Sustaining U.S. Economic Growth

J. Bradford DeLong, Claudia Goldin, and Lawrence F. Katz

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I. Introduction

With rapid economic growth, social and economic problems become far less of a burden. A fast growing economy is a rich economy. A rich economy is one in which people have more options and better choices: the people can—through their individual private and collective public decisions—decide to consume more, lower tax rates, increase the scope of public education, take better care of the environment, strengthen national defense or accomplish any other goals they might choose. For an economist these are sufficient reasons to consider growth a good thing. A fast-growing economy is one in which people will have greater wealth, higher incomes, and more of the necessities, conveniences, and luxuries of life.

Moreover, in America at least, slow economic growth appears to heighten political gridlock, and thus reduce the quality of political decisions. The era of slow economic growth that began in 1973 produced, according to Paul Krugman (1994), an *Age of Diminished Expectations.* Slower growth in private incomes led to a political backlash that greatly reduced the ability of the U.S. government to undertake large-scale projects. From a small-government perspective, skepticism toward government expansion may be a good thing. But it was the relatively conservative President George H.W. Bush (1989) who lamented at his inauguration that the American government "had more will than wallet." And it was his administration that found itself—largely due to political choices made as a result of the slow-growth age of diminished expectations—a large drain through its borrowing on America's ability to invest in its future, unable to respond in a constructive large-scale way to the end of the Cold War and the fall of communism in eastern Europe, and unable to even think about whether and how increases or shifts in the direction of government spending could improve opportunity in America.

Although faster economic growth is *a* good thing, it is not *the only* good thing. The future benefits of more rapid economic growth come at a cost. Resources have to be diverted from consumption, and devoted to physical capital deepening, education and training, and research and development. Faster economic growth empowers the future: it increases options, capabilities, and choices. But the decisions required to accelerate growth foreclose other options in the present. There is, of course, a trade-off. It is the purpose of this chapter to sketch out what this trade-off is: what kinds of policies might sustain and enhance economic growth, and how one should go about assessing whether their benefits are worth the costs they impose.

Before we begin, it is important to admit up front that economists know less about the effects of policies and the causes of change in the rate of economic growth than we would like. For example, in the early 1970s, U.S. productivity growth fell off a cliff. Measured output per person-hour worked in nonfarm business had averaged a growth rate of 2.8 percent per year from 1947 to 1973. It averaged a growth rate of only 1.3 percent per year from 1973 to 1995. This productivity slowdown meant that, according to official statistics, Americans in 1995 were only 70 percent as productive as their predecessors back in the early 1970s would have expected them to be. Yet the causes of this productivity slowdown remain, even today, the subject of active debate, and largely a mystery.[1] Then, in the second half of the 1990s, American productivity

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[1] Baily (2002) calls the growth-accounting literature on the slowdown "large but inconclusive." No single factor provides a convincing and coherent explanation, and the residual position that a large number of growth-retarding factors suddenly happened to hit at once is but the least unlikely of the residual explanations (see Griliches (1988), Jorgenson (1988), and Gordon (2002)). Jorgenson (1988) convincingly demonstrates that the oil price shocks can

growth reversed itself and resumed its pre-1973 pace. Between the beginning of 1995 and the semi-official NBER business cycle peak in March 2001, U.S. measured nonfarm-business output per person-hour worked appeared once again to grow at an annual rate of 2.8 percent per year.[2] Economists today are confident that the cause of this productivity speed-up was the attainment of critical mass by the ongoing technological revolutions in data processing and data communications,[3] yet few if any had forecast such a speed-up in advance.

In this paper, we look sequentially at the three broad factors that have driven modern American economic growth: human capital, the formal knowledge and the skills acquired through practice and experience of our labor force; physical capital, the machines, buildings, and infrastructure that amplify worker productivity and embody much of our collective technological knowledge; and the ideas that make up our modern industrial technology and that are in the end the crucial factor making our society so rich in historical and comparative perspective. Of these, ideas—technology—must take first place when ultimate causes are discussed. But it is human capital—education and skills—that must take first place when we think about policy. This is so for four reasons: First, human capital has played the principal role in driving America's edge in twentieth-century economic growth: the increase in average schooling by some seven years

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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.

[2] 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. 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.

between 1875 and 1975 appears to be *the* principal factor behind America's twentieth-century economic edge over the rest of the world economy's industrial core. Second, we understand more about the effects of some policies intended to boost the knowledge and skills of the labor force than about the effects of policies intended to increase directly either the physical capital stock or the stock of ideas.

Third, and probably most important, efforts to upgrade the knowledge and skills of America's workers promise not only higher levels of output but also a less badly skewed distribution of income. 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 them to lead better lives. A measure of well-being like the geometric mean of household consumption comes closer to capturing our intuitions of what a prosperous and wealthy society is than does simply total GDP per capita. Thus policies to improve educational opportunity are, as Alan Blinder has repeatedly said, a "two-fer." Thus we begin the body of this chapter with a survey of U.S. human capital trends and policies. Only afterwards do we turn to policies aimed at increasing physical investment, and enhancing technological progress.

II. Human Capital

A. America in the Human Capital Century

Ever since the industrial revolution, "capital" has been the key to a nation's economic success. Long before, land and natural resources were the indispensable factors. Sometime in the nineteenth century their role was usurped by physical capital. And the most scarce factor shifted

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

once again in the twentieth century—this time to the human side. Human capital, not physical capital, became the key to economic growth. The twentieth century became the "human capital century," just as the nineteenth had been that of physical capital.

Investments in human capital—formal schooling, on-the-job training, informal learning—directly contribute to economic growth by increasing the productivity or "quality" of a nation's work force. Human capital investments also contribute to expanding the technological frontier, since educated labor is a key to the creation of new ideas. A more-educated work force, furthermore, facilitates the initial adoption and rapid diffusion of new technologies (Nelson and Phelps 1966).

The United States led the world in mass education during the nineteenth century, and it substantially widened its lead in the twentieth century. Sometime in the early twentieth century the United States became the world's premiere economy in per capita terms and its lead has survived to the present. Thus the "human capital century" was also the "American century."

The United States widened its lead in education by instituting mass secondary schooling at the dawn of the twentieth century and by having a flexible and multifaceted higher education system (Goldin 2001). Toward the end of the twentieth century, however, the increase in schooling for young cohorts in the United States had slowed whereas that in other advanced OECD nations continued to expand. The educational attainment of recent cohorts in some countries has actually surpassed that of the United States (OECD 2001). Because the educational quality of the labor force is a moving average of that of the surviving birth cohorts, the quality of the U.S. labor force has now begun to stagnate, whereas that for many other countries has been rapidly increasing.

