveloped financial markets in sub-Saharan and Latin American countries explain between 30 and 50 percent of the difference in school enrollment between these countries and those in the OECD.

Due to the credit constraints, investment in schooling in poor countries is rarely market-determined. Instead, the decision to invest is largely an "exogenous" decision made by charities, religious groups, or more commonly the state to provide schooling to

the poor [Easterlin, 1981]. Historically these decisions were made first in northern Europe and its colonies, later in southern Europe and Japan, and only relatively recently in Asia, Africa, and most of South America [Benavot and Riddle, 1988, and Morrisson and Murtin, 2009].

The countries that historically provided the most charitable or public support for elementary schooling are the most educated today. And due to the complementary effect of human capital on the productivity of physical capital, the most-educated countries also have the highest levels of physical capital/adult. Some of these countries, like the U.S., developed slowly over a long period of time, and others, like Japan and Korea, developed later in a more accelerated fashion. Nevertheless, their development processes were similar in that the state provided considerable support for education, and the private sector then responded to the rising labor productivity by investing heavily in physical capital [Breton, 2013c].

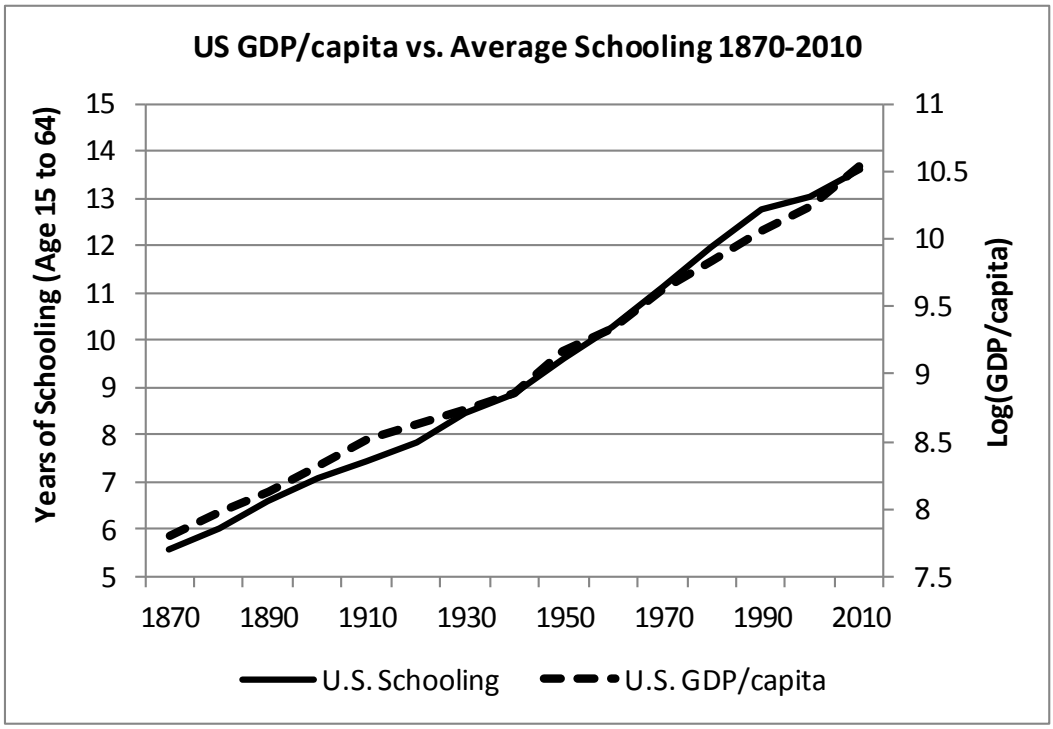
As mentioned earlier, in the augmented Solow growth model, investment in physical capital is subject to diminishing returns. What this means is that the return on investment falls as physical capital/worker increases. But the complementary nature of the two kinds of capital means that the return on physical capital rises if the investment in human capital rises. As a consequence, continuing investment in physical capital (e.g., in factories) is attractive primarily if a continually rising stock of human capital offsets the diminishing return that accompanies the growing stock of physical capital. This is why those countries that have grown steadily for a long time have a history of continually raising their level of schooling.

Figure 5 shows the growth in the average level of schooling and national income/capita in the U.S. from 1870 to 2010. Growth in income/capita has closely

tracked growth in the average level of schooling attainment, except in periods of economic crisis (not shown).

