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The Economic Value of Education and Cognitive Skills

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Education is one of the top priority policy areas of governments around the world. It is often viewed as an essential element in global economic competition. It is further taken as a force for improving the economic standing of disadvantaged populations within borders and, in the case of foreign aid, across borders. At the same time, some question whether this common model is true as many economic outcomes appear impervious to increased schooling. This chapter reviews the evidence on the economic impact of education with a special emphasis on cognitive skills.

In terms of student performance, most developed countries are acutely aware of how their students do in comparison to students elsewhere in the world. The now frequent scores on PISA and TIMSS provide direct feedback on the performance of students.[1] But, as comparative test scores have become more plentiful, two key questions arise. First, do scores on these tests make any difference? Second, how can they be changed by any governmental policies? This chapter emphasizes the first but addresses both of these questions.

Economists are now accustomed to looking at issues of skill development from the vantage point of human capital theory. The simplest notion is that individuals make investments in skills that have later payoffs in outcomes that matter. And, in this, it is commonly presumed that formal schooling is one of several important contributors to the skills of an individual and to human capital. It is not the only factor. Parents, individual abilities, and friends undoubtedly contribute. Schools nevertheless have a special place because they are most directly affected by public policies.

The human capital and investment perspective immediately makes it evident that the real issues are ones of long-run outcomes. Future incomes of individuals are related to their past investments. It is neither their income while in school nor their income in their first job. Instead, it is their income over the course of their working life. These later outcomes are the focus of this chapter.

The distribution of income in the economy similarly involves both the mixture of people in the economy and the pattern of their incomes over their lifetime. Specifically, most measures of how income and well-being vary in the population do not take into account the fact that some of the low-income people have low incomes only because they are just beginning a career. Their lifetime income is likely to be much larger as they age, gain experience, and move up in their firms and career. What is important is that any noticeable effects of the current quality of schooling on the distribution of skills and income will only be realized years in the future, when those currently in school become a significant part of the labor force. In other words, most workers in the economy were educated years and even decades in the past—and they are the ones that have the most impact on current levels of productivity and growth, if for no reason other than that they represent the larger share of active workers.

Much of the early and continuing development of empirical work on human capital concentrates on the role of school attainment, that is, the quantity of schooling. The revolution in the United States during the 20th century was universal schooling. This has spread around the world, encompassing both developed and developing countries. Quantity of schooling is easily measured, and data on years attained, both over time and across individuals, are readily available. But quantity of schooling proves to be a poor measure of the skills of individuals both within and across countries.

Today, policy concerns in most corners of the world revolve much more around issues of school quality than issues of quantity. This brings us back to PISA and TIMSS. Do standardized tests such as these identify qualities that have economic benefits? The next sections assess what we know about the payoff to cognitive skills for individuals and for nations. In short, there are very large payoffs to such skills. Individuals with more measured cognitive skills systematically do better than those with less, and nations

with a more skilled population grow faster than those with a less skilled population. Again, however, because cognitive skills reflect a variety of factors, the level of cognitive skills may or may not reflect varying school quality.

School Attainment

Quantity of Schooling A look at the history of the 20th century suggests that schooling has generally been a good investment, buoyed by steady increases in the demand for skilled workers.[2] Individuals have dramatically increased their own investments in education, presumably in response to these potential rewards. In the United States, at the beginning of the 20th century, only 6% of the adult population had finished high school. After World War I, high school graduation rates began to increase rapidly. But changes in education work their way slowly through the overall population. By 1940, only half of Americans aged 25 or older had completed more than eight years of school, that is, had any high school education at all. Not until 1967 did the median attainment for an adult aged 25 or over exceed high school.[3] Since 1967, however, the increase in the number of years of schooling completed by Americans has begun to level off. The young adult population, aged 25 to 29, has had stable completion rates for almost two decades. At the turn of the 21st century, over 80% of Americans over age 25 had completed high school or more.[4]

The changes in other nations have been even more dramatic. Table 3.1 shows the percentages of different age groups completing upper secondary schools for a sample of the Organization for Economic Cooperation and Development (OECD) and other countries.[5] By examining the oldest age cohort (column 1), and comparing them with each successive one, a trend increased educational attainment can be observed. The different age groups effectively trace the normal schooling in different decades in the past, so that the changes with age show the rate of increase in schooling. While the United States has been stable since the 1960s, most of the other countries have undergone massive increases in high school completion—mirroring the historical developments in the U.S. before and immediately after World War II (Goldin, 1998).

By 2003, however, the secondary completion rates in the United States were below the average of the developed countries in the OECD. As Figure 3.1 shows, the United States actually trails many developed and developing countries in terms of expected school completion.

The benefits of education to individuals also appear clear. The average incomes of workers with a high school education remain significantly above those of the less educated, and the average income of workers with a college education now dwarf those of the high-school educated. In the United States, the rapidly increasing earnings of college-educated workers during the past two decades currently provides them with a premium of more than 70% higher earnings than a high school graduate with similar job experience.[6]

For individuals, the rate of return on investments in

TABLE 3.1
Percentage of Population Attaining Upper Secondary Education or More, by Country and Age: 1999

	Ages 25–64	Ages 25–34	Ages 35–44	Ages 45–54	Ages 55–64
OECD countries					
Australia	57	65	59	55	44
Austria[a]	74	83	78	69	59
Belgium	57	73	61	50	36
Canada	79	87	83	78	62
Czech Republic	86	93	89	85	75
Denmark	80	87	80	79	70
Finland	72	86	82	67	46
France[a]	62	76	65	57	42
Germany	81	85	85	81	73
Greece	50	71	58	42	24
Hungary	67	80	76	70	36
Iceland	56	64	59	53	40
Ireland[a]	51	67	56	41	31
Italy	42	55	50	37	21
Japan	81	93	92	79	60
Korea	66	93	72	47	28
Luxembourg	56	61	57	52	41
Mexico	20	25	22	16	9
New Zealand	74	79	77	71	60
Norway[a]	85	94	89	79	68
Poland[a]	54	62	59	53	37
Portugal	21	30	21	15	11
Spain	35	55	41	25	13
Sweden	77	87	81	74	61
Switzerland	82	89	84	79	72
Turkey	22	26	23	18	12
United Kingdom[a]	62	66	63	60	53
United States	87	88	88	88	81
OECD mean	**62**	**72**	**66**	**58**	**45**
World Education Indicators participants					
Brazil[a]	24	29	27	21	12
Chile[a]	43	55	45	35	24
Indonesia	22	33	21	15	9
Jordan	51	55	55	43	25
Malaysia[a]	35	50	35	20	10
Peru[a]	46	58	48	35	24
Philippines	44	55	45	34	24
Sri Lanka[a]	36	46	36	31	21
Thailand[a]	16	23	17	9	6
Tunisia	8	11	9	6	3
Uruguay[a]	32	39	34	28	20
Zimbabwe	29	51	19	11	7

Note: [a]Year of reference is 1998. Source: Organisation for Economic Co-operation and Development (2001).
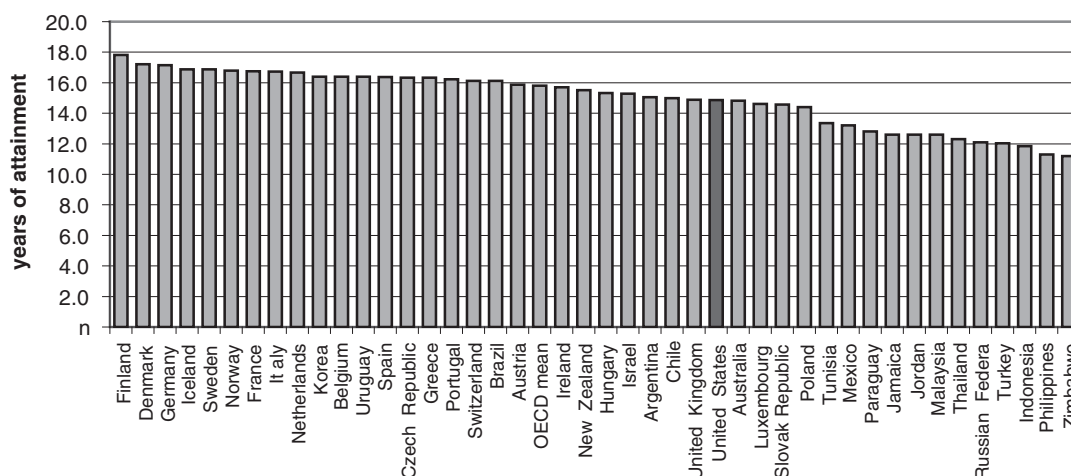
Figure 3.1 Expected school completion by country, 2003. Data Source: Organisation for Economic Co-operation and Development (2005).

higher education has been sufficient to offset the costs.[7] An individual can expect significant financial benefit from extended schooling, even after appropriately considering costs.[8] Individuals also gain non-financial benefits from education. For example, there is evidence that more educated people make better choices concerning health, so they tend to live longer and to have healthier lives. There is also evidence that the children of more educated parents get more out of school. They attend longer and learn more. Such benefits of schooling simply reinforce those from the labor market.[9] The common interpretation of the overall returns is that high technology economies produce large demands for skilled workers, workers who can adapt to new technologies and manage complicated production processes effectively.[10]

Society as a whole also benefits from education. National income rises directly with earnings from workers with more and better skills. The more educated are more prone to be civically involved, to vote in local and national elections, and to be better informed and a more responsible electorate.[11] Increases in the level of education are associated with reductions in crime (e.g., Lochner & Moretti, 2001).

Recent economic studies argue that education may provide economic benefits to society greater than the sum of its benefits to individuals—by providing a rich environment for innovation and scientific discovery—education can accelerate the growth rate of the economy (see, e.g., the analyses of growth by Lucas, 1988; Romer, 1990; Barro, 1991; Jorgenson & Fraumeni, 1992; Barro & Sala-i-Martin, 2004). The economics literature has focused on different ways to model the relationship between schooling and growth, but the basic idea is that human capital will directly affect the improvements in productivity and national income. Indeed, in the analysis of differences in economic growth across countries, measures of the amount of schooling—either enrollment rates or attainment—are one of the most common measures of international differences.[12]

Recent studies suggest that education is important both as an investment in human capital and in facilitating re-

search and development and the diffusion of technologies (see Benhabib & Spiegel, 2005). Extending this, Vandenbussche, Aghion, and Meghir (2006) suggest that innovation is more important than imitation for countries close to the technological frontier. As a consequence, the composition of human capital between basic and higher education may be important, with initial levels of education being more important for imitation and higher education being more important for innovation. They provide evidence from a panel of OECD countries in line with this argument, but the small number of countries makes this analysis difficult and leaves some ambiguity.