In this section we explore the full century of educational progress in the United States, its contribution to economic growth, and the implications of the educational slowdown for the future of the U.S. economy. We find that educational expansion by increasing labor force quality was a major contributor to economic growth in the United States throughout most of the twentieth century. But we also find that there has been a distinct slowdown in the rate of growth in educational attainment for cohorts of U.S. natives born after 1951 and thus for the U.S. labor force starting in the 1980s. The deceleration of educational attainment has occurred despite an increase in the rate of return to educational investment. The slowdown is surprising because the return to education has been substantial during the past twenty years and it is troubling because it has been concentrated among youth from lower-income households. The slow growth in the educational attainment of the U.S. work force, if it continues, could be a potent drag on future economic growth.

Investments in people are likely to be undersupplied by the private market, and governments have subsidized schooling for that reason, among others. Governments typically provide schooling as well as mandate some minimum level. Capital market imperfections that lead to financial constraints, particularly for younger and poorer families, are a crucial rationale for government subsidization. Because parents might not invest optimally in their children and because children are not always rational and compliant, public subsidies and compulsory schooling might be justified. Many argue that the social returns to educational investments exceed the private returns since human capital has wide ranging positive externalities, such as those concerning peer effects, social capital, knowledge spillovers, and reductions in crime (Acemoglu and Angrist 2000). An equity case can also be made for government interventions to increase the educational attainment and earnings of those from disadvantaged backgrounds.

Not all governments have seen investments in brainpower alike. Most of the industrial powerhouses in 1900 and for some time after were not favorably disposed to investing in broad-based education for the masses. Rather, schooling in Europe during much of the twentieth century was either a strictly elite system, as in France and England, or a bifurcated system, 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, education in America was "virtuous" because it was, largely, a non-elite system that educated the masses. It was publicly funded and provided by large numbers of fiscally independent districts, highly forgiving and open, gender neutral, primarily academic rather than industrial and vocational, and secular in terms of control (Goldin 2001). It still is, although some of the virtuous aspects of the features that enabled mass education are now questioned. The open and forgiving nature of the system that enable those who did poorly in one grade to exonerate themselves in another, for example, is now being criticized for lacking strict standards. The large numbers of small, fiscally independent school districts that allowed parents to express their different tastes for education and that once fostered educational expansion are now excoriated for resulting in vastly different amounts spent per pupil.

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 (Goldin and Katz 1998, 2001a). Around the turn of the twentieth century the rise of big business and the growth of large retail, insurance, and banking operations increased the relative 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 not only increased the relative demand for professionals, such as chemists and engineers, and office workers, but they also increased the demand for educated blue-collar workers. The spread of electricity, the internal combustion engine, and various chemical processes meant that the worker who could read blueprints, knew algebra, geometry, chemistry, and some rudiments of physics was considerably more valuable. The farmer who had some chemistry, botany, and accounting under his belt had a competitive edge over his less educated neighbors. Education above the elementary grades was no longer just for the professionals. It was for all.

With increasing demands for various types of skill in the early twentieth century, more youths continued to the upper grades. The earnings of the more highly educated, relative to others, were substantial in the early twentieth century and the returns to a year of high school were about 12 percent in 1915, the earliest year for which we can estimate them (Goldin and Katz 2000, 2001a). 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 and the increased demand for education could be fulfilled only with substantial investment in the building of schools and the hiring of teachers. These investments were made by numerous local governments, often small school districts or municipalities. The highly decentralized system of U.S. educational finance enabled the spread of mass secondary schooling. In contrast, the centralized school systems of Europe delayed 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 seventeenth century. With the increased demand for more education, the public sector expanded relative to the private sector. Whereas in 1900 almost 80 percent of all four-year college enrollments were in the private sector, 30 percent were by the end of the twentieth century (Goldin and Katz 1999).

B. Educational Advance in the Human Capital Century

1. Measuring Human Capital

We measure the human capital of the nation by using school or grade attainment for those who completed their education. We recognize that investments in human capital neither begin nor end with the school. Investments occur in the home, the workplace, and formal settings apart from the usual schools and colleges. Commercial and vocational institutions proliferated in the early twentieth century and offered instruction in office skills, such as stenography, typing, accounting, real estate, and business machine use, and in mechanical skills, such as automotive repair. They remain important in transmitting knowledge about new technologies, such as the Internet and computer software packages. Investments in human capital also take place outside instructional institutions, as they do, for example, on the job and in the home. But non-formal and non-standard forms of education and training are difficult to measure and, for that reason, we do not formally incorporate them in our tracking of the educational attainment of Americans and the role of human capital in economic growth.

Another complication concerns the quality of a year of education. The school year increased across the twentieth century particularly for the elementary years and in rural schools. But because all cohorts born after 1900 attained at least grade nine, and the length of the school year was already high for the upper grades by the 1910s, we do not adjust the school data for days. The adjustment, furthermore, would be imprecise. For somewhat the same reason we do not adjust for other aspects of educational quality such as teacher certification, school facilities, and curriculum. It is likely that these adjustments, if they could be made, would increase the growth in our measure of educational attainment.

2. Educational Attainment by Birth Cohort

We use U.S. census data (the decennial Censuses of Population for 1940 to 1990 and the Current Population Survey for 1999 and 2000) to measure years of schooling by birth cohort for the U.S. born and standardize to the year closest to when the cohort was 35 years old. In the cases where this could not be done, 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 twentieth century, just as the quality issue probably does.

For the entire United States native-born population, educational attainment for those who already completed their education (those in their mid-thirties) increased by 6.7 years for cohorts born from 1876 to 1975 (see Figure 1). 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 every decade. But educational attainment remained roughly constant for the next 12 years and it increased by just 0.44 years per decade for the last 12 years of the data. The increase in educational attainment, therefore, was extremely rapid for the 1876 to the 1951 cohorts but then sharply slowed.

There are important differences in the levels and trends in educational attainment by race, sex, and ethnicity. The schooling gap between whites and blacks was enormous—about 3.6 years—for cohorts born in the late nineteenth century. But starting with those born around 1910—thus far earlier than *Brown v. Board of Education* in 1954—black schooling began to expand relative to that for whites (Figure 1). The convergence between the two series later slowed for cohorts born from 1940 to 1960 and further slowed for those born since 1960. The black-white schooling gap is 0.6 years for cohorts born in the 1970s or one-sixth its level at the beginning of the period.

