SUSTAINING U.S. ECONOMIC GROWTH
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After two decades in the economic doldrums, growth of U.S. productivity in the late 1990s doubled. This shift represented a return to the rapid growth typical of the three decades following World War II. For reasons that are still subjects of heated debate, productivity growth slowed in the mid 1970s and remained depressed for the succeeding two decades. Continued rapid growth over the next couple decades is certainly possible but not assured. The stakes in achieving this potential are enormous. In this chapter, we outline the sources of U.S. economic growth and speculate on possible steps that policymakers—public and private—can take to realize this potential.

Economic Growth: Benefits, Costs, Uncertainties

Rapid economic growth boosts private incomes and government revenues. It thereby expands options for private and collective action. Increased output permits the people—through their private individual decisions and through government action—to boost consumption, lower tax rates, extend or enrich schooling, clean up the environment, strengthen national defense, or tackle other goals. In contrast, slow economic growth appears to foster diminished national expectations and political gridlock.[1] A lower growth rate in private incomes and the resultant slowdown in growth of tax collections from 1973 through the mid-1990s reduced the ability of the U.S. government to undertake costly projects. Advocates of small-government may regard such constraints as a benign side-effect of slow growth, but it was the relatively conservative President George H.W. Bush who lamented at his inauguration in 1989 that Americans "have more will than wallet." And it was during his administration and that of his predecessor, Ronald

Reagan, that large government deficits diverted private savings from growth-enhancing investments to finance current government consumption. Sluggish revenue growth removed any chance for the Bush administration to respond constructively to the end of the Cold War and the fall of communism in Eastern Europe. Whether or not it had the will, it did not have the wallet even to think about increases in government spending to improve opportunity in America.

Policies to improve economic growth prospects typically involve a trade-off between present costs and uncertain future benefits. The payoffs from increased economic growth are deferred. The investments that contribute to that growth—in physical capital, education and training, and research and development—come at the price of resources diverted from current consumption. Thus, the decisions required to accelerate growth may foreclose current options even as they increase future choices and capabilities.

This chapter examines this trade-off. It indicates policies that might sustain and enhance economic growth and explains how to weigh their benefits and costs. Candor requires that we acknowledge an uncomfortable fact: knowledge about why economic growth varies over time and how public policies affect growth is quite incomplete. In the early 1970s, for example, growth of U.S. productivity—measured by output per person-hour worked in nonfarm business—fell more than half, from an average of 2.8 percent per year between 1947 and 1973, to 1.3 percent per year from 1973 to 1995. Had productivity not slowed down output per worker would have been 38 percent higher in 1995 than it actually was.

Although the growth slowdown was a watershed event, its causes remain somewhat mysterious and the subjects of continuing intense discussion.[2] Many analysts believe they have a better fix on why growth rebounded in the second half of the 1990s and resumed its pre-1973 pace.[3] They are confident that the cause of speed-up in productivity growth was the technological revolution in data processing and data communications, yet few if any had forecast such a speed-up.[4]

Three broad factors have driven modern American economic growth. The first is human capital—the accretion of formal knowledge and the skills acquired through practice and experience of our labor force. The second is physical capital—the machines, buildings, and infrastructure that amplify worker productivity and embody much of our collective technological knowledge. The third is the body of ideas that comprise modern technology and management techniques. This body of knowledge is the crucial factor that makes us so much richer than our forbears were. Ideas—technology—are the primary long-term cause of economic growth. But, beyond maintaining secure property rights, government policy may have its largest effect on economic growth by facilitating additions to human capital—education and skills.

Human capital policy represents a crucial lever on growth for three reasons. First, increases in educational investments have been a major factor in American economic growth for, at least, the last century and a principal source of America's 20th century economic edge over other industrial nations. Between 1900 and 2000 the average completed schooling of U.S. young adults increased almost 7 full years from 7.4 to 14.1 years. And the measured economic payoffs to increased schooling were substantial throughout the 20th century. Second, we understand more about the effects of some policies to boost the knowledge and skills of the labor force than about the effects of policies to increase either physical capital or the stock of ideas. Third, and probably most important, efforts to upgrade the knowledge and skills of America's workers promise not only to raise output but also to lower income inequality. The goal of economic growth cannot be simply the volume of output alone, but a high volume of output distributed to Americans in a way that enables as many as possible to lead better lives. For that reason, we begin our examination of measures to promote economic growth by describing trends of U.S. human capital formation and policies to encourage it. We shall then turn to policies to raise physical investment and enhance technological progress.

Human Capital

Ever since the industrial revolution, "capital" has been central to a nation's economic success. Until then, land and natural resources largely determined a nation's economic capacity. Sometime in the 19th century their role was usurped by physical capital. In the 20th century human capital accumulated through formal schooling became a key to economic growth. And the human capital of a nation's work force is likely to be crucial in determining a nation's success in the increasingly knowledge-driven economy of the 21st century.

Investments in human capital—formal schooling, on-the-job training, and informal learning—directly contribute to economic growth by increasing the productivity or "quality" of a nation's work force. We caution that the word "quality" implies nothing about people's innate characteristics; it refers only to their economic contributions as valued in the marketplace. Education and training also contribute to technological advance, because educated scientists, managers, and other highly trained and experienced workers are instrumental to the creation and application of new ideas. A more-educated work force, furthermore, facilitates the initial adoption and rapid diffusion of new technologies.[5]

Governments and Education

Governments mandate and subsidize schooling in part because people, if left to their own devices, may invest in less education than is socially optimal. Many families are too poor to pay directly for much education. Neither children nor their parents can borrow against the future earnings that education will help pupils to earn. Some parents, even those who can afford to pay for education, may not act in the best long-term interests of their children. Furthermore, children are not always rational and compliant. Many also argue that, in addition to the direct benefits for students and their families, education benefits society at large through peer effects, social capital, knowledge spillovers, and reductions in crime.[6] Education can also facilitate the economic advance of those from disadvantaged backgrounds.

For all these reasons and others, governments typically both maintain schools and mandate some minimum level of education. Not all governments have seen investments in brainpower alike. For example, most of the early 20th century industrial powerhouses were not favorably disposed to mass education. In Europe during the first half of the 20th century, schooling was either for the elite, as in France and England, or bifurcated, as in Germany in which those who did well or had resources could attend the upper grades and others did apprenticeships.

Not in America. With few exceptions, schooling in America was for the masses throughout the 20th century. It was publicly funded and provided by large numbers of fiscally independent districts. It has permitted students to make up for early poor performance. It has been open, sex neutral, primarily academic rather than industrial and vocational, and subject to secular control.[7] It retains these characteristics, although some are now questioned. The movement to strict standards, which promises benefits in some directions, also threatens to prevent students who do poorly from recovering ground later. The system of many small, fiscally independent school districts is now subject to judicial scrutiny. Though that system has the shortcoming of perpetuating unequal resources across school districts that led to huge variations in per pupil spending, it also allowed parents to express different tastes for education and fostered educational expansion.

America in the Human Capital Century

The United States led the world in mass education during the 19th century and substantially widened its lead in the 20th century. The United States forged ahead by instituting mass secondary schooling at the dawn of the 20th century and by establishing a flexible and multifaceted higher education system.[8] And, by early in the 20th century, the United States achieved the world's highest per capita income. It held on to this lead for the remainder of that century.[9] Thus the "American century" was also the "human capital century."

The twentieth century became the human capital century because of wide ranging changes that increased the relative demand for mental skill and various cognitive abilities.[10] The early 20th century rise of big business and the growth of large retail, insurance, and banking operations increased the demand for literate and numerate office workers. Technological changes in industries ranging from petroleum refining to food processing intensified the use of science by industry. These changes increased the demand not only for professionals and office workers, but also for educated blue-collar workers. The relative value of workers who could read blueprints and knew algebra, geometry, chemistry, and some rudiments of physics increased enormously with electrification, and the spread of the internal combustion engine and complex chemical processes. Farmers who understood chemistry, botany, and accounting had a competitive edge over their less educated neighbors. Education above the elementary grades was no longer just for the professionals. It was for all.

Post-elementary education paid high returns. Youths responded by continuing to upper grades. In 1915—the earliest year for which estimates have been made—an additional year of high school raised earnings about 12 percent.[11] These high returns and the rising demand for more educated workers greatly increased the demand for education. But America was more than 50 percent rural before World War I. Meeting the increased demand for education was costly. It required large investments to build schools and hire teachers. Local governments and school districts, many of them quite small, made these investments. The highly decentralized system of U.S. educational finance enabled the spread of mass secondary schooling. In contrast, the centralized school systems of Europe hampered its spread.

Greater secondary school completion rates spilled over into increased college and university attendance. Higher or tertiary education in the United States has been a patchwork quilt of public, private, secular, religious, coed, and single-sex institutions almost from its beginnings in the 17th century. With the increased demand for education, the public sector expanded relative to the private sector. The proportion of enrollments in public four-year colleges soared from 20 percent to 70 percent over the course of the 20th twentieth century.[12]

Toward the end of the twentieth century, however, the rate of increase of schooling declined substantially in the United States. Improvement in the educational attainment of cohorts of U.S. natives born starting around 1950 slowed perceptibly (see figure 1). This slowdown has translated into a reduced rate of increase in the educational level of the U.S. labor force starting in the 1980s. Because increasing labor force quality contributed significantly to economic growth in the United States throughout most of the 20th century, this pattern threatens to retard future economic growth. It also threatens to increase economic inequality, especially because it has been concentrated among minority youth and those from lower-income households. The deceleration of improvement in educational attainment has occurred despite rising economic returns to education during the past twenty years. Schooling is now advancing faster in other advanced OECD nations than in the United States, and the educational attainment of young adults in some countries appears to have surpassed that of the United States.[13]

Educational Advance in the 20th Century

An ideal measure of "human capital" would not be limited to formal schooling. It would also include parental and institutional care during pre-school years, training in commercial and vocational institutions, on-the-job training, and learning in other non-formal settings. Because such an ideal measure does not exist, we measure human capital by the number of years of formal schooling or the highest grade attained. Even this measure inadequately represents formal education because it does not incorporate the quality of a year of education.[14]

Americans born in 1975 spent nearly twice as many years in school—14.1 years *versus* 7.4 years, an increase of 6.7 years—as did Americans born a century earlier (see figure 1).[15] For cohorts born from 1876 to 1951—the first 75 years of the period examined—the increase was 6.2 years or 0.82 years per decade. Educational attainment was then roughly constant for cohorts born from 1951 to 1961, and it increased by only 0.5 years for the last fifteen years of birth cohorts. Of the increase in educational attainment of almost seven years over the full century, about half is attributable to the rise in high school attendance and graduation and about a quarter to the increase in college and post-college 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 educational attainment of native-born Americans in the 20th century.