Education appears also to have helped to achieve both greater social equality and greater equity in the distribution of economic resources. Schooling was a centerpiece of the U.S. War on Poverty in the 1960s, and the benefits of improved schooling are demonstrated in comparisons of the earnings of different social and ethnic groups. Earnings by Blacks and Whites have converged noticeably since World War II, and much of this convergence is attributable to improved educational opportunities for African Americans (see Smith & Welch, 1989; Jaynes & Williams, 1989). However, that convergence slowed down noticeably in the 1980s with skill differences being cited as a prime determinant (Juhn, Murphy, & Pierce, 1993; Neal, 2006).

While there are many well-documented associations between amount of schooling—either individually or in the aggregate—and desirable economic outcomes, significant questions remain about the magnitude and interpretation of these relationships. First, the association may misstate the causal impact of changes in schooling for individuals and the aggregate. Two studies focus on how school attainment affects growth. Bils and Klenow (2000) suggest that the causal effect of higher economic growth to additional education may be at least as important as the effect of education on economic growth across countries.[13] Pritchett (2001, 2006) notes the fragility of the evidence linking changes in education to economic growth and suggests that the institutional framework of the economy may

be a primary concern.[14] Second, the measurement issues, as highlighted in the next section, are significant.[15] These topics have received surprisingly limited attention and are a fertile area for future work. In many contexts, they are key to both analytical and policy concerns.

Consideration of Cognitive Skills

Most policy and analytical attention has now switched to quality dimensions of schooling. In the United States, with the slowing of individual income growth[16] and of income convergence by race,[17] improving the quality of schooling, or how much is learned for each year, has been seen as the natural policy focus. Similar concerns, albeit generally with a lag, have diffused to other developed and developing countries.

The economic effects of differences in the cognitive skills of graduates of elementary and secondary schools are now becoming clearer, particularly with regard to the performance of the aggregate economy. It is natural to focus on the knowledge base and analytical skills that are the focal point of schools. Moreover, to add concreteness to this discussion, much of it relies on information provided by standardized tests of academic achievement, ability, and general cognitive skills.

Policy concerns revolve much more around issues of achievement and cognitive skills than issues of quantity of schooling or attainment. The U.S. completion rates for high school and college have been roughly constant for a quarter of a century (see Heckman & LaFontaine, 2007). Meanwhile, the standards movement in schools has focused on what students know as they progress through schools. This trend is substantially reinforced by federal accountability legislation (the No Child Left Behind Act of 2001), which emphasizes student proficiency in basic subjects as measured by standardized achievement tests.[18]

Much of the discussion of school quality—in part related to new efforts to provide better accountability—has identified cognitive skills as the important dimension. And, while there is ongoing debate about the testing and measurement of these skills, most parents and policy makers alike accept the notion that cognitive skills are a key dimension of schooling outcomes. The question here is whether these measured skills—students' performance on standardized tests—are systematically and causally related to individuals' performance in the labor market and the economy's ability to grow. Until recently, little comprehensive data have been available to show any relationship between differences in cognitive skills and any related economic outcomes. Such data are now becoming available.

But, again, a word of caution about interpretation is important. Cognitive skills and measured test scores are not synonymous with school quality. Just as much of the discussion surrounding accountability relates to the preparation of students entering the schools and the influence of nonschool factors on assessments, cognitive skills must be recognized as broader than just school quality. Higher quality schools undoubtedly contribute to higher cognitive skills, but so do other things such as families, peers, neighborhoods, and health status. From a policy perspective, improving school quality may be the most viable way to improve cognitive skills, but it is neither the only way nor the only contributor to observed differences in skills across individuals and across countries.

Impacts of Cognitive Skills on Individual Incomes— Developed Countries   There is now considerable evidence that cognitive skills measured by test scores are directly related to individual earnings, productivity, and economic growth. A variety of researchers document that the earnings advantages to higher achievement on standardized tests are quite substantial.[19] While these analyses emphasize different aspects of individual earnings, they typically find that measured achievement has a clear impact on earnings after allowing for differences in the quantity of schooling, the experiences of workers, and other factors that might also influence earnings. They also span different time periods so that they give some support to the long term nature of skills in the U.S. economy. In simplest terms, skills measured by tests similar to those currently used in accountability systems are closely related to individual productivity and earnings.

Three recently published studies provide direct and quite consistent estimates of the impact of test performance on earnings (Mulligan, 1999; Murnane, Willett, Duhaldeborde, & Tyler, 2000; Lazear, 2003). These studies employ different nationally representative data sets that follow students after they leave schooling and enter the labor force. When scores are standardized, they suggest that one standard deviation increase in mathematics performance at the end of high schools translates into 12% higher annual earnings.[20] By way of summary, median earnings in 2001, while differing some by age, were about $30,000, implying that a one standard deviation increase in performance would boost these by $3,600 for each year of work life. The full value to individual earnings and productivity is simply the annual premium for skills integrated over the working life.

A limited number of additional studies are available for developed countries outside of the United States. McIntosh and Vignoles (2001) study wages in the United Kingdom and find strong returns to both numeracy and literacy.[21] Finnie and Meng (2002) and Green and Riddell (2003) investigate returns to cognitive skills in Canada. Both suggest that literacy has a significant return, but Finnie and Meng (2002) find an insignificant return to numeracy. This latter finding stands at odds with most other analyses that have emphasized numeracy or math skills.

There are reasons to believe that these estimates provide a lower bound on the impact of higher achievement. First, these estimates are obtained fairly early in the work career (mid-20s to early 30s), and other analysis suggests that the impact of test performance becomes larger with experience.[22] Second, these analyses concentrate on labor market experiences from the mid-1980s and into the mid-

1990s, but these might not be entirely representative of the current situation because other evidence suggests that the value of skills and of schooling has grown throughout and past that period.

These problems are partially avoided by Hanushek and Zhang (2008) who analyze the situation in a set of countries. Their analysis relies on data from the International Adult Literacy Survey (IALS), which collected consistent data on basic skills of literacy and numeracy for a representative sample of the population aged 15–65 for a sample of countries between 1994 and 1998. Hanushek and Zhang (2008) estimate returns to school attainment and to literacy scores for the 13 countries where continuous measures of individual earnings are available.[23] As in the prior analyses, both school attainment and cognitive skills are seen to enter into the determination of individual incomes. With the exception of Poland, literacy scores have a consistent positive impact on earnings, lending more support to the significance of cognitive skills as a consistent measure of human capital.[24] All of the estimated returns to cognitive skills may be too low if the demands for skilled workers continuous to evolve as in the past few decades. Future general improvements in productivity might lead to larger returns to skill if the recent trends of higher rewards to more skilled workers continue.[25]

Another part of the return to higher skills comes through continuation in school. There is substantial U.S. evidence that students who do better in school, either through grades or scores on standardized achievement tests, tend to go farther in school.[26] Murnane, Willett, Duhaldeborde, and Tyler (2000) separate the direct returns to measured skill from the indirect returns of more schooling and suggest that perhaps one-third to one-half of the full return to higher achievement comes from further schooling. Note also that the effect of quality improvements (measured by increases in cognitive skills of students) on school attainment incorporates concerns about dropout rates. Specifically, higher student achievement keeps students in school longer, which leads to, among other things, higher graduation rates at all levels of schooling.

This work has not, however, investigated how achievement affects the ultimate outcomes of higher education. For example, if over time lower-achieving students tend increasingly to attend college, colleges may be forced to offer more remedial courses, and the variation of what students know and can do at the end of college may expand commensurately. This possibility, suggested in *A Nation at Risk*, has not been fully investigated but may fit into considerations of the widening of the distribution of income within schooling categories.[27]

The impact of test performance on individual earnings provides a simple summary of the primary economic rewards to an individual. This estimate combines the impacts on hourly wages and on employment/hours worked. It does not include any differences in fringe benefits or nonmonetary aspects of jobs, nor does it make any allowance for aggregate changes in the labor market that might occur over time. These estimates also do not directly provide information about the source of any skill differences. As the education production function literature suggests, a variety of factors influence achievement, including family background, peers, school factors, and individual ability (Hanushek, 1979, 1986). This analysis suggests that skill improvements, regardless of their source, have strong economic effects.[28]

Impacts of Cognitive Skills on Individual Incomes—Developing Countries Questions remain about whether the clear impacts of quality in the United States and developed countries generalize to other countries, particularly developing countries. The literature on returns to cognitive skills in developing countries is restricted to a relatively limited number of countries: Ghana, Kenya, Morocco, Pakistan, South Africa, and Tanzania. Moreover, a number of studies actually employ the same basic data—albeit with different analytical approaches, but come up with somewhat different results.

Table 3.2 provides a simple summary to the quantitative estimates available for developing countries. The summary of the evidence permits a tentative conclusion that the returns to quality may be even larger in developing countries than in developed countries. This, of course, would be consistent with the range of estimates for returns to quantity of schooling (e.g., Psacharopoulos, 1994), which are frequently interpreted as indicating diminishing marginal returns to schooling.

There are some reasons for caution in interpreting the precise magnitude of estimates. First, the estimates appear to be quite sensitive to the estimation methodology itself. Both within individual studies and across studies using the same basic data, the results are quite sensitive to the techniques employed in uncovering the fundamental parameter for cognitive skills.[29] Second, the evidence on variations within developing countries is not entirely clear. For example, Jolliffe (1998) finds little impact of skills on farm income, while Behrman, Ross, and Sabot (2008) suggest an equivalence across sectors at least on theoretical grounds.

Nevertheless, the overall summary is that the available estimates of the impact of cognitive skills on outcomes suggest strong economic returns within developing countries. The substantial magnitude of the typical estimates indicates that quality concerns are very real for developing countries and that this aspect of schools simply cannot be ignored.

Impacts of Cognitive Skills on Economic Growth The relationship between measured labor force quality and economic growth is perhaps even more important than the impact of human capital and cognitive skills on individual productivity and incomes. Economic growth determines how much improvement will occur in the overall standard of living. Moreover, the education of each individual has the possibility of making others better off (in addition to the individual benefits just discussed). Specifically, a more skilled society may lead to higher rates of invention; may

TABLE 3.2
Summary of Estimated Returns to a Standard Deviation Increase in Cognitive Skills

Country	Study	Estimated effect[a]	Notes
Ghana	Glewwe (1996)	0.21**–0.3** (government) 0.14-0.17 (private)	Alternative estimation approaches yield some differences; math effects shown generally more important than reading effects, and all hold even with Raven's test for ability.
Ghana	Jolliffe (1998)	0.05–0.07*	Household income related to average math score with relatively small variation by estimation approach; effect from off-farm income with on-farm income unrelated to skills.
Ghana	Vijverberg (1999)	?	Income estimates for math and reading with nonfarm self-employment; highly variable estimates (including both positive and negative effects) but effects not generally statistically significant.
Kenya	Boissiere, Knight, and Sabot (1985); Knight and Sabot (1990)	0.19**–0.22**	Total sample estimates: small variation by primary and secondary school leavers.
Morocco	Angrist and Lavy (1997)	?	Cannot convert to standardized scores because use indexes of performance; French writing skills appear most important for earnings, but results depend on estimation approach.
Pakistan	Alderman, Behrman, Ross, and Sabot (1996)	0.12–0.28*	Variation by alternative approaches and by controls for ability and health; larger and more significant without ability and health controls.
Pakistan	Behrman, Ross, and Sabot (2008)	?	Estimates of structural model with combined scores for cognitive skill; index significant at .01 level but cannot translate directly into estimated effect size)
South Africa	Moll (1998)	0.34**–0.48**	Depending on estimation method, varying impact of computation; comprehension (not shown)generally insignificant.
Tanzania	Boissiere, Knight, and Sabot (1985); Knight and Sabot (1990)	0.07–0.13*	Total sample estimates: smaller for primary than secondary school leavers.