Schooling gaps are even larger between recent cohorts of non-Hispanic whites and Hispanics: 2.32 years for those born 1970 to 1975 (CPS 2000). Because of their large and rapidly growing share of the U.S. labor force, the educational attainment of Hispanics is of critical importance for the future of U.S. labor productivity (Ellwood 2001; Kodrzycki 2002).

Differences by sex in educational attainment reveal changes that are magnified in the series for college graduation. Years of schooling were somewhat higher for females than for males until the 1921 birth cohort (see Figure 2), but with the birth cohorts corresponding to those in the main draft years for World War II—1921 to 1927—male educational attainment began to exceed that for females. Equality began to prevail around the 1950 cohort and it remained so until about the 1970 birth cohort when female educational attainment began to exceed that for males, just as it had a century before.

The series for the separate school levels—college graduate, some college, and high school graduate—add important detail. In the interest of space we will present just one of them—for college graduates by sex (Figure 3). The college data reveal much about changes in educational attainment in general and they are the series of most critical importance for the future of education in America.

The data on the share of college graduates in the population, by sex, demonstrate the enormous changes that occurred to the cohorts eligible to be drafted for the three wars—World War II, Korea, and Viet Nam. The peak World War II draft cohorts experienced a large increase in the share of college graduates and the trend continued with the cohorts drafted for Korea. Part of the run-up in college graduation rates was due to the compensatory effect of the G.I. Bill of Rights (Bound and Turner 2002; Stanley 2000). Those who interrupted their education because of the war were enabled, by the generosity of the act, to make it up. But the G.I. Bill also appears, from these data, to have been more than compensatory.

College graduation rates also soared for cohorts born from 1940 to 1950 due in part to the Viet Nam War. The Selective Service Act, which affected men born after 1944, gave a draft deferment to those attending college and thus could have affected only cohorts born in the latter part of the decade. The fraction graduating from college plummeted at the conclusion of the draft (it officially ended in 1973), only to increase again with the cohort born around 1960. Interestingly, the female college graduation rate largely mimics that for males, except for the World War II cohorts. Because the impact of the wars on the education of women would have been largely indirect, something else must have been responsible for their college going.

Although the fraction graduating from college increased substantially starting with cohorts born in the early 1960s, the college graduation rate for African-Americans increased far less than that for whites. Moreover, differences in college enrollment and completion rates by family income expanded during the period of sharply rising educational wage differentials of the 1980s (Carneiro, Heckman, and Manoli 2002; Ellwood and Kane 2000).

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.

In summary, the increase in educational attainment by native-born cohorts was almost seven years from 1876 to 1975. Of this increase 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 human capital century.

3. Educational Attainment of the Work Force and Educational Wage Differentials

To estimate the impact of human capital accumulation on economic growth, we must first measure the educational attainment of the work force. The educational attainment of the work force differs from the birth cohort series for U.S. natives since the composition of work force depends on differences in cohort size and on variation in labor force participation and employment rates by age and sex. The U.S. work force, moreover, includes a substantial share of immigrants that has increased over the past several decades.

We present summary measures of the educational attainment of the civilian work force (aged 16 or older) that weight individual workers equally (Table 1) or by their hours worked (Table 2). 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 (Table 1).[4] Comparable data are also given for 1915 from the Iowa State

[4] The 1940 federal population census was is the first to ask educational attainment.

Census, the earliest large-scale representative U.S. sample with information on educational attainment and earnings.[5] 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.

The educational attainment of the U.S. work force increased rapidly from 1940 to 1980 and then slowed from 1980 to 2000 (Tables 1 and 2). Schooling on average increased by 4.4 years—9 to 13.4 years from 1940 to 2000. In 1940, the vast majority of workers—70 percent—had less than a high school degree and fewer than 6 percent had a college degree. In 2000, only 11 percent had less than a high school degree and 28 percent had a college degree. The increase in mean years of schooling from 1960 to 1980 was more than twice that from 1980 to 2000 and all other 20-year periods from 1940 to the present had larger increases than that for the most recent two decades. The Iowa data reveal that even though the increase was most rapid from 1960 to 1980, substantial advances occurred from 1915 to 1940. The expansion of U.S. educational attainment throughout most of the twentieth century was driven by the rapid increase in high school completion in the first half of the century. The expansion of college education has been more important in recent decades.

The proximate causes for the fast growth in educational attainment from 1915 to 1980 and for the subsequent slowdown are clear. Better-educated young people replaced the less well-educated older cohorts from 1915 to 1980, but the new cohorts of the 1980s and 1990s are not sufficiently more educated than the older cohorts they have replaced.

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

How have the private economic returns to educational investments (as measured by educational wage differentials) evolved? The private economic return to a year of either high school or college in 1915 was substantial and must have helped spur the rapid educational advances characterizing the high school movement. Educational wage differentials narrowed substantially from 1915 to 1950, 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 4).

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 (Katz and Autor 1999). Throughout the twentieth century, the industrial and occupational distribution of employment has shifted in favor of more-educated workers and persistent skill-biased technological changes have led to large within-industry (and within-occupation) demand shifts favoring more-skilled workers (Autor, Katz and Krueger 1998; Goldin and Katz 1995, 1998). The rapid expansion of the supply of more-educated workers more than offset the secular rise in demand for more-skilled workers over much of the twentieth century and led to a substantial long-term narrowing of educational wage differentials from 1915 to the 1970s. The slowdown in the rate of growth of educational attainment over the past two decades has been a key contributor to rising educational wage differentials since 1980.

Countries with a decelerating rate of educational advance for recent cohorts—the United States, United Kingdom and Canada—have experienced greater increases in educational wage differentials, especially for younger cohorts, than have countries with continued rapid expansions of educational attainment—France, Netherlands, and Germany (Card and Lemieux 2001; Freeman and Katz 1995). Slower growth in the relative supply of college-equivalent workers combined with rapid growth in the demand for more-educated workers, driven in part by computerization and related technological and organizational change, have been a recipe for rising educational wage differentials and wage inequality. The weakening of unions, changes in pay-setting norms at the top, and the erosion of the minimum wage further expanded the U.S. wage structure in the 1980s. In contrast, during the second half of the 1990s, tight labor markets, a minimum wage increase, and rapid productivity growth played an important role in role in raising real wages at the bottom, slowing the growth of overall wage dispersion, and even narrowing wage inequality in the bottom half of the wage distribution.