The gap in education attainment between whites and African American was enormous at the start of the period. Whites spent nearly twice as long in school, on average, as did blacks—a gap of 3.6 years. The gap began to close, starting with those born around 1910 (figure 1). The convergence slowed for cohorts born from 1940 to 1960 and slowed further for those born since 1960. The black-white schooling gap is currently 0.6 years (for cohorts born in the 1970s), one-sixth of that a century earlier. The current gap between educational attainment of non-Hispanic whites and Hispanics—2.32 years for those born 1970 to 1975—is larger than that between whites and blacks.[16] Because Hispanics are a large and rapidly growing share of the U.S. labor force, their educational attainment is critically important for future U.S. labor productivity.[17]

Men and women have spent similar amounts of time in school *on average* over the past century (figure 2), but men born before about 1955 were more likely to have graduated from college (figure 3). Male college graduation rates surged for the peak World War II draft cohorts born starting in the early 1920s and continued growing rapidly for the cohorts drafted for the Korean War. Part of this expansion in college graduation rates reflects the consequences of the GI bill educational benefits available to veterans of World War II and the Korean War.[18] Male college graduation rates also soared for cohorts born in the 1940s with increased college attendance to avid the Vietnam draft. The male college graduation rate plummeted following the end of the draft in 1973, only to increase again in the face of high and rising labor market returns in the 1980s (apparent for cohorts born starting in the early 1960s). The female college graduation rate largely mimics that for males with some exceptions such as the World War II cohorts. The female college graduation rate has overtaken the male college graduation rate for cohorts born since the early 1960s.[19]

Differences in educational attainment by race and socioeconomic status have persisted and, in some cases, increased over the past two decades. The college graduation rate for African-Americans increased far less than that for whites for cohorts born since 1960. Moreover, differences in college enrollment and completion rates by family income expanded during the period of sharply rising educational wage differentials of the 1980s.[20]

<u>Educational Attainment of the Work Force and Educational Wage Differentials</u>

To estimate the impact of human capital accumulation on economic growth, we must measure the educational attainment of the work force and the economic returns to educational investments. Behind the large contribution of human capital to U.S. economic growth in the 20th century lies a spectacular increase in the educational attainment of American workers (figure 4—for more detailed information, see Appendix A).[21] Between 1940 and 2000 the average schooling of the work force increased by 4.4 years—from 9 to 13.4 years. In 1940, 70 percent of U.S. workers had less than a high school degree and fewer than 6 percent had a college degree. By 2000, only 11 percent had less than a high school degree and 28 percent had a college degree. During the first half of the 20th century the major change in the educational attainment of the labor force was the replacement of workers who had less than a high-school education with workers who had completed high school. Late in the 20th century the major change was the entrance of workers with at least some college education. Educational attainment of the U.S. work force progressed with particular speed from 1940 to 1980 as better-educated young people replaced less-educated older cohorts in the work force.[22] Progress slowed thereafter from 1980 to 2000.

How have the private economic returns to education, as measured by educational wage differentials, evolved? The private economic return to a year of either high school or college was substantial in 1915. Those returns must have helped spur the rapid educational advances characterizing the era of the high school movement, from around 1910 to 1940. Educational wage differentials narrowed substantially from 1915 to 1950. They then expanded modestly in the 1950s and 1960s before narrowing again in the 1970s. They then increased significantly in the 1980s, with some continued modest advance in the 1990s (figure 5).

The evolution of the wage structure is largely shaped by a race between the demand for skills, driven by technological changes and industrial shifts of employment, and the supply of skills, driven by changes in educational investments across cohorts, demographic shifts, and immigration.[23] Throughout the 20th century, demand has shifted toward industries and occupations that employ workers with higher-than-average education. At the same time, technological change has also increased demand for well-educated workers within-industries and within-occupations.[24] Increasing supply more than offset the added demand for skilled workers from 1915 to the 1970s. Over that period educational wage differentials narrowed. Since 1980, added demand for well-educated workers has outpaced added supply. Rising educational wage differentials have been the result.

Countries in which educational advance has recently slowed—the United States, United Kingdom and Canada—have experienced greater increases in educational wage differentials, especially for younger cohorts, than have countries where educational attainment continued to expand rapidly—France, Netherlands, and Germany.[25] Since about 1980, several factors have contributed to increasing wage differentials and wage inequality. Growth in the supply of college-educated workers has slowed. The demand for more-educated workers has risen, driven in part by computerization and related technological and organizational change. Unions have lost membership. Compensation for the top achievers in many fields, including business, sports, and entertainment, has greatly increased. The real value of the minimum wage has fallen. Starting in 1995, tight labor markets, an increase in the minimum wage increase, and rapid productivity growth contributed to wage growth among low earners. These developments slowed the trend to increasing wage inequality, and even narrowed wage inequality for workers with less-than-median earnings in the late 1990s. Current returns to college in the United States are now at least as large as they have been in sixty years. An increase in the ranks of college-educated workers should boost economic growth and reduce economic inequality.

Education, Labor Quality, and Economic Growth

For nearly fifty years, economic analysis has shown that an increase in the economic quality of the labor force will boost output growth. Quality is measured by the difference in wages paid to workers with different characteristics.

Education. Well-educated workers earn more than poorly educated workers. Analysts have differed on the channels through which education affects growth, but they have concurred that the effect is large.[26] Analysis of economic growth among countries indicates *per capita* output grows faster in nations with a high level and rapid growth of schooling.[27]

We estimate the *direct* contribution to economic growth of increases in the educational attainment of the U.S. labor force from 1915 to 2000 employing standard "growth-accounting."[28]

The procedures of growth accounting are straightforward. One measures the change in each measurable factor of production and assumes that it is paid a price—wages, profits and rents—that equals its contribution to production. The proportionate change in the quantity of a measurable input multiplied by its share of national product measures its contribution to rate of economic growth. Usually, changes in measurable factors of production do not account for all changes in output. The residual is regarded as a change in total factor productivity. We measure how much improvements in education, work experience, and other labor force characteristics have contributed to economic growth. We then report on the implications of recent demographic and educational trends for future economic growth.

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 work force directly boosts output by 0.7 percent.[29] We find that on average from 1915 through 2000 increases in educational attainment boosted the effective size of the work force by 0.5 percent a year (table 1).[30] Thus, education contributed an average of 0.35 percentage points a year to economic growth (0.7 times 0.5) over an eighty-five year span. This contribution equals 22 percent of the average annual increase in labor productivity of 1.62 percent.[31] (The contribution of education to economic growth depends partly on how the changes are measured. We explain in detail how we measure the contribution of education to the effective labor force in the box and appendix B.)

Improvements in educational attainment and the educational contribution to productivity varied during the 20th century. Mean educational attainment of the labor force rose by only 0.9

years in the two decades from 1980 through 2000 (table 1). By comparison, it increased 1.93 years during the preceding two decades, 1.52 years from 1940 to 1960, and 1.38 years from 1915 to 1940. The change in educational productivity accelerated in the two decades from 1960 to 1980. It then fell by nearly half from 1980 to 2000—the lowest levels of the 20th century. The slower growth in the educational attainment of the work force from 1980 to 2000 shaved productivity growth by about 0.13 percent a year relative to its average for 1915 to 1980.

Prospects for a return to rapid increases in educational attainment and high contributions of human capital to economic growth do not appear favorable. Recent projections indicate that over the next two decades the proportion of the labor force that is college educated will increase from 1.5 to 5 percentage points.[32] By comparison, it rose 8.6 percentage points from 1980 to 2000. We project that the annual rate of growth of educational productivity, which was 0.35 percent from 1980 to 2000, will decline to only 0.06 to 0.17 percent from 2000 through 2020.[33]

Although it is difficult to precisely quantify, the *indirect* contribution to economic growth of educational improvements was also large. Education not only boosted labor productivity but also fueled innovation and the adoption of new technology. For example, firms and establishments with more educated workers were earlier adopters of new technologies and showed greater productivity benefits from information-technology investments.[34] Furthermore, highly-educated labor is the primary input into research and development (R&D), and some estimates suggest that rising R&D intensity in the United States and other major advanced economies has been a significant (and possibly the largest measurable) contributor to growth in U.S. labor productivity over the last fifty years.[35]

Other Aspects of Labor Quality. Wage rates vary not only with education but also with experience, sex, and race. If one makes the critical assumption that differences in wage rates reflect differences in worker productivities, worker characteristics and associated wage differences can be used to construct an "augmented" measure of labor force quality. Such an index would encompass all worker characteristics—not only education, but also work experience, sex, nativity, and race—that are associated with significant wage differentials. To the extent that direct discrimination by race, nativity, or sex distorts wages, the critical assumption that wage differentials measure differences in economic productivity is not justified.[36] Indirect effects of discrimination—such as those arising from denial of access to good schools or in-service training—do affect productivity and are included, however.

Labor force quality, measured in this fashion, grew by an annual average of 0.42 percent from 1915 to 2000 (table 2). This contribution is almost identical to that of increasing educational attainment. In other words, educational upgrading accounted for all of the secular improvement in measured labor force quality since 1915. The rising share of women in the work force slightly lowered measured labor quality. Changes in the age composition of the work force had effects that varied by sub-period. As children increasingly remained in school until their late teens, the share of youth in the labor force declined. This factor contributed to faster growth of labor quality from 1915 to 1940. The entrance into the labor force during 1960 to 1980 of the large baby boom cohorts decreased labor force quality because the baby-boomers were then young and inexperienced. The resulting large increase in the share of inexperienced younger workers almost completely offset the rapid educational advance. As a result, the period from 1960 to 1980 saw unusually large increase in educational attainment, but unusually small improvement in overall labor quality growth. As baby-boomers acquired experience, the corresponding increase in labor force quality from 1980 through 2000 offset the unusually small increase in educational attainment. As a result, the increase in the quality of the labor force was equal to the average for the 20th century.

Once again, prospects for the future are not good. Gains in labor quality from changes in the age structure of the work force are projected to stop over the next twenty years as baby boom cohorts move beyond the age of peak earnings.[37] Because improvement in educational attainment is also projected to be slow over the next two decades, it appears that improvement in the quality of the labor force will contribute less to increased worker productivity over the next several decades than it did on the average during the 20th century.

Human Capital Policy

Increased human capital investments offer an unusual opportunity to promote economic growth and reduce inequality. Children, and their families, face great difficulties in borrowing on their future labor market earnings to finance educational investments. These credit market imperfections, along with the possible broader social benefits of education, help justify substantial government subsidies for human capital investments. The key policy question is whether, given the current level of government support for education in the United States, many families still face large financial and information barriers to making high-return educational investments ranging from early childhood education to post-secondary schooling and training. Much evidence suggests that such constraints remain significant for low-income families and that expanded targeted investments in education and training have the potential to generate social rates of return at least comparable to other private investments.[38]

A first area of concern involves the access to and affordability of college for low-income and minority youth. Since 1980, the earnings of college graduates have risen substantially relative to those with less education. This evidence suggests the existence of large economic returns to expanding college attendance and completion. Although college attendance has increased over the period—the proportion of high school graduates continuing to college rose from 49 percent in 1980 to 60 percent in 1990, and then to 63 percent in 1999[39]—the gap in college attendance rates by parental income, race, and ethnicity remains large. These differences appear, if anything, to have widened over the past twenty-five years.[40] Family income remains an important factor in explaining differences in college enrollment rates among students having similar academic grades and achievement test scores.[41]

Thus, financial constraints appear to remain a barrier to college going for low- and moderate-income youths.[42] Furthermore, reductions in college costs (from reductions in tuition and increases in financial aid) greatly increase college-going rates for youths from moderate-income families.[43] Recent estimates using "natural experiments" involving changes in access to college, changes in college costs, and compulsory schooling laws indicate high rates of return accruing to the marginal (typically low-income) youth affected by such policy interventions.[44] College attendance costs (tuition and fees minus financial aid) rose far more rapidly than did income for low- and moderate-income families from the early 1980s to the mid-1990s.[45] Rising net college costs for low-income youth are likely to have played a role in hindering them from increasing college attendance. Reductions in college costs for low-income youth from improved targeting of private and public college financial aid and a more transparent financial aid application and information system could expand college-going by disadvantaged youth.