*significant at .05 level; **significant at .01 level.

Note. [a]Estimates indicate proportional increase in wages from a one standard deviation increase in measured test scores.

make everyone more productive through the ability of firms to introduce new and better production methods; and may lead to more rapid introduction of new technologies. These externalities provide extra reason for being concerned about cognitive skills and the quality of schooling.

The potential effect of differences in growth rates on economic well-being is easy to see. Figure 3.2 begins with the value of gross domestic product (GDP) per capita for a medium income country in the year 2000 and shows its value in 2050 under different growth rates.[30] If it grows at 1% each year, this measure (in U.S. dollars) would increase from $5,500 to $9,000—or increasing by almost two-thirds over the period. If it were to grow at 2% per year, it would

reach $15,000 in 2050. For the United States, the numbers are also dramatic. The level of gross domestic product (GDP) per capita in 2000 was roughly $30,000 per person. Other things equal, a 1% higher growth rate would increase this to $50,000 over 50 years. Small differences in growth rates have huge implications for the income and wealth of society.

The current economic position of the United States, for example, is largely the result of its strong and steady growth over the 20th century. As previously suggested, economists have developed a variety of models and ideas to explain differences in growth rates across countries—invariably featuring the importance of human capital.[31]
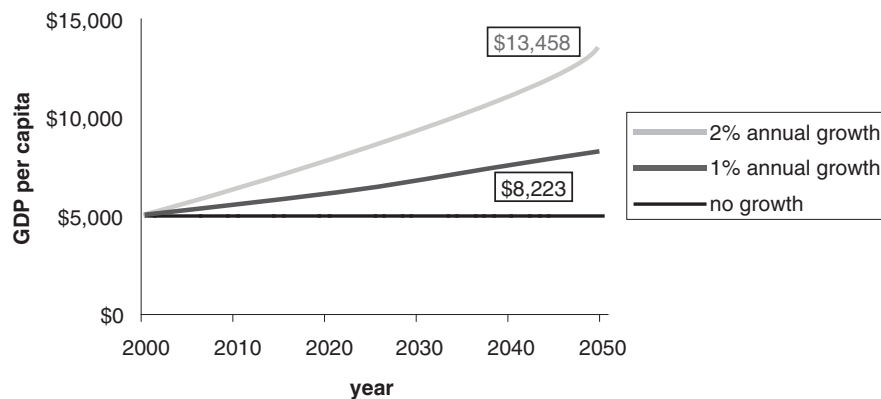

Figure 3.2 Effect of economic growth on GDP per capita (medium income country). Source: Author's calculations.

The empirical work supporting growth analyses has, as mentioned, largely emphasized school attainment differences across countries. Again, this is natural because, while compiling comparable data on many things for different countries is difficult, assessing quantity of schooling is more straightforward. The typical study finds that quantity of schooling is highly related to economic growth rates. But, quantity of schooling is a very crude measure of the knowledge and cognitive skills of people—particularly in an international context. A year of schooling in Egypt is not the same as a year of schooling in France. Additionally, formal schooling is just one element of cognitive skills; other factors may also impact cognitive skills.

Hanushek and Kimko (2000) go beyond simple quantity of schooling and delve into the role of cognitive skills in growth.[32] They incorporate the information about international differences in mathematics and science knowledge that has been developed through testing over the past four decades. They find a remarkable impact of differences in school quality on economic growth.

The international comparisons of quality come from piecing together results of a series of tests administered over the past four decades. In 1963 and 1964, the International Association for the Evaluation of Educational Achievement (IEA) administered the first of a series of mathematics tests to a voluntary group of countries. These initial tests suffered from a number of problems, but they did prove the feasibility of such testing and set in motion a process to expand and improve on the undertaking.[33]

Subsequent testing, sponsored by the IEA and the OECD, has included both math and science and has expanded on the group of countries that have been tested. In each, the general model has been to develop a common assessment instrument for different age groups of students and to work at obtaining a representative group of students taking the tests. An easy summary of the participating countries and their test performance is found in Figure 3.3. This figure records performance aggregated across the age groups and subject area of the various tests and scaled to a common test mean of 500.[34]

Figure 3.3 Performance on international student achievement tests. Note. Simple average of the mathematics and science scores over all available international tests, using the re-scaled data by Hanushek and Wößmann (in preparation) that puts performance at different international tests on a common scale.

The United States and the United Kingdom are the only countries to participate in all 13 of the past testing opportunities, but participation in one or more of the tests has expanded quite broadly as can be seen by the figure. This figure, and the subsequent analysis of the data, aggregate scores across any testing experience. There is some movement across time of country performance on the tests, but for the one country that can be checked—the United States—the pattern on the international tests is consistent with other data. The National Assessment of Educational Progress (NAEP) in the United States is designed to follow performance of U.S. students for different subjects and ages. The movement of scores on NAEP follows the same rough pattern as U.S. scores on the individual international tests.[35]

The Hanushek and Kimko (2000) analysis of economic growth is very straightforward. They combine all of the available earlier test scores into a single composite measure of quality and consider statistical models that explain differences in growth rates across nations during the period 1960 to 1990. The basic statistical models, which include the initial level of income, the quantity of schooling, and population growth rates, explain three-fourths of the variation in economic growth across countries.

Most important, the quality of the labor force as measured by math and science scores is extremely important. One standard deviation difference on test performance is related to 1% difference in annual growth rates of gross domestic product (GDP) per capita.[36]

This effect of cognitive skills, while possibly sounding small, is actually very large and significant. Because the added growth compounds, it leads to powerful effects on national income and on societal well-being. One needs only to return to the calculations presented in Figure 3.2 to understand the impact of such skill based improvements in economic growth.

This analysis of cognitive skills and growth has been confirmed and extended by a variety of authors. Another early contribution, by Lee and Lee (1995), found an effect size similar to Hanushek and Kimko (2000) using data from the 1970–71 First International Science Study on the participating 17 countries; also leaving quantitative measures of education with no significant effect on growth. Using a more encompassing set of international tests, Barro (2001) also finds that, while both the quantity of schooling and test scores matter for economic growth, measured cognitive skills are much more important. Employing the measure of cognitive skills developed by Hanushek and Kimko (2000) in a development accounting framework, Woessmann (2002, 2003) finds that the share of cross-country variation in levels of economic development attributable to international differences in human capital rises dramatically when cognitive skills are taken into account. Building on Gundlach, Rudman, and Woessmann (2002), this work analyzes output per worker in 132 countries in 1990. The variation that can be attributed to international differences in human capital rises from 21% to 45% once the international

achievement measures are taken into account, and to over 60% in samples with reasonable data quality.

Extensions of the measure of Hanushek and Kimko (2000) and its imputation in Woessmann (2003) are also used in the cross-country growth regressions by Bosworth and Collins (2003) and in the cross-country industry-level analysis by Ciccone and Papaioannou (2005). Both also find that measured cognitive skills strongly dominate any effect of educational quantity on growth.[37] Coulombe, Tremblay, and Marchand (2004) and Coulombe and Tremblay (2006) use test-score data from the International Adult Literacy Survey in a panel of 14 OECD countries, confirming the result that the test-score measure outperforms quantitative measures of education.

Jamison, Jamison, and Hanushek (2007) further extend the Hanushek and Kimko (2000) framework. They replicate and strengthen the previous results by using test data from a larger number of countries, controlling for a larger number of potentially confounding variables, and extending the time period of the analysis. Using the panel structure of their growth data, they suggest that cognitive skills seem to improve income levels mainly though speeding up technological progress, rather than shifting the level of the production function or increasing the impact of an additional year of schooling.

Finally, the newest estimates of the impact of cognitive skills on economic growth are found in Hanushek and Woessmann (2006). They expand the number of countries with tests from 31 to 50. They also add the decade of the 1990s, which is important because of the potential impacts of economic disruptions during that period. Interestingly, the results from this extension are very similar to those from the earlier period. In both qualitative and quantitative terms, the impacts of cognitive skills over the longer period of time point to the same strong influences on differences in growth. Moreover, the results are very similar in developed and developing countries—all countries seem to benefit from having a well-educated population.

While Hanushek and Woessmann (2006) confirmed that the results would apply to developing countries, they did find that the size of the impact of cognitive skills depends on whether a nation's economy is open to outside trade and other external influences. For greatest positive economic impact, the more open the economy, the more important it is that a country's students are acquiring high levels of cognitive skills. This analysis confirms the arguments by Pritchett (2006) that the institutional framework is very important in determining the impact of schooling and cognitive skills.

Importance of Cognitive Skills The frequent focus of governmental programs has been increasing school attainment and expanding on the years of schooling of the population. The previous discussion, however, highlights the central importance of cognitive skills. While years of schooling attainment are important, that holds only if the student outcomes in terms of skill are maintained. The
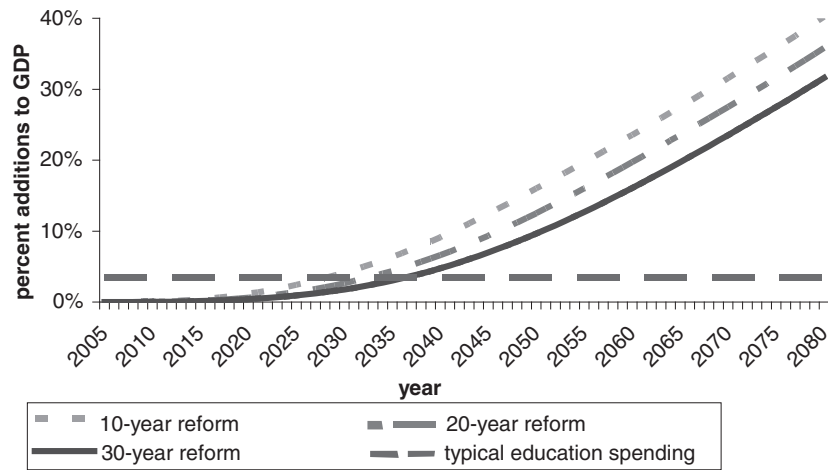
Figure 3.4 Improved GDP with moderately strong knowledge improvement. Source: Author's calculations.

impact of improved cognitive skills can be calculated from the considerations of how quality affects growth rates for economies. Consider the effects of beginning a successful school improvement program in 2005. Of course, school reform takes time. And, even if successful, it takes some time before the school graduates work their way into the labor force and thus some time before the impact will be felt.

