The Race between Education and Technology

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The Race between Education and Technology

Introduction

At the dawn of the twentieth century the United States became the richest nation in the world. Its people had a higher average standard of living than those in Britain, the previous leader. America was poised to ascend further. The gap between it and other front-runners would widen and the standard of living of its residents would continue to grow, even when its doors were open to the world's poor. American economic supremacy would be maintained to the end of the century, and beyond. In economic terms, the twentieth century fully merits the title "The American Century."

The twentieth century could also be titled the "Human Capital Century." By the end of the twentieth century all nations, even the poorest, provided elementary schooling and beyond to most of their citizens. At the start of the century and even by its midpoint many nations, including relatively rich ones, educated only those who could personally afford to attend school. The United States was different. Its educational system had always been less elite than those of European countries. By 1900, if not before, it had begun to educate its masses at the secondary level not just in primary schools, at which it had remarkable success in the nineteenth century.

That the twentieth century was both the American Century *and* the Human Capital Century is no historical accident. Economic growth in the more modern period requires educated workers, managers, entrepreneurs, and citizens. Modern technologies must be invented, innovated, put in place, and maintained. They must have capable workers at the helm. Rapid technological advance, measured in various ways, has characterized the twentieth century. Because the American people were the most educated in the world, they were in the best position to invent, be entrepreneurial, and produce goods and services using advanced technologies.

The connection between the American Century and the Human Capital Century concerns the role of education in economic growth and individual productivity. A greater level of education results in higher labor productivity. Moreover, a greater level of education in the entire nation tends to foster a higher rate of aggregate growth. The nation that invested the most in education, and did much of that investment during the century in which education would critically matter, was the nation that had the highest level of per capita income.

We do not mean to imply that economic growth is a simple matter of investing in education. If it were, then any poor nation could invest in education, wait a few years, and reap enormous economic returns. But given a set of important preconditions, such as the type of government and the security of property rights, the notion that the American Century and the Human Capital Century occurred together follows directly from the relationships among growth, technology, and education. Invest in education, get higher levels of technology and productivity, and attain a rapid rate of economic growth and a higher standard of living. However, the benefits from economic growth might be unequally distributed and a high average standard of living might not translate into betterment for all.

If these statements regarding the role of education in technological change and economic growth are correct, then rapid technological change would also increase the demand for more educated workers at all levels. With increased demand for their services, the earnings of the more educated would rise relative to the less educated. In the absence of an increased supply of educated workers, the gap between the earnings of those with more and less education would expand. If there are various educational groups in society, ranging from the lowest to the most highly educated, and if the groups were fixed in relative proportions, then technological advances would unambiguously increase economic inequality since the relative income gap between the less and the more educated would rise. Yet if, in addition to technological progress, the quantity and possibly the quality of education increases, then inequality could decrease.

The American Century with its great technological progress and economic growth could well have been an era of ever-expanding inequality. Economic growth could have entailed considerably more income for some, with scant increases, if any, for others. Instead, the first three-quarters of the American Century was an era of long-term economic growth and *declining* inequality. For much of the twentieth century the gains from economic growth became *more* equally distributed. But by the end of the 1970s, an abrupt and substantial rise in economic inequality ensued. In addition, average real wage growth slowed. In the last three decades of the century there were times when most Americans gained, although those at the top gained considerably more. However, there were also times when the real incomes of those in the lowest third of the distribution stagnated.

The economic well-being of Americans increased monumentally and almost continuously throughout the twentieth century despite various setbacks, such as several small recessions and the Great Depression of the 1930s. Income per capita in 2000 was five to six times its level in 1900, using standard measures of income and of the price level. Adjustments to the quality of goods and services would serve to increase the figure, perhaps substantially. The rate of increase in the income of the entire nation, known as Gross Domestic Product (GDP), was rapid and remarkably constant across the century at around 3.2 percent average annually. On a per capita basis, the measure increased somewhat more after the 1940s. From 1900 to 1929 real income per capita increased by about 1.7 percent on an average annual basis. It increased to 1.9 percent after 1950. Thus, there was a slight acceleration in economic growth in per capita terms across the century.

In sharp contrast to economic growth, which was relatively continuous, economic inequality was highly discontinuous. The twentieth century contains two distinct inequality components. Inequality initially declined, in several stages, from 1900 to about the third quarter of the century. Inequality then rose, often spectacularly, to the end of the century. By most measures, economic inequality is now as high as it was prior to its great decline. That is, inequality today is as high as it was during the Great Depression and probably for some time before.

One of the key links between these two parts of the economic system—technological change and inequality—is educational progress. Educational attainment, as measured by the completed schooling levels of successive cohorts, was exceptionally rapid and continuous for the first three-quarters of the twentieth century. But educational advance slowed considerably for young adults beginning in the 1970s and for the overall labor force by the early 1980s. For cohorts born from the 1870s to about 1950, every decade was accompanied by an increase of about 0.8 years of education. During that 80-year period the vast majority of parents had children whose educational attainment greatly exceeded theirs. Educational change between the generations then came to an abrupt standstill. An important part of the American dream, that children will do better than their parents, was threatened, and this danger was even greater than the educational data would suggest. The reason is that the decrease in inequality and then the increase in inequality during the American Century are mimicked in another important economic indicator—productivity change.

Productivity change in the United States, as measured by the increase in output per worker hour, had been rapid during much of the twentieth century but it slowed during the latter part. The slowdown, it appears, ended in the late 1990s, but not soon enough. National income was considerably lower than it would have been had productivity change kept pace. In fact, the only reason that real income per capita could sustain its rapid clip in the face of a slowing of labor productivity was that the labor force expanded more rapidly than did the population. Americans were running harder just to maintain their previous rate of economic growth.

At the beginning of the twentieth century America was confident, even exuberant. There were, to be sure, industries such as steel and chemicals that still lagged behind their European competitors. But a vast sea of manufactured goods flowed from American ports. In industries such as book publishing, carriages, business machines, agricultural equipment, and industrial machinery Americans were portrayed as invaders. We were, as well, superior producers of raw and semiprocessed goods, such as grains, flour, meat, leather, and a host of nonreproducible resources including petroleum. In the first two decades of the twentieth century America emerged as the world's leading producer of manufactured goods, including the automobile—the symbol of the modern age.

America's economic competitors watched over their shoulders to see what Americans were doing and what they could emulate. The British, aware that they were losing their competitive edge, were frantically searching for "the secret of American success," as one account, *The American Invaders*, noted. Chief among the reasons offered for American supremacy was "their better education." Americans were winning the "battle" of economic competition with their "brains, enterprise and energy . . . their longer worker hours, their willingness to receive new ideas, their better plant, and perhaps most of all . . . their freedom from hampering traditions."[1] Some of these "hampering traditions" concerned education.

Today, at the start of the twenty-first century, the United States is somewhat less exuberant than it was a hundred years earlier. It had once demonstrated to the world the importance of universal education. The nations of Europe and Asia eventually followed America's lead, and some, in recent years, have begun to exceed U.S. high school and college graduation rates among younger cohorts. On standardized reading, math, and science exams the United States has lagged considerably, as demonstrated by the Third [also Trends in] International Math and Science Study (TIMSS) and Program for International Assessment (PISA).

The U.S. educational system from almost its inception was built on a set of "virtues" that contain many elements of American egalitarianism. The existence of slavery and the absence of equal access to education for most free African Americans during slavery and for some time after must qualify our use of the term *egalitarianism*. By the mid-nineteenth century schooling was, for most European-descent children, publicly funded, open, forgiving, gender neutral in most respects, secular, and publicly provided by a multitude of competing school districts.[2] In the chapters that follow we will explain in detail what we mean by each of these virtues and why they were meritorious at many moments in U.S. history. The important point here is that these virtues once furthered education at all levels but that they appear, to some, to be failing us today.

Rising inequality, lagging productivity for a prolonged period, and a rather non-stellar educational report card have led many to question the qualities that once made America the envy of all and a beacon for the world's people. Americans have never been complacent about the quality of their children's schooling, and the recent past has brought an onslaught of proposed and enacted reforms. Many of these reforms alter the qualities of American schooling that had been the virtues of the past. Vouchers, charter schools, public funding for church-based schools, and high-stakes testing with real consequences are some of the enacted reforms. Whether the virtues have run their course and whether the reforms will have praiseworthy outcomes is yet to be determined.

More important is that we have developed a form of collective amnesia about our past accomplishments. We may well be doing something wrong now that we once did right and there may be ways of altering our institutions to create an even more productive and equitable society. But an obsession with current problems has caused us to forget the special and spectacular history of American education and has led us, as well, to overlook the fact that higher education in America is still the finest in the world.

Our recent experience with rising inequality has also led to several misunderstandings about the role of technological change in the economy. Advancing technology does *not* inevitably produce an increase in the relative demand for skilled and educated workers. Grand technological changes during much of the nineteenth century probably did not increase the relative demand for skill; however, during most of the twentieth century technological change did increase the relative demand for skill and therefore was skill biased.

Rapid technological change does not always increase economic inequality, even when it is skill biased. Similarly, rising inequality in the latter part of the twentieth century does not imply that the rate of technological change accelerated the relative demand for educated and skilled workers. Economic inequality can decrease even with rapidly increasing demands for educated workers. Likewise, soaring inequality need not be due to acceleration in the relative demand for educated workers. In both instances, the supply of educated workers could be varying, increasing rapidly at some times and slowing down at others. This scenario is precisely what happened. One must not overlook the crucial other half of the inequality equation: the supply side.

The supply of educated Americans increased greatly and almost unceasingly from 1900 to around 1980. The enormous increase in educational attainment in the early part of the twentieth century came primarily from a grass-roots movement that propelled the building and staffing of public high schools. It was not due to a top-down mandate or pressure from the federal government, nor did it a result from powerful local interest groups or arise because of legal compulsion. Later in the century, after high schools had spread and attendance in them had grown, the expansion of state colleges and universities led to further increases in education.