Facilitating access to college comes too late for many low-income youth who do not have sufficient academic preparation. Mentoring programs that offer social and emotional support to poor kids, as well as financial assistance for post-secondary training, can substantially improve their academic preparation and likelihood of going to college.[46] Some second chance job training programs for disadvantaged youth who have dropped out of high school also appear promising. In particular, the residential-based Job Corps program, which serves mostly poor, urban dropouts aged 16 to 24 years, has consistently produced high social returns through increased labor earnings and reduced participant criminal activity.[47] Expanded funding for these successful mentoring programs and increases in the number of Job Corps slots are warranted.

Human capital policies must also target early childhood. The bulk of existing research indicates large returns from investments in high-quality early childhood education programs targeted to low-income families.[48] Enhanced funding of Head Start, the federal government's largest pre-school program, could increase program quality, increase access, and possibly also allow the targeting of younger children (those from infancy to 3 years of age).

Less agreement exists about the effectiveness of specific policies to improve the quality of primary and secondary schooling. The impact of increases in school resources within current public school systems is a controversial area. For example, evidence from the large-scale, random-assignment Tennessee STAR experiment strongly suggests that smaller class sizes in the early grades, holding teacher quality constant, serve to improve academic performance, particularly for poor and minority children.[49] Research also indicates that teacher quality, although difficult to measure, is especially important for pupils from disadvantaged backgrounds. But attempts to reduce class size for all students, such as California's recent statewide policy, are unlikely to hold teacher quality constant. Universal reductions in class size require more teachers for a given number of pupils and may require the utilization of more inexperienced and less qualified teachers. Richer schools and districts are likely to outbid their poorer counterparts for the most qualified teachers. Thus, broad attempts to reduce class size might wind up having little benefit for students from low-income backgrounds. More targeted attempts to increase teacher quality and reduce class size for schools with low-income students appear to be more promising and are less expensive than universal policies to reduce class size.

School competition that has operated through residential location choices in a system of local school finance and many small and medium-size school districts played an important role in the expansion of schooling in the United States throughout much of the 20th century. But such a system does not work as well for those from disadvantaged backgrounds with more limited residential choices. Expanded options for low-income families, including public school choice, charter schools, and vouchers, deserve further experimentation.

The substantial growth in the geographic concentration of poverty in inner cities and the sharp rise in residential segregation by family income since 1970 have worsened the human capital investment in children from low-income families.[50] Recent research on programs that enabled low-income families to move from troubled neighborhoods to middle-class communities indicates that concentrated neighborhood poverty greatly harms children and that lower-poverty neighborhoods enhance children's educational performance, health, and behavior.[51] This research suggests that policies to promote residential mobility, such as a greater availability of housing vouchers, would also improve human capital of children from low-income families.

Physical Capital

Could shifts in government policy produce large enough changes in rates of investment in physical capital to significantly boost economic growth? In the 1950s, Robert Solow (1956, 1957) and Moses Abramovitz's (1956) published theoretical and empirical studies that first highlighted that physical capital was not the most important factor driving increases in labor productivity and living standards in the twentieth century. Physical capital deepening—increases in the economy's capital-output ratio—has played second or perhaps third fiddle. Nearly all economists have agreed that "total factor productivity"—the "residual" growth not directly accounted for by increases in the quantity or quality of labor or capital, as Denison (1962) put it—was the primary cause of rising incomes and labor productivity.

Moreover, the capacity for shifts in policy to generate faster growth through higher physical capital investment is lower than one would suppose from a standard growth-accounting analysis dividing growth between labor, capital, and the "residual." With a constant investment (or savings) rate as a share of national product, increases in incomes arising from growth in total factor productivity will induce increases in investment so that the capital stock will grow roughly as fast as total output. In this case, a standard growth-accounting analysis will attribute perhaps a third of labor productivity growth to this increased physical capital stock. But this higher income-driven increase in the physical capital stock is, in some sense, mechanical. Policies—whether good or bad—that attempt to affect growth through affecting investment and saving must do so by *changing* the economy's capital-output ratio. Significant changes in the economy-wide capital-output ratio have been rare since the nineteenth century, and are difficult to accomplish through economic policy.

Since World War II, total factor productivity growth has swung from 2 percent per year from 1947 to 1973, down to near zero from 1973 to 1995, and back to 1.5 percent per year since then: changes in total factor productivity growth have been the primary source of fluctuations in U.S. economic growth. We have highlighted the extraordinary commitment of America in the twentieth century to mass education at all levels. By contrast, there were no signs of any increase in the physical capital-output ratio from before World War I until the past decade: neither economic policies nor changes in private-sector behavior had a material impact on investment rates and thus on overall economic growth.[52]

Starting in 1994, however, measured gross physical investment has risen sharply as a share of gross domestic product (see figure 6). The result is likely to be a noticeable long-run increase in the economy's measured ratio of capital to output, especially for data processing and data communications equipment. The extraordinary and ongoing technological revolutions in data processing and data communications technologies have led to substantial physical capital deepening so far, and promise further capital deepening in the future. Almost all analysts conclude that two factors account for much of the mid-1990s acceleration in the rate of American economic growth: (a) a greatly increased share of total incomes devoted to investment in information-technology capital and (b) increases in total factor productivity in the manufacturing of information-technology capital goods. These two factors have boosted the rate of growth of gross output by an amount estimated to be near one percentage point per year (see table 3).

Should Government Care About Physical Capital Investment?

Higher rates of investment in physical capital increase growth and boost the economy's physical capital-output ratio in the long run, but they also reduce current private consumption or spending on government programs. As economists, we begin from the baseline presumption that the allocation of output between investment and consumption is best left to individual decisions through free markets. Market allocation will produce inferior results, however, in at least some situations. The first occurs when physical capital investment has powerful effects—spillovers or externalities—on people and businesses that are not parties to the investment decision. For example, research investments produce knowledge that can be of immense value to businesses or individuals other than the company that sponsors the research. In such cases, the social value of the investment exceeds the private gain. The second occurs because taxes reduce the private return to saving below total social returns. The third occurs when preferences are (dynamically) inconsistent in such a way that older individuals, looking back, conclude that their younger selves were short-sighted and that they should have saved and invested more. In these cases, the government should not leave the amount or composition of saving and investment to the market.

A fourth case in which individual decisions will not lead to the best investment decisions—this time in human capital—arises because individuals cannot normally borrow in advance against the increased earnings that education will produce, and so often individuals have a hard time financing education that is clearly beneficial. Such "capital market imperfections" justify active government intervention to remove them, or to neutralize their effects. In addition there is "capital-education complementarity" to consider: without substantial investments in physical capital, workers will not be able to use their skills effectively; without the requisite education, workers will not be able to use capital equipment effectively.[53] Because companies that finance investments in new production technology do not normally capture all the social gains from the labor force's experiential process of learning how to use new types of capital equipment, there is a clear case for believing that private market decisions will not produce the right amount but too little physical capital investment.

Studies of the cross-country pattern of economic growth provide suggestive evidence that external complementarities between investments in physical capital on the one hand and other growth-promoting factors on the other hand are important. High investment rates—especially in machinery and equipment that embody modern technology—are positively correlated across countries with rates of labor productivity growth much more strongly than the private profits of investing firms would lead one to expect. Of course, correlation is not causation. However, the cross-country correlation appears to hold whether the source of high investment rates is a relatively high national savings rate or a domestic price structure tilted toward making investment goods relatively cheap.[54] The cross country data are not inconsistent with net *social* returns to investment of 20 percent per year or more—in striking contrast to after-tax *private* returns to investment of 5 to 10 percent per year.

Microeconomic evidence also points to important external complementarities between physical capital investment rates and total factor productivity growth. Successful work place reorganizations to take advantage of new information technologies require substantial upfront investments in physical capital goods. Organizational reconfiguration costs much more than the associated physical investment.[55] Once a particular company has made such investments and figured out how to reorganize its operating procedures to benefit from them, other companies can replicate its accomplishments at lower cost: if other companies can save even a small proportion of these costs incurred by the innovating company, the social returns to investments in physical capital that embody newly-developed technologies are much larger than the private returns.

A historical example illustrates such complementarities.[56] The key benefit of the diffusion of electric power for total factor productivity within U.S. manufacturing a century ago resulted from learning-by-using and the invention of complementary technologies such as small motors. Only after the new technology had diffused sufficiently widely through an economy could the social learning and experimentation that produced serendipitous efficiencies take place. Relatively few firms used the flexibility made possible by electric power to undertake the organizational experimentation and reconfiguration that led to "mass production." Imitation and diffusion then spread mass production throughout the economy, producing vastly larger benefits.

Thus government should concern itself with the level of physical investment, for it is likely that private returns to investment in physical capital are lower than social returns. This economist's externality-based case is strengthened by the secular fall in the private savings rate seen in the U.S. over the past generation. To be the result of rational household decisions, this shift must be the result of either an extraordinary shift in tastes that reflects a radical devaluation of the future in favor of the present, or by an extraordinarily large reduction in perceived riskiness that has greatly reduced the insurance motive to build up wealth.[57] It seems more likely to be the result not of rational household optimizing behavior but of changes in institutions and in rules-of-thumb that the government needs to examine, and perhaps try to offset.[58]

Precisely estimating the size of the gap between private and social returns to investment is difficult.[59] Nevertheless the balance of evidence suggests that society gets more form investments than do the private parties that make them.[60] That means that the social benefits of policies to boost physical investment are likely to exceed their costs.

Ways to Boost Physical Investment

Three classes of interventions can boost investment. Government can try to encourage private saving. It can contribute directly to boosting national saving by running government budget surpluses. And it can try to make investment more attractive.

Savings Incentives. Traditional incentive-based efforts to promote saving have been consistently difficult to design and implement. They also appear to have been relatively ineffective. They produce two roughly offsetting effects. On the one hand, savings incentives such as tax concessions raise savers' real lifetime wealth. When their wealth increases people want to spend more. Thus this effect increases current consumption. Because current saving is the difference between current income and current consumption, this wealth effect decreases the quantity saved. On the other hand, tax and other saving incentives that make saving cheaper in terms of how much current consumption must be sacrificed. That is, a saver can "buy" a given amount of future consumption at a lower "price" of foregone current consumption. When the price of any good falls—holding real income constant—people want more of it. This tendency to substitute future for current consumption is called the "substitution effect." Research to determine which effect dominates has reached conflicting conclusions. The lack of clear findings suggests that whatever effect conventional saving incentives have, they are almost surely small.[61]

Unconventional saving incentives may prove to be more promising.[62] To the extent that household saving behavior is dominated by "rules of thumb" or "mental accounts"[63] that restrict the availability of certain classes of wealth for current consumption, public policies that mandate or encourage the setting-aside of chunks of current income may prove to have large net effects on savings rates. However, economists are still very far from a consensus on the importance of such "behavioral finance" effects. And they are even further from having a well-informed view on how government economic policy can take advantage of these effects to raise social welfare.