Figure 3.4 illustrates the impact that reform could be expected to have over time if it is successful at achieving moderately strong knowledge improvement (corresponding to a 0.5 standard deviation increase in test score achievement, or cognitive skills).[38] The curves sketch out the path of GDP improvement that would occur with a reform plan that reaches its improvement goal within 10, 20, or 30 years.[39] An increase in performance of this magnitude (one-half of a standard deviation) roughly corresponds the goals set out by the U.S. governors in 1989—that is, making the United States first in the world in math and science by 2000. (Note that this pledge of the governors also corresponded to a very fast reform, making it similar to the 10 years portion of Figure 3.4). Of course, the United States did not meet these ambitious goals, but the figure gives some indication of what meeting those goals might have meant for the country.[40] An increase of this magnitude also corresponds to bringing a number of developing countries—for example, Mexico or Brazil—halfway to the average scores in Europe.

The impact of improvements in cognitive scores is vividly shown. Consider just the slow improvement of schools over a 30-year period. In 2040, the GDP would be almost 4% higher than projected without the schooling reforms. Of course, faster reforms would yield even greater gains in GDP. This magnitude of gain would cover total school spending in most countries of the world. In other words, the projected gains in GDP holding other things constant would be greater than our current expenditure on schooling.

Causality One common concern in analyses such as these is that schooling or cognitive skills might not be the actual cause of growth but, in fact, may just reflect other attributes

of the economy that are beneficial to growth.[41] For example, as seen in Figure 3.3, the East Asian countries consistently score very highly on the international tests, and they also had extraordinarily high growth over the 1960–2000 period. It may be that other aspects of these East Asian economies have driven their growth and that the statistical analysis of labor force quality simply is picking out these countries. But in fact, even if the East Asian countries are excluded from the analysis, a strong—albeit slightly smaller—relationship is still observed with test performance (see Hanushek & Kimko, 2000; Hanushek & Woessmann, 2006). This test of sensitivity of the results seems to reflect a basic importance of school quality, a factor that contributes also to the observed growth of East Asian countries.

Another concern might be that other factors that affect growth, such as efficient market organizations, are also associated with efficient and productive schools—so that, again, the test measures are really a proxy for other attributes of the country. In order to investigate this, we concentrate on immigrants to the United States who received their education in their home countries. Hanushek and Kimko (2000) find that immigrants who were schooled in countries that have higher scores on the international math and science examinations earn more in the United States. This analysis makes allowance for any differences in school attainment, labor market experience, or being native English-language speakers. In other words, skill differences as measured by the international tests are clearly rewarded in the United States labor market, reinforcing the validity of the tests as a measure of individual skills and productivity.

Finally, the observed relationships could simply reflect reverse causality, that is, that countries that are growing rapidly have the resources necessary to improve their schools and that better student performance is the result of growth, not the cause of growth. As a simple test of this, Hanushek and Kimko (2000) investigated whether the international math and science test scores were systematically related to the resources devoted to the schools in the years prior to the tests. They were not. If anything, they found relatively

better performance in those countries spending less on their schools. This finding is reinforced by Hanushek and Woessmann (2006), Hanushek (1995, 2003a), and Woessmann (2005, 2007)

In sum, the relationship between math and science skills on the one hand and productivity and growth on the other comes through clearly when investigated in a systematic manner across countries. This finding underscores the importance of policies that can increase cognitive skills.

Why Has U.S. Growth been so Strong?

Figure 3.3 on international test score differences introduces an important issue of interpretation. Namely, that the United States has not been truly competitive on an international level in terms of tests. It has scored below the median of countries taking the various tests. Moreover, this figure—which combines scores across different age groups—disguises the fact that performance on tests of U.S. students is much stronger at young ages but falls off dramatically at the end of high school (Hanushek, 2003b).

Earlier, we introduced the discussion of the importance of growth by recounting America's successful economic growth during the 20th century. Yet, looking at Figure 3.3, we see that the United States has been, at best, mediocre in mathematics and science ability. Regardless of the set of countries taking the test, the United States has performed in the middle of the pack or below. Some people find this anomalous: How could math and science ability be important in light of the strong U.S. growth over a long period of time?[42]

The answer is that quality of the labor force and the level of cognitive skills are just one component of the economy that enters into the determination of growth. A variety of factors clearly contribute, and these factors work to overcome any deficits in quality. These other factors may also be necessary for growth. In other words, simply providing more or higher-quality schooling may yield little in the way of economic growth in the absence of other elements, such as the appropriate market, legal, and governmental institutions to support a functioning modern economy.[43] Past experiences investing in less developed countries that lack these institutional features demonstrate that schooling is not itself an entirely sufficient engine of growth.

Indeed, some have questioned the precise role of schooling in growth. Easterly (2001), for example, notes that education without other facilitating factors such as functioning institutions for markets and legal systems, may not have much impact. He argues that World Bank investments in schooling for less developed countries that do not ensure that the other attributes of modern economies are in place have been quite unproductive.

It is useful to describe some of the other contributing factors to U.S. growth. This is done in part to understand more fully the character of economic growth, but more importantly to highlight some important related issues that are central to thinking about human capital policies.

Economic Structure Almost certainly the most important factor sustaining the growth of the U.S. economy is the openness and fluidity of its markets. The United States maintains generally freer labor and product markets than most countries in the world. The government generally has less regulation on firms (both in terms of labor regulations and in terms of overall production), and trade unions are less extensive than those in many other countries. Even broader, the United States has less intrusion of government in the operation of the economy—not only less regulation but also lower tax rates and minimal government production through nationalized industries. These factors encourage investment, permit the rapid development of new products and activities by firms, and allow U.S. workers to adjust to new opportunities. While identifying the precise importance of these factors is difficult, a variety of analyses suggest that such market differences could be very important explanations for differences in growth rates.[44]

Substitution of Quantity for Quality Over the 20th century, the expansion of the education system in the United States outpaced that around the world. The United States pushed to open secondary schools to all citizens (Goldin, 1998, Goldin & Katz, 2008). With this came also a move to expand higher education with the development of land grant universities, the G.I. bill, and direct grants and loans to students. In comparison with other nations of the world, the U.S. labor force has been better educated, even after allowing for the lesser achievement of its graduates. In other words, more schooling with less learning each year has yielded more human capital than found in other nations that have less schooling but learn more in each of those years.

This historical approach, however, has reached its limits for the United States. Other developed and developing nations have rapidly expanded their schooling systems, and many now surpass the United States (see Figure 3.1 and Table 3.1). The past advantage of the United States in amount of school completed has gone away as other nations have discovered the importance of schooling. Thus, going into the future, the United States appears unlikely to continue dominating others in human capital unless it can improve on the cognitive skills dimension.

Note, however, that this story about U.S. school quality does not generalize well to developing countries—countries that are often not close in any quality dimension. Indeed, as discussed below and as argued in Hanushek (1995) and Hanushek and Woessmann (2006), it appears to be a considerable mistake for developing countries to expand quantity or access to schools while ignoring quality, or what is being learned. Indeed there is an argument that improving quality would actually make it easier to expand access by reducing repetition and other counterproductive aspects of schools (see Harbison & Hanushek, 1992; Hanushek, Lavy, & Hitomi, 2008).

Quality of U.S. Colleges The analysis of growth rates across countries emphasizes quality of the elementary and

secondary schools of the United States. It did not include any measures of the quality of U.S. colleges. By most evaluations, U.S. colleges and universities rank at the very top in the world. Few broad measurements of quality of colleges across countries exist.[45] However, there is indirect evidence. Foreign students by all accounts are not tempted to emigrate to the United States to attend elementary and secondary schools—except perhaps if they see this as a way of gaining entry into the country. They do emigrate in large numbers to attend U.S. colleges and universities. They even tend to pay full, unsubsidized tuitions at U.S. colleges, something that few American citizens do.

A number of the models of economic growth in fact emphasize the importance of scientists and engineers as a key ingredient to growth (e.g., Romer, 1990). By these views, the technically trained college students who contribute to invention and to development of new products provide a special element to the growth equation. Here, again, the United States appears to have the best programs. If this view is correct, U.S. higher education may continue to provide a noticeable advantage over other countries. But the raw material for U.S. colleges is the graduates of our elementary and secondary schools. As has been frequently noted, the lack of preparation of our students leads to extensive remedial education at the postsecondary level, detracting from the ability of colleges and universities to be most effective. Moreover, pre-college preparation is likely an important factor driving the increased proportions of foreign-born students graduating from the science and engineering programs of U.S. colleges and universities (Committee on Science, 2005).

Improving Cognitive Skills

The value of improving school quality and cognitive skills has been intuitively grasped by policy makers around the world. Unfortunately, school reforms or other policies have often not achieved their objectives. Much of school policy is traditionally thought of as an exercise in selecting and ensuring that the optimal set of resources, however defined, is available. Matched with this policy perspective has been a line of research considering the relationship between resource use and student performance. If the effectiveness of different resources or combinations of resources were known, it would be straightforward to define an optimal set of resources. Moreover, we could often decide about policies that would move us toward such an optimal set of resources. Unfortunately, this eludes us.

Schools in the United States have been the focus of extensive research. Both aggregate data about performance of schools over time and more detailed school and classroom data point to a simple conclusion: There is a lack of any consistent or systematic effect of resources on student achievement. While controversial, partly because of the conflict with existing school policies, the evidence is very extensive (Hanushek, 2003a).[46] Existing statistical analyses in less developed countries have shown a similar incon-

sistency of estimated resource effects as that found in the United States (Hanushek, 1995; Glewwe & Kremer, 2006). The evidence on resources is remarkably consistent across countries, both developed and developing. Had there been distinctly different results for some subsets of countries, issues of what kinds of generalizations were possible would naturally arise. Such conflicts do not appear particularly important.

In sum, a wide range of analyses indicate that overall resource policies have not led to discernible improvements in student performance. It is important to understand what is and is not implied by this conclusion. First, it does not mean that money and resources *never* matter. There clearly are situations where small classes or added resources have an impact. It is just that no good description of when and where these situations occur is available, so that broad resource policies such as those legislated from central governments may hit some good uses but also hit bad uses that generally lead to offsetting outcomes. Second, this statement does not mean that money and resources *cannot* matter. Instead, as described below, altered sets of incentives could dramatically improve the use of resources.

Many countries have, of course, attempted to improve their schools. While some have succeeded, many have not. One explanation for past failure is simply that insufficient attention has been paid to teacher quality (see Loeb & Beteille, this volume). By many accounts, the quality of teachers is the key element to improving student performance. The research evidence also suggests that many of the policies that have been pursued around the world have not been very productive. Specifically, the chosen policies of individual countries may have led to changes in measured aspects of teachers such as degrees or teacher qualifications, but they have not tended to improve the quality of teachers—at least when quality is identified by student performance.[47]

Rivkin, Hanushek, and Kain (2005) describe estimates of differences in teacher quality on an output basis.[48] Specifically, the concern is identifying good and bad teachers on the basis of their performance in obtaining gains in student achievement.[49] An important element of that work is distinguishing the effects of teachers from the selection of schools by teachers and students and the matching of teachers and students in the classroom. In particular, highly motivated parents search out schools that they think are good, and they attempt to place their children in classrooms where they think the teacher is particularly able. Teachers follow a similar selection process (Hanushek, Kain, & Rivkin, 2004a, 2004b; Boyd, Lankford, Loeb, & Wyckoff, 2005). Thus, from an analytical viewpoint, it is difficult to sort out the quality of the teacher from the quality of the students that she has in her classroom. In their analysis of teacher performance, Rivkin et al. (2005) go to great lengths to avoid contamination from any such selection and matching of students and teachers.