But after around 1980 the supply of educated Americans slowed considerably. The sluggish growth in the educated workforce in the last quarter century has been mainly due to a slowing down in the educational attainment of those schooled in the United States, rather than to an increase in the foreign-born component of the workforce.

This book concerns a remarkable century of economic growth, technological change, advancing education, and even a narrowing of inequality during many of its years. It is about a unique set of enabling institutions that allowed the United States to have mass education and a level of schooling that far exceeded that of other rich nations until late in the twentieth century. It is also about why rapid technological advance in the twentieth century did not produce ever-increasing inequality and why the fruits of economic growth were often more equally distributed, at least until the last three decades.

The book is also concerned with what many see as the current malaise. In the years since the end of the 1970s, economic inequality has widened to levels as great as they were in the early twentieth century. We address the educational response and why, after generations of enormous advance, increases in years of schooling have stalled. The slowdown in the growth of educational attainment has been most extreme and disturbing for those at the bottom of the income distribution, particularly for racial and ethnic minorities. On the positive side, however, educational advances for women relative to men have been substantial. In fact, gender differences in both education and earnings relative to those for comparable men have gone against the general rising inequality tide of the past three decades.

The three main topics of this book—technological change, education, and inequality—are intricately related in a kind of "race." During the first three-quarters of the twentieth century, the rising supply of educated workers outstripped the increased demand caused by technological advances. Higher real incomes were accompanied by lower inequality. But during the last two decades of the century the reverse was the case and there was sharply rising inequality. Put another way, in the first half of the century, education raced ahead of technology, but later in the century, technology raced ahead of educational gains.[3] The skill bias of technology did not change much across the century, nor did its rate of change. Rather, the sharp rise in inequality was largely due to an educational slowdown.

The virtues of the past may not function as well in the present, and part of the recent rise in inequality may be a consequence. We are not advocating a particular way of fixing the system, but some aspects about what is wrong are fairly obvious. We end the book with a discussion of these issues.

I

ECONOMIC GROWTH AND DISTRIBUTION

1

The Human Capital Century

Investment in physical capital became vital to a nation's economic growth with the onset of the Industrial Revolution in the nineteenth century. But the path to ongoing economic success for nations and individuals eventually became investment in human capital. Human capital became supreme in the twentieth century and America led the way. At the start of that century, Americans had embraced the novel idea that the "wealth of nations" would be embodied in its human capital stock; it would take even the richer nations of Europe about five decades or more to catch on to that notion.

For most Americans in the early twentieth century access to schooling, at least through high school, was largely unlimited by personal station and residence. Education was publicly provided and funded and was free of direct charge, except at the highest levels. Even the most rural Americans had the privilege of sending their children to public secondary schools, although African Americans, especially in the South, were often excluded from various levels of schooling, especially above the common school.[1] Americans had a strong tradition of educating their youth at public charge and the expansion of education beyond the common school and elementary grades continued a commitment rooted in basic democratic and egalitarian principles. These "virtues" were many and together they created a commitment to equality of opportunity.[2]

Rather than being praised throughout the world, American educational institutions in the early twentieth century were roundly criticized. "There are those who are critical of the American high school because its doors are open to pupils of all types," said one notable commentator.[3] Because they allowed youths of all abilities to use public resources, European observers termed the American educational system "wasteful." In contrast, most European national systems tested boys and girls at an early age and promoted only the best, a system they viewed as meritocratic.[4] But targeting talent at a young age, such as at age 11, privileged those with social standing and more educated parents.[5] Americans chafed at selection and deemed it elitist.[6] Their system was not improvident; it was egalitarian.

By the early twentieth century America educated its youth to a far greater extent than did most, if not every, European country. Secondary schools in America were free and generally accessible, whereas they were costly and often inaccessible in most of Europe. Even by the 1930s America was virtually alone in providing universally free and accessible secondary schools.

America's approach to schooling was critically important to its technological dynamism, rapid economic growth, more equal income distribution, assimilation of great waves of immigrants, and transition to mass college education. In this chapter we present the trends in formal educational attainment for the United States and make comparisons with European nations at various moments in the twentieth century. We also set forth a framework to understand the economic significance of human capital for individuals and for the nation. But first we must demonstrate how the twentieth century became the Human Capital Century, and why the Human Capital Century turned out to be the American Century.

Human Capital and Income across Nations

Worldwide Schooling Rates at the Beginning of the Twenty-First Century

By the end of the twentieth century no country could afford *not* to educate its citizens beyond the elementary grades. The technologies of richer nations have spread throughout the globe. Workers now have to read complicated documents, master blueprints, work computers, solve formulas, and use the Internet, among other tasks. Simple literacy and numeracy are no longer sufficient. To be a full-fledged member of the global economy requires higher levels of education for most workers.

An educated citizenry does not guarantee rapid growth and inclusion in the "convergence club" of nations,[7] but the inverse of that statement is generally true.[8] Low levels of education nowadays prevent a nation from reaching the technological frontier and taking full advantage of the global economy. Most low-income nations today have schooling levels that are relatively high in contrast with historical standards. To demonstrate the enormous change in the role of education across the twentieth century, it is helpful to look at a cross section of nations at the start of the twenty-first century. We compare the secondary schooling rates and real income levels of more than one hundred nations at the start of the twenty-first century with the United States at various moments in its twentieth-century history.

Our demonstration reveals that at the beginning of the twenty-first century even nations with low income per capita have schooling rates that are high in comparison to the historical standards set by early twentieth-century America. When the United States had a per capita income level equal to that of many of today's low-income nations, its education rate was often less. The poorer nations of the current century appear to understand that they must endow their citizens with a secondary school education to operate in the world economy.

Consider Figure 1.1, in which the (net) secondary school enrollment rate is graphed against real gross domestic product (GDP) per capita, both in the year 2000, for 114 nations.[9] A positive correlation between income and schooling is revealed. Although the causality of the relationship (more education leads to greater income) has been the subject of much research, that is not the issue at the moment.[10] The main point of the figure is to demonstrate that secondary school enrollment rates in 2000 for low-income nations were substantial by the standards of the early to mid-twentieth century, even compared with higher-income nations of that period.

Because the United States was the leader in education in the twentieth century it will be the historical gold standard for this example. The solid vertical line that goes through the dot in Figure 1.1 gives U.S. real per capita GDP in 1900, immediately prior to the great

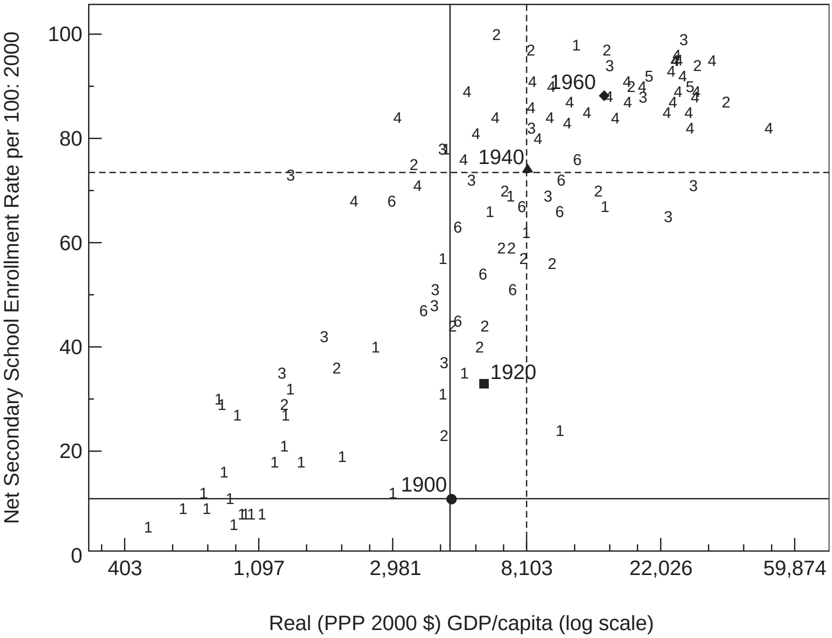


Figure 1.1. Net Secondary School Enrollment Rate and Real Per Capita GDP in 114 Countries: 2000. The numerical markers for each country refer to geographic groupings in the UNESCO data: 1 = Africa; 2 = Central and North America and the Caribbean; 3 = Asia, including the non-African Middle East; 4 = Europe; 5 = Oceania; and 6 = South America. The net secondary school enrollment rate nets out individuals who are not between the usual ages for students in these schools. The four markers with the circle (1900), square (1920), triangle (1940), and diamond (1960) refer to U.S. GDP/capita and net secondary school enrollment rates for the years given. Sources: Net secondary enrollment rates from United Nations Organization for Education, Science and Culture (UNESCO), http://unescostat.unesco.org/en/stats/stats0.htm. Real GDP/capita from the Penn World Table, http://pwt.econ.upenn.edu/ (Heston, Summers, and Aten 2002). "Real" in the Penn World Table means PPP (purchasing power parity).

increase of high school education in America. We will use the 1900 level of per capita GDP in year 2000 dollars, $4,596, as a loose definition of low per capita income in 2000.[11] The solid horizontal line, also going through the dot, represents the public and private secondary school rate that existed in the United States in 1900.[12] These two solid lines divide the graph into four quadrants. Our interest is in both the South-East and the North-West quadrants. Similar lines (dashed) have been drawn for the point given by the triangle, which gives the data for 1940. A box corresponds to the data for 1920 and a diamond signifies 1960. Lines for those years have been omitted for clarity.

Our interest in the South-East quadrant is as follows. Any country situated in that quadrant has an *income per capita higher* than that existing in the United States in the year being considered but an *enrollment rate that is lower*. One might think of the area as the "bad education" outcome quadrant. There are no countries in the bad education quadrant when the year given is 1900 and just one when the comparison date is 1920.[13] For the 1940 comparison there are nine bad education countries out of the 114, but just five are clearly within the quadrant whereas the others are on the margin. And for 1960, when both the secondary school enrollment rate and income per capita are quite high, about a dozen nations are in the bad education quadrant, but only six are clearly within it.[14]

The point is that almost all countries with incomes greater than the United States in a particular year have a secondary school enrollment rate that exceeds that attained in the United States for that year. Something fundamental changed during the twentieth century in the relationship between income per capita and schooling.