Investment Incentives. Direct investment incentives have considerable intuitive appeal. If the goal is to promote the external complementarities induced by investment, direct investment incentives are focused on the proper goal.[64] However, the government lacks the capacity to reliably distinguish between investments that would have been made without the incentives, and those induced by the incentives.[65] Thus an important argument against the broad-based investment tax credit the U.S. has periodically offered is that most of the credit rewarded investments that would have been undertaken in any case. The argument against a narrow incremental investment tax credit is that administrative complexities and incentives for businesses to dissipate time, energy, and resources in making their normal investment project "incremental" greatly reduce the effectiveness of such a program.

The Government Budget. The most direct and effective public policy to boost the physical capital investment rate is one that was proposed forty years ago in the *1962 Economic Report of the President*—that over the business cycle as a whole, on average there should be a "tight" high-surplus fiscal policy to boost national savings accompanied by a "loose" low interest-rate monetary policy to assure that the savings are invested and that full employment is maintained. This investment may be domestic or foreign, to the extent that domestic saving supplants borrowing from abroad. Either way, public saving powerfully affects U.S. investment. Given that alternate direct investment incentives are difficult to target accurately and that the effects of savings incentives are uncertain at best, it seems highly likely that the best way to use a federal government dollar to boost rates of physical capital investment is to use it as part of a budget surplus: to save it, and thus to have public saving adding to the flow of private saving to finance investment.[66]

Investment in Technology

Society invests not only in human capital and in physical capital, but in ideas—investments in better technology. Improvements in knowledge have the important advantage that they are "non-rival" goods, meaning that their supply is not restricted: use by one person does not reduce the supply available for others.[67] Thomas Jefferson put it best: "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me."[68]

To encourage investment in ideas, the larger the market the better. For more than two centuries, economists have focused on comparative advantage as the most important reason for large markets and free trade. However, from the perspective of providing appropriate incentives to invest in technology, it may well be that comparative advantage is less important than division of labor: increasing returns to scale and the growing extent of the market may be more important factors.

Because ideas are non-rival, the most basic of economic principles suggests that technology should be distributed freely because its marginal cost is zero. But here different economic principles cut in different directions. If the price equals zero, the idea cannot be created and produced by private firms: private developers of technology will not do so if they cannot charge for it, because they must cover their costs. If the government is to subsidize investment in technology on a large scale, it needs mechanisms to determine where subsidies should flow. Government bureaucracies are unlikely to be able to choose and assess the directions of applied research and development very well. There is a good deal of truth in the insights of economist Friedrich von Hayek that market competition is a discovery mechanism and the best way to promote innovation, and that there are powerful administrative defects produced by the top-down control that comes with centralized funding.

Complicating the issues still further, basic research must be widely disseminated because basic research and applied research are cumulative enterprises. Isaac Newton said that the only reason he was able to see farther than others was that he stood on the shoulders of giants. Restrictions on the dissemination of intellectual property may well do less to create incentives for research and development and more to destroy the web of scientific and technical communication that make research and development effective. [69]

We today simply do not know enough to know how to design the right systems of intellectual property and other forms of government's setting the rules of the market economy game in order to nurture investment in ideas and technology. New institutions and new kinds of institutions—perhaps even some that have been tried before, like the French government's purchase and placing in the public domain of the first photographic patents in the early nineteenth century—may well be necessary to come as close as possible to achieving the objectives of (a) price equal to marginal cost, (b) entrepreneurial energy, (c) supporting cumulative research, and (d) providing the right incentives for research and development.[70]

Overall, the problems with managing the rewards to innovation and the diffusion of knowledge have not proved crippling. The American economy today appears to be undergoing a knowledge-driven long-run productivity boom. Even in the recession of 2001 productivity growth remained remarkably high, strongly suggesting that the pickup in economic growth that started in the mid-1990s is not a phenomenon limited to the late-1990s business-cycle boom. The inventions and innovations that have fueled this information technology-driven boom are remarkably impressive, and give promise of a relatively bright future for labor productivity growth in America.

On the other hand, estimates of the social rate of return to research and development (R&D) investments using a wide range of methodologies often exceed 25 percent and are typically at least twice as high as estimates of the private returns to R&D.[71] These findings are suggestive of substantial under-investment in R&D by the U.S. private sector. The large gap between social and private returns to R&D investments suggests even imperfect tax subsidies for private R&D efforts (that leave the decisions in private hands) may have substantial economic growth payoffs.

Nevertheless, our lack of knowledge about how to design economic institutions for this area is especially frustrating, for here is where the stakes involved in policies to boost economic growth may well be the largest. Whether or not we can sustain rapid economic growth in the 21st century may well rest on our ability to build the right systems of intellectual property and market competition to underpin an economy of which non-rival goods become a more and more important component.

Conclusion

Rapid economic growth will facilitate solutions to virtually every problem examined in other chapters of this book. Fast economic growth not only raises household incomes and consumer living standards directly, it also softens many other policy trade-offs that Americans face. Because so many different factors affect economic growth, a wide range of policies can contribute to growth—revisions of rules governing intellectual property to encourage technological advance, increases in public saving, incentives for private saving, incentives to boost private investment, and policies to boost the skills of the labor force.

However, we have much uncertainty concerning how to design effective policies to boost growth in many of these areas. Designing the right intellectual property system to accelerate technological progress in the twenty-first century is an extremely hard problem. Puzzles remain when it comes to the task of designing effective incentives for private saving. Things are only a little easier when it comes to the task of designing cost-effective policies to encourage private investment in physical capital and research and development. One line of policy remains both straightforward and effective in boosting capital accumulation and growth: the government should run a budget surplus.

By contrast, we believe policies to increase human capital investments in younger cohorts, especially for minorities and those from low-income families, are promising tools both for raising U.S. growth and reducing wage inequality. The enormous rise in the college wage premium since 1980 has created incentives for increased education. Not all groups have invested equally, however. A lack of resources continues to deter enrollment of able children from low-income families. Differences in college enrollment rates by race and Hispanic-origin have actually widened since 1980. Improved targeting of college financial aid, earlier mentoring policies, and a more transparent financial aid system promise large payoffs not only for affected families but for the United States as a whole. Greater access of poor youth to effective second-chance training programs such as the Job Corps is also warranted.

Moreover, since "learning begets further learning," human capital policies must also target early childhood. The United States also should be willing to experiment further with policies (possibly involving school choice) that promise to improve the quality of primary and secondary schooling. And policies, such as housing vouchers, that may serve to reduce the trend towards rising residential segregation by economic status could also prove beneficial.

During the twentieth century America's investment in education was a principal source of its extraordinary economic performance. This category of investment is lagging. Projections indicate much reduced rates of increase in the educational attainment of the American labor force. A renewed commitment to invest in education embodied in well-designed public policies is probably the most important and fruitful step federal, state, and local officials could take to sustain American economic growth.

APPENDIX A: Educational Attainment of the Work Force

We present summary measures of the educational attainment of the civilian work force (aged 16 or older) that weight individual workers equally (Table A1) or by their hours worked (Table A2). The "person weights" provide a sense of the education of a typical worker, whereas the "hours weights" make more sense for evaluating the contribution of education to labor productivity (output per hour worked). We estimate the distribution of highest grade attained of the U.S. work force using the U.S. population census, for 1940 to 1990, and the Current Population Survey, for 2000. The 1940 federal population census was the first to ask educational attainment. Comparable data are also given for 1915 from the Iowa State Census, the earliest large-scale representative U.S. sample with information on educational attainment and earnings.[72] Iowa was a leading state in education early in the century and had a more educated population than did the rest of the United States in 1940. But by the end of the twentieth century, Iowa was no longer a leading state and was far more like the U.S. average.

Table A1
Educational Attainment of the Work Force, 1915 to 2000

	United States					Iowa					
	1940	1960	1980		2000	1915	1940	1960	1980		2000
Education	Census	Census	Census	CPS	CPS	Census	Census	Census	Census	CPS	CPS
Mean years	9.01	10.53	12.46	12.54	13.40	8.45	9.83	10.87	12.49	12.51	13.40
Fraction, by years											
0-8	0.522	0.303	0.087	0.079	0.034	0.726	0.476	0.289	0.077	0.062	0.021
9-11	0.174	0.218	0.154	0.142	0.080	0.129	0.165	0.184	0.126	0.132	0.074
12	0.185	0.262	0.346	0.368	0.322	0.083	0.229	0.316	0.424	0.461	0.340
13-15	0.061	0.121	0.228	0.219	0.288	0.037	0.076	0.128	0.210	0.188	0.326
16+	0.058	0.096	0.185	0.192	0.275	0.026	0.055	0.083	0.164	0.157	0.240

Sources: 1915 Iowa State Census; 1940, 1960 and 1980 Census IPUMS; and 1980 and 2000 CPS MORG samples.

Notes: Samples are restricted to those aged 16 years or older and exclude those in the military and the institutionalized. The work force in each year from 1940 to 2000 consists of those who are employed at the survey reference week. The work force for Iowa in 1915 consists of those reporting occupational earnings for 1914; each individual is weighted by their months worked in 1915. Years of schooling for 1940 to 2000 are measured using the same approach as Figure 1. The construction of measures of years of schooling and months worked for Iowa in 1915 use 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.

Table A2
Educational Attainment of the U.S. Work Force Weighted by Hours, 1940 to 2000

	United States					Iowa				
	1940	1960	1980		2000	1940	1960	1980		2000
Education	Census	Census	Census	CPS	CPS	Census	Census	Census	CPS	CPS
Mean years	9.10	10.61	12.58	12.65	13.51	9.81	10.88	12.58	12.62	13.50
Fraction by years										
0-8	0.514	0.299	0.084	0.076	0.033	0.484	0.296	0.078	0.059	0.021
9-11	0.173	0.210	0.138	0.126	0.066	0.161	0.168	0.103	0.104	0.052
12	0.191	0.269	0.354	0.375	0.323	0.229	0.332	0.443	0.480	0.352
13-15	0.063	0.119	0.224	0.219	0.285	0.073	0.117	0.201	0.188	0.328
16+	0.060	0.102	0.199	0.204	0.292	0.053	0.086	0.175	0.169	0.247

Sources: 1940, 1960 and 1980 Census IPUMS; and 1980 and 2000 CPS MORG samples.

Notes: Methods are the same as for Table 1, except the summary statistics weight all individuals by their hours worked during the reference week times their sampling weight.

APPENDIX B: Educational Productivity and Labor Quality Indexes

We follow the approaches of Goldin and Katz (2001b) and Aaronson and Sullivan (2001) in constructing educational productivity and labor quality indexes for the U.S. work force for selected years from 1915 to 2000. We assume the impact of worker characteristics on productivity equals their impact on wages. We identify the impact of worker characteristics on wages (and productivity) through standard regressions of (log) wages on education, experience, sex, and other control variables. These regression coefficients are combined with micro data on the characteristics of the work force to compute an average predicted wage (using only the education variables for the education productivity index and using a wider range of variables for the augmented labor quality index). Using the same base period regression coefficients to predict wages for two different years (t and t'), we measure the change in labor quality from t to t' as the change in the average predicted wage.