Estimates of the differences in annual achievement growth between an average and a good teacher are large.

Within one academic year, a good teacher can move a typical student up at least four percentiles in the overall distribution (equal to a change of 0.12 standard deviations of student achievement). From this, it is clear that having a series of good teachers can dramatically affect the achievement of any student. In fact, a series of good teachers can erase the deficits associated with poor preparation for school.

The difficulty, as pointed out in the preceding discussion, is that hiring good teachers is not easily done. Teaching ability is not closely related to training or experience. Moreover, common salary systems do not target particularly high quality teachers. From a policy viewpoint the primary objective should be improving the overall quality of the teaching force. If one were simply to redistribute existing teachers, the overall policy goals would not be achieved. Moreover, the historical reforms in many countries of the world have failed to improve teacher quality by significant amounts that are reflected in student outcomes.

Conclusions

For most of the 20th century, the international debate over the economic consequences of schooling concentrated on the amount of school attained or, simply, the quantity of schooling of the population. Policy deliberations focused on school completion rates, on the proportion of the population attending postsecondary schooling, and the like. Analyses of the benefits of schooling were most concerned with the effects of quantity of schooling—whether benefits are seen in terms of individual incomes or social benefits like the improved voting participation of citizens.

These discussions have now moved to consider more quality dimensions of schooling and of individual skills. This policy attention to student achievement is most easily seen through attention to test-based accountability. The recent economic analysis into impacts of human capital has underscored the correctness of this policy focus. Cognitive skills, as measured by commonly available achievement scores, have a clear and powerful impact on individual earnings and on aggregate outcomes through altering national growth rates.

In making decisions about schools, countries always face limited budgets. If there are the commonly accepted two objectives of expanding access and of improving quality, these objectives will conflict because they must compete for the same budget. Thus, by this standard policymakers are faced with a particularly unpleasant dilemma: choose between broad availability of schools and good schools.

An alternative view, while apparently different, is actually quite closely related. Analyses of labor market implications and the rate of return to schooling in developing countries suggest strongly that schooling is a very good investment. A year of schooling typically shows a 25%–30% real rate of return. Such a return often looks noticeably better than other investment alternatives. At the same time, school completion rates in low-income countries are very low. These two facts do not go together. If it is such a high

rate of return activity, why are people not taking advantage of those high returns?

Work on the role of cognitive skills has something to say about both elements of education policy, since the historic concentration on school attainment ignores variations in cognitive skills and in the value-added of schools. First, the simple trade-off story about access and school quality is very misleading, if not wrong in important ways. In fact, in many circumstances, there may not really be the trade-off suggested, but quality may support added attainment. Second, the unifying idea is that school quality may be an important explanation for the "strange" investment behavior that does not take advantage of the available high returns, because those not taking advantage of the high returns may in fact have low skills.

School quality is directly related to decisions about attending schools and to promotion through schools. High quality schools raise student achievement and speed students through primary (and perhaps secondary) schools, thus conserving on costs. Additionally, students respond to school quality in deciding whether or not to drop out of school. They tend to stay in high quality schools and drop out of low quality schools.[50]

Both of these mechanisms indicate a direct relationship between the quantity of schooling attained and the quality of that schooling. Thus, studies of the rate of return to schooling which only consider quantity of schooling produce a misleading estimate of the potential gains. Estimation of the rate of return to schooling that does not account for quality differences will systematically overstate the productivity gains that are associated with additional years of schooling, because the estimates will include quality differences that are correlated with quantity.

Notes

1. The Programme for International Student Assessment (PISA) has been conducted in 2000, 2003, and 2006; retrieved January 12, 2008, from http://www.oecd.org/pages/0,2966,en_32252351_32235731_1_1_1_1_1,00.html. TIMSS is the Trends in International Mathematics and Science Study (formerly the Third International Mathematics and Science Study) and is a continuation of international testing begun in the 1960s; retrieved January 12, 2008, http://timss.bc.edu/

2. A history of changing demands for skills along with changes in schooling can be found in Goldin and Katz (2008).

3. See U.S. Bureau of the Census (1975, 2000) and Goldin (1998).

4. The data have themselves been questioned. Different sources provide very different views about graduation rates overall and by subgroup. Heckman and LaFontaine (2007) show how the various estimates of graduation rates can be reconciled by allowing, among other things, for changes in the attainment of GEDs.

5. A comprehensive comparison of schooling across nations can be found in Barro and Lee (2001).

6. More detail on the patterns of earnings can be found in Murphy and Welch (1989, 1992), Kosters (1991), Pierce and Welch (1996), and Deere (2001). McMahon (1991) reports slightly lower private rates of return for high school completion than for college completion, although they remain substantial. These calculations all rely on just salary differentials, and greater equality in the provision of fringe benefits may act to compress the differences for total compensation. However, no analysis of schooling returns in terms of total compensation is available.

7. Costs and benefits generally occur at different times with costs occurring early in life and benefits accruing later. Thus, in order to compare them, it is necessary to discount all costs and benefits back to a common time. For this reason, the simple sum of costs or of future earnings does not give an accurate picture of the economic value of different investments.

8. While most economists think of schooling as involving the production of human capital in individuals, the screening or signaling perspective is a clear alternative (e.g., Spence, 1973; Wolpin, 1977; Weiss, 1995). The screening model in the extreme suggests that individuals begin schooling with differing abilities and that schooling merely allows employers to identify those with more ability. From the individual's viewpoint, it does not matter what the source of earnings enhancement is, be it production by schools or screening. The individual will be equally induced to make schooling investments based on the comparison of returns and costs. The two may, however, yield quite different incentives to governments to invest, because signaling may lead to different social and private returns to schooling. As a general matter, these models are not identified with just labor market outcome data. A variety of specialized tests under different maintained assumptions about individual motivations and firm behavior has been conducted but has not provided clear support for screening. These tests include looking for "sheepskin effects," particularly high returns to completing given institutional levels, as in Layard and Psacharopoulos (1974). Some support of screening does come from analysis of incentives to complete high school when there are fewer college graduates Bedard (2001). Tyler, Murnane, and Willett (2000) also interpret the earnings outcomes of GED receipt as reflecting signaling. See Riley (2001) for a review of general theoretical and empirical work. The key difficulty with these tests, however, remains that they focus on labor market outcomes, where the private returns to schooling are generally expected to exist independent of the underlying causal mechanism. The analysis below concentrates importantly on outcomes that relate directly to the schooling process (the point where the two models are hypothesized to differ significantly).

9. See, for example, Michael (1982); Haveman and Wolfe (1984); Wolfe and Zuvekas (1995); and Leibowitz (1974). Many factors are unclear, however, because of questions of causality; see, for example, Farrell and Fuchs (1982).

10. Formal models with this character are developed in Nelson and Phelps (1966) and Welch (1970) and summarized in the ideas of dealing with disequilibrium in Schultz (1975).

11. The pattern of U.S. voting over time can be found in Stanley and Niemi (2000). An analysis of the partial effects of educational attainment (which are positive in the face of overall declines in voter turnout over time) is presented in Teixeira (1992).

12. The exact form of the growth relationship is open to dispute. Much of the empirical analysis relates growth to the aggregate level of education in the economy. These so-called endogenous growth models imply that the overall level of schooling in society affects the earnings ability and productivity of the individual, creating an externality where individuals both gain from the investment and affect the earnings of others. In the terminology of economists, this would be called an "externality," because the actions of one person have direct impacts on others. Here, when one person becomes more educated, the value of everybody else's schooling increases. Estimation by Acemoglu and Angrist (2000), however, questions the presence of such an externality, at least at the U.S. state level.

13. See also the perspectives in Mankiw, Romer, and Weil (1992) and Benhabib and Spiegel (1994). At the individual level, see Card (1999).

14. Much of these arguments relates more directly to school attainment, as opposed to cognitive skills that is the subject of the subsequent discussion; see Hanushek and Woessmann (2006).

15. A third topic is whether schooling creates an externality that raises the value of schooling for others. In general externalities have been notoriously elusive and difficult to estimate convincingly, and education proves to be no exception.

16. See, for example, Levy and Murnane (1992) and Welch (1999) for reviews and interpretation of distributional patterns. An updated evaluation is found in Deere and Vesovic (2006).

17. Discussion of distributional issues including earnings differences by race can be found in Smith and Welch (1989); O'Neill (1990); Card and Krueger (1992); Levy and Murnane (1992); Bound and Freeman (1992); Boozer, Krueger, and Wolkon (1992); Juhn, Murphy, and Pierce (1993); Hauser (1993); Kane (1994); Grogger (1996); Welch (1999); and Deere (2001). Reviews of general trends plus Black-White changes can be found in Deere and Vesovic (2006) and Neal (2006).

18. For a discussion and analysis of accountability systems, see Hanushek and Raymond (2005) and Figlio and Ladd (2007).

19. These results are derived from different specific approaches, but the basic underlying analysis involves estimating a standard "Mincer" earnings function and adding a measure of individual cognitive skills. This approach relates the logarithm of earnings to years of schooling, experience, and other factors that might yield individual earnings differences. The clearest analyses are found in the following references (which are analyzed in Hanushek, 2002). See Bishop (1989, 1991); O'Neill (1990); Grogger and Eide (1993); Blackburn and Neumark (1993, 1995); Murnane, Willett, and Levy (1995); Neal and Johnson (1996); Mulligan (1999); Murnane, Willett, Duhaldeborde, and Tyler (2000); Altonji and Pierret (2001); Murnane, Willett, Braatz, and Duhaldeborde (2001); Lazear (2003); and Rose (2006).

20. Murnane, Willett, Duhaldeborde, and Tyler (2000) provide evidence from the High School and Beyond and the National Longitudinal Survey of the High School Class of 1972. Their estimates suggest some variation with males obtaining a 15% increase and females a 10% increase per standard deviation of test performance. Lazear (2003), relying on a somewhat younger sample from NELS:88, provides a single estimate of 12%. These estimates are also very close to those in Mulligan (1999), who finds 11% for the normalized AFQT score in the NLSY data. By way of comparison, estimates of the value of an additional year of school attainment are typically 7%–10%, suggesting that the economic value of an additional year of schooling is equivalent to 0.6 to 0.8 standard deviations of test scores. For policy purposes, the right comparison would reflect the costs of the alternatives. While these comparisons are not currently feasible, we return to this discussion below.

21. Because they look at discrete levels of skills, it is difficult to compare the quantitative magnitudes directly to the U.S. work.