The other quadrant of note is the North-West, which we term the "good education" quadrant.[15] Nations found here have *education levels that are higher* than that in the United States in the given year, but *income levels that are lower*. They are, in some sense, overachieving on the education front (or, alternatively, underachieving on the income front). The good education quadrant is generally more crowded than is the bad education quadrant, until the comparison year has both high income and high schooling levels.

Of the 42 nations in the year 2000 with per capita income below our 1900 low income standard, 15 (36 percent) had net secondary school enrollment rates that exceeded 0.4.[16] If the income standard is set higher, say U.S. per capita income in 1920, 53 nations are below that cutoff and 25 (47 percent) had enrollment rates in the year 2000 that exceeded 0.4. We have chosen a secondary school enrollment rate of 0.4 as the standard. Secondary school enrollment rates, including full-time pupils in either general or technical schools, attained in European nations in the mid-1950s were never more than 40 percent and they were generally far lower (see Figure 1.7, below). The low-income nations we just described using either the 1900 or the 1920 income standard, therefore, had secondary school enrollment rates that were considerable even by the standards of mid-twentieth-century Europe. From 36 to 47 percent of youth from those low-income nations were enrolled in secondary school although their per capita incomes were substantially lower in real terms than were those in the European comparison group. In real per capita terms the average European nation in 1955 had a per capita income that was between three to four times that of the median low-income nation in 2000, even using 1920 as the low-income benchmark.[17]

The assertion we made at the outset is borne out by these data. Today's low-income nations and their people invest in education to a far greater degree, in terms of secondary school enrollment rates, than did the richer countries of the past.[18] They do so to partake in a global economy.[19] Some may eventually succeed and attain high growth rates, while others have such serious structural problems that they may be swimming against a strong tide.

Gender Differences in Schooling across Nations

The less well off a country, not surprisingly, the lower is the secondary school enrollment rate for all youth. Of equal interest, but somewhat less obvious, is that low-income nations have higher relative enrollment rates for males. In fact, when income per capita is above that achieved by the United States in 1900 (the low-income standard we used previously), gender distinctions in enrollment evaporate. Yet almost all the nations with incomes below the low-income standard have relative enrollment rates that favor males and in about one third the advantages for males are substantial (see Figure 1.2). Many of the low-income nations with relatively low levels of female schooling are predominantly Muslim countries (as indicated by the size of the country marker in Figure 1.2) and most are the poorer nations of Africa. Gender neutrality seems to be a virtue purchased with higher incomes. Similarly, gender differences in enrollment favoring males are apparent only when the enrollment rate is below about 0.4 (Figure 1.3). Almost all the nations to the left of the 0.4 dotted line are low income nations, all but two of the 27 are in Africa, and most are predominantly Muslim.

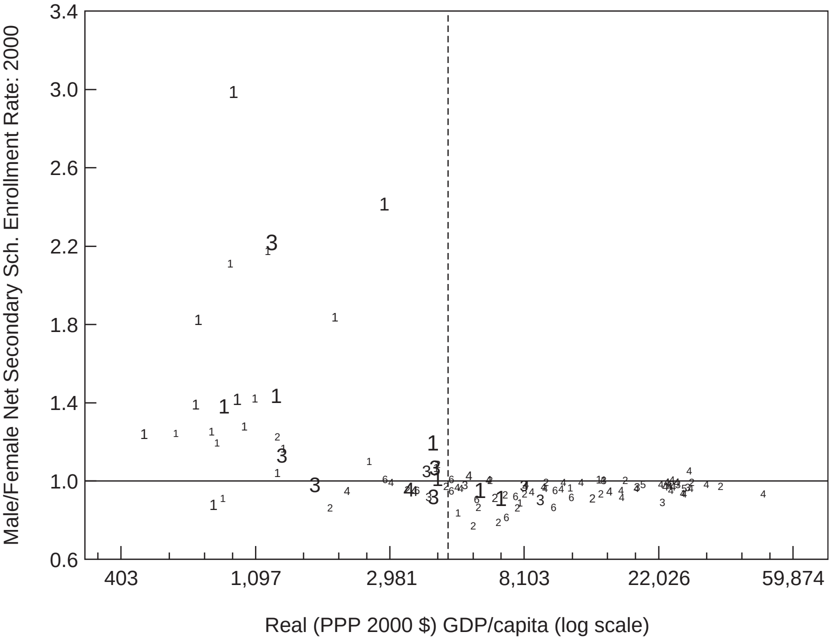


Figure 1.2. Ratio of Male to Female Secondary School Enrollment and Real GDP per Capita: 2000. The numerical markers for each country refer to the same regional groupings used in Figure 1.1. The size of the region marker indicates the fraction of the population that is Muslim. Sources: See Figure 1.1. Religion data by nation for the year 2000 are from Robert Barro (personal communication) who used Barrett, Kurian, and Johnson (2001).

We noted above that only the very poorest nations can afford not to educate their people. We now add to that concept by asserting that no nation today, save the very poorest, can afford not to educate its girls to the same degree as its boys.[20] The United States has led the world in both ideas. America began a major transformation to mass secondary schooling at the start of the Human Capital Century, and girls were educated in secondary schools to the same, and very often to a greater, degree than were boys.

The Human Capital Century became the American Century. Not only did the United States lead in education, it also began to lead in income per capita early in the twentieth century. It then expanded its lead in both education and income. Is the relationship causal or merely coincidental? Before we can judge the relationship between human capital and economic indicators, we first need estimates of the

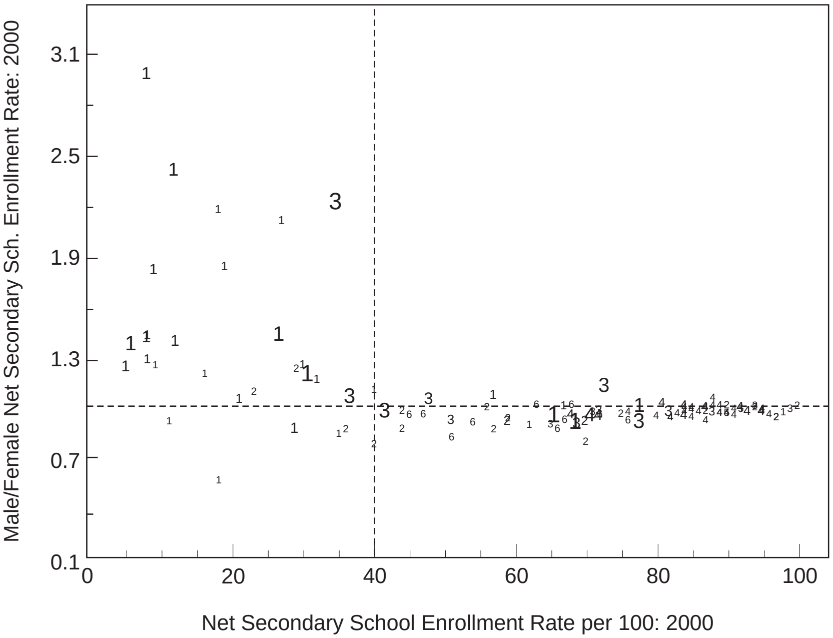


Figure 1.3. Ratio of Male to Female Secondary School Enrollment: 2000. Sources and Notes: See Figures 1.1 and 1.2.

educational stocks of the labor force built from educational attainment and other data.

America in the Human Capital Century

Educational Advance in the Twentieth Century

The United States expanded its lead in education in the twentieth century by instituting mass secondary schooling and then by establishing a flexible and multifaceted higher education system. These transformations to mass education are considered in detail in Part II. At this point, we summarize the broad outlines of schooling advances in the twentieth century by exploring the educational attainment of successive birth cohorts of native-born Americans.[21] In doing so we are observing changes in schooling across the twentieth century for those directly affected by the U.S. educational system. These estimates are then inputs to the computation of the educational stock of the U.S. labor force.[22] We focus on the educational attainment of each birth cohort measured at age 35, when almost all have completed their formal schooling.[23]

From the beginning of the twentieth century to the early 1970s, and for all groups considered here, the increase in years of schooling for the native-born population was substantial, as illustrated in Figure 1.4. For cohorts born between 1876 and 1951 (who were 24 years old from 1900 to 1975) the increase was 6.2 years, or 0.82 years per decade. The increase was sufficiently continuous and unbroken that a straight line would nicely fit the data, especially for the 1880 to 1940 birth cohorts.[24] After the 1951 birth cohort, however, a great slowdown ensued. Educational attainment barely changed for cohorts born between 1951 and 1965 (24 years old between 1975 and 1989), and for cohorts born from 1965 to 1975 (24 years old between 1989 and 1999), educational attainment started rising again but increased by just 6 months overall.

After increasing nonstop for the first three quarters of the twentieth century, educational attainment among the native-born population slowed considerably during the last quarter of the century. The educational attainment of a child born in 1975 was just 0.50 years more than that of his or her parents born in 1951, but the educational attainment of a child born in 1945 was 2.18 years more than that of his or her parents born in 1921. A well known dream of many American families is that their children will do better than they did. But that dream began to unravel in the latter part of the twentieth century, at least with regards to educational attainment.

Both men and women shared in the increase in educational attainment during the first three quarters of the twentieth century (Figure 1.5). Women gained more than did men both at the beginning and the end of the century. Men gained more during the middle decades. Women began the period with more education than did men, in large part because they attended and graduated from high school to a greater degree. In addition, women attended college at about the same rate as did men, although they graduated from four-year institutions to a lesser extent. Because college was but a small part of total schooling during the first few decades of the century and high school was far more important, native-born women accumulated more years of education than did their male counterparts.