Current returns to college in the United States are now as large as they have been in 60 years, possibly more. A more rapid expansion in the share of college-educated workers should have a large economic growth payoff and should serve to reduce economic inequality.

B. Educational Change, Labor Quality, and Economic Growth

The neoclassical growth model (Solow 1956) and some endogenous growth models (Lucas 1988) suggest that the *rate of growth* of the human capital stock will affect the rate of output growth. Other growth models (Romer 1990) emphasize the *level* of the educational attainment of the work force as affecting the economic growth rate by increasing the rate of creation of new ideas and the rate of technological progress. Cross-country growth regressions indicate a positive relationship between both the level and rate of growth of schooling on the growth in output per capita, although measurement error and omitted variable bias raise questions concerning the causal interpretation of such estimates (Krueger and Lindahl 2001).

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 a standard growth-accounting framework of the type pioneered by Edward F. Denison (1962). We also examine the implications of recent demographic and educational trends for future economic growth.

Our basic approach is to compute an educational productivity index (E_t) of the U.S. work force for selected years, *t*. The index measures the productivity of workers with different education levels by computing the relative wage of each education group, adjusted for differences in various observable wage determinants such as potential work experience.[6] That is, we compute $E_t = \sum_i w_{i\tau} S_{it}$, where $w_{i\tau}$ is the (adjusted) wage of education group *i* (relative to a reference education group) in a base period τ, and S_{it} is the share of education group *i* in employment (or total hours) in year t. The growth in E_t measures the contribution of educational upgrading to aggregate labor-input growth (through improvements in the average human capital or "quality" of the work force). Using a neoclassical growth model under an assumption of an aggregate production function with constant returns to scale, the direct impact of educational expansion on economic growth is the (log) change in the index (E_t^*) times labor's share (〈) of national product (_ ≅ 0.7 across the entire twentieth century). A key assumption underlying this approach is that wage differentials by educational attainment reflect the causal impact of schooling investments on productivity. The bulk of the existing evidence suggests this is a reasonable approximation (Card 1999).

Two components are needed to compute the educational productivity index: S_{it} , as given in Tables 1 and 2, and $w_{i\tau}$. The relative productivities by education, $w_{i\tau}$, are based on national estimates of educational wage differentials in each period, starting in 1940, and are obtained by estimating log earnings regressions for non-farm workers, 18 to 65 years old, on education group

[6] The Appendix provides further details on the estimation of the educational productivity index.

dummies and other relevant covariates (including controls for potential experience, sex, race, nativity, and region). Educational wage differentials are estimated for Iowa in 1915 using a similar technique and then adjusted to be nationally representative.

Relative productivities, $w_{i\tau}$, for the period in question or an average over the entire period can be used. The first method produces a "chain weighted" index and the second results in one that is "fixed weighted." The fact that both methods produce similar values for the educational productivity index (see Table 3) indicates that quantity changes in education did most of the heavy lifting and that changes in the relative productivities by education were less important. There are some important caveats. From 1915 to 1940 the fixed weight estimates are smaller than the chain weighted because returns from secondary school were particularly high, and from 1960 to 1980 the reverse held with low average returns to both high school and college.

The educational productivity of the work force expanded by about 0.5 percent a year on average from 1915 to 2000.[7] For all the reported measures (chain weighted or fixed weighted, employment and hours) the change in the educational productivity index is highest from 1960 to 1980 and lowest in the last two decades of the twentieth century. The slowdown in the growth of educational attainment across successive birth cohorts has meant that the improvement in the educational productivity of the work force of last two decades of around 0.35 percent per year is low relative to *all* earlier periods of the twentieth century, not just to the 1960 to 1980 period. Mean educational attainment of the work force expanded by 0.83 years (or 0.042 years per annum) from 1980 to 2000, as opposed to 1.93 years from 1960 to 1980, 1.52 years from 1940 to 1960, and 1.38 years from 1915 to 1940 (or 0.074 years per annum from 1915 to 1980).

[7] 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 the estimates in each of these papers for the overlapping time periods.

Increases in the educational attainment of the work force, across the entire period 1915 to 2000, directly contributed about 0.35 percent per year (0.5 H 0.7) to output growth per labor hour. Thus, the direct effect of educational advance accounts for about 22 percent of the 1.62 percent average annual increase in U.S. labor productivity (Gordon 2000, non-farm, non-housing business GDP per worker 1913 to 1996). Educational advances also fueled innovation and the adoption of new technology. The indirect contribution of education is difficult to measure and any estimate would be an educated guess. Because most estimates of the role of physical capital deepening are far smaller than our estimate of the direct role of education, the expansion of human capital provides the greatest single measurable factor in explaining productivity growth in the twentieth century. The twentieth century was, indeed, the human capital century.

Had the growth in the past two decades of the educational attainment of the work force kept pace with that from 1915 to 1980, the economy would have experienced a 0.13 percent ([0.53 – 0.35] H 0.7) increased rate of productivity average annually or an 8 percent improvement. Projections for 2000 to 2020 of the increased labor force share of college graduates (25 and older) yield a range from 1.5 to 5.0 percentage points (Ellwood 2001), in contrast to the actual increase of 8.6 percentage points for 1980 to 2000.[8] Using our estimates of educational wage differentials for 2000, we project that the annual rate of growth of educational productivity for the adult labor force (25 and over) will decline during the next 20 years from 0.43 percent for 1980 to 2000 to between 0.06 to 0.17 percent.

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[8] Ellwood (2001), using standard demographic projections, forecasts the educational attainment of the adult work force (25 years and older) in 2020 under a “low-scenario” (with new cohorts having the same educational attainment as young cohorts from 1997-2000) and a “high-scenario” (with modest increases in the high school graduation rate and the college going rate over the next 20 years).

Thus far, we have used years of education to construct a labor "quality" index. An "augmented labor quality index" would consider work experience, sex, nativity, and race, in addition to educational attainment, and would measure change in the mean predicted wage of the work force based on this broader set of worker characteristics.[9] The critical assumption in this approach is that differences in wage rates by worker characteristics reflect differences in marginal productivities. But the assumption may not fully apply to differences by race, nativity, and sex if wages are affected by direct labor market discrimination.[10] We caution that the word "quality" does not refer here to the innate characteristics of the individual but, rather, to a broader interaction between the characteristics and the labor market.

Labor force quality, measured in this fashion, grew by 0.42 percent average annually from 1915 to 2000 using a chain-weighted index (Table 4). 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 imparted a small negative drift to the labor quality index, whereas changes in the age composition of the work force had effects that varied by sub-period.