**Figure 5**

**Average Schooling and Income/capita in the U.S. 1870-2000**




Sources: Morrisson and Murtin [2009], Maddison [2003], and Feenstra, Inklaar, and Timmer [2013]

## III. The Quantitative Effects of More Schooling on National Income

Now that we understand the direct and external, or spill-over, effects of increased schooling and the dynamics of the economic growth process, we can turn to the empirical literature quantifying the size of the various effects of schooling on growth. There are two ways that these effects have been quantified; as a return on

investment in schooling and as the effect of an additional year of schooling on national income.

Hanushek and Woessmann [2008] have argued that the return on investment in schooling is small and unreliable, but as we have seen, their conclusion is not based on estimates from the exogenous growth model. So we need to look at other studies to obtain these estimates, and we need to confirm that these estimates are not biased because they have not controlled adequately for the reverse effect that rising national income has on investment in schooling.

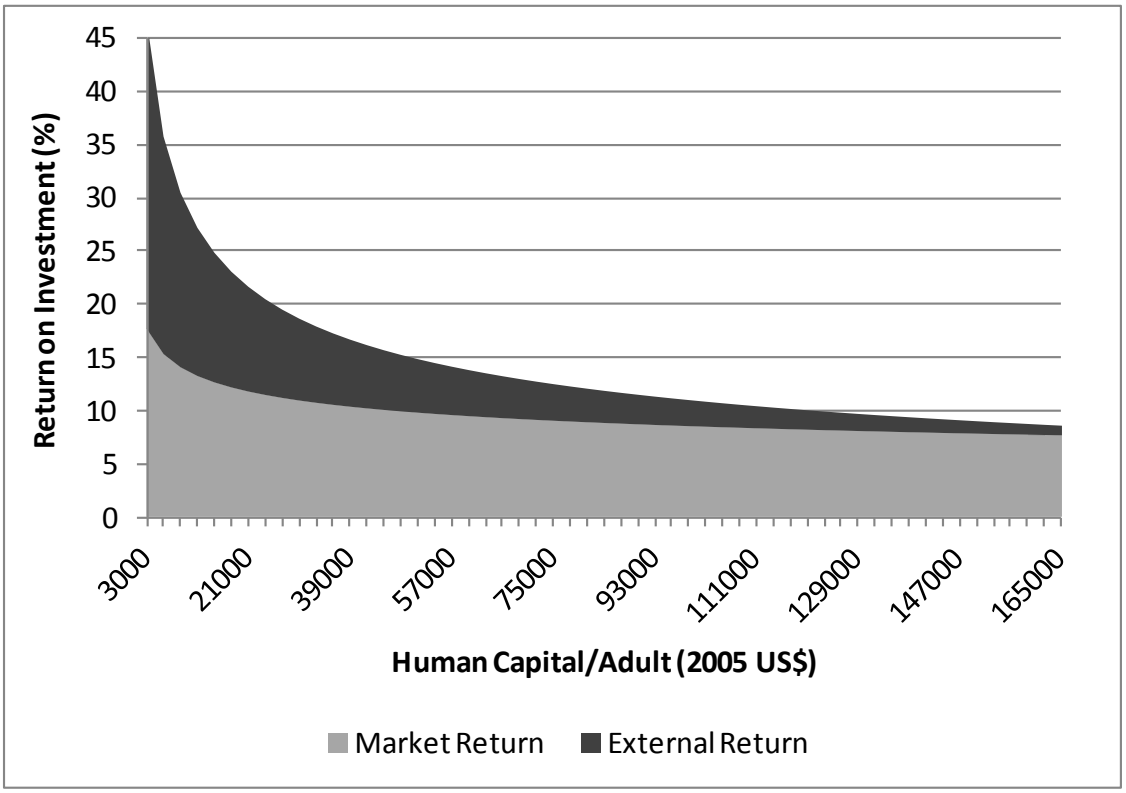
Breton [2013a] presents estimates of the marginal product of schooling on national income in 1990, as well as estimates of the market return on investment in schooling through the associated salary increases in 36 countries around 1990. Using the quantitative relationships in Breton's various studies, Figure 5 shows the estimated market and total national return on investment in schooling for the range of human capital/adult that existed across countries in 2005. The national estimates in Figure 5 are calculated from the marginal product of human capital in Figure 2, which holds constant the stocks of physical capital and labor. The marginal product would be higher if the stock of physical capital were not held constant.