We use data from the 1915 Iowa State Census, the 1940, 1960 and 1980 Censuses (IPUMS), and the 1980 and 2000 CPS MORG samples. Our first step is to estimate a wage regression in each year of the following form:

$$\log w_{it} = E_{it}\alpha + X_{it}\beta + R_{it}\delta + \varepsilon_{it} ,$$

where w_{it} is the wage of worker i in year t; E_{it} is a vector of dummy variables for educational attainment levels (0-4, 5-6, 7-8, 9-11, 12, 13-15, and 16 or more years of schooling); X_{it} contains other potentially productivity-related variables including a quartic in potential experience, a female dummy and its interaction with the experience variables, a nonwhite dummy, and a U.S. born dummy; R_{it} are Census region dummies; and ε_{it} is the error term. The wage regressions are estimated for national samples of civilian, nonagricultural, wage and salary workers, aged 18 to

65 years. The estimates for 1915 only cover Iowa and include the self-employed. We adjust the estimates of wage differentials for Iowa in 1915 to be representative for wage and salary workers for the entire United States following the approach of Goldin and Katz (2001a). The educational attainment categories for 1940 to 1980 are based on highest grade completed, except all those with 13 years attended are placed in the 13-15. The computation of years of schooling and potential experience for the 2000 CPS follows the approach of Autor, Katz and Krueger (1998). Log hourly wages are the dependent variable used in the wage regressions for the hours-weighted indexes. Hours worked data are not available for the 1915 Iowa state sample so a monthly wage measure is used for 1915. The wage regressions for the employment-weighted indexes are restricted to samples of full-year workers (50 or more weeks) and use log annual earnings as the dependent variable, except hourly wages for full-time workers are used for the 1980 to 2000 changes.

The next step is to estimate average predicted wages in each year for the entire civilian work force (aged 16 or older). A chain-weighted index for t to t' uses the average of the wage regression coefficients for t and t'. The fixed-weighted indexes use the average regression coefficients prevailing for the entire 1915 to 2000 period. The predicted wage for the education productivity index for i in year t using base period b regression coefficients is given by

$$W^{e}_{it} = \exp(E_{it}\alpha^{b}).$$

The analogous predicted wage for the labor quality index is given by

$$W^{q}_{it} = \exp(E_{it}\alpha^{b} + X_{it}\beta^{b}).$$

The educational productivity index for t (E_t) is the weighted mean of W^{e}_{it} for all members of the civilian, noninstitutional work force (16 or older) with person sampling weights used for employment-based indexes and the product of the sampling weight and hours worked last week used for the hours-based indexes. Thus,

$$E_t = \Sigma_i \, \omega_{it} \, W^e{}_{it} = \Sigma_j \, W^e{}_{jt} S_{jt} \, ,$$

Where ω_{it} is the appropriate sampling weight, j indexes education groups, and S_{jt} equals the share of the work force in education group j in year t. The augmented labor quality index for t is given by the analogous weighted mean of $W^q{}_{it.}$

The civilian, noninstitutional work force in each year from 1940 to 2000 includes those 16 or older who are employed during the survey reference week, excluding those in the military and those who are institutionalized. Changes in the educational productivity index from 1915 to 1940 in Table 1 use data on the distribution of education of the Iowa work force for 1915 (from the Iowa State Census) and for 1940 (from the U.S. Census). The 1915 Iowa work force is given by (civilian, noninstitutional) individuals aged 16 or older reporting positive occupational earnings for 1914. We assume the growth of educational productivity from 1915 to 1940 is the same for Iowa and the United States. The U.S. labor quality index in Table 2 uses information on the age, sex, race, and nativity distribution of the U.S. workforce from 1915 to 1940 and uses information only from Iowa for changes in the education component. The characteristics of the U.S. work force for 1915 are the average of characteristics for 1910 and 1920 using the 1910 and 1920 U.S. Census IPUMS data. The work force for 1910 and 1920 includes those aged 16 to 65 with gainful occupations and excludes students. The 1940 Census sample used for the 1915 to 1940 change in augmented labor quality includes labor force participants aged 16 to 65 and also excludes students. In both Tables 1 and 2, changes from 1940 to 1960 and from 1960 to 1980 use the U.S. Census IPUMS data, and changes from 1980 to 2000 use the CPS MORG data.

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Box

Measuring the Contribution of Education to Economic Growth

We compute an education productivity index, E_t, for the U.S. work force in year t. multiply the relative wage, $w_{i\tau}$, of a particular education group, i, relative to a reference education group in a base year, τ, by its share in total employment or hours, S_{it}, in year t. The resulting index measures the educational upgrading of the labor force. It also measures the impact of education on productivity if one assumes that differences in education reflect the impact of schooling on productivity. An alternative view holds that education signals inherent differences in the productivity of workers that education uncovers but does not cause. The bulk of evidence supports the assumption that education actually contributes to increased economic productivity.[73]

Tables A-1 and A-2 in appendix A provide detailed information on the changes in educational attainments over the course of the 20th century that are summarized in figure 4. Relative wages can be computed either period by period, with changing weights in each period (a "chain weighted" index), or with fixed weights. These two approaches produce similar results (see table 3).