A declining share of youth labor, because of rising school enrollment, contributed to faster labor quality growth from 1915 to 1940 (compare Tables 3 and 4). The large baby boom cohorts served to decrease labor force quality from 1960-1980 when they were young and inexperienced, but to increase quality during 1980-2000 when they were older. The share of less-experienced workers (those with fewer than 10 years of potential experience) increased from 22.4 percent in 1960 to 37.3 percent in 1980 before falling to 26.5 percent in 2000. From 1960 to 1980 the large

[9] The Appendix documents the construction of the augmented labor quality index.

[10] 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.

increase in the share of younger workers from the labor market entrance of the baby boom cohorts almost completely offset the rapid educational advance and produced low overall labor quality growth. The movement of baby boom cohorts into their peak earning ages, together with the small relative size of recent labor market entrants, contributed to labor quality growth from 1980 to 2000. Labor quality gains from changes in the age structure of the work force are forecasted to stop over the next 20 years as baby boom cohorts move beyond the age of peak earnings (Aaronson and Sullivan 2001; Ellwood 2001).

In summary, increases in completed schooling have been a driving force behind U.S economic growth in the twentieth century and played a key role in expanding economic opportunity. But the rate of educational advance of the work force has declined substantially in the last 20 years. Demographic trends, such as the aging of the baby boom cohorts, suggest a further slowing in the growth of labor force quality and thus labor productivity over the medium-term.

C. Policy Implications

Increased human capital investments in younger cohorts, especially for minorities and those from low-income families, could play an important role in enhancing U.S. economic growth prospects and ameliorating the growth in wage inequality of the past two decades. The large rise in the college wage premium since 1980 has created incentives for increased educational investments. But all groups have not invested equally. Family income remains an important explanatory factor in differences in college enrollment rates for students having similar academic grades and achievement test scores (Ellwood and Kane 2000). Although the share of recent high school graduates who enroll in college increased from 49 percent in 1980, to 60 percent in 1990, and then to 63 percent in 1999, differences in college enrollment rates by race and Hispanic-origin have actually widened since 1980 (U.S. Department of Education 2001).

Financial constraints, it would appear, remain a substantial barrier to college going for low- and moderate-income youths who would earn high economic returns from further educational investments.[11] College-going rates for low-income youth increase substantially in response to decreases in college costs through financial aid, for example (Dynarski 2002). Recent estimates using "quasi-experimental" variation in access to college and college costs indicate high rates of return to the marginal (typically low-income) youth affected by such policy interventions (Card 1999). Improved targeting of college financial aid, earlier mentoring policies, and a more transparent financial aid application and information system could have substantial payoffs for disadvantaged youth and could feed back into secondary school performance by creating better incentives for high academic achievement.

But greasing the wheels for low-income high school graduates may come too late for many, and human capital policies must also target early childhood. The existing research suggests potentially large returns from further expansions of high-quality early childhood education programs. Less agreement exists about the effectiveness of specific policies to improve the quality of primary and secondary schooling.[12] 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 problems for children from low-income families (Watson 2002). Recent work on the quasi-experimental Gautreaux and random-assignment Moving to Opportunity housing mobility programs indicate that concentrated neighborhood poverty greatly harms a child's human capital development (Katz, Kling, and Liebman 2001; Rosenbaum 1995).

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[11] Carneiro and Heckman (2002) provide a more skeptical interpretation of the evidence on credit constraints.

[12] Carneiro, Heckman and Manoli (2002) and Krueger (2002) offer comprehensive evaluations of the evidence on the early childhood interventions, primary and secondary schooling, and second-chance training programs for youth.

Housing mobility policies may be an important complementary policy to educational policies in improving human capital investments for low-income children.

III. Physical Capital

A. The Relatively Low Salience of Physical Capital as a Growth Factor

Ever since Robert Solow's (1956, 1957) and Moses Abramovitz's (1956) studies that first highlighted the limited importance of physical capital deepening for increases in labor productivity and living standards in the twentieth century, investment in physical capital has played second—or perhaps third—fiddle. Nearly all economists have agreed that total factor productivity, the "residual" as careful analysts call it (Denison 1962), has been the most important factor driving higher incomes and productivity standards.

Investment in physical capital has also, in the past, not been the major contributor to variations in the rate of economic growth. In the past two generations total factor productivity growth has swung from 2 percent per year to near zero, and now back to 1.5 percent per year. The previous section has highlighted the extraordinary commitment of America in the twentieth century to mass education at all levels. By contrast, up until a decade or so ago there had been no signs of any increase in the physical capital-output ratio since before World War I (Abramovitz and David 1973); see Figure 5.

However, the past decade has seen a startling change in the magnitude of measured physical investment (see Figure 6), which seems likely to produce noticeable long-run changes in the aggregate economy's measured capital-output ratio. The extraordinary and ongoing technological revolutions in data processing and data communications technologies have led to a substantial amount of capital deepening for that category of equipment. Almost all analysts conclude that a large chunk of the mid-1990s acceleration in the rate of American economic growth has been due to a combination of (a) information-technology capital deepening and (b) multifactor productivity increases in the manufacturing of information-technology capital. 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 5).

B. Should the Government Care About the Volume of Physical Capital Investment?

That something changes in a way that affects the rate of economic growth does not mean that government should try to control it. Is there in fact reason to believe that the government should care about the rate of investment in physical capital? Higher rates of investment boost the rate of economic growth and boost real GDP, labor productivity levels, and living standards in the future. But such higher rates of investment are overwhelmingly likely to foreclose alternative private and public expenditures in the present. Is there any reason to think that the government should take more of an interest in the quantitative course of demand for investment goods than it takes in the quantitative course of demand for electricity, or for personal services?

If there are powerful external complementarities to physical capital, or if there is a large wedge between the private and social returns to investment in physical capital, then an economist will argue that the level of investment spending is not something that the government should leave to the market. In the case of investment in education, liquidity constraints caused by loan market failures and the fact that individuals cannot easily insure themselves against the risk that they will not personally reap the average return to education together create a case for public intervention. In the case of investment in physical capital, the large-scale mechanisms for insurance through diversification provided by financial markets and the ability to effectively use the accumulated capital stock as collateral reduce the magnitude of analogous market failures.