These estimates indicate that the national real rate of return on investment (i.e., net of inflation) in the least-educated countries, such as Pakistan, was over 40%, while in the most-educated countries it was only 8.5%. These estimates also indicate that the market real rate of return was about 17% in the least-educated countries and 7.5% in the most-educated countries. The difference between the national and the market rates is the external or indirect "spill-over" effect of schooling on national income, which is

very large in the least educated countries, but almost disappears in the most educated countries.

**Figure 5**

**Marginal Real Rate of Return on Investment in Schooling in 2005**




Source: Calculated from Breton [2013a, 2013b, and 2013c]

An analysis of the relative size of the components of the marginal product reveals that in the most educated countries, the total effect of schooling on national income is about 10% larger than the direct effect on workers' salaries. In countries with average human capital of about $20,000/adult, e.g., Colombia, the total effect of schooling is about 70% larger than the direct effect. In countries with very little human capital, such as Pakistan, the total effect of schooling on national income is more than

twice the direct effect. The implication is that increases in schooling have huge effects on national income in the least-educated countries, but the magnitude of this effect is not widely appreciated because over half of it does not accrue to the individuals receiving the schooling.

Another way to measure the effect of schooling on national income is to estimate how an incremental year of average schooling attainment affects national income per adult across countries. These estimates are available from a number of recent cross-country studies. In these estimates researchers assume that an incremental year of schooling raises national income by the same percentage, regardless of the initial average level of schooling. They make this assumption because this log-linear (Mincerian) relationship between income and years of schooling provides a good fit with the national income data [Breton, 2013a].

Table 1 presents the implied estimates of the effect of an additional year of schooling on income/adult or on income/capita from recent articles in peer-reviewed journals. The table presents two sets of estimates. The first set is the partial effect of additional schooling, holding constant the level of physical capital/worker in the economy. As mentioned earlier, increases in schooling make physical capital more productive, encouraging additional investment in physical capital. The first set of estimates does not include this indirect effect of additional schooling on national income. The second set of estimates, denoted "full effect," includes the direct effect of schooling on national income and the indirect effect associated with the related increase in physical capital.

Table 1 shows two types of statistical estimates, one estimated with ordinary least squares (OLS) and the other with two-stage least squares (2SLS). OLS measures

the correlation between schooling and national income, but it does not distinguish whether this correlation is due to the effect of schooling on national income, or the *reverse* effect of national income on schooling (labeled "4" in Figure 4). The 2SLS technique attempts to eliminate the reverse effect of national income on schooling from the correlation, so it is likely to provide a more accurate estimate of the true effect of more schooling on national income.

**Table 1**
**Effect of an Incremental Year of Schooling on National Income/Adult**

| | **Partial Effect** | | **Full Effect** | |
|---|---|---|---|---|
| | **OLS** | **2SLS** | **OLS** | **2SLS** |
| Cohen & Soto 2007 | | 8% | | |
| Gennaioli, et. al. 2013 | | | 22%* | |
| Breton 2013a | 13% | 11% | | |
| Breton 2013b | 17% | 10% | 27% | 19% |
| | | | | |
| **Likely Effect** | | **10%** | | **19%** |

*Adjusted down from 26% to account for differences in estimated years of schooling.

The number of available estimates of the effect of additional schooling on national income is limited, but their consistent magnitudes are reassuring. These estimates indicate that an additional year of schooling initially raises national income by about 10 percent, but that after the external effect of more human capital on physical capital productivity has resulted in more physical capital investment, the total increase in national income is 19%, or almost twice as much.

As mentioned earlier, Gennaioli, et. al. found that each additional year of schooling is associated with a 26% increase in regional income. Since they did not control for differences in physical capital across regions, their estimate measures the full effect of additional schooling on national income. Their estimate is not directly

comparable to the other estimates because their measure of average schooling attainment only includes years related to completion of a degree. Since their average schooling level is 16% lower than Cohen and Soto's estimate, a comparable estimate of the full effect of an additional year of schooling on income in their study is 22%. This estimate is still likely to be too high because it does not control for the reverse effect of higher regional income on investment in schooling.