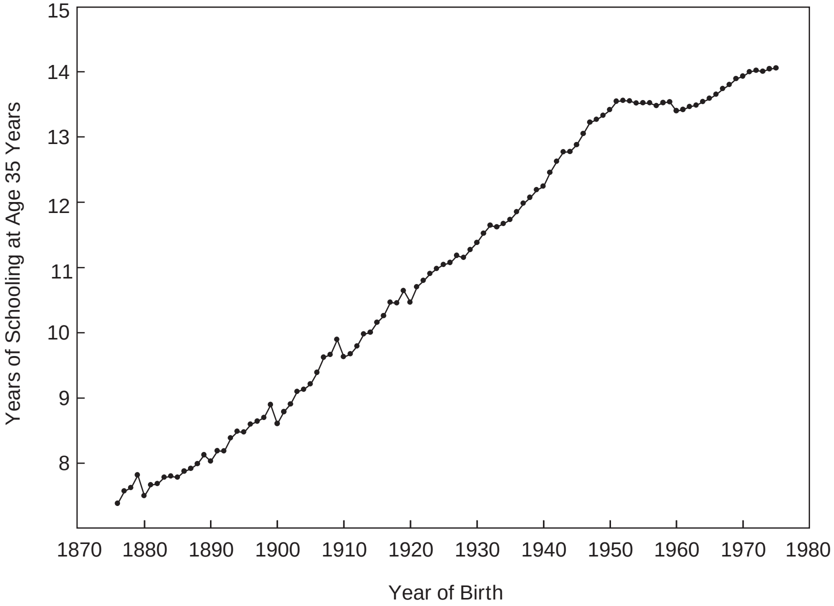


Figure 1.4. Years of Schooling by Birth Cohorts, U.S. Native-Born: 1876 to 1975. The figure plots the mean years of completed schooling by birth cohort adjusted to 35 years of age for the U.S.-born. For the 1940 to 1980 samples, years of schooling are given by the highest grade completed, top coded at 18 years for 1960 to 1980 and at 17.6 years for 1940 and 1950. The categorical education variable for the 1990 and 2000 samples was converted to years of completed schooling. Categories covering more than a single grade were translated as follows: 2.5 years for those in the first through fourth grade category; 6.5 years for those in the fifth through eighth grade category; 12 years for those with a general equivalency diploma or a high school diploma; 14 years for those with some college or with an associate's degree; 16 years for those with a bachelor's degree; 17.6 years for those with a master's degree; and 18 years for those with a professional or doctoral degree. The log of the mean years of schooling for a birth cohort-year cell is the dependent variable in the age-adjustment regression that includes a full set of birth-cohort dummies and a quartic in age as covariates. The age-adjustment regression is run on birth cohort-census year cells, pooling all the IPUMS for 1940 to 2000. The samples include all U.S.-born residents aged 25 to 64 years. For further details on the method, see DeLong, Goldin, and Katz (2003), notes to figure 2.1. Sources: 1940 to 2000 Census of Population Integrated Public Use Micro-data Samples (IPUMS).

The advantage women had in education disappeared rapidly with cohorts born in the 1910s and 1920s. Many men in these cohorts fought in World War II or in the Korean War and attended college on the G.I. Bill (other reasons for the vast relative increase in college among men are discussed in Chapter 7). Whatever the reason, the out-

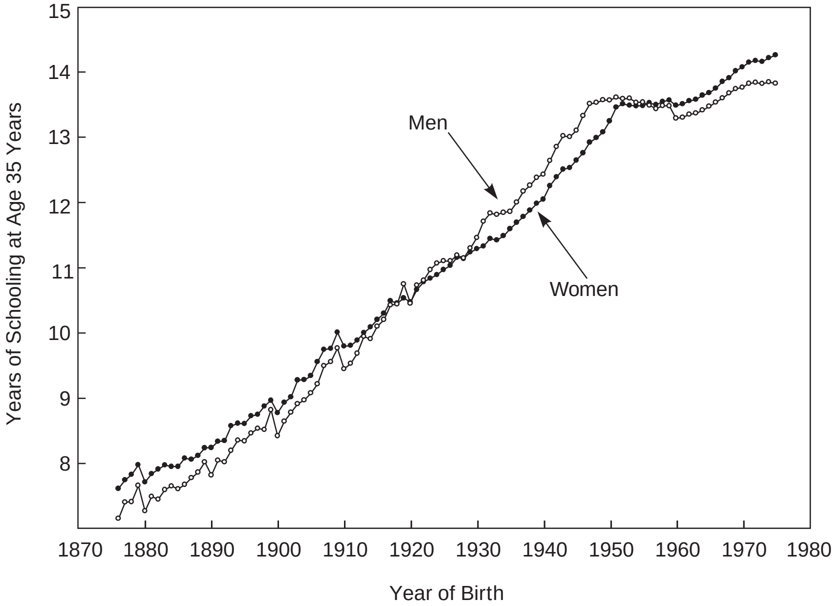


Figure 1.5. Years of Schooling by Birth Cohorts, U.S. Native-Born, by Sex: 1876 to 1975. This figure plots the mean years of completed schooling for U.S. native-born residents by birth cohort and sex, adjusted to age 35 using the approach described in the notes to Figure 1.4. Sources: 1940 to 2000 IPUMS.

come that is clear is that by the birth cohorts of the 1920s men caught up with women in educational attainment, and for the cohorts from the 1930s to the early 1950s they exceeded women in educational attainment. These gains, however, were reversed with cohorts born in the 1960s, as women rapidly increased their attendance at and graduation from college. At the end of the twentieth century women's educational attainment exceeded that of men just as it had during the early decades of the century.

Educational gains for African Americans were far greater than for the total population because their educational attainment began at so low a level. At the start of the period (for cohorts born in the late 1870s), the gap in educational attainment between whites and African Americans was 3.7 years. On average, white students spent nearly twice as long in school as did black students. Furthermore, differences in the actual level of schooling are understated by the attainment figures because there were wide discrepancies in the quality of schooling between the races. Beginning with the cohorts born around 1910 the absolute gap in years of schooling began to close (Figure 1.6). This convergence slowed with cohorts born around 1940 and slowed even more for those born after 1960. The black-white schooling gap for cohorts born in the 1970s was 0.8 years, about one-fifth its level a century earlier. The gap in educational attainment between non-Hispanic whites and U.S.-born Hispanics was 1.1 years for the 1970s birth cohorts, somewhat larger than the difference (0.7 years) between non-Hispanic whites and non-Hispanic blacks.[25]

Educational attainment during the twentieth century expanded by 5.27 years for those born in the United States from 1895 to 1975. About 50 percent of that gain was attributable to the rise of high school education (60 percent or more for cohorts born from 1895 to 1935), 30 percent was due to the increase in college and post-college education, and 20 percent to continued increases in elementary education. Thus the spread of mass secondary schooling, a movement that began in earnest around 1910, was responsible for much of the increase in the schooling of native-born Americans in the twentieth century. (For this reason and others, we devote several chapters in Part II to the push for universal secondary school education.)

In sum, rapid educational advance characterized cohorts born from the late nineteenth century to 1950, and that was especially true for black Americans, but those advances stagnated for cohorts born after 1950. Although an increase in years of schooling is discernible for cohorts born after 1965, for cohorts born from 1950 to 1975 the increase was only about one tenth of that for cohorts born from 1876 to 1950.

A full century of educational advance can therefore be divided into two parts. During the first three quarters of the century educational attainment rose rapidly, but during the last quarter of the century it stagnated. As we will see in Chapter 2, twentieth-century trends in economic inequality also occurred in two parts—first declining and then rising. The relationship between the two trends is made clear in Chapter 8.

European Comparisons

To understand the slowdown in U.S. educational attainment, one must seek comparisons with other nations. Is a slowdown a natural occurrence as educational levels increase to very high levels? Is the phenom-

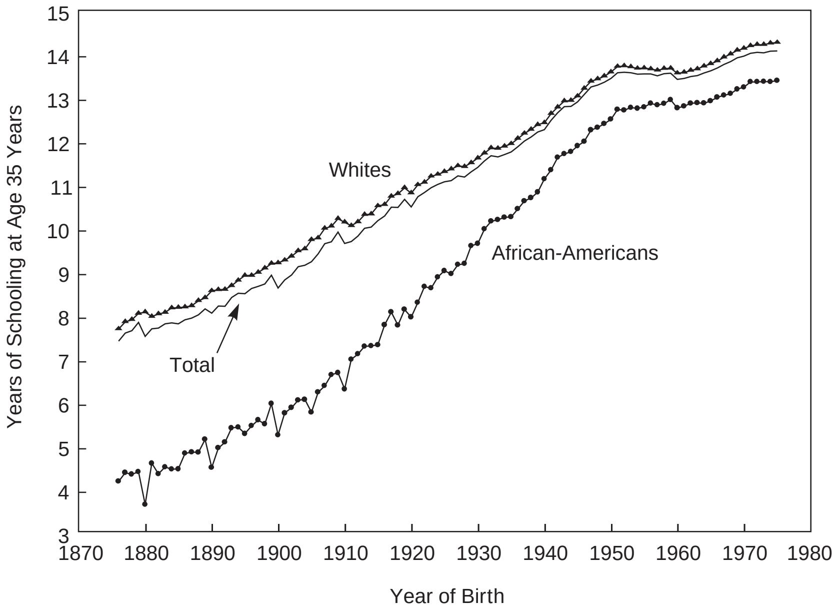
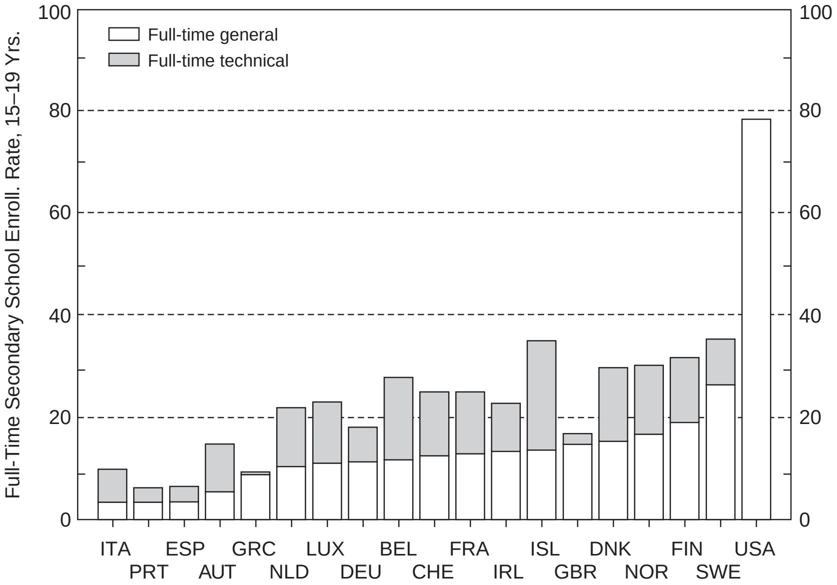


Figure 1.6. Years of Schooling by Birth Cohorts, U.S. Native-Born, by Race: 1876 to 1975. This figure plots the mean years of completed schooling for U.S. native-born residents by birth cohort and race, adjusted to age 35 using the approach described in the notes to Figure 1.4. Sources: 1940 to 2000 IPUMS.