Thus the case for public concern about the volume of physical capital investment depends on the existence of significant external complementarities that do not enter into the profit-and-loss calculation of a firm undertaking an investment project. It may well be the case that there are strong external complementarities between physical capital and human capital—between the kinds and quantities of machines installed in an economy and the formal skills and informal craft knowledge of its labor force. Without substantial investments in physical capital, workers will not be able to use their skills effectively (see Goldin and Katz 1998; Autor, Levy and Murnane 2002).[13] With wage levels set through bilateral bargaining or out of efficiency wage considerations, the marginal private benefits to a firm undertaking investment projects will fail to reflect social benefits.

The plausibility of such external complementarities is strengthened by the existence of forms of learning-by-using that cannot be effectively appropriated by those who own newly-installed machines and that may be an important source of economic growth. The macroeconomic evidence that there are strong external complementarities between investments in physical capital and total factor productivity growth comes from examining the cross-country pattern of economic growth. As DeLong and Summers (1991) pointed out, there is a strong correlation between high levels of investment—especially investment in machinery and equipment that seems a likely carrier of so much of modern technology—across countries and rapid rates of total factor productivity growth. As Sala-i-Martin (1997) and others have noted, the association

[13] The case for government policies to encourage accumulation is reinforced by the probability that a substantial share of what would otherwise be the privately-appropriated returns to investment may be captured by workers in the form of labor rents.

between investment in physical capital and growth is remarkably robust to changes in the specification of the regression analysis.[14]

Of course, correlation is not causation. Perhaps the strong correlation holds because countries that are growing fast are countries in which profits are rising rapidly, and firms have a tendency to spend rapidly rising profits on investment goods. Perhaps the strong correlation holds because countries that are growing fast are countries in which the return to capital is high, and far-sighted firms seeking to increase their profits are attracted to investments in such countries. However, the cross-country correlation appears to hold whether the source of high investment is a relatively high national savings rate or a domestic price structure tilted toward making investment goods relatively cheap.[15] And the correlation is not inconsistent with net social returns in the range of 20 percent per year or more—in striking contrast to after-tax private returns to investment in the 5 to 10 percent per year range.

The microeconomic evidence for external complementarities between physical investment and total factor productivity growth concerns how businesses adopt new, more efficient technologies, and looks retrospectively at historical patterns of economic growth and technology diffusion. For example, Brynjolffson and Hitt (2000) find, in a sample of firms in the 1990s, that successful work place reorganizations taking advantage of new information technologies required substantial upfront investments in physical capital goods. Once a particular firm in an industry has made those investments and figured out how to reorganize its operating procedures to benefit from them, its competitors then have a much easier time replicating its accomplishments at lower

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[14] For example, Temple (1998) finds that the rate of return is extraordinarily high in developing countries, and appears lower in developed countries.

[15] See DeLong and Summers (1991).

cost: they do not have to make the same organizational mistakes. Brynjolffson and Hitt's finding that the costs of organizational reconfiguration are a large multiple of those of physical investment implies that even a small degree of competitors' learning-by-observing creates a large wedge between the private and social returns to investments in physical capital that embody newly-developed technologies.

The key benefit of the diffusion of electric power for total factor productivity within U.S. manufacturing a century ago, to use an example from history, came about largely through learning-by-using and the invention of complementary technologies such as small motors (David 1991; Devine 1983). Only after a new technology has diffused sufficiently widely through an economy can the process of social learning and experimentation that produces knowledge of the serendipitous efficiencies it makes possible take place. The process of organizational experimentation and reconfiguration that produced “mass production” was undertaken by a relatively few firms that incurred the costs, yet the process of imitation and diffusion that then spread mass production throughout the economy had vastly larger benefits.

Thus there is reason for government concern about the level of physical investment: the probability of a substantial wedge between the private return to businesses undertaking investment projects and the social return is high. The social return is raised above the private return to the extent that workers' market power forces firms to share quasi-rents with labor—a consideration that, in the private sector at least, has fallen in importance over the past two generations. The private return is boosted above the social return to the extent that firms have market power: monopoly and oligopoly rents are a transfer, not a social return. The measured private return is boosted above the social return to the extent that the rents earned by other factors of production—entrepreneurship, risk-bearing, and so on, are attributed to physical capital.[16] The social return is boosted above the private return by taxes.

Obtaining bounds on the sum of all these effects is next to impossible (however, see Summers 1990). Nevertheless the balance of evidence seems to be—and in this essay we will assume—that insofar as physical capital is concerned, we get more than we pay for: policies to boost physical investment are worth analyzing and pursuing, as likely to have social benefits in excess of their costs.[17]

This conclusion is strengthened by the secular fall in the private savings rate—especially the household savings rate—seen in the U.S. economy over the past 25 years or so. If this shift in savings reflects optimizing behavior in households, it must be driven either by an extraordinary shift in tastes that reflects a radical devaluation in the utility of future consumption spending, or by a reduction in the perceived riskiness of the future that has greatly reduced the insurance

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[16] 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 social returns to marginal units of capital and risk bearing (Mehra and Prescott 1985; Shiller 1987).

[17] 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.

motive desire to accumulate wealth.[18] To the extent that it is the result not of optimizing behavior but of changes in institutions and in rules-of-thumb, then the decline in savings in recent years, as shown in Figure 7, may well strengthen the case for government to concern itself with boosting investment in physical capital.

C. How Should the Government Try to Boost Physical Investment?

1. Savings Incentives

What kinds of policies a government seeking to affect saving and investment should pursue depends on what kind of market failure it believes it is repairing. A government that sees the key problem as one of "impatience" or "myopia" on the part of its citizens would wish to focus on undoing the consequences of that market failure. Incentives to boost private savings would then be appropriate.[19]

Unfortunately, traditional incentive-based savings-focused public policy programs appear to be difficult to design and implement, and to be relatively ineffective. The reason for their relative ineffectiveness is clear. Income and substitution effects are working against each other.

Incentives that reward private saving increase the real lifetime wealth of savers. Such an increase in real lifetime wealth will, through the income effect, tend to increase current consumption. Since current savings are the difference between current income and current consumption,

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[18] See Kimball (1990)

[19] 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.

rewards to saving tend to decrease the quantity saved—at least through this income-effect channel. Opposed to the income-effect channel is the substitution effect. Tax and other incentives that increase the reward to saving make savings cheaper in terms of its resource cost. If we could hold lifetime wealth constant, we would find that such incentives would unambiguously increase the quantity saved.