Breton [2013b] finds that across 42 countries in 2000 an additional year of schooling is associated with a 27% increase in national income, but after controlling for the reverse effect, an additional year of schooling only raises national income by 19%. His results indicate that OLS estimates of the effect of schooling on national income include a substantial upward bias. Accordingly, Breton's lower 2SLS estimate of 19% is likely to be a more accurate estimate of the full effect of schooling than Gennaioli, et. al.'s adjusted estimate of 22%.

The assumption that each additional year of schooling raises national income by the same percentage appears to conflict with the diminishing returns to investment shown in Figures 2 and 5. But it turns out that the effect of an additional year of schooling on national income is constant across levels of schooling because each additional year of schooling attainment has a higher unit cost.

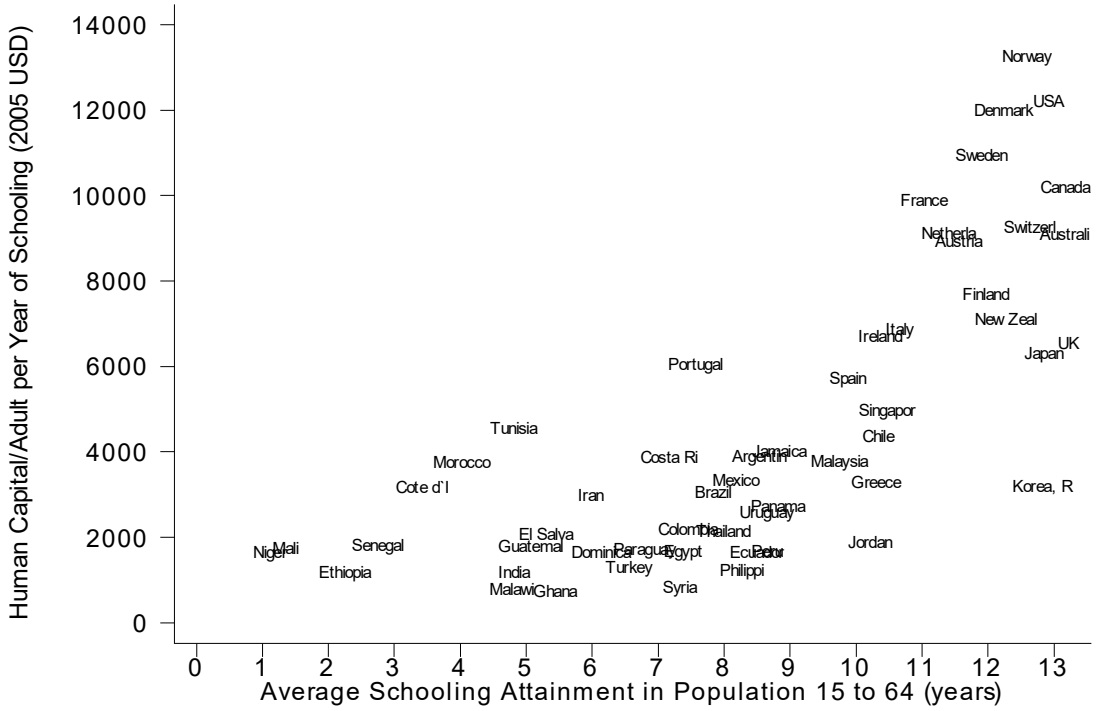
Figure 6 shows the relationship between human capital/adult *per year of schooling* adjusted for purchasing power parity (i.e., cumulative investment net of depreciation) and average years of schooling across countries in 2005. [3] The data show that some countries with the same average schooling attainment have invested

[3] The stock/adult is estimated from cumulative investment in schooling less depreciation in each country over the period 1960-2000. Documentation for the calculations is provided in Breton [2010 and 2013a]. Years of schooling in 2005 are the mean of the average schooling attainment of the population 15 to 64 in 2000 and 2010 estimated by Cohen and Soto [2007].

considerably more in each year of schooling. For example, Portugal and Syria both had about 7.5 years of average schooling attainment, but Portugal had invested about six times as much per year of schooling. The data also show that there is a strong tendency for countries to spend more per year of schooling as they raise the average level of schooling. On average the most educated countries spend six times as much per year of schooling as the least educated countries.

**Figure 6**

**Human Capital/Adult per Year of Schooling vs. Average Schooling in 2005**




Average investment per year of schooling rises with higher average attainment, in part because higher levels of schooling have higher unit costs than lower levels. But in addition, as average schooling levels rise, countries become wealthier and spend more on the lower levels of schooling. In this process as a country's average years of

schooling rise, the investment per year of schooling, and potentially the average quality of a year of schooling, also rises.