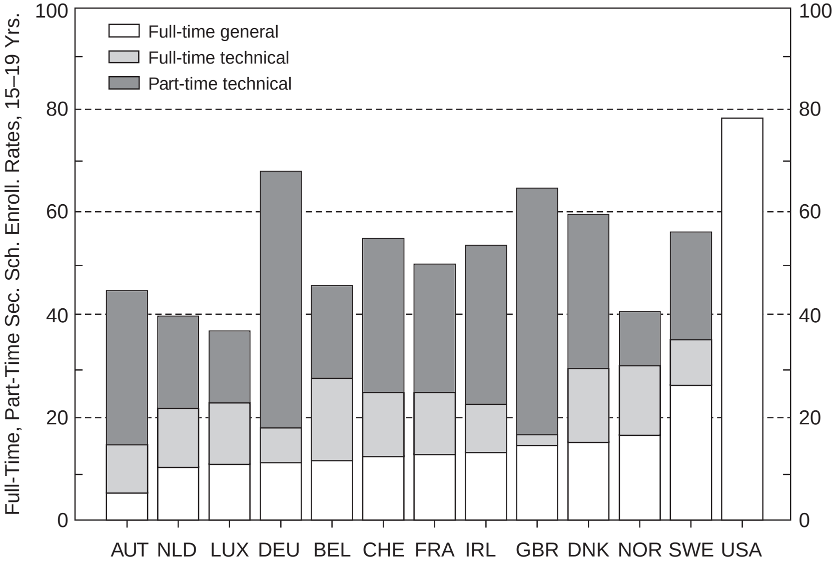
enon unique to the United States? Many other nations now have education rates for their younger cohorts that exceed those in the United States. And, in the past few decades, they have caught up to and some have even surpassed the high education levels that had once been set by the United States.

At the start of the twenty-first century, young people in many European nations attended college to about the same extent as did young people in the United States. Among 25- to 34-year-olds, 39 percent in the United States had attained two- or four-year college degrees. Four European nations equaled or exceeded that figure in 2004, and eight others were close behind.[26] At the same time, a much smaller fraction of the 55- to 64-year-olds in these 12 countries had attained college or university training relative to the same group in the United States; their educational attainment represents the state of higher education four decades earlier. For these 12 European nations, the average college completion rate for the older group was 56 percent of the U.S. figure.

Part A: Europe and the U.S. 1955/56



Part B: Europe and the U.S. 1955/56



The educational attainment in these nations advanced rapidly in the last several decades of the twentieth century. In almost all cases the college rates achieved by the 25- to 34-year-olds in these European nations were more than 1.5 times the rates of the 55- to 64-year-olds, and in four of the twelve cases the increase was more than twofold. In contrast, the college degree rate of U.S. 25- to 34-year-olds (39 percent) was only 1.08 times that for U.S. 55- to 64-year-olds (36 percent) in 2004.

In essence, many of the nations with college degree rates that were considerably behind that of the United States in the last third of the twentieth century had rates placing them ahead or very close to the United States by the start of the twenty-first century. The slowdown in the educational attainment of young Americans at the end of the twentieth century is especially striking when compared with the acceleration of schooling among many nations in Europe and in parts of Asia, where educational change has been exceedingly rapid.

The fact that Europe was far behind the United States in higher education until the last several decades of the twentieth century

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Figure 1.7. (opposite page) Secondary School Enrollment Rates for European Nations and the United States, c.1955. The data refer to the number of youths in public and private upper and lower secondary schools (of the types listed) ranging from those who turned 15 years old during the school year to those who turned 19 years old during that year. Thus, the age group under consideration is approximately all 15- to 18-year-olds, plus one-half of 14- and 19-year-olds. No youths in elementary schools or colleges and universities are included even if they were in the included ages. The procedure ensures consistency but implicitly favors countries, such as the Nordic nations, that have late starting ages and penalizes those, such as France and the United States, that have earlier starting ages. The computation for the United States assumes 100 percent enrollment for the 14-year-olds and then adds those enrolled in ninth through twelfth grades and divides by the age group given above. The six nations that did not give data on part-time technical schools are excluded from Part B. All data are for c.1955. Abbreviations are: Italy (ITA), Portugal (PRT), Spain (ESP), Austria (AUT), Greece (GRC), Netherlands (NLD), Luxemburg (LUX), Germany (DEU), Belgium (BEL), Switzerland (CHE), France (FRA), Ireland (IRL), Iceland (ISL), Great Britain (GBR), Denmark (DNK), Norway (NOR), Finland (FIN), and Sweden (SWE). Sources: European nations: Dewhurst et al. (1961, tables 10-2 and A). The data for England and Wales, France, Germany (including the Saar and West Berlin), and Sweden, have been checked against the original administrative records and small errors have been corrected. United States: U.S. Department of Education (1993, tables 1 and 9).

should not be surprising. European nations had lagged considerably in providing secondary schooling. According to a careful analysis of data from 18 European nations in the 1950s, none enrolled more than 30 percent of older teen youth in full-time academic (general) secondary schools and most were below the 20 percent mark (see Figure 1.7, Part A). In addition, enrollment did not exceed 40 percent in both full-time academic and full-time technical schools. Even the inclusion of enrollment in part-time technical schools does not materially alter the conclusion (Figure 1.7, Part B). At the same time, the United States enrolled more than 70 percent of its teen youth in secondary schools. The United States was a clear leader in mass secondary school education in the mid-twentieth century.[27]

A possible response to these facts is that Western Europe was set back by World War II and had not fully recovered by 1955. Yet levels of schooling for teenagers in Britain, for example, seriously lagged those in the United States during the first half of the twentieth century. As shown in Table 1.1, the fraction of 17-year-olds attending secondary schools in England and Wales was abysmally low for all years shown, including those in the 1950s. High school graduation rates in the United States, on the other hand, reached almost 30 percent nationwide as early as 1930 and were in the 60 percent range in the 1950s.[28] By 1960 Great Britain was about 35 years behind the United States in the educational attainment of its high-school aged youth even though it had had a fully supported public secondary school system since 1944.

Another possibility is that Europe was far behind America in secondary education because it was generally less wealthy than was the United States, but secondary school rates in Europe in the 1950s trailed those that had existed in the United States at the same level of real per capita income. Although real per capita income in the United States in 1940, as the nation was just coming out of a decade-long depression, was about equal to the incomes in much of Europe in 1955,[29] secondary school enrollment rates in the United States were more than twice those in the Europe of 1955, including students in full-time technical schools.[30] One would have to return to the 1910s to find levels of secondary school enrollment in the United States that match those in 1950s Western Europe.

A clear statement of the differing commitments to publicly provided and funded education can be seen in the response of the governments

Table 1.1. Schooling of 14- to 18-Year-Olds in Great Britain and the United States: 1870 to 1960

	British School Attendance Rates (in percent)				U.S. High School Enrollment and Graduation Rates (in percent)	
Year	14-year-olds	17-year-olds	15- to 18-year-olds[a]	Year	Enrollment/14- to 17-year-olds	High school graduates/ 17-year-olds
1870	2	1	n.a.	1870	n.a.	2.0
1900/02	9	2	n.a.	1900	10.6	6.4
1911/12	12	1	n.a.	1910	14.5	8.8
1931	n.a.	n.a.	9.4–10.6	1930	51.1	29.0
1936/38	38	4	n.a.	1938	67.7	45.6
1950	100[b]	10.5	12.6 [14.4][c]	1950	74.5	59.0
1956	100	n.a.	14.9	1956	83.5	63.1
1957	100	9.0	16.0			
1960/62	100	15	17.5	1960	86.9	69.5

Sources and Notes: The term "attendance" for England and Wales is from Ringer (1979); the term "enrollment" for the United States is from the *Biennial Reports*. "Attendance" in England and Wales often meant "on the registers," which is similar to enrollment. Attendance figures are almost always lower than enrollment data within a country, but for these comparisons, the difference may be slight.

England and Wales: Ringer (1979) all years, except those that follow. The 15- to 18-year-old group in attendance is 15 years and over divided by the 15- to 18-year-old group in England and Wales only. The 14- and 17-year-old percentages are for full-time attendance at any school and refer to all of Great Britain.

1911/12: U.S. Bureau of Education, *Biennial Reports* (1916–18, p. 25), the Lewis Report 1917, is given as the source. See also Matthews (1932) whose data are derived from the Lewis Report.

1931: Board of Education for England and Wales (1932) provides information on "students on the registers" by age for schools receiving public funds. The number of youths 15 to 18 years old in entirely private institutions is estimated from university enrollments and makes assumptions regarding the proportion of secondary students who continued to university based on evidence from 1948. A set of reasonable assumptions results in the 9.4 percent figure and 10.6 percent is the upper bound estimate.

1956: Carr-Saunders et al. (1958, p. 60) give the number of pupils on school registers by age and the total in the age group. The figure will not include youths at university.