Which effect tends to dominate is unclear. And the fact that the literature is so unclear leads to the presumption that the effects of savings incentives, in whatever direction they point, are likely to be small.[20]

2. Investment Incentives

To the extent that the externality to be managed takes the form not of a gap between the private and public benefits of saving, but of external complementarities induced by investment, it is clear that appropriate growth-promoting policies would focus on providing incentives for higher levels of investment (rather than providing incentives for savings and hoping that those incentives would indirectly create higher investment). Once again, however, the government has limited competence at program design. There is the prospect that even policies that are successful at providing incentives to boost investment will also create large rents that flow to those whose behavior remains unchanged.[21]

Thus the argument against a broad-based permanent investment tax credit was that the overwhelming bulk of the credit would flow to reward investments that would have been made

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[20] 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).

[21] See Auerbach and Hines (1988).

in any case. The argument against a narrow incremental investment tax credit was that administrative complexities and incentives for firms to dissipate time, energy, and resources in making their normal investment projects appear “incremental” would raise massive implementation problems for any program that did not sunset rapidly.

3. The Government Budget

A government that did wish to increase investment and savings would, therefore, be well-advised to look to its own budget: to look at public savings, rather than less-than-fully-effective incentives to boost private savings or difficult-to-target incentives to boost investment. In the long run, after all, public savings *are* private savings: a lower government debt means either lower taxpayer tax payments or higher levels of services delivered to citizens. And even in the short run, except to the extent that changes in government fiscal balances flow through to changes in net exports,[22] changes in public savings produce powerful changes in investment.[23]

Thus the combination of a thumb-fingered government's difficulties in targeting incentives and the possible perverse effects of savings incentives drives a modern government seeking to boost physical investment back to the policy stance proposed in those sections of the *1962 Economic Report of the President* drafted by Robert Solow: a government seeking to promote economic growth through physical investment will pursue a “loose” low interest-rate monetary policy (to

[22] This assumes that fiscal policy is not seen as an effective stabilization policy tool. Recent concerns about the very low level of interest rates, a possible “liquidity trap,” and the so-called "zero nominal interest rate bound" seem to call for some qualification of this point.

[23] That Robert Barro's (1974) doctrine of Ricardian equivalence is of limited applicability in the contemporary United States seems demonstrated by the failure of private savings rates to offset either the rise in the federal deficit

achieve full employment), and a "tight" high-surplus fiscal policy (to boost national savings). Thus what we conclude now is, in large part, what we knew forty years ago.

IV. Investment in Technology

There is a third kind of investment society undertakes: investment not in human capital or in physical capital, but investment in ideas—investment in better technology. Ideas are non-rival goods (Romer 1986). 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."

To encourage investment in ideas, the larger the market the better. Ever since David Ricardo 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 and division of labor are less important than increasing returns to scale and extent of the market.

Because ideas are non-rival, technology should be distributed at freely—at its marginal cost of zero. But here is where different economic principles cut in different directions. If the price equals zero, the idea cannot be created and produced by firms that 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 have never been able to choose and assess the directions of applied research and development very well. There is a good

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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.

deal of truth in the Hayekian insights of market competition as a discovery mechanism, and of the administrative defects of 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 (Gallini 2002).

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 (Kremer 1998).

V. Conclusion

Sustaining and accelerating American economic growth is a policy goal that, if achieved, will do much of the heavy lifting for other policy goals. Not only will faster economic growth raise household incomes and consumer living standards directly, it will reduce the sharpness of the horns of many of the other policy dilemmas Americans face. Since so many different factors affect the rate of economic growth, policies to sustain and accelerate growth can be pursued in almost any direction—attempting to restructure the system of intellectual property to provide incentives and opportunities for faster technological advance, policies to boost public saving, policies to boost private saving, policies to boost private investment, and policies to boost the skills of the labor force.

However, we do not yet know 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. On the physical capital-technology side, only one line of policy seems both straightforward to accomplish and likely to be effective in boosting accumulation and growth: run a surplus.

By contrast, we believe policies to increase human capital investments in younger cohorts, especially for minorities and those from low-income families, could play an important role both in enhancing U.S. growth and in reversing the social welfare-harm of the recent rise in wage inequality. The enormous rise in the college wage premium since 1980 has created incentives for increased education, but not all groups have invested equally. Family resources remain an important explanatory factor in differences in enrollment rates. 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 application and information system could have substantial payoffs.

Moreover, since "learning begets further learning," human capital policies must also target early childhood. We need, as well, to be willing to experiment further with policies (possibly involving school choice, competition, standards, and accountability) that promise to improve the quality of primary and secondary schooling.

During the twentieth century it was America's willingness to invest in education that was one of the principal, if not *the* principal, source of its extraordinary economic performance throughout the entire century. Simple extrapolation suggests that, with our current policies, this willingness to invest in people is not keeping pace: projections see much slower rates of increase in the educational attainment of the American labor force in the future than in the past. Adopting policies that renew America's commitment to invest in education and to do it smartly is probably the most important and fruitful step that could be taken to sustain American economic growth.

APPENDIX: *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:

$$\log w_{it} = E_{it}\_ + X_{it}\_ + R_{it}\_ + \_{it} ,$$

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 (age minus years of schooling minus 6), 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 $\_{it}$ 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 since the 1915 Iowa State Census does not provide a self-employment indicator. 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 log 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

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

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

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

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,

$$E_t = \mathbf{E}_i \text{—}_{it} W^{e}_{it} = \mathbf{E}_j W^{e}_{jt} S_{jt} \, ,$$

Where —_{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 3 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. Changes in the U.S. labor quality index in Table 4 use information on the age, sex, race, and nativity distribution of the U.S. workforce from 1915 to 1940 and use 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 3 and 4, 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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Figure 1: Years of Schooling by Birth Cohort, All U.S. Natives and by Race: 1876 to 1975