As the average level of schooling rises, the decline in the return on investment and the increase in the cost of an additional year of schooling approximately offset, leaving an approximately constant effect (10%) of an incremental year of schooling on national income. Again the seemingly inconsistent estimates of the effect of schooling on national income in different studies are actually consistent.

**IV. The Quantity vs. the Quality of Schooling**

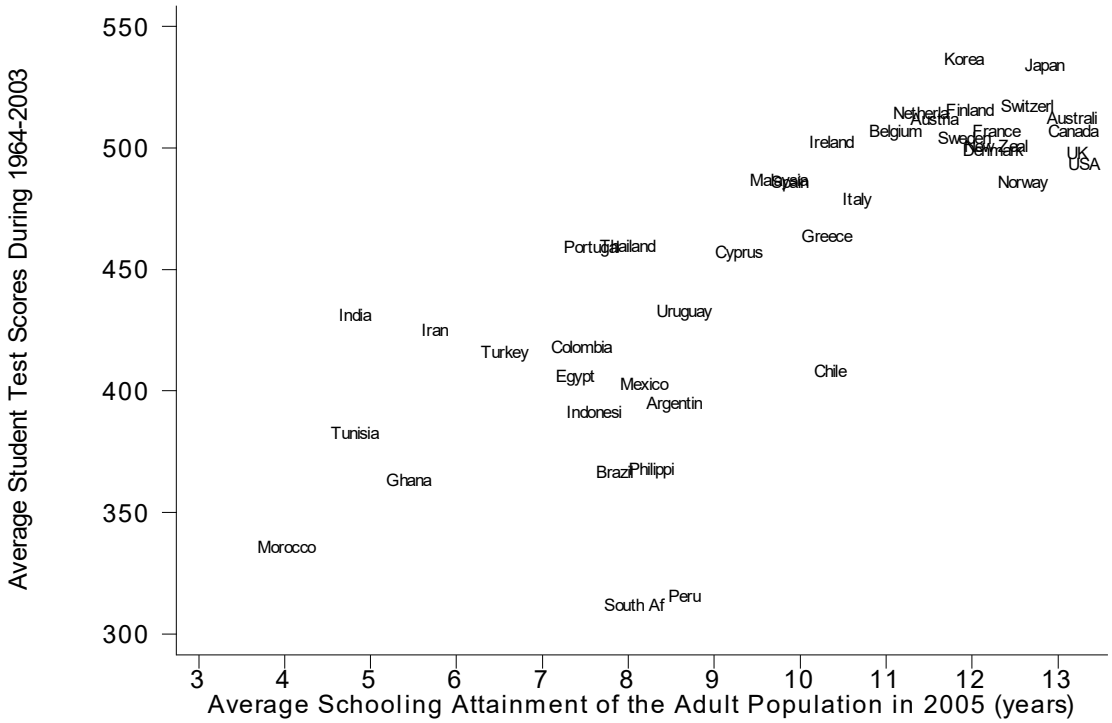
Hanushek and Woessmann argue that the low average test scores in most poor countries on international tests shows that educational policy has not focused on raising cognitive skills. They argue that existing educational policy is misdirected because it focuses on extending schooling coverage, rather than on raising skills, and their statistical results show that higher test scores, rather than more schooling, increase economic growth [Hanushek and Woessmann, 2008].

But as mentioned earlier, Hanushek and Woessmann's results showing that more schooling does not increase growth are related to the *endogenous* growth model, which has little empirical support. In addition, their comparison of the effect of average test scores and average schooling uses data that implicitly measure human capital/adult in periods 50 years apart. They compare the effect of adults' schooling in 1960 and student test scores obtained between 1964 and 2003, or mostly after 1990 for developing countries. Breton [2011] observes that the average test score for students age 9 to 15 between 1964 and 2003 is implicitly the average score for the adult work force in about 2010.

So a valid comparison of Hanushek and Woessmann's average test scores and adult's average schooling attainment would use attainment in 2010, not 1960. Figure 7 shows how their average test scores relate to average (adult) schooling attainment in 2005. The two measures are highly correlated across countries, except for South Africa and Peru, which are outliers with very low scores. In the data an increase in average schooling attainment from 7 to 11 years is associated with an increase in average test scores of about 100 points, or about 25 points per year of additional schooling.