1957: Dewhurst et al. (1961). The 15- to 18-year-old group is a simple average of the four years.

United States, all years: U.S. Department of Education (1993).

a. The 15- to 18-year-old group includes those who are just 15 years old but excludes those who are just 19 years old.

b. The 100 percent figure is assumed for 14-year-olds because their attendance at some school was mandatory after 1944.

c. The 14.4 percent figure is estimated for males only, using data for 1948.

in Britain and the United States during World War II. When the United States entered World War II, the median American 18-year-old was a high school graduate and, outside the South, more than 60 percent had recently graduated from high school. When President Franklin Roosevelt signed the GI Bill of Rights into law in 1944, the average GI was able to attend college for he had already graduated from high school. Nothing more clearly demonstrates the difference in schooling between the United States and Britain than the simultaneous passage by the Labour Government of the long-awaited 1944 Education Act. The GI Bill paid the tuition and a stipend for military veterans attending college, while the Education Act did no more than guarantee to all British youth a publicly-funded grammar or secondary school education.

We referred earlier to statements by Western European commentators in the early twentieth century that Americans wasted resources in educating the masses in secondary schools. These nations, instead, promoted a cadre of extraordinary children and gave the residual a fair elementary education. Great Britain, France, and Germany all tested children, generally before their twelfth birthday, to see who would be tracked to enter secondary school. Many European nations of the early twentieth century followed this general scheme, although their educational systems were structured differently. These nations provided three different models or templates that the United States could have followed.

The British emphasized classical training for those who were allowed to go beyond the compulsory grades. The French system produced a small group of civil servants and well-trained professionals for technical and scientific fields. The German system contained a number of tracks—for industrial work, for commercial pursuits, and an elite course for students who would attend universities. The American system can be characterized (as we do in Chapter 4) as open, forgiving, lacking in universal standards, and having an academic yet practical curriculum. The European system, in contrast, was generally closed, unforgiving, with uniform standards, and an academic curriculum for some and an industrial one for others. One system was egalitarian; the other was elite.

Why Was America Different?

Why did the United States pioneer a novel and distinctively American form of secondary and higher education and break from the educational templates of Europe? Why did Americans engage in investments in human capital that Europeans viewed as wasteful of resources?

Part of the answer can be found in considering the choice between engaging in *general* training, such as formal schooling, and engaging in *specific* training, such as an apprenticeship or on-the-job training. Investment in general schooling may be more costly than an apprenticeship, but it produces skills that are flexible and thus transferable across place, occupations, and industries. Thus formal education is more highly valued when geographic mobility and technical change are greater. It is favored when the costs of specific training, such as for family businesses or apprenticeships, are higher, possibly because community ties are fewer. When education is publicly funded, formal schooling, moreover, has a lower direct cost for students and their parents.[31]

General schooling for the masses fit American circumstances more than it did those of early twentieth-century Europe. Many insightful historians and demographers have commented on the generally accepted notion that Americans were more geographically mobile than were Europeans, within their nations.[32] Extensive evidence exists for this greater geographic mobility for the post-1960s.[33] Although evidence for the nineteenth and early twentieth century is less plentiful, a careful analysis of inter-county migration for the mid-nineteenth century demonstrates that two-thirds of all American adult males shifted county at least once but that only one-quarter of all British men did.[34] Moves within the United States, furthermore, were considerably longer.

Formal, school-based education enabled American youths to change occupations over their lifetimes, to garner skills different from those of their parents, and to respond rapidly to technological change.[35] Apprenticeships and highly specific training were more cost effective for individuals who expected to spend their lives in the same place and in the same industry and occupation, but apprenticeships were not as valuable for others and clearly not for their employers.[36] As economic historian Stanley Lebergott noted: "incessant mobility [of Americans] made it thoroughly unwise for any employer to invest much in training his employees" (1984, p. 372).

Europeans may have been correct in their assessment that an American educational system was wasteful of resources, at least in their circumstances. But it was not wasteful in the technologically dynamic, socially open, and geographically mobile New World setting. And it assuredly enhanced the dynamism.

Human Capital and Economic Growth

Human Capital Stock of the Workforce

Measuring how much human capital enhances the dynamism of an economy would be extremely valuable. Measuring how much human capital increases income by making individual workers more productive is equally important and conceptually simpler. We will do the latter and compute how growth was increased by a more educated workforce.

To produce estimates of the impact of education on growth, we first need to measure the *human capital stock of the workforce* at various points in time. Human capital includes a broad class of inputs such as education, on-the-job training, and health. We use a definition that includes only formal education and does not adjust for potential school quality differences across cohorts and years.[37] A well-established growth accounting framework is employed to guide the analysis of the direct effect of a more educated workforce on labor productivity. The estimates of the educational attainment of the native-born population by birth cohort, discussed above, provide a starting point for constructing estimates for the human capital stock of the workforce and its evolution over the twentieth century.

The human capital stock of the workforce differs in several important ways from the educational attainment of the native-born population by cohort. For instance, the human capital stock depends also on the foreign-born population, which was a large fraction of the workforce in both the earlier and later parts of the twentieth century. The two measures also differ because the stock estimates aggregate the educational attainment data by the relative sizes of the cohorts. Yet another difference is that the stock estimates are for the workforce, whereas educational attainment by birth cohort was presented for the entire population. The educational attainment of the workforce can differ from that of the population to the extent employment (and labor force participation) rates vary across schooling groups.

We are able to construct estimates of the human capital stock of the workforce for the years after 1940 because the U.S. Population Census asked about educational attainment starting with 1940. For the previous period we employ a state census that asked detailed information (more comprehensive than in any federal population census) about educational attainment. The Iowa State Census of 1915 is a unique group of records, and is discussed at greater length in Chapter 2. Suffice it to say here that we have collected a large and representative sample from original documents, consisting of some 60,000 individuals living in both cities and rural areas. Although we make no claim that Iowa was a microcosm of America, the educational attainment of its workforce was not much different from that of the nation's in the last several decades of the twentieth century. It was, however, a more educated place than was the rest of the country earlier in the twentieth century. We primarily use the Iowa data to obtain changes in the educational attainment of the workforce.

From 1915 to 2005, the period shown in Table 1.2, the increase in the educational stock of the U.S. workforce, as measured by mean years of schooling, was just short of 6 years or 0.66 years per decade.[38] The educational stock progressed with great speed from 1940 to 1980, when the increase was 0.86 years per decade and as better-educated young people replaced lesser-educated older cohorts in the workforce. Progress slowed thereafter, from 1980 to 2005, when the increase barely exceeded one year, or 0.43 years per decade.

The rapid growth of the educational attainment from 1915 to 1980 was driven largely by the sharp increases in the schooling of successive cohorts of the U.S native-born population through the early 1950s birth cohorts (illustrated in Figure 1.4) Similarly, the slowdown of growth of the human capital stock of the workforce since 1980 mainly reflects the slower rate of increase of educational attainment for post-1950 birth cohorts.

What about the possibility that changes in the share of workers who are foreign-born drove the aggregate human capital stock changes? In 1910, amidst the great migration from Europe, the fraction of foreign-born among U.S. workers reached 22 percent. The vast majority of immigrants came from countries that had far lower levels of education

Table 1.2. Educational Attainment of the Workforce, 1915 to 2005

	United States					Iowa				
	1915	1940	1960	1980	2005	1915	1940	1960	1980	2005
Mean years	7.63	9.01	10.53	12.46	13.54	8.45	9.83	10.87	12.49	13.55
Fraction, by years										
0–8	0.756	0.522	0.303	0.087	0.034	0.726	0.476	0.289	0.077	0.020
9–11	0.129	0.174	0.218	0.154	0.070	0.129	0.165	0.184	0.126	0.060
12	0.064	0.185	0.262	0.346	0.309	0.083	0.229	0.316	0.424	0.322
13–15	0.028	0.061	0.121	0.228	0.290	0.037	0.076	0.128	0.210	0.338
16+	0.026	0.058	0.096	0.185	0.297	0.026	0.055	0.083	0.164	0.261

Sources: 1915 Iowa State Census; 1940, 1960, and 1980 Integrated Public Use Microsamples (IPUMS) of the U.S. federal population censuses. 2005 Current Population Survey (CPS), Merged Outgoing Rotation Groups (MORG). 1915 U.S. data are extrapolated from the 1915 Iowa data. U.S. mean years of education for 1915 is given by the U.S. mean for 1940 minus the difference between 1940 and 1915 means for Iowa. The fraction, by years, is an extrapolation from the Iowa data that is scaled to sum to one.

Notes: Samples are restricted to those aged 16 or older and exclude those who were in the military or institutionalized. The workforce in each year from 1940 to 2005 consists of those who are employed at the survey reference week. The workforce for Iowa in 1915 includes those reporting occupational earnings for 1914; each individual is weighted according to the number of months worked in 1914. Years of schooling for 1940 to 1980 are measured using the same approach as that used for Figures 1.4, 1.5, and 1.6. Years of schooling in 2005 are measured using the approach to post-1991 CPS MORG of Autor, Katz, and Krueger (1998). Measures of years of schooling and months worked for Iowa in 1915 were constructed using the methods of Goldin and Katz (2000). For 1960 to 1980 we follow Autor, Katz, and Krueger (1998) in including all those who attended 13 years of schooling (whether or not they completed the final year) in the 13–15 schooling category. Sampling weights are used for all samples.

than did the United States. In the 1915 Iowa Census, the typical foreign-born worker had almost 1.5 fewer years of schooling than the typical native-born worker. Because Congress restricted immigration in the 1920s, the labor force began to age without a steady influx of immigrants, and the fraction of foreign-born in the workforce fell.