22. Altonji and Pierret (2001) find that the impact of achievement grows with experience, because the employer has a chance to observe the performance of workers.

23. An element of the analysis in Hanushek and Zhang (2008) is adjusting the years of schooling obtained in different time periods to be equivalent in quality terms. This procedure involves equating the marginal impact of a year of schooling on literacy scores across time (after allowing for other influences on literacy scores). All references to school attainment here refer to their quality-adjusted school attainment.

24. Analysis by Altonji and Pierret (2001) can reconcile the difference in quantitative magnitudes of the impact of cognitive skills on U.S. earnings. Hanushek and Zhang (2008) find that the impact of literacy scores rises from that for the youngest workers. These findings are consistent with Altonji and Pierret, who argue that the impact of cognitive skills will become greater as employers have more time to observe individual skills.

25. These estimates of labor market returns typically compare workers of different ages at one point in time to obtain an estimate of how earnings will change for any individual. If, however, productivity improvements occur in the economy, these will tend to raise the earnings of individuals over time. In the past few decades, these increases have favored the more educated and skilled, thus increasing the return to skill. If these trends continue, the impact of improvements in student skills are likely to rise over the work life instead of being constant as portrayed here. On the other hand, such skill-biased change has not always been the case, and technology

could push returns in the opposite direction. See the longer historical look of Goldin and Katz (2008).

26. See, for example, Dugan (1976) and Manski and Wise (1983). Rivkin (1995) finds that variations in test scores capture a considerable proportion of the systematic variation in high school completion and in college continuation, so that test score differences can fully explain Black-White differences in schooling. Bishop (1991) and Hanushek, Rivkin, and Taylor (1996), in considering the factors that influence school attainment, find that individual achievement scores are highly correlated with continued school attendance. Neal and Johnson (1996) in part use the impact of achievement differences of Blacks and Whites on school attainment to explain racial differences in incomes. Behrman, Kletzer, McPherson, and Schapiro (1998) find strong achievement effects on both continuation into college and quality of college; moreover, the effects are larger when proper account is taken of the various determinants of achievement. Hanushek and Pace (1995) find that college completion is significantly related to higher test scores at the end of high school.

27. This logic is most clear for the college graduates. For high school graduates, the movement into the college category could leave the high school group more homogeneous and could work in the opposite direction. Empirical evidence on income inequality within schooling groups suggests that inequality has increased over time for both college and high school groups, but the increase for college is larger (Murnane, Willett, & Levy, 1995). This analysis also suggests that increased demand for skills is one of the elements in this growing inequality.

28. Note that this does take into account recent work that has introduced the possibility that noncognitive skills also enter into economic outcomes. Because evidence suggests that cognitive and noncognitive skills are correlated and are both affected by school factors, our evidence is interpreted as the effects of cognitive skills including their correlated components with noncognitive skills. See Bowles, Gintis, and Osborne (2001); Heckman, Stixrud, and Urzua (2006); and Cunha, Heckman, Lochner, and Masterov (2006). Hanushek and Woessmann (2008) integrate noncognitive skills into the interpretation of general models such as above and show how this affects the interpretation of the parameter on school attainment and other estimates.

29. The sensitivity to estimation approach is not always the case (see, e.g., Jolliffe, 1998). A critique and interpretation of the alternative approaches within a number of these studies can be found in Glewwe (2002).

30. These calculations indicate how changing the growth, holding other things equal, affects incomes. Specifically, if other processes also influence growth, these calculations show the *added* effect from an increase in growth rates.

31. Barro and Sala-i-Martin (2004) review recent analyses and the range of factors that are included.

32. Barro and Lee (2001) provide an analysis of qualitative differences that also includes literacy.

33. The problems included issues of developing an equivalent test across countries with different school structure, curricula, and language; issues of selectivity of the tested populations; and issues of selectivity of the nations that participated. The first tests did not document or even address these issues in any depth.

34. For a description of past testing, see Hanushek and Woessmann (2006).

35. See Hanushek and Woessmann (2006) for a description of how tests are equated across time.

36. The details of this work can be found in Hanushek and Kimko (2000) and Hanushek and Woessmann (2006). Importantly, adding other factors potentially related to growth, including aspects of international trade, private and public investment, and political instability, leaves the effects of labor force quality unchanged.

37. Bosworth and Collins (2003) cannot distinguish the effect of cognitive skills from the effect of quality of government institutions. The analysis below shows, however, that they can be separated when we use our new measure of cognitive skills that also extends the country sample by several additional data points on international tests scores.

38. These calculations are calibrated to scores on international mathematics and science exams. The "moderately strong" improvement implies an increase in scores by 0.5 standard deviations across the international comparisons. This is equivalent of bringing a country at the 31st percentile of performance up to the median for the world.

39. For the calibration, policies are assumed to begin in 2005—so that a 20-year reform would be complete in 2025. The actual reform policy is presumed to operate linearly such that, for example, a 20-year reform that ultimately yielded one-half standard deviation higher achievement would see the performance of graduates increasing by 0.025 standard deviations each year over the period. It is assumed that the impact on the economy is proportional to the average achievement levels of prime age workers. Finally, for this exercise we project the growth impact according to the basic achievement model that also includes the independent impact of economic institutions.

40. A direct discussion of these goals and the implications is found in Hanushek, Jamison, Jamison, and Woessmann (2008).

41. This issue, in terms of school attainment, was forcefully raised by Bils and Klenow (2000).

42. In fact, Gerald Bracey (2002) and other commentators have used evidence about U.S. economic performance as rebuttal of the argument that there is any real need to improve the schools. For example, Bracey argues that people calling for reform are simply wrong: "None of these fine gentlemen provided any data on the relationship between the economy's health and the performance of schools. Our long economic boom suggests there isn't one—or that our schools are better than the critics claim."

43. See the analysis in Hanushek and Woessmann (2006).

44. See, for example, Krueger (1974), World Bank (1993), and Parente and Prescott (1994, 1999).

45. In the 2007 academic rankings of the world's research universities by the Institute of Higher Education, Shanghai Jiao Tong University, the United States had 17 of the top 20 universities and 54 of the top 99 (see http://ed.sjtu.edu.cn/rank/2007/ARWU2007TOP500list.htm, accessed January 12, 2008). In a 2007 professional ranking by the Ecole des mines de Paris based on graduates who were CEOs at Global Fortune 500 countries, U.S. institutions had 10 of the top 22 places and 24 of the top 59 places (see http://www.ensmp.fr/Actualites/PR/EMP-ranking.html, accessed January 12, 2008). These remain, however, narrow measures of the quality of the overall higher education sector.

46. For more on the historical debates about resources, see Hedges, Laine, and Greenwald (1994) and Hanushek (1994). The discussion of specialized topics such as class size reduction can be found in Krueger (1999), Hanushek (1999), and Mishel and Rothstein (2002); for more on teacher salaries, see Loeb and Page (2000).

47. For a review of existing U.S. literature, see Hanushek and Rivkin (2004, 2006). Those papers describe various attempts to estimate the impact of teacher quality on student achievement. Similar studies are currently much less available in other countries.

48. A number of other analyses similarly pursue this approach. See Hanushek, Kain, O'Brien, and Rivkin (2005), and Hanushek and Rivkin (2006).

49. For other analyses of this sort, see among others Hanushek (1971, 1992), Murnane (1975), Armor et al. (1976), Murnane and Phillips (1981), Aaronson, Barrow, and Sander (2007), Rockoff (2004), Boyd, Grossman, Lankford, Loeb, and Wyckoff (2006), and Kane, Rockoff, and Staiger (2006).

50. In Egyptian schools, Hanushek, Lavy, and Hitomi (2008) find that students tend to dropout much more frequently from low value-added schools as compared to high value-added schools. Similarly, in U.S. charter schools student exit rates are significantly higher for low value-added schools as compared to high value-added schools (Hanushek, Kain, Rivkin, & Branch, 2007).

References

Aaronson, D., Barrow, L., & Sander, W. (2007). Teachers and student achievement in the Chicago public high schools. *Journal of Labor Economics, 25*, 95–135.

Acemoglu, D., & Angrist, J. D. (2000). How large are the social returns to education? Evidence from compulsory schooling laws. In B. S. Bernanke & K. Rogoff (Eds.), *NBER Macroeconomics Annuals, 2000* (pp. 9–59). Cambridge, MA: MIT Press.

Alderman, H., Behrman, J. R., Ross, D. R., & Sabot, R. (1996). The returns to endogenous human capital in Pakistan's rural wage labour market. *Oxford Bulletin of Economics and Statistics, 58*, 29–55.

Altonji, J. G., & Pierret, C. R. (2001). Employer learning and statistical discrimination. *Quarterly Journal of Economics, 116*, 313–350.

Angrist, J. D., & Lavy, V. (1997). The effect of a change in language of instruction on the returns to schooling in Morocco. *Journal of Labor Economics, 15*(S1), S48–S76.

Armor, D. J., Conry-Oseguera, P., Cox, M., King, N., McDonnell, L., Pascal, A., et al. (1976). *Analysis of the school preferred reading program in selected Los Angeles minority schools*. Santa Monica, CA: RAND Corp.

Barro, R. J. (1991). Economic growth in a cross section of countries. *Quarterly Journal of Economics, 106*, 407–443.

Barro, R. J. (2001). Human capital and growth. *American Economic Review, 91*, 12–17.

Barro, R. J., & Lee, J-W. (2001). International data on educational attainment: Updates and implications. *Oxford Economic Papers, 53,* 541–563.

Barro, R. J., & Sala-i-Martin, X. (2004). *Economic growth* (2nd ed.). Cambridge, MA: MIT Press.

Bedard, K. (2001). Human capital versus signaling models: University access and high school dropouts. *Journal of Political Economy, 109*, 749–775.

Behrman, J. R., Kletzer, L. G., McPherson, M. S., & Schapiro, M. O. (1998). The microeconomics of college choice, careers, and wages: Measuring the impact of higher education. *Annals of the American Academy of Political and Social Science, 559*, 12–23.

Behrman, J. R., Ross, D., & Sabot, R. (2008). Improving the quality versus increasing the quantity of schooling: Estimates of rates of return from rural Pakistan. *Journal of Development Economics, 85*, 94–104.

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development: Evidence from aggregate cross-country data. *Journal of Monetary Economics, 34,* 143–174.

Benhabib, J., & Spiegel, M. M. (2005). Human capital and technology diffusion. In P. Aghion & S. N. Durlauf (Eds.), *Handbook of economic growth* (pp. 935–966). Amsterdam: North Holland.

Bils, M., & Klenow, P. J. (2000). Does schooling cause growth? *American Economic Review, 90*, 1160–1183.

Bishop, J. H. (1989). Is the test score decline responsible for the productivity growth decline? *American Economic Review, 79*, 178–197.

Bishop, J. H. (1991). Achievement, test scores, and relative wages. In M. H. Kosters (Ed.), *Workers and their wages* (pp. 146–186). Washington, DC: The AEI Press.