Figure 1

Years of Schooling by Birth Cohort,
All U.S. Natives and by Race: 1876 to 1975

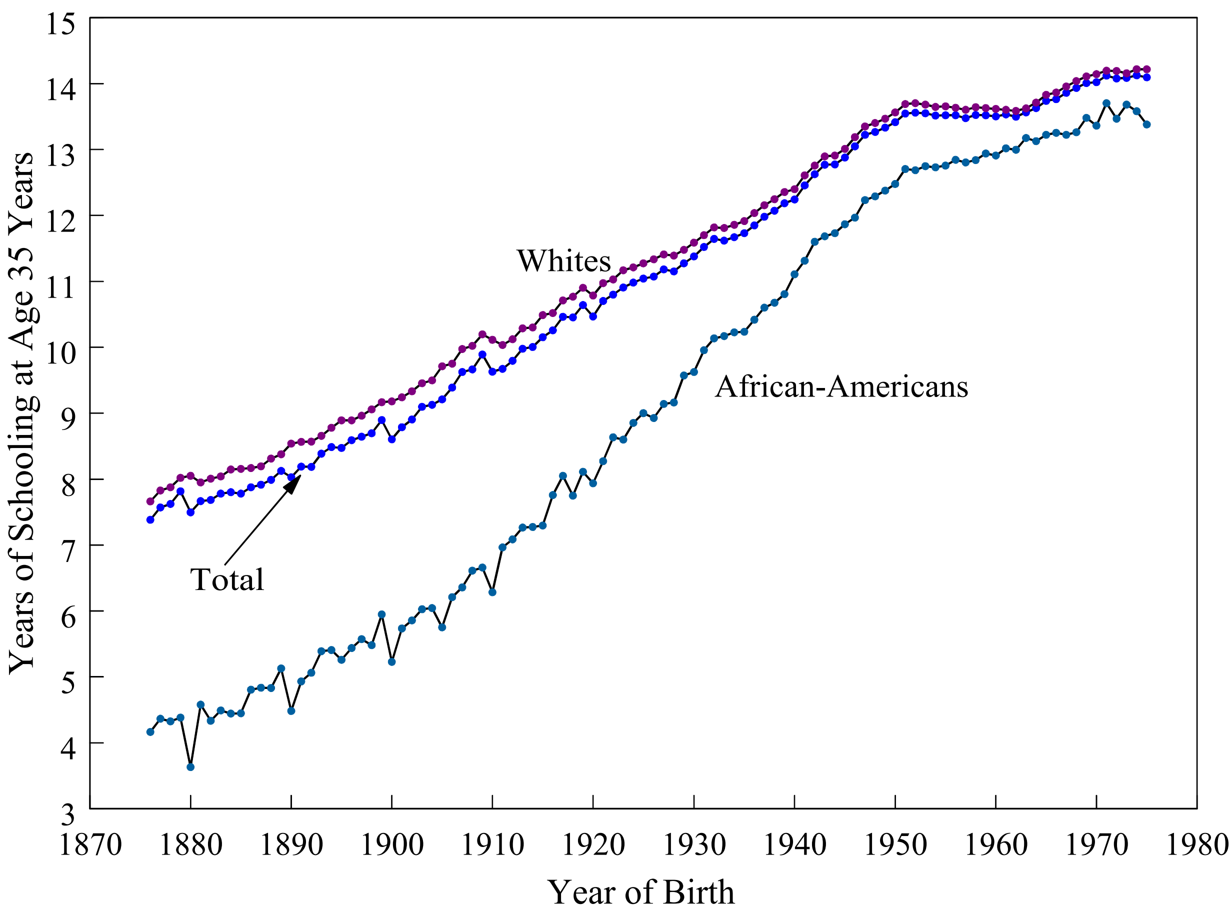


Figure 2

Years of Schooling by Birth Cohort, U.S. Natives by Sex: 1876 to 1975

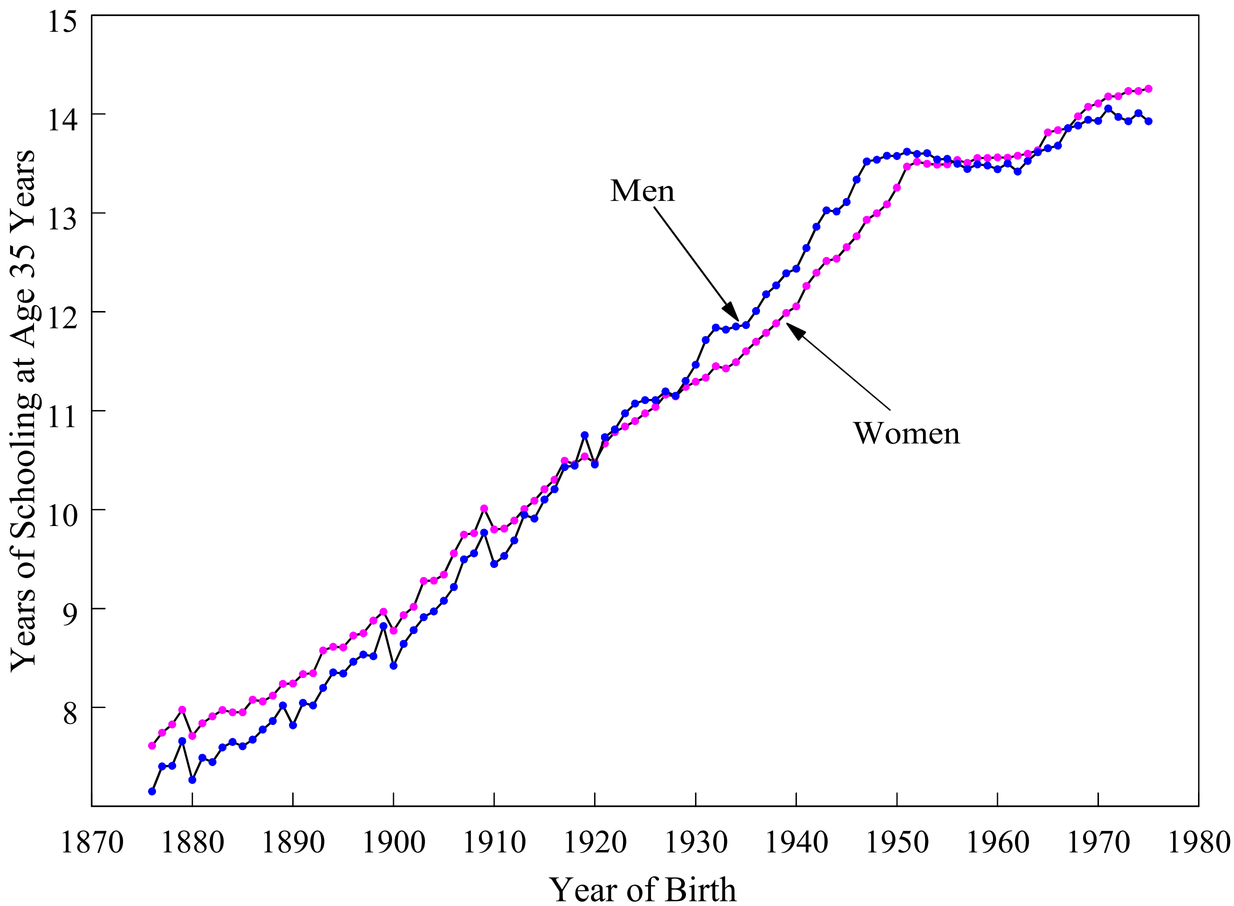


Figure 3

Fraction Graduating College by Birth Cohort, U.S. Natives by Sex: 1876 to 1975

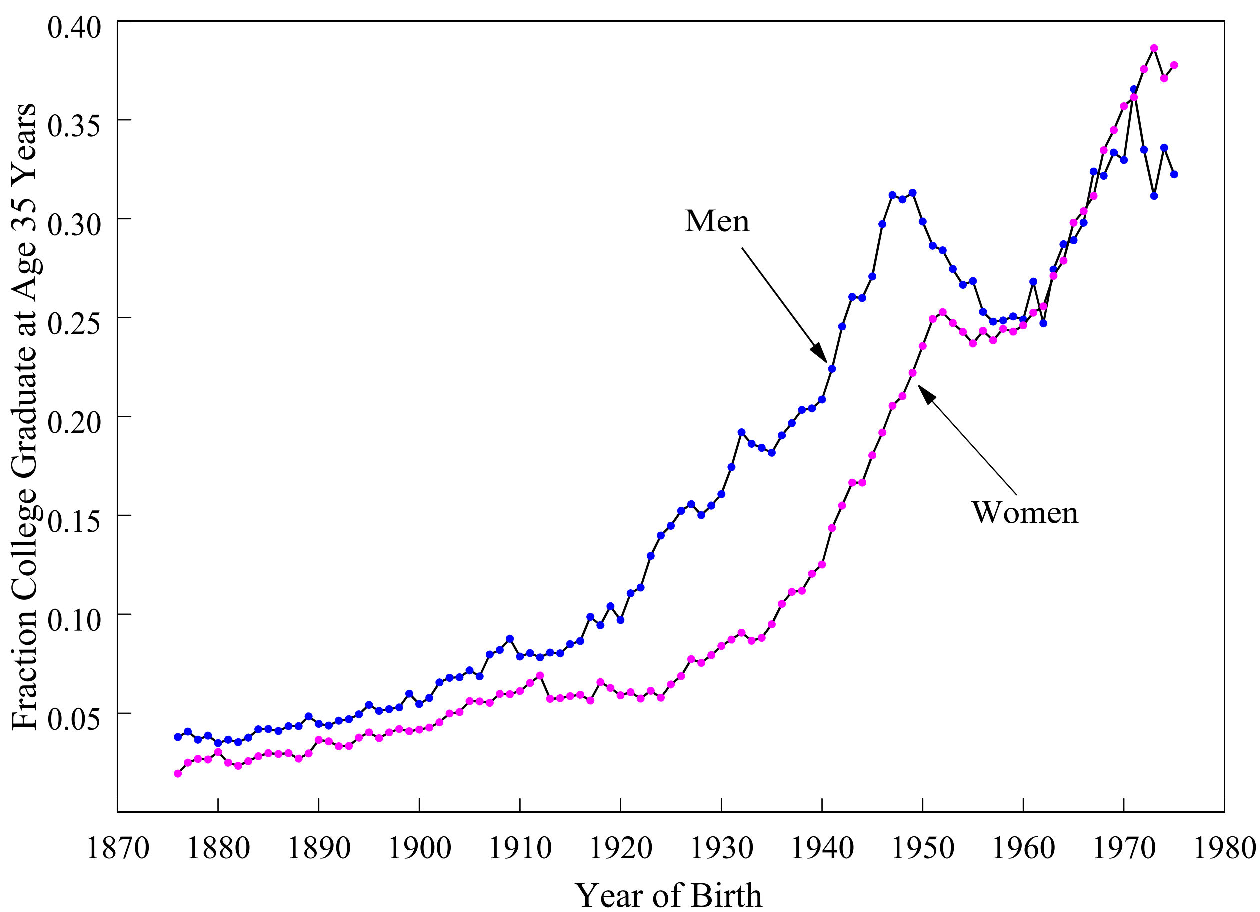
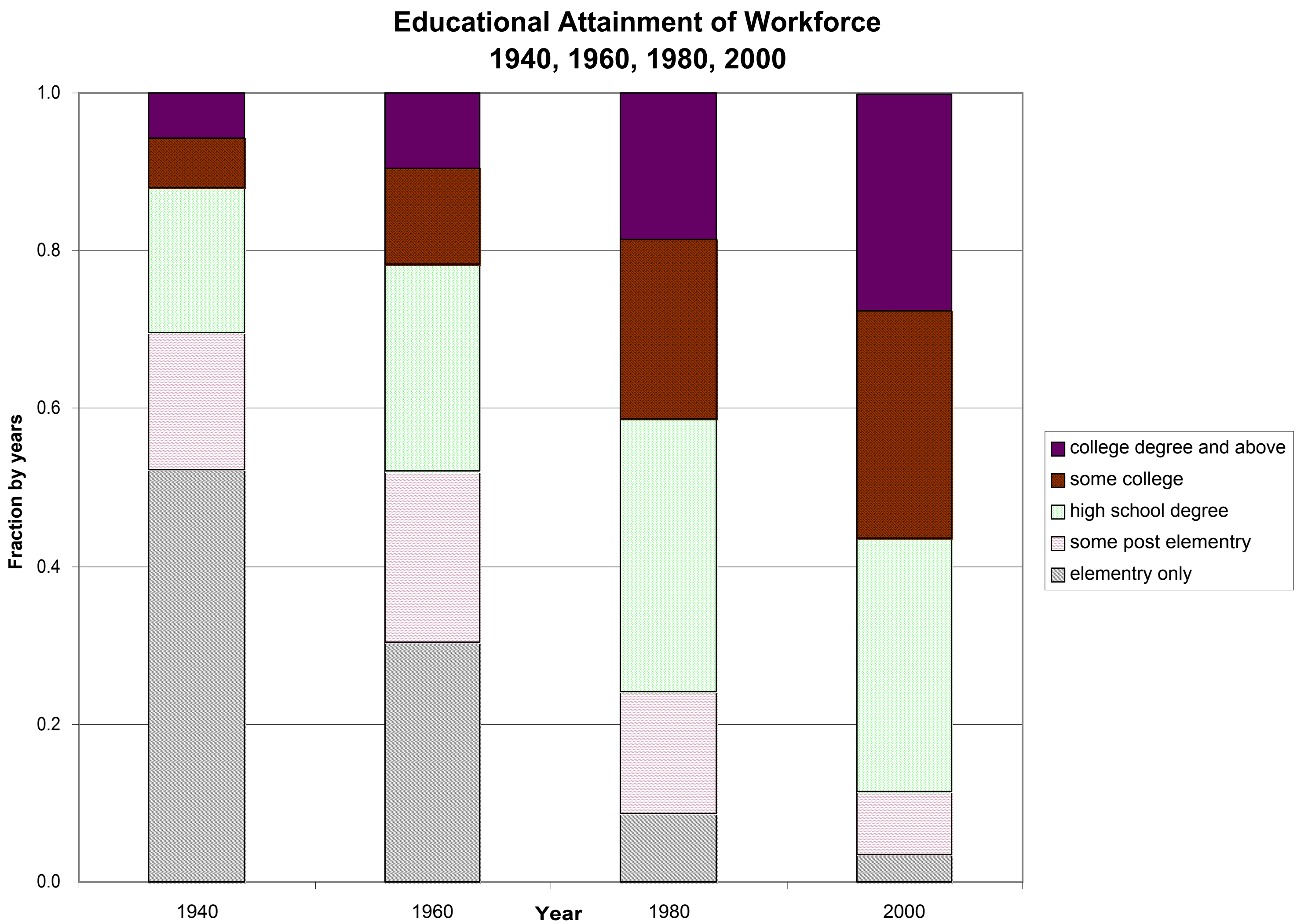


Figure 4



Mean Years: 9.01 10.53 12.46 13.40

For details, see Appendix A.