If we look at the overall and U.S.-born workforces, years of schooling increased by 0.64 and 0.59 years per decade, respectively, from 1915 to 1960. The net effect of the decline in the foreign-born share of the workforce, from 21 percent in 1915 to 7 percent in 1960, was to raise the educational attainment of the workforce by 0.05 years per decade. The immigrant workforce share barely changed from 1960 to 1980, and thus there was a negligible impact from immigration during that period. In contrast to the earliest period examined, the foreign-born share of the workforce increased from 7.6 percent in 1980 to 16.3 percent in 2005. From 1980 to 2005 the schooling of the overall and U.S.-born workforces increased by 0.43 and 0.48 years per decade, respectively. The impact from immigration during 1980 to 2005, therefore, was to reduce the growth in workforce schooling by 0.05 years per decade, or the same magnitude but opposite in sign for the 1915 to 1960 period.[39]

Thus, changes in the schooling levels of those born and educated in the United States not the relative shares of immigrants in the population and the labor force, have been the driving force behind the evolution of the educational stock of the U.S. workforce. Although the declining foreign-born share of the workforce from 1915 to 1960 contributed to an increase in the educational attainment of the workforce, and the large rise in immigration during the last 25 years placed a small drag on educational attainment both of these changes have been modest compared with the changes for the native-born population.

During the first half of the twentieth century the major change in the educational attainment of the labor force was a result of the replacement of workers who had less than a high school education with workers who had completed high school (see Figure 1.8).[40] In the late twentieth century, this change was furthered by the entrance of workers with at least some college education. The fraction of the U.S. workforce with no more than a common or elementary school education exceeded 75 percent in 1915, declined to 30 percent by 1960, and decreased to a trivial 3 percent by the early twenty-first century. In

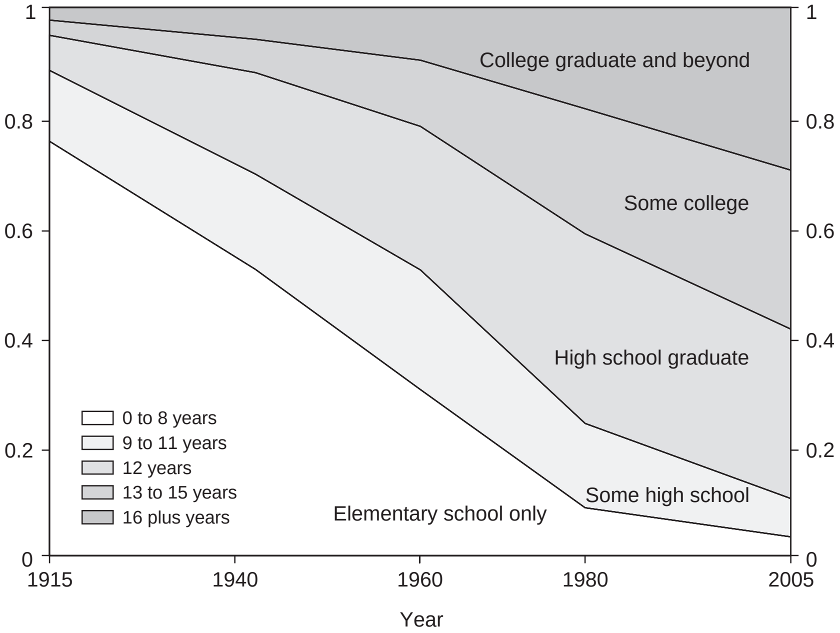

Figure 1.8. Distribution of Educational Attainment of the Workforce: 1915 to 2005. Sources: See Table 1.2.

1915 barely more than 5 percent had some college or university training, but 22 percent did in 1960 and more than 58 percent did by 2005. Finally, whereas less than 3 percent had a college degree in 1915, 30 percent did by 2005.

Measuring the Contribution of Education to Growth

HISTORY AND THEORY

The twentieth century, as we noted earlier, was both the Human Capital Century and the American Century. It was the century when education became the dominant factor determining the wealth of nations and it was the century when America was first to discover that notion. It was the century when America began to lead the world economically and it was the century during which America remained at the top. Armed with our estimates of the human capital stock of the workforce, we can now return to the relationship between human capital and economic growth at various moments in U.S. history. Later, in

Chapter 2, we address who shared in the benefits of economic growth and the relationship between changes in distribution and education.

Across the twentieth century the American economy grew at a remarkable pace. In per capita or per labor hour terms, economic growth was moderate at best, certainly relative to the impressive rates of various transition and emerging nations in recent decades. But the impressive growth of the American economy is to be found in its continuous nature over the century and thus in its compounding over the century. Productivity (or output) per labor hour grew at an average of 2.2 percentage points annually across the entire century. There were periods of a quickening in the pace of growth, such as the 1920s, the 1940s, and the 1960s, and there were moments of rather sluggish performance, as in the late 1970s and 1980s (and, of course, the 1930s). By and large, however, the growth was moderate but steady over long periods, and thus was impressive overall.

The impressive growth of the United States at mid-century amidst the flagging development of many parts of the world provided a strong impetus for economists to find the factors that caused economic growth. Some believed they could create a recipe for economic success or an inoculation against economic disaster, akin to the "magic bullet" for disease. Great minds worked in various ways on the problem. A few believed that economic growth began in certain capital-intensive sectors, such as transportation or manufacturing, and that a particular infrastructure would provide the key to success.[41] Others modeled the growth process in a more general fashion. Output, they posited, is a function of the various inputs in the economy and, therefore, economic growth occurs when these inputs increase.

Growth can also occur when the inputs become more productive or if the functional relationship between the inputs and the output changes. For example, capital could become more productive, and technological change could be embodied in capital. Laborers themselves could become smarter, more able, healthier, and simply better workers. Advances in this manner would be embodied in human capital. Furthermore, technological change could be neutral with regard to the inputs. Output could increase even if none of the inputs changed, as in Adam Smith's famed pin factory in which workers became more productive due to the division of labor rather than an increase in individual skill. By formalizing these notions of inputs, outputs, and the production function we are able to estimate the impact of educational advance on economic growth.

Following a long literature in economic growth, assume that output (*Y*) is a function of a set of inputs, which will be hours of labor (*L*) and capital (*K*). Other inputs, such as land, could be added with no loss in generality. The functional form chosen is additive in the logs of these factors, with a multiplicative component known as total factor productivity (*A*), since it reflects the productivity of all the factors, taken together. The functional form just described is known as the Cobb-Douglas production function. We consider the case when the exponents sum to one:

$$Y = A\,K^{(1-\alpha)}\,L^{\alpha} \tag{1.1}$$

which implies the per unit labor input or intensive form of

$$y = A\,k^{(1-\alpha)} \tag{1.2}$$

where $y = Y/L$ and $k = K/L$. In rate of change form, where an asterisk (*) denotes dlog {·}/dt:

$$y^* = A^* + (1-\alpha)\,k^* \tag{1.3}$$

Eq. 1.3 is the formulation described in Robert Solow's pioneering papers on economic growth (1956, 1957). One of the many virtues of the formulation is that it places few demands on the data since y^* is labor productivity change, k^* is the growth of the capital stock per worker (or capital to labor ratio), and the exponent on labor (α) in the production function, under reasonable assumptions, is the share of labor in national income.[42] Total factor productivity change, A^*, is derived as a residual.

The early growth empiricists fitted data to eq. 1.3 and found, to their surprise, that most of the labor productivity change was due to changes in total factor productivity, and not to an increase in the measured inputs, mainly the change in the ratio of capital to labor. The conclusion was that the residual, dubbed the "measure of our ignorance," was the driving factor. If growth theorists were searching for a recipe to provide to the world's poor nations, their advice would have been simple: "Do something economists are not very good at measuring."

But economists soon realized that the simple formulation used crude measures of the inputs.[43] Labor, for example, was measured simply as hours of work when labor actually had two main components: raw labor in hours (L) and labor in efficiency units (E). The full, augmented labor input was ($L \cdot E$). The augmented labor input could change if labor hours changed and it could also change if labor efficiency per hour changed. The change in efficiency units could be due to changes in formal education, on-the-job training, age, health, or a host of other factors that enhance the effectiveness of workers.

Augmenting the labor input implies that eq. 1.1 becomes:

$$Y = A'K^{(1-\alpha)}(L \cdot E)^{\alpha} \qquad (1.1')$$

and that eq. 1.3, in turn, becomes:

$$y^* = (A')^* + (1-\alpha)\, k^* + \alpha E^* \qquad (1.3')$$

Whereas growth empiricists focus on all components of eqs. 1.3 and 1.3′, our interest here is in the relationship between αE^* and y^*. We want to know the degree to which changes in the efficiency units of labor, in particular those due to changes in formal education, can explain changes in labor productivity over the course of U.S. history. Put simply, we want to know the direct effect of education on economic growth. We turn now to the estimation of that relationship.

DIRECT EFFECT OF EDUCATION ON GROWTH

There are three components of the estimation. The first is y^* or the growth in labor productivity (output per hour). For the period since 1947 we use the official Bureau of Labor Statistics (BLS) estimates and for the previous years we use data based on the work of John Kendrick (1961).

The second component is the change in the educational productivity index, E^*. We compute the index $E_t = \Sigma_i w_{it} S_{it}$, where w_{it} is the (adjusted) wage of education group i (relative to a reference education group) in base period t, and S_{it} is the share of education group i in total hours in year t.[44] When differences in earnings by education reflect the impact of schooling on productivity, the growth in the index measures the contribution of educational upgrading to aggregate labor-input growth through improvements in the average human capital or quality of the workforce. The estimation of S_{it} was discussed in the previous section and is given in Table 1.2. Educational wage differentials, the w_{it} part of the formula, will be only briefly summarized here because Chapter 2 will concern how the economic returns to education evolved across the twentieth century. In 1915, at the start of the period under examination here, the private economic return to a year of either high school or college was substantial, upwards of 11 percent per year. Educational wage differentials then narrowed considerably from 1915 to 1950. They expanded modestly in the 1950s and 1960s before narrowing again in the 1970s. Educational wage differentials increased significantly in the 1980s, with a modest advance in the 1990s. At the end of the twentieth century educational wage differentials remained quite high, although at the start of the period they were higher still.