Blackburn, M. L., & Neumark, D. (1993). Omitted-ability bias and the increase in the return to schooling. *Journal of Labor Economics, 11*, 521–544.

Blackburn, M. L., & Neumark, D. (1995). Are OLS estimates of the return to schooling biased downward? Another look. *Review of Economics and Statistics, 77*, 217–230.

Boissiere, M. X., Knight, J. B., & Sabot, R. H. (1985). Earnings, schooling, ability, and cognitive skills. *American Economic Review, 75*, 1016–1030.

Boozer, M. A., Krueger, A. B., & Wolkon, S. (1992). Race and school quality since *Brown v. Board of Education*. In M. N. Baily & C. Winston (Eds.), *Brooking papers on economic activity: Microeconomics* (pp. 269–338). Washington, DC: Brookings.

Bosworth, B. P., & Collins, S. M. (2003). The empirics of growth: An update. *Brookings papers on economic activity, 2003, No. 2* (pp. 113–206). Washington, DC: Brookings.

Bound, J., & Freeman, R. B. (1992). What went wrong? The erosion of relative earnings and employment among young black men in the 1980s. *Quarterly Journal of Economics, 107*, 201–232.

Bowles, S., Gintis, H., & Osborne, M. (2001). The determinants of earnings: A behavioral approach. *Journal of Economic Literature, 39*, 1137–1176.

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (2006). How changes in entry requirements alter the teacher workforce and affect student achievement. *Education Finance and Policy, 1,* 176–216.

Boyd, D., Lankford, H., Loeb, S., & Wyckoff, J. (2005). The draw of home: How teachers' preferences for proximity disadvantage urban schools. *Journal of Policy Analysis and Management, 24*, 113–132.

Bracey, G. W. (2002, May 5). Why do we scapegoat the schools? *Washington Post*, p. B01.

Card, D. (1999). Causal effect of education on earnings. In O. Ashenfelter & D. Card (Eds.), *Handbook of labor economics* (pp. 1801–1863). Amsterdam: North-Holland.

Card, D., Krueger, A. B. (1992). School quality and Black-White relative earnings: A direct assessment. *Quarterly Journal of Economics, 107*, 151–200.

Ciccone, A., & Papaioannou, E. (2005). *Human capital, the structure of production, and growth* (CEPR Discussion Paper No. 5354). Barcelona, Spain: Universitat Pompeu Fabra.

Committee on Science, Engineering, and Public Policy. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Coulombe, S., & Tremblay, J-F. (2006). Literacy and growth. *Topics in Macroeconomics, 6*, 1404.

Coulombe, S., Tremblay, J-F., Marchand, S. (2004). *Literacy scores, human capital and growth across fourteen OECD countries*. Ottawa: Statistics Canada.

Cunha, F., Heckman, J. J., Lochner, L., & Masterov, D. V. (2006). Interpreting the evidence on life cycle skill formation. In E. A. Hanushek & F. Welch (Eds.), *Handbook of the Economics of Education, Vol. 1* (pp. 697–812). Amsterdam: Elsevier.

Deere, D. (2001). Trends in wage inequality in the United States. In F. Welch (Ed.), *The causes and consequences of increasing inequality* (pp. 9–35). Chicago: University of Chicago Press.

Deere, D. & Vesovic, J. (2006). Educational wage premiums and the U.S. income distribution: A survey. In E. A. Hanushek & F. Welch (Eds.), *Handbook of the economics of education, Vol. 1* (pp. 55–306). Amsterdam: North Holland.

Dugan, D. J. (1976). Scholastic achievement: Its determinants and effects in the education industry. In J. T. Froomkin, D. T. Jamison, & R. Radner (Eds.), *Education as an industry* (pp. 53–83). Cambridge, MA: Ballinger.

Easterly, W. (2001). *The elusive quest for growth: An economists' adventures and misadventures in the tropics*. Cambridge, MA: MIT Press.

Farrell, P., & Fuchs, V. R. (1982). Schooling and health: The cigarette connection. *Journal of Health Economics, 1*, 217–230.

Figlio, D. N., & Ladd, H. F. (2007). School accountability and student achievement. In H. F. Ladd & E. B. Fiske (Eds.), *Handbook of research in education finance and policy* (pp. 166–182). Mahwah, NJ: Erlbaum.

Finnie, R., & Meng, R. (2002). Minorities, cognitive skills, and incomes of Canadians. *Canadian Public Policy, 28*, 257–273.

Glewwe, P. (1996). The relevance of standard estimates of rates of return to schooling for educational policy: A critical assessment. *Journal of Development Economics, 51*, 267-290.

Glewwe, P. (2002). Schools and skills in developing countries: Education policies and socioeconomic outcomes. *Journal of Economic Literature, 40*, 436–482.

Glewwe, P., & Kremer, M. (2006). Schools, teachers, and educational outcomes in developing countries. In E. A. Hanushek & F. Welch (Eds.), *Handbook of the economics of education, Vol. 2* (pp. 943–1017). Amsterdam: North Holland.

Goldin, C. (1998). America's graduation from high school: The evolution

and spread of secondary schooling in the twentieth century. *Journal of Economic History, 58*, 345–374.

Goldin, C., & Katz, L. F. (2008). *The race between education and technology: The evolution of U.S. educational wage differentials, 1890 to 2005*. Cambridge, MA: Harvard University Press.

Green, D. A., & Riddell, W. C. (2003). Literacy and earnings: An investigation of the interaction of cognitive and unobserved skills in earnings generation. *Labour Economics, 10*, 165–184.

Grogger, J. T. (1996). Does school quality explain the recent black/white wage trend? *Journal of Labor Economics, 14*, 231–253.

Grogger, J. T., Eide, E. (1993). Changes in college skills and the rise in the college wage premium. *Journal of Human Resources, 30*, 280–310.

Gundlach, E., Rudman, D., & Woessmann, L. (2002). Second thoughts on development accounting. *Applied Economics, 34*, 1359–1369.

Hanushek, E. A. (1971). Teacher characteristics and gains in student achievement: Estimation using micro data. *American Economic Review, 60*, 280–288.

Hanushek, E. A. (1979). Conceptual and empirical issues in the estimation of educational production functions. *Journal of Human Resources, 14*, 351–388.

Hanushek, E. A. (1986). The economics of schooling: Production and efficiency in public schools. *Journal of Economic Literature, 24*, 1141–1177.

Hanushek, E. A. (1992). The trade-off between child quantity and quality. *Journal of Political Economy, 100*, 84–117.

Hanushek, E. A. (1994). Money might matter somewhere: A response to Hedges, Laine, and Greenwald. *Educational Researcher, 23*, 5–8.

Hanushek, E. A. (1995). Interpreting recent research on schooling in developing countries. *World Bank Research Observer, 10*, 227–246.

Hanushek, E. A. (1999). The evidence on class size. In S. E. Mayer & P. E. Peterson (Eds.), *Earning and learning: How schools matter* (pp. 131–168). Washington, DC: Brookings Institution.

Hanushek, E. A. (2002). Publicly provided education. In A. J. Auerbach & M. Feldstein (Eds.), *Handbook of public* economics (pp. 2045–2141). Amsterdam: Elsevier.

Hanushek, E. A. (2003a). The failure of input-based schooling policies. *Economic Journal,* 113, F64–F98.

Hanushek, E. A. (2003b). The importance of school quality. In P. E. Peterson & J. E. Chubb (Eds.), *Our schools and our future: Are we still at risk?* (pp. 141–173). Stanford, CA: Hoover Institution Press.

Hanushek, E. A., Jamison, D. T., Jamison, E. A., & Woessmann, L. (2008). Education and economic growth: It's not just going to school but learning that matters. *Education Next, 8*(2), 62–70.

Hanushek, E. A., Kain, D. F., O'Brien, J. F., Rivkin, S. G. (2005, February). *The market for teacher quality* (Working Paper No. 11154). Cambridge, MA: National Bureau of Economic Research.

Hanushek, E. A., Kain, J. F., & Rivkin, S. G. (2004a). The revolving door. *Education Next, 4*(1), 77–82.

Hanushek, E. A., Kain, J. F., & Rivkin, S. G. (2004b). Why public schools lose teachers. *Journal of Human Resources, 39*, 326–354.

Hanushek, E. A., Kain, J. F., Rivkin, S. G., & Branch, G. F. (2007). Charter school quality and parental decision making with school choice. *Journal of Public Economics, 91*, 823–848.

Hanushek, E. A., & Kimko, D. D. (2000). Schooling, labor force quality, and the growth of nations. *American Economic Review, 90*, 1184–1208.

Hanushek, E. A., Lavy, V., Hitomi, K. (2008). Do students care about school quality? Determinants of dropout behavior in developing countries. *Journal of Human Capital, 1*, 69–105.

Hanushek, E. A., & Pace, R. R. (1995). Who chooses to teach (and why)? *Economics of Education Review, 14*, 101–117.

Hanushek, E. A., & Raymond, M. E. (2005). Does school accountability lead to improved student performance? *Journal of Policy Analysis and Management, 24*, 297–327.

Hanushek, E. A., & Rivkin, S. G. (2004). How to improve the supply of high quality teachers. In D. Ravitch (Ed.), *Brookings Papers on Education Policy, 2004* (pp. 7–25). Washington, DC: Brookings Institution Press.

Hanushek, E. A., & Rivkin, S. G. (2006). Teacher quality. In E. A. Hanushek & F. Welch (Eds.), *Handbook of the economics of education, Vol. 2* (pp. 1051–1078). Amsterdam: North Holland.

Hanushek, E. A., Rivkin, S. G., & Taylor, L. L. (1996). Aggregation and the estimated effects of school resources. *Review of Economics and Statistics, 78*, 611–627.

Hanushek, E. A., & Woessmann, L. (2006, October). The role of school improvement in economic development (NBER Working Paper No. 12832). Cambridge, MA: National Bureau of Economic Research.

Hanushek, E. A., & Woessmann, L. (2008). The role of cognitive skills in economic development. *Journal of Economic Literature, 46,* 607–668.

Hanushek, E. A., Woessmann, L. (in preparation). *The human capital of nations*.

Hanushek, E. A., & Zhang, L. (2008, March). *Quality consistent estimates of international returns to skill* [mimeo]., Stanford, CA: Stanford University, Hoover Institution.

Harbison, R. W., & Hanushek, E. A. (1992). *Educational performance of the poor: Lessons from rural northeast Brazil*. New York: Oxford University Press.

Hauser, R. M. (1993). The decline in college entry among African Americans: Findings in search of explanations. In P. M. Sniderman, P. E. Tetlock, & E. G. Carmines (Eds.), *Prejudice, politics, and the American dilemma* (pp. 271–306). Stanford, CA: Stanford University Press.

Haveman, R. H., & Wolfe, B. L. (1984). Schooling and economic well-being: The role of nonmarket effects. *Journal of Human Resources, 19*, 377–407.

Heckman, J. J., & LaFontaine, P. A. (2007, December). *The American high school graduation rate: Trends and levels* (NBER Working Paper No. 13670). Cambridge, MA: National Bureau of Economic Research.