Figure 5

Educational Wage Differentials

All Workers and Young Male Workers, 1915 to 2000

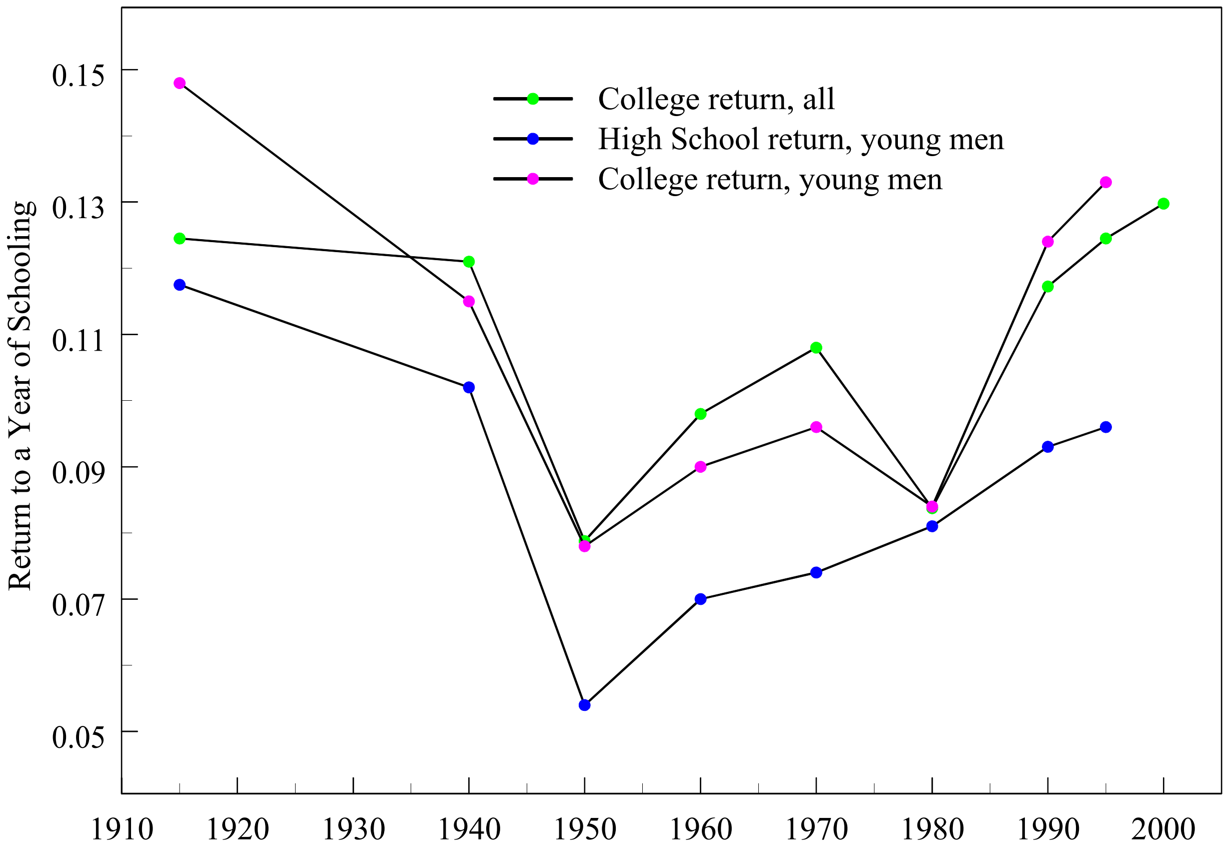


Figure 6

Real Private Investment Divided by Real GDP

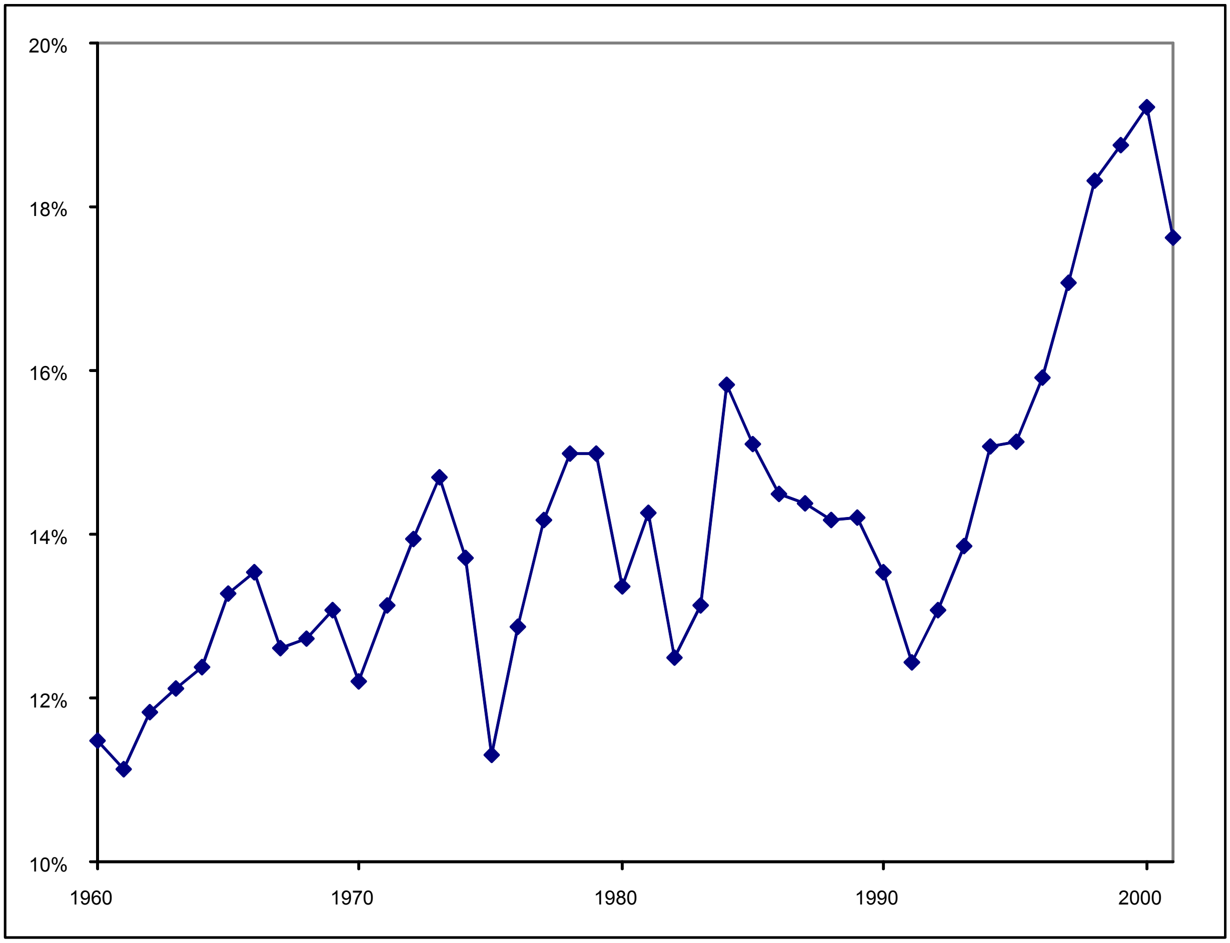


Table 1
Educational Growth Accounting: 1915 to 2000

	annual percent change in the educational productivity index of the work force using:				Change in the educational attainment of the work force (in years)
	Chain weighted prices		Fixed weight prices		
Period	Employment	Hours	Employment	Hours	
1915-40	0.52	0.50	0.41	0.39	1.38
1940-60	0.50	0.49	0.51	0.49	1.52
1960-80	0.61	0.59	0.69	0.69	1.93
1980-2000	0.35	0.35	0.34	0.35	0.86
1915-2000	0.50	0.48	0.48	0.47	5.69

Sources: 1915 Iowa State Census sample (Goldin and Katz 2000); 1940, 1960, and 1980 U.S. population censuses (IPUMS); 1980 and 2000 CPS MORG samples.

Notes: Details on the construction of the educational productivity indexes are given in Appendix B. The indexes cover the civilian work force (ages 16 or older) in each year. 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 wage differentials for *t* and *t'*. The fixed-weight index uses the average educational wage differentials for 1915 to 2000. Employment-based indexes weight workers by their sampling weights; hours-based indexes weight workers by the product of their sampling weight and hours worked in the survey reference week. Annual percent changes in the educational productivity index are given by 100 time the annual log change in the educational productivity index.

Table 2

Augmented Labor Quality Index: Annual Percent Changes, 1915-2000

Chain-Weighted Prices

Period	Employment	Hours
1915-1049	0.61	n.a.
1940-1960	0.47	0.46
1960-1980	0.12	0.14
1980-2000	0.43	0.43
1915-2000	0.42	n.a.

Sources: 1915 Iowa State Census sample (Goldin and Katz 2000); 1910, 1920, 1940, 1960, and 1980 U.S. population censuses (IPUMS); 1980 and 2000 CPS MORG samples.

Notes: Details on the construction of the labor quality index are given in the Appendix. The indexes cover the civilian work force (ages 16 or older) in each year. The chain-weighted index covering years t to t' uses predicted wage based on average wage differentials for t and t'. Employment-based indexes weight workers by their sampling weights; hours-based indexes weight workers by the product of their sampling weight and hours worked in the survey reference week.

Table 3

Estimates of Sources of the Late 1990s Productivity Growth Acceleration
(percent)

Acceleration in labor productivity 1996 to 2000 *versus* 1991-1995	**1.00**
Contributions from:	
Capital deepening	***0.57***
Information technology	0.54
Computer hardware Computer software Telecommunications equipment	0.36 0.13 0.07
Other capital	0.02
Multifactor productivity	***0.62***
Semiconductors	0.30
Computer hardware manufacture	0.06
All other sectors	0.26
Labor Quality	***-0.20***

Source: Oliner and Sichel (2002). Notes: Updated versions of the growth-accounting estimates found in Oliner and Sichel (2000). Detail may not add to total because of rounding.

Sources and Notes for Figures

Figure 1:

Sources: 1940 to 1990 Integrated Public Use Microsamples (IPUMS) of the U.S. population censuses; and 1999 and 2000 Current Population Survey (CPS) Merged Outgoing Rotation Group (MORG) samples.

Notes: The figure plots mean years of completed schooling for the U.S. born by birth cohort at 35 years of age (or adjusted to age 35 for cohorts not observed at exactly 35). Years of schooling are given by highest grade completed for the 1940 to 1980 samples, top coded at 18 years. Those with 17 years in 1940 and 1950 (the highest category in those years) are assigned 17.6 years (the mean for those with 17 or 18 years of schooling in 1960). The categorical education variable for the 1990, 1999, and 2000 samples is converted to years of completed schooling. We translated the categories covering more than a single grade as follows: 2.5 years for those in the 1st – 4th grade category; 6.5 years for those in the 5th-8th grade categories; 12 years for those with 12 years of schooling, a GED, or a high school diploma; 14 years for those with some college or with an associate 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.

We use the proportional life-cycle change in reported years of schooling for U.S. birth cohorts from 1876 to 1975 to age-adjust reported years of schooling. Specifically, we collapse the data into birth cohort-year cells. We then run a regression of the log of mean years of schooling on a full set of birth cohort dummies and a quartic in age, pooling all the samples from 1940 to 2000 for those U.S. born aged 25 to 64 (covering birth cohorts from 1876 to 1975). The age coefficients from this regression are used to create age-adjusted schooling measures evaluated at age 35. We use actual mean years of schooling at age 35 for birth cohorts observed at 35 in one of our sample year. Mean years of schooling adjusted to age 35 for the observed year closest to age 35 (or the average of a pair of years in the case of a tie) are reported for cohorts not observed in our samples at exactly age 35. The results are quite similar we average the age-adjusted years of schooling of a birth cohort across all years observed.

Figure 2:

Sources: 1940 to 1990 Census IPUMS, 1999 and 2000 CPS MORG Samples.

Notes: The figure plots the mean years of completed schooling by birth cohort and sex adjusted to 35 years of age for the U.S. born using the approach described in the notes to Figure 1.

Figure 3:

Sources: 1940 to 1990 Census IPUMS, 1999 and 2000 CPS MORG Samples.

Notes: The figure plots the fraction of college graduates by birth cohort and sex adjusted to 35 years of age for the U.S. born. College graduates are those with 16 or more completed years of schooling for the 1940 to 1980 samples and those with a bachelor's degree or higher in the 1990 to 2000 samples. The log of the college graduation rate for a birth cohort-year cell is the dependent variable in the age-adjustment regressions. The approach is the same as that used for years of schooling and described in the notes to Figure 1.

Figure 4:

Source: Appendix table A1

Figure 5:

Sources: The returns to a year of high school and of college for young men are from Goldin and Katz (2001a, Table 2.4 and Figure 2.6) based on data from the 1915 Iowa state census, the 1940 to 1970 Census IPUMS, and the 1970 to 1996 March CPSs. The samples include full-year, nonfarm male workers with 0 to 19 years of potential experience.

The returns to a year of college for all workers use data from the 1915 Iowa state census, 1940 to 1980 Census IPUMS, and 1980-2000 CPS MORG samples. The returns to a year of college equals the regression-adjusted wage differential between a worker with exactly 16 years of schooling (or a bachelor's degree) and with 12 years of schooling (or a high school degree) divided by 4. These college returns for 1940 to 2000 are derived from log hourly wage regressions for samples of all workers (males and females) aged 18 to 65 years using the same specifications and data processing procedures as Autor, Katz, and Krueger (1998, Table 1). The wage regressions include educational attainment dummies; a quartic in experience; a nonwhite dummy; a marital status dummy; a female dummy and its interaction with the experience, marriage and race variables; region dummies; and a part-time dummy. The evolution of the college premium from 1940 to 1980 uses the IPUMS data and changes from 1980 to 2000 are estimated from the CPS MORG samples. The 1915 to 1940 change in the college wage premium uses samples of full year workers from Iowa and the methods of Goldin and Katz (2000).

Figure 6:

Sources: National Income and Product Accounts, as constructed by the Bureau of Economic Analysis of the Department of Commerce. NIPA revision of December 2001. Gross private domestic investment estimates.