**Figure 7**

**Average Test Scores vs. Average Schooling of the Adult Population in 2005**




Breton [2011] examines the relationship between average test scores and average schooling attainment and national income across countries in 2000 and finds that either

measure explains the variation in national income, although schooling differences explain slightly more of the variation. So Hanushek and Woessmann's [2008, 2012a, and 2012b] findings that higher test scores cause growth and more schooling does not is rejected. Instead both measures are proxies for a nation's human capital and either can explain income differences.

It is not obvious why these two measures of human capital are so highly correlated, since they measure different aspects of a country's human capital. Average test scores measure students' skills in science and math at ages 9 to 15, while average schooling attainment measures how long the average student stayed in school.

The various relationships presented in this paper and elsewhere provide a possible explanation for the correlation between these two measures. The estimates in Table 1 show that national income rises 10% with each additional year of average schooling in the adult population. Figure 6 shows that as countries raise their average schooling attainment, they invest more in their schools. The increased investment in schools corresponds to better training and higher salaries for teachers, or to smaller classes, both of which tend to occur as countries become wealthier. Lee and Barro [2001] have shown that as countries invest more in schools, students' skills, as measured by test scores, improve. So the likely relationship between the two measures is from more years of schooling to more income/capita to more investment in schools to higher test scores at ages 9 to 15.

Hanushek and Woessmann [2008] recommend that educational policy in poor countries be redirected from providing more years of schooling to raising student test scores, because more schooling does not reliably raise income/capita. But as we have

already shown, their claim that more schooling does not raise income/capita is based on an invalid analysis.

Even if the goal is to increase students' cognitive skills related to science and mathematics, there are two ways to do this. One way is to increase students' skills at ages 9 to 15. But the other way is to keep students in school longer. Fuchs and Woessmann [2006], Juerges and Schneider [2004], and Woessmann [2003] present evidence that in European countries students' scores on the same international tests increase 32 points (compared to a mean of 500) after one additional year of schooling. These results indicate that keeping students in school longer, i.e., raising average schooling attainment, is a viable strategy for raising their cognitive skills.

If either higher test scores at ages 9 to 15 or more schooling raise national income, then a policy focused on raising average schooling attainment is a more reliable growth strategy. Hanushek and Woessmann [2008] report that policy initiatives focused on raising student test scores often fail. So Hanushek and Woessmann's argument against a strategy focused on higher schooling attainment is reversed. Raising average schooling attainment is a more reliable strategy for raising income/capita than trying to raise test scores at ages 9 to 15.

**V. More Elementary or More Post-Secondary Schooling?**

In poor countries average schooling attainment can be increased by increasing the share of the school age population in elementary school or by increasing the number of students in post-secondary schooling. Governments in these countries must decide where to invest their limited funds available for the expansion of schooling.

Breton [2013c] examines whether the share of post-secondary schooling affects national income in 2005, holding constant total investment/adult in schooling. He finds

that this share has no effect, indicating that it is the total investment in schooling that drives economic growth, not the relative shares of this investment allocated to elementary or post-secondary schooling. The implication of these results seems to be that governments can allocate available funding for schooling in any way they wish, without worrying about how this distribution affects the rate of economic growth. But it seems that this interpretation of these results is incorrect.

Ben Mimoun [2008] finds that the allocation of public funds to different levels of schooling affects the total national (public and private) investment in schooling. He finds that total enrollment at the secondary and post-secondary school levels are lower if governments allocate more of their limited funds to post-secondary schooling. This result apparently occurs for two reasons. First, reduced funding at the primary and secondary level reduces the quality of this schooling, which has an adverse effect on student decisions to continue in school. Second, due to the credit-constraints on the private financing of primary and secondary schooling, lower funding at the primary and secondary levels reduces the enrollment of poor students at these levels, which then leads to lower total enrollment at the post-secondary level. As a consequence, higher allocation of limited government funds to the primary and secondary levels of schooling raises the overall national (public and private) investment in schooling, which then raises national income.

**VI. The Central Role of Human Capital in the Growth Process**

After World War II the Bank of Reconstruction and Development was created to spur economic growth in rich and poor countries. At the time economists thought that increases in physical capital determine economic growth. Theodore Schultz [1961] observed that Europeans rapidly and efficiently made use of enormous quantities of

financial capital to rebuild their countries, while the small quantities of financial capital provided to poor countries often were poorly utilized. He argued that human capital is required to manage physical capital and that human capital is the type of capital most likely to be in short supply.