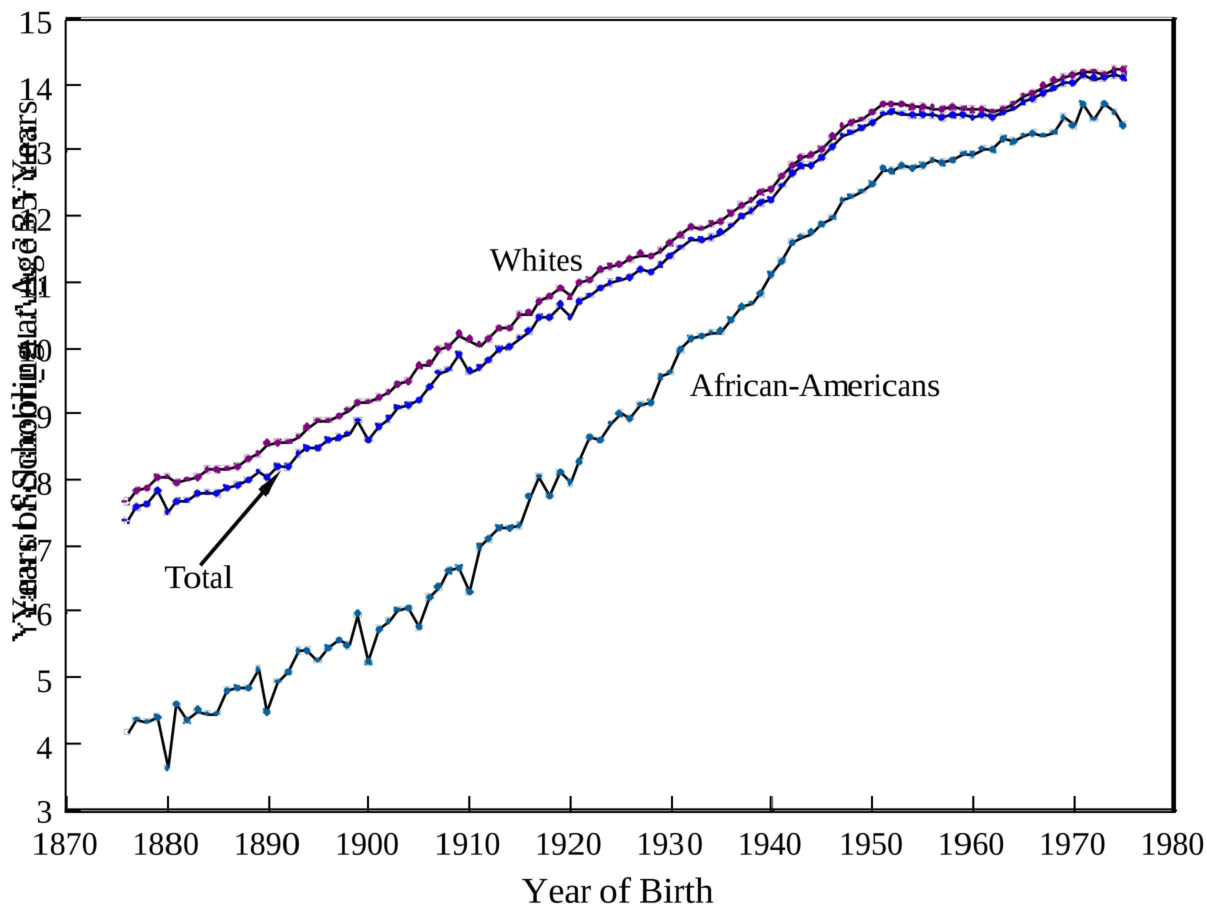

Figure 2: Years of Schooling by Birth Cohort, U.S. Natives by Sex: 1876 to 1975

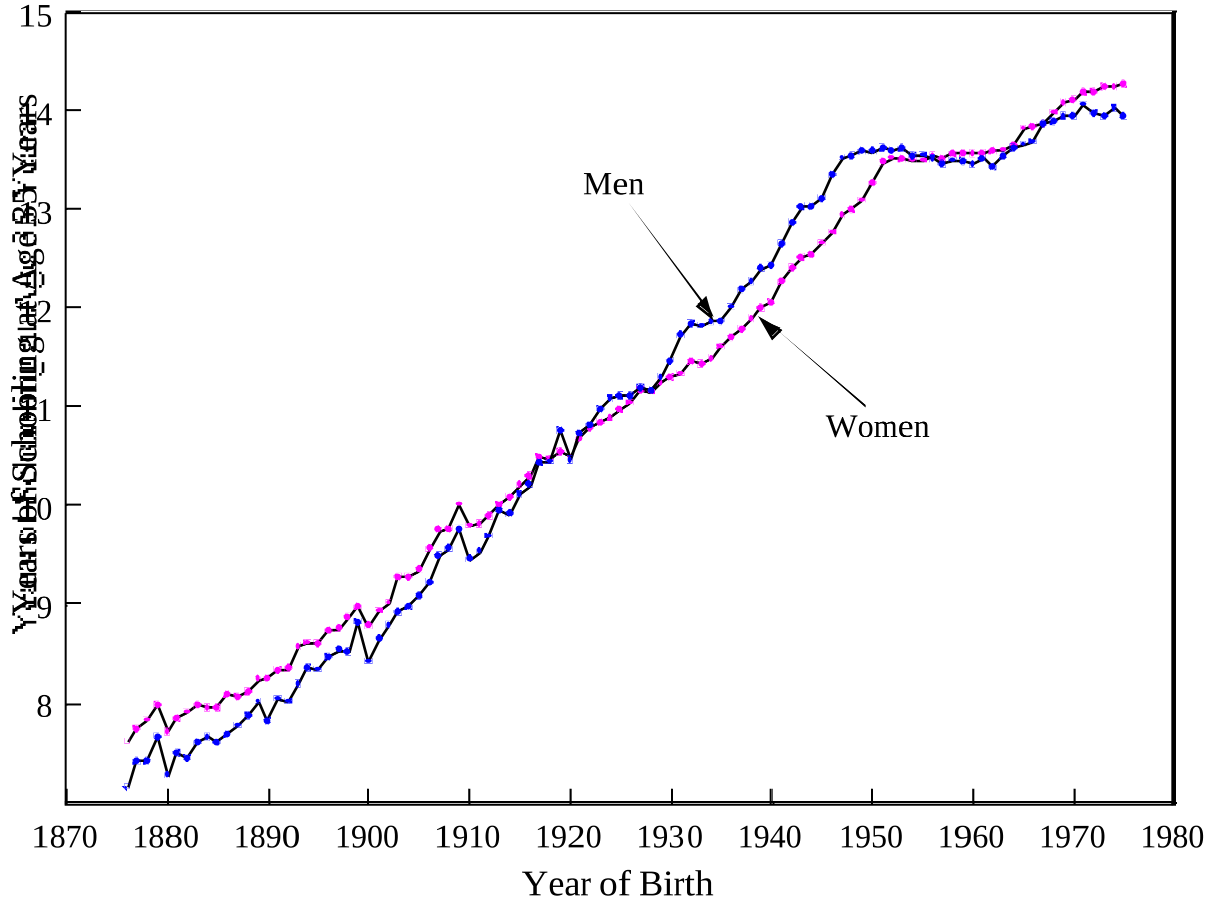

Figure 3: Fraction Graduating College by Birth Cohort, U.S. Natives by Sex: 1876 to 1975