Endnotes

1. Krugman (1994).

2. Baily (2002) summarizes the growth-accounting literature on the productivity slowdown as "large but inconclusive." No single factor provides a convincing and coherent explanation, and the position that a large number of growth-retarding factors suddenly happened to hit at once is but the least unlikely of the proposed explanations (see Griliches (1988), Jorgenson (1988), and Gordon (2002)). Jorgenson (1988) convincingly demonstrates that the oil price shocks can plausibly account for slow growth in potential output in the 1970s, but why did potential output growth remain slow after 1986 after real oil prices fell? Griliches (1988) finds that an explanation in terms of a slowdown in innovation is unattractive, yet Gordon (2002) finds the opposite.

3. Figuring out what the growth rate of real output was between 1994 and the end of the decade of the 1990s poses unusual challenges. The most important of these is the large and recent change in the statistical discrepancy between national product and national income. In 1994 the statistical discrepancy between the two—the amount you had to add to national product in order to get to national income after making all of the conceptual and definitional adjustments—was $59 billion. By 2000 this statistical discrepancy was –$130 billion. In other words, national income grew by an extra $190 billion relative to national product between 1994 and 2000 not because of conceptual definitions but because of inconsistent and changing patterns of errors and omissions. Baily (2002) recommends splitting the difference between the two measures.

4. See, for example, Gordon (2002); Oliner and Sichel (2000); Jorgenson, Ho, and Stiroh (2001); and DeLong (2002).

5. Nelson and Phelps (1966).

6. Acemoglu and Angrist (2000).

7. Goldin (2001).

8. Goldin (2001).

9. The text refers to industrial nations. Some oil rich countries have higher per capita incomes.

10. Goldin and Katz (1998), (2001a).

11. Goldin and Katz (2000), (2001a).

12. Goldin and Katz (1999).

13. OECD (2001).

14. The school year increased during the 20th century, particularly for the elementary years and in rural schools. Nonetheless, we do not adjust education for education days, although such an adjustment, if it could be made, would probably increase the growth in our measure of educational attainment. All cohorts born after 1900 attained at least grade nine, on the average. The length of the school year was already high for the upper grades by the 1910s. Furthermore, the adjustment would be imprecise. We also do not adjust for such aspects of educational quality as teacher certification, school facilities, and curriculum.

15. We use the decennial U.S. Censuses of Population for 1940 to 1990 and the Current Population Survey for 1999 and 2000 to estimate the mean years of schooling and the share of college graduates by birth cohort for the U.S. born standardized to age 35. Where the data permit, we use the actual educational attainment of each cohort at age 35. In other cases, we predict what the cohort's attainment was (or will be) at age 35 using the observed within-cohort historical patterns of changes in (reported) educational attainment over the life cycle from ages 25 to 64 for birth cohorts born from 1876 to 1975. We know from comparisons with administrative records that census respondents, especially in 1940, occasionally overstated their educational attainment (Goldin 1998). We do not adjust the data for the overstatement and this factor imparts a downward bias to the increase in educational attainment across the 20th century, just as the quality issue probably does.

16. These calculations are based on the Current Population Surveys for 2000.

17. Ellwood (2001).

18. Bound and Turner (2002); Stanley (2000).

19. The trends in the fraction of men and women who ever attended college are similar to those for college graduation with a few exceptions. One surprising difference is that because women often attended teachers' colleges, which offered two-year programs, there was equality in the fraction of men and women who ever attended college. This equality remained until cohorts born in the mid-1910s. Another difference is that the run-up with the Viet Nam War is more gradual for attendance than graduation.

20. Carneiro, Heckman, and Manoli (2002); Ellwood and Kane (2000).

21. The evolution of educational attainment of the work force (figure 4) differs from the birth cohort series for U.S. natives (figures 1 to 3) because of the inclusion of immigrants, differences in cohort size over the last century, and variation in labor force participation rates by age and sex.

22. Data from the state of Iowa—see appendix A—indicate that progress was also rapid from

1915 to 1940.

23. Katz and Autor (1999).

24. Autor, Katz and Krueger (1998); Goldin and Katz (1995, 1998).

25. Card and Lemieux (2001); Freeman and Katz (1995).

26. Robert Solow (1956) and Robert Lucas (1988) posit that the rate of growth of the human capital stock (the educational attainment of the work force) affects the economic growth rate by changing the effective quantity of labor. Paul Romer (1990) posits that the level of the educational attainment of the work force affects growth by influencing the creation of new ideas and technological progress.

27. Krueger and Lindahl (2001). Measurement error issues and the likelihood of important omitted variables correlated with national schooling levels (and changes) raise questions concerning the causal interpretation of the estimates from such cross-country growth regressions.

28. Denison (1962).

29. Jones (2002) argues that the standard growth accounting framework *understates* the growth contribution of human capital since it does not include the indirect effect on capital investment from the higher incomes generated by increased human capital. Jones' alternative framework implies a 1 percent increase in human capital per worker boosts output by a full 1 percent. In contrast, Bils and Klenow (2000) argue that standard growth accounting *overstates* human capital's causal contribution to growth to the extent that increased schooling endogenously responds to other sources of improvements in productivity.

30. Jorgenson and Ho (1999), using a slightly different methodology, provide estimates of the educational quality growth of the U.S. work force since 1948, and Aaronson and Sullivan (2001), using a methodology close to ours, provide estimates for the post-1960 period. Our estimates of the growth of the educational productivity of the work force are quite similar to these estimates.

31. This estimate is that of Robert Gordon (2000) for the increase in non-farm, non-housing, business GDP per worker. Using the alternative growth accounting framework of Jones (2002), our estimates imply the full contribution of education to labor productivity growth over the 20th century was 0.5 percent per year or 31 percent of the overall increase.

32. Ellwood (2001).

33. These projections use our estimates from the Current Population Survey of educational wage differentials in 2000 and Ellwood's (2001) estimates of the change in the educational attainment of the U.S. labor force (25 and over) from 2000 to 2020.

34. See, for example, Doms, Dunne, and Troske (1997) and Bresnahan, Brynjolfsson, and Hitt

(2002).

35. Jones (2002) estimates the increasing R&D intensity can account for 49 percent of the growth in U.S. output per worker from 1950 to 1993.

36. In practice, the inclusion or exclusion of race and nativity as productivity-related variables makes little difference in the estimates of the labor quality index. But changes in the sex composition of the work force are significant for certain sub-periods.

37. Aaronson and Sullivan (2001); Ellwood (2001).

38. Carneiro, Heckman and Manoli (2002) and Krueger (2002) offer comprehensive recent evaluations of the evidence on the early effectiveness of a wide range of targeted education and training policies including early childhood interventions, changes in resources for primary and secondary schooling, second-chance training programs for youth, and financial aid for college.

39. U.S. Department of Education (2001).

40. Carneiro, Heckman and Manoli (2002); Ellwood and Kane (2000).

41. Ellwood and Kane (2000).

42. Carneiro and Heckman (2002) provide a more skeptical interpretation of the evidence on credit constraints affecting low-income youth in making post-secondary schooling investments.

43. Dynarski (2002); Kane (1999).

44. Card (1999).

45. Kane (1999, Table 3-1, p. 60) estimates that mean real net tuition for public two-year and four-year colleges increased by 107 percent and 106 percent respectively from 1980-81 to 1994-95. Reductions in the share of expenditures on public college subsidized by state governments contributed substantially to these rising college costs. In contrast, real family incomes were essentially stagnant for the bottom 40 percent of families from 1980 to 1995.

46. Heckman and Lochner (2000).

47. Krueger (2002).

48. Currie (2001); Krueger (2002).

49. Krueger (1999, 2002).

50. Watson (2002).

51. Katz, Kling, and Liebman (2001); Rosenbaum (1995).

52. Abramovitz and David (1973); Jones (2002).

53. Acemoglu (1996); Goldin and Katz (1998).

54. See DeLong and Summers (1991). Sala-I-Martin (1997) and others have noted that the association between investment in physical capital and growth is remarkably robust to changes in the specification of the regression analysis. Temple (1998) finds that the rate of return is extraordinarily high in developing countries, and appears lower in developed countries.

55. Brynjolffson and Hitt (2000).

56. David (1991); Devine (1983).

57. See Kimball (1990).

58. There might be an additional case for government action to affect the level of investment if the government were sure that private decisions led to the wrong balance of resources and well-being across generational cohorts. Unfortunately (or, perhaps, fortunately) economists have reached no consensus on whether the past and the likely future cross-generational cohort pattern of consumption is (a) unfairly weighted toward early generations, (b) unfairly weighted toward later generations, or (c) about right. The likelihood that future cohorts will be richer than their ancestral cohorts coupled with a simplistic utilitarianism suggests that current consumption is too low, current saving is too high, and the current rate of American economic growth too fast. The likelihood that an America rich and powerful enough in relative terms to be a global superpower confers massive positive external benefits on the rest of the world—defeating the Nazis, for example—suggests that the current rate of American economic growth is too slow. The behavioral economic literature on "impatience" and "myopia" suggests that Americans devote less attention and foresight to the distant future than they "really want to" and thus that the current rate of savings is too low (Laibson 1997). These issues may be the most important of all. However, they are currently beyond our technical competence to analyze in a fully satisfactory manner.

59. Perhaps the most conceptually intractable issue involves the return to risk bearing. It is difficult to believe that the risk-return relationship observed in U.S. history corresponds to any utilitarian assessment of the social returns to marginal acts of investment in capital and of risk bearing. See Mehra and Prescott (1985), Shiller (1987).

60. See Summers (1990).

61. See, for example, Engen, Gale, and Scholz (1996). But recent work in behavioral economics suggests potentially powerful effects on retirement savings from changes in financial education and in the plan rules (and default options) of private defined contribution pensions (Choi,

Laibson, Madrian and Metrick 2002).

62. See Benartzi and Thaler (2001); Laibson (1998); and Choi, Laibson, Madrian and Metrick (2002).

63. As Lusardi, Skinner, and Venti (2001) have pointed out, such "impatience" or "myopia" can be generated by the interaction of even fully rational and far-sighted households with a means-tested social insurance system. If the chances are high that health problems late in life will eat up all accumulated private wealth before Medicaid kicks in, this will serve as a powerful disincentive to private saving. Such a distortion might well call for a countervailing focus by the government on savings incentives to offset its effects.

64. The belief that such incentives can be counterproductive because they encourage foreign investment in the United States, and thus a significant part of the returns from the increased capital stock would flow abroad, is simply wrong: the point of the exercise is to capture the external benefits from a higher capital stock. It is true that the normal--private--profits from investment in America by foreigners flow abroad, but it is also true that foreigners' investing in America entails no reduction in current American consumption to finance the investment. These two effects balance each other, leaving the positive external benefits from investment as an improvement in social welfare.

65. Auerbach and Hines (1988).

66. That Robert Barro's (1974) doctrine of Ricardian equivalence is likely to be of limited applicability in the contemporary United States apppears to be demonstrated by the failure of private savings rates to offset either the rise in the federal deficit in the 1980s or the fall in the federal deficit in the 1990s. Bernheim and Bagwell (1988) argue that the assumptions needed for Ricardian equivalence to be effective carry other powerful unobserved and unrealistic consequences.

67. See Romer (1990).

68. Quoted in Summers (1990).

69. Gallini (2002).

70. Kremer (1998).

71. Jones and Williams (1998).

72. Goldin and Katz (2000) describe and document the data from the Iowa 1915 state census.

73. Card (1999).