In a global capitalist economy, financial capital flows to those countries that have attractive opportunities for investment in physical capital. As a consequence, financial capital flows to any country with relatively high expected returns until the expected return declines to the level that characterizes other countries. As a consequence, the marginal product of physical capital is similar across the globe. Caselli and Feyrer [2007] estimate this marginal product across rich and poor countries in 1996 and confirm that the returns for reproducible capital (i.e., excluding exploitation of natural resources) are similar everywhere.

In a global market a country that seeks foreign investment must take actions to raise the marginal product of capital. One common approach is to provide investors with tax-free, enterprise zones. These zones provide higher after-tax returns by eliminating the tax. But the exogenous growth model suggests that a better way to raise the productivity of physical capital is raise human capital/adult. This policy makes physical capital more productive without giving away the country's tax revenues.

Since the return on physical capital rises in countries that are raising the level of human capital, global financial capital flows to these countries. Unless a country has natural resources to extract, financial capital does not flow to countries where levels of human capital are not rising. Instead the limited financial capital in these countries flows out, looking for a more attractive return elsewhere.

The implication is that in a global financial capital market, income growth will be determined by the growth in human capital, since only in those countries will investments be made in both human capital and physical capital. Breton [2013b] has examined whether increases in human capital/adult, as measured by average schooling attainment, explain the growth in GDP/capita in 42 countries between 1910 and 2000, two years that followed periods of high global mobility of financial capital. He shows that increased schooling and world productivity growth explain 82% of the growth in GDP/capita over this period, after controlling for reverse causality.

Most of this growth was caused directly or indirectly by the increase in the average level of schooling, which was quite large in every country. Average GDP/capita increased by 1.9%/year, of which 0.3% was due to TFP growth, while 1.6% was due to capital accumulation [Breton, 2013b]. But since much of the investment in physical capital was due to the increase in its productivity related to rising human capital, the increase in schooling attainment was the principal driving force for the growth in these countries over this period.

**VII. Conclusions**

Empirical studies of the effect of increased schooling on national income have provided conflicting estimates for a long time. But it is now evident that these estimates differ because the different studies quantify different effects of schooling.

The principal difference recently has been that some studies examine the effect of changes in schooling on national income that occur *during* the growth period (denoted exogenous growth), while other studies examine the effect of changes in the *initial* level of schooling on national income during a subsequent period (denoted endogenous growth). A review of these studies reveals that studies of exogenous

growth consistently find a similar, very substantial effect, while studies of endogenous growth consistently find little or no effect.

Breton's [2013a] estimates of the exogenous growth model indicate that increases in schooling have a real return on investment (i.e., net of inflation) that varies from 8.5% in the most educated countries to over 40% in the least educated countries. The magnitude of this effect has not been evident in the least-educated countries because less than half of it accrues directly to the recipients of schooling. The remaining effect is the external or spill-over effect of schooling that affects the economy by raising the productivity of physical capital and (unschooled) labor.

Empirical studies using exogenous growth models estimate that an additional year of average schooling attainment raises national income by about 10% directly and by about 19% in total, if the indirect effect of greater schooling on investment in physical capital is included in the estimate. The effect of an additional year of average schooling attainment on national income is constant across levels of average attainment, despite the diminishing returns to investment, because the unit cost of a year of schooling rises with the increase in average schooling attainment.

The studies that have found that higher test scores raise growth, while more schooling does not, are invalid, since they inappropriately compare the estimated effect of more schooling in an endogenous growth model to the effect of test scores in an exogenous growth model. When the effect of higher test scores and additional schooling are examined in a comparable manner in an exogenous growth model, both measures explain growth about equally well because average levels of schooling and average test scores are highly correlated across countries and rise together.

Historic studies show that not only does raising average schooling attainment increase national income, this increase is required to make investment in physical capital financially viable. Countries do not have high levels of physical capital/adult unless they also have high levels of human capital/adult. As a consequence, in a global financial market, capital flows predominantly to countries that continually raise their average schooling attainment.

Since credit constraints preclude private investment in the primary and secondary schooling of the poor, growth in the least-educated countries cannot proceed and has never proceeded unless charities or governments provide or subsidize the schooling of the poor. Countries that are well-educated and have high incomes today have a long history of providing public schooling, or subsidized private schooling, to the poor.

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