The third component is α, which in a competitive pricing economy is the share of labor in national income. Compensation of labor (wages plus fringe benefits) accounts for approximately 70 percent of production. On the assumption that labor is paid its marginal contribution to output and that output is proportional to inputs, a 1 percent increase in effective labor through an increase in the average human capital of the workforce directly boosts output by 0.7 percent.[45] The results of the computation are shown in Table 1.3. We find that on average across the 90-year period from 1915 through 2005 increases in educational attainment boosted the effective size of the workforce by 0.48 percent per year.[46] Thus, education *directly* contributed an average of 0.34 percentage points a year to economic growth (0.7×0.48) over the 90-year span. Differences in the contribution of human capital exist across the four subperiods we employ. Educational advance contributed 0.49 percent per year to labor productivity growth from 1915 to 1960, but from 1960 to 1980 the contribution increased greatly to 0.59 percent per year and then sharply decreased in the remaining 25 years to 0.37 percent per year. Similar changes, given in last column of Table 1.3, can be seen in the average years of schooling of the workforce, especially the slowing of growth since 1980.

One might wonder how immigration affected educational productivity. We noted before that immigration slightly increased the growth in workforce education on average from 1915 to 1960, that it had almost no effect from 1960 to 1980, and that it reduced schooling

Table 1.3. Educational Growth Accounting, 1915–2005

	(1)	(2)	(3)	(4)
	Average annual percentage point change in:		Fraction "explained" by educational change	Change in mean years of workforce education
Period	y^*	E^*	$\alpha \cdot E^*/y^*$	
1915–40	2.45	0.50	0.143	1.38
1940–60	2.92	0.49	0.118	1.52
1960–80	2.41	0.59	0.171	1.93
1980–2005	2.18	0.37	0.119	1.08
1915–2005	2.47	0.48	0.136	5.91

Sources: Col. 1: *Historical Statistics, Millennial Edition* (2005), table Cg265–272, series Cg265 for 1915–40 and table Cg273–280, series Cg273 for 1940–60, and U.S. Bureau of Labor Statistics (BLS), "Major Sector Productivity and Costs Index," series PRS84006093, for 1960–80 and 1980–2005 from the BLS Internet site (www.bls.gov). Col. 2: 1915 Iowa State Census; 1940, 1960, and 1980 IPUMS; 2005 CPS MORG. Col. 3 multiplies col. 2 by 0.7 and divides by col. 1. Col. 4: see Table 1.2.

Notes: The labor productivity measure (y) in col. 1 is real gross private domestic product per labor hour for 1915 to 1960 and output per hour of the business sector for 1960 to 2005. The construction of the educational productivity index used in col. 2 follows the procedures used in DeLong, Goldin, and Katz (2003). The index covers the civilian workforce (ages 16 or older) in each year. The reported educational productivity changes (E^*) are based on chain-weighted prices. (Fixed-weighted prices give similar results.) Changes from 1915 to 1940 are for Iowa; changes for the other time periods cover the entire United States. The education groups used are 0–4, 5–6, 7–8, 9–11, 12, 13–15, and 16 or more years of schooling. The chain-weighted index covering years t to t' uses the average educational hourly wage differentials for t and t'. The index is hours-based and weights workers by the product of their sampling weight and hours worked in the survey reference week. Because hours data are not available in the 1915 Iowa state census we use employment weights for the 1915–40 educational productivity change and educational wage differentials based on monthly earnings for 1915. Mean years of workforce education used in col. 4 are employment weighted. See DeLong, Goldin, and Katz (2003, appendix 2B) for further details on the methodology.

growth within the workforce by a small amount from 1980 to 2005. Similarly, immigration had only a modest impact on educational productivity growth. The falling immigrant share of the workforce increased educational productivity by 0.03 percent per year from 1915 to 1960. The immigration effect was almost nil from 1960 to 1980. From 1980 to 2005 the rising immigrant share reduced educational productivity by 0.03 percent per year, from 0.40 percent per year for the U.S.-born workforce to an overall rate of 0.37 percent per year with immigration.[47] The immigration effects are considerably smaller than one might have thought given past and current debates over immigration.

Across the entire period from 1915 to 2005, the direct contribution of educational advance within the workface of 0.34 percent per year explains about 14 percent of the average annual increase in labor productivity of 2.47 percent (see Table 1.3).[48] The differences by subperiod are slight. Generally, the explanatory power of the direct effect of education is greater when labor productivity is lower except for the most recent period when labor productivity was relatively sluggish and the increase in the educational attainment of the workforce was low. If we used, instead, output per capita as our benchmark, educational advance within the workforce would account for about 15 percent of the 2.23 percent per year gain in real GDP per capita from 1915 to 2005, or about the same as in the case of labor productivity.[49]

Worker characteristics other than education also affect labor productivity and can be incorporated into the analysis. Such characteristics include work experience, sex, nativity, and race. If wage differentials by these characteristics largely reflect differences in worker productivity, the broader group of worker characteristics and associated wage differences can be used to construct an augmented measure of labor force quality. We find that labor force quality, using the augmented set of characteristics, grew on average by 0.42 percent per year from 1915 to 2000, whereas that for education alone grew by 0.48. In other words, educational upgrading accounted for nearly all of the secular improvement in measured labor force quality since 1915.[50]

INDIRECT EFFECT OF EDUCATION ON GROWTH

There are various ways in which education increases productivity and thus economic growth. We have estimated the direct effect, which is the increase in productivity for a given technology and capital stock through an increase in the *quality* (efficiency units) of the workforce. But there are also various indirect effects. The higher income generated by the direct effect of education indirectly contributes to labor productivity by raising physical capital investment and consequently increasing the capital-to-labor ratio. A better educated workforce facilitates the adoption and diffusion of new technologies.[51] Finally, education contributes to innovation and technological advance because scientists, engineers, and other highly educated workers are instrumental to the research and development (R&D) sector as well as to the creation and application of new ideas.[52] Although it is difficult to quantify these indirect contributions of education to economic growth, they are bound to have been quite large.

Suggestive evidence exists that the magnitude of the indirect effects of education on labor productivity is substantial. For example, firms and establishments with more educated workers have long been found to be earlier adopters of new technologies and have been shown recently to garner greater productivity benefits from information–technology investments.[53] Furthermore, highly educated labor is the primary input to R&D, and some estimates suggest that rising R&D intensity in the United States and other advanced economies has been a significant (and possibly the largest measurable) contributor to growth in U.S. labor productivity over the last 50 years.[54]

America at the End of the Human Capital Century: A Summary

At the end of the twentieth century almost all nations have discovered what America knew at the beginning of the century. Human capital, embodied in one's people, is the most fundamental part of the wealth of nations. Other inputs, such as natural resources and financial capital, can be acquired at world prices in global markets, but the efficiency of one's labor force rarely can be. Not only does more education make the labor force more efficient, it makes people better able to embrace all kinds of change including the introduction of new technologies. And for some extraordinary individuals, more education enables them to create new technologies.

The Human Capital Century rapidly became the American Century. The United States became and remained the most economically advanced nation in the world. Was the relationship causal or was it merely coincidental? We have shown in this chapter that advances in education across the twentieth century account for almost 15 percent of the labor productivity change. That is, labor productivity increased by 2.47 percent, on average, each year for 90 years from 1915 to 2005. Education directly increased worker efficiency by 0.48 percent per year, thus directly increasing labor productivity by 0.34 percent per year (0.7×0.48). The actual role of more education must have been considerably greater because of omitted indirect effects, primarily faster technological diffusion and more innovation.

Thus the relationship between the Human Capital Century and the American Century is not at all coincidental. The fact that virtually all other nations have followed suit and invested heavily in the education of their people is testimony to how important human capital became in the twentieth century and how important it is in the twenty-first.

The educational attainment of the American people even near the start of the twentieth century was substantial, particularly in comparison with other nations whose income levels were fairly comparable. The increase during much of the twentieth century was large. We estimated educational attainment by birth cohort for Americans born in the United States from 1876 to 1975 to gain a measure of what the U.S. educational system produced. We then added foreign-born workers and weighted by cohort size, age, and labor force status to obtain the human capital stock of the nation at various moments in U.S. history.

For both the human capital stock of the nation and that of each cohort, we found that the twentieth century was a tale in two parts with regard to educational change. For the first three-quarters of the century, educational attainment advanced by 6.2 years or 0.82 years per decade. But change in the subsequent decades was not all that rosy. During the 15-year period from 1975 to around 1990, there was almost no increase at all. A gain was recorded during the next decade, but it was just half a year.

The gain in educational attainment for the entire century, from the cohort born in 1876 to that born in 1975, was 6.7 years. About 50 percent of this increase was entirely due to increased attendance at and graduation from high school; for cohorts born from 1876 to 1935, fully 60 percent of the increase was due to high school. The high school, not the college, was primarily responsible for some of the largest gains in educational attainment in U.S. history. In Part II we investigate the factors that drove the increase in high school attendance and graduation.

Although recent and past debate over foreign-born workers would suggest that the aggregate impact on education was large, it was, in fact, relatively small during the twentieth century. For the 1915 to 1960 period, when the foreign-born were becoming a smaller share of the workforce, the gain from less immigration was just 0.05 years per decade. Similarly, the loss from 1980 to 2005, when the foreign-born increased their share of the workforce, was also just 0.05 years per decade.

Educational attainment in the United States was high for most of the twentieth century by the standards of other nations, and the increase in years of education was substantial for most of the century. However, gains in educational attainment in Europe and parts of Asia in the past three decades have been simply staggering. Younger cohorts in these nations have considerably more education than do older cohorts, and many of the younger cohorts have higher education levels than exist in the United States. The U.S. educational system would appear to be flagging not only in terms of quantity but also with respect to quality. These are subjects to which we return in Chapter 9.

Great educational change occurred in the United States during the first three-quarters of the Human Capital Century, but these achievements gave way to a rather flaccid performance in the subsequent decades. Likewise, the history of inequality in the twentieth century contains several distinct turning points. In Chapter 2 we explore who gained from economic growth and when.

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