Heckman, J. J., Stixrud, J., & Urzua, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics, 24*, 411–482.

Hedges, L. V., Laine, R. D., & Greenwald, R. (1994). Does money matter? A meta-analysis of studies of the effects of differential school inputs on student outcomes. *Educational Researcher, 23*(3), 5–14.

Jamison, E. A., Jamison, D. T., & Hanushek, E. A. (2007). The effects of education quality on income growth and mortality decline. *Economics of Education Review, 26*, 772–789.

Jaynes, G. D., & Williams, R. M., Jr. (Eds.). (1989). *A common destiny: Blacks and American society*. Washington, DC: National Academy Press.

Jolliffe, D. (1998). Skills, schooling, and household income in Ghana. *World Bank Economic Review, 12*, 81–104.

Jorgenson, D. W., & Fraumeni, B. M. (1992). Investment in education and U.S. economic growth. *Scandinavian Journal of Economics, 94*(Suppl.), S51–S70.

Juhn, C., Murphy, K. M., & Pierce, B. (1993). Wage inequality and the rise in returns to skill. *Journal of Political Economy, 101*, 410–442.

Kane, T. J. (1994). College entry by Blacks since 1970: The role of college costs, family background, and the returns to education. *Journal of Political Economy, 102*, 878–911.

Kane, T. J., Rockoff, J. E., & Staiger, D. O. (2006, April). What does certification tell us about teacher effectiveness? Evidence from New York City (NBER Working Paper No. 12155) Cambridge, MA: National Bureau of Economic Research.

Knight, J. B., & Sabot, R. H. (1990). *Education, productivity, and inequality: The East African Natural Experiment*. New York: Oxford University Press.

Kosters, M. H. (1991). Wages and demographics. In M. H. Kosters (Ed.), *Workers and their wages* (pp. 1–32). Washington, DC: The AEI Press.

Krueger, A. B. (1999). Experimental estimates of education production functions. *Quarterly Journal of Economics, 114*, 497–532.

Krueger, A. O. (1974). The political economy of the rent seeking society. *American Economic Review, 64*, 291–303.

Layard, R., & Psacharopoulos, G. (1974). The screening hypothesis and the returns to education. *Journal of Political Economy, 82*, 985–998.

Lazear, E. P. (2003). Teacher incentives. *Swedish Economic Policy Review, 10*, 179–214.

Lee, D. W., & Lee, T. H. (1995). Human capital and economic growth: Tests based on the international evaluation of educational achievement. *Economics Letters, 47*, 219–225.

Leibowitz, A. (1974). Home investments in children. *Journal of Political Economy, 82*, S111–S131.

Levy, F., & Murnane, R. J. (1992). U.S. earnings levels and earnings inequality: A review of recent trends and proposed explanations. *Journal of Economic Literature, 30*, 1333–1381.

Lochner, L., & Moretti, E. (2001, November). *The effect of education on crime: Evidence from prison inmates, arrests, and self-reports* (NBER Working Paper No. 8605). Cambridge, MA: National Bureau of Economic Research.

Loeb, S., & Page, M. E. (2000). Examining the link between teacher wages and student outcomes: The importance of alternative labor market opportunities and non-pecuniary variation. *Review of Economics and Statistics, 82*, 393–408.

Lucas, R. E. (1988). On the mechanics of economic development. *Journal of Monetary Economics, 22*, 3–42.

Mankiw, N. G., Romer., D., & Weil, D. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics, 107*, 407–437.

Manski, C. F.,& Wise, D. A. (1983). *College choice in America*. Cambridge, MA: Harvard University Press.

McIntosh, S., & Vignoles, A. (2001). Measuring and assessing the impact of basic skills on labor market outcomes. *Oxford Economic Papers, 53*, 453–481.

McMahon, W. W. (1991). Relative returns to human and physical capital in the U.S. and efficient investment strategies. *Economics of Education Review, 10*, 283–296.

Michael, R. T. (1982). Measuring non-monetary benefits of education: A survey. In W. W. McMahon & T. G. Geske (Eds.), *Financing education: Overcoming inefficiency and inequity* (pp. 119–149). Urbana: University of Illinois Press.

Mishel, L., & Rothstein, R. (Eds.). (2002). *The class size debate*. Washington, DC: Economic Policy Institute.

Moll, P. G. (1998). Primary schooling, cognitive skills, and wage in South Africa. *Economica, 65*(258), 263–284.

Mulligan, C. B. (1999). Galton versus the human capital approach to inheritance. *Journal of Political Economy, 107*, S184–S224.

Murnane, R. J. (1975). *The impact of school resources on the learning of inner city children*. Cambridge, MA: Ballinger.

Murnane, R. J., & Phillips, B. (1981). What do effective teachers of inner-city children have in common? *Social Science Research, 10*, 83–100.

Murnane, R. J., Willett, J. B., Braatz, M. J., & Duhaldeborde, Y. (2001). Do different dimensions of male high school students' skills predict labor market success a decade later? Evidence from the NLSY. *Economics of Education Review, 20*, 311–320.

Murnane, R. J., Willett, J. B., Duhaldeborde, Y., & Tyler, J. H. (2000). How important are the cognitive skills of teenagers in predicting subsequent earnings? *Journal of Policy Analysis and Management, 19,* 547–568.

Murnane, R. J., Willett, J. B., & Levy, F. (1995). The growing importance of cognitive skills in wage determination. *Review of Economics and Statistics, 77*, 251–266.

Murphy, K. M., & Welch, F. (1989). Wage premiums for college graduates: Recent growth and possible explanations. *Educational Researcher, 18*(4), 17–26.

Murphy, K. M., & Welch, F. (1992). The structure of wages. *Quarterly Journal of Economics, 107*, 285–326.

Neal, D. (2006). Why has Black-White skill convergence stopped? In E. A. Hanushek & F. Welch (Eds.), *Handbook of the economics of education, Vol. 1* (pp. 511–576). Amsterdam: North Holland.

Neal, D. A., & Johnson, W. R. (1996). The role of pre-market factors in Black-White differences. *Journal of Political Economy, 104*, 869–895.

Nelson, R. R., & Phelps, E. (1966). Investment in humans, technological diffusion and economic growth. *American Economic Review, 56*, 69–75.

O'Neill, J. (1990). The role of human capital in earnings differences between Black and White men. *Journal of Economic Perspectives, 4*(4), 25–46.

Organisation for Economic Co-operation and Development (OECD). (2001). *Education at a glance: OECD Indicators 2001*. Paris: Author.

Organisation for Economic Co-operation and Development (OECD). (2005). *Education at a glance: OECD Indicators 2005*. Paris: Author.

Parente, S. L., & Prescott, E. C. (1994). Barriers to technology adoption and development. *Journal of Political Economy, 102*, 298–321.

Parente, S. L., & Prescott, E. C. (1999). Monopoly rights: A barrier to riches. *American Economic Review, 89*, 1216–1233.

Pierce, B., & Welch, F. (1996). Changes in the structure of wages. In E. A. Hanushek & D. W. Jorgenson (Eds.), *Improving America's schools: The role of incentives* (pp. 53–73). Washington, DC: National Academy Press.

Pritchett, L. (2001). Where has all the education gone? *World Bank Economic Review, 15*, 367–391.

Pritchett, L. (2006). Does learning to add up add up? The returns to schooling in aggregate data. In E. A. Hanushek & F. Welch *Handbook of the Economics of Education*, *Vol. 1* (pp. 635–695). Amsterdam: North Holland.

Psacharopoulos, G. (1994). Returns to investment in education: A global update. *World Development, 22*, 1325–1344.

Riley, J. G. (2001). Silver signals: Twenty-five years of screening and signaling. *Journal of Economic Literature, 39*, 432–478.

Rivkin, S. G. (1995). Black/White differences in schooling and employment. *Journal of Human Resources, 30*, 826–852.

Rivkin, S. G., Hanushek, E. A.,& Kain, J. F. (2005). Teachers, schools, and academic achievement. *Econometrica, 73*, 417–458.

Rockoff, J. E. (2004). The impact of individual teachers on student achievement: Evidence from panel data. *American Economic Review, 94*, 247–252.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy, 98*, S71–S102.

Rose, H. (2006). Do gains in test scores explain labor market outcomes? *Economics of Education Review* 25, 430–446.

Schultz, T. W. (1975). The value of the ability to deal with disequilibria. *Journal of Economic Literature, 13*, 827–846.

Smith, J. P., & Welch, F. (1989). Black economic progress after Myrdal. *Journal of Economic Literature, 27*, 519–564.

Spence, A. M. (1973). Job market signalling. *Quarterly Journal of Economics, 87*, 355–374.

Stanley, H. W., & Niemi, R. G. (2000). *Vital statistics on American politics*. Washington, DC: CQ Press.

Teixeira, R. A. (1992). *The disappearing American voter*. Washington, DC: Brookings Institution.

Tyler, J. H., Murnane, R. J., & Willett, J. B. (2000). Estimating the labor market signaling value of the GED. *Quarterly Journal of Economics, 115*, 431–468.

U.S. Bureau of the Census. (1975). *Historical statistics of the United States, colonial times to 1970, bicentennial edition* (Parts 1-2). Washington, DC: U.S. Government Printing Office.

U. S. Bureau of the Census. (2000). *Statistical abstract of the United States: 2000*. Washington, DC: U.S. Government Printing Office.

Vandenbussche, J., Aghion, P., & Meghir, C. (2006). Growth, distance to frontier and composition of human capital. *Journal of Economic Growth, 11*, 97–127.

Vijverberg, W. P. M. (1999). The impact of schooling and cognitive skills on income from non-farm self-employment. In P. Glewwe (Ed.), *The economics of school quality investments in developing countries: An empirical study of Ghana* (pp. 206–252). New York: St. Martin's Press.

Weiss, A. (1995). Human capital vs. signalling explanations of wages. *Journal of Economic Perspectives, 9*(4), 133–154.

Welch, F. (1970). Education in production. *Journal of Political Economy, 78*, 35–59.

Welch, F. (1999). In defense of inequality. *American Economic Review, 89*(2), 1–17.

Wolfe, B. L., & Zuvekas, S. (1995, May). Nonmarket outcomes of schooling (Discussion Paper No. 1065-95), Madison: University of Wisconsin, Institute for Research on Poverty.

Wolpin, K. I. (1977). Education and screening. *American Economic Review, 67*, 949–958.

World Bank. (1993). *The East Asian miracle: Economic growth and public policy*. New York: Oxford University Press.

Woessmann, L. (2002). *Schooling and the quality of human capital* Berlin, Germany: Springer.

Woessmann, L. (2003). Specifying human capital. *Journal of Economic Surveys, 17*, 239–270.

Woessmann, L. (2005). Educational production in Europe. *Economic Policy, 20*, 446–504.

Woessmann, L. (2007). International evidence on expenditure and class size: A review. In *Brookings Papers on Education Policy 2006–2007* (pp. 245–272). Washington DC: Brookings Institution.