Long-Run Changes in the U.S. Wage Structure: Narrowing, Widening, Polarizing

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From the close of World War II to 1970—the year the *Brookings Papers on Economic Activity* commenced—America enjoyed widespread prosperity. Not only did the nation grow rapidly, all parts of the income distribution expanded at fairly similar rates. America was "growing together." But in the mid-1970s, economic growth slowed. By the early 1980s the wage structure began a period of widening that has lasted until the present day. Even though productivity growth surged again starting in the mid-1990s, the benefits of economic growth have been concentrated at the top end of the distribution.[1] America has been "growing apart."

The "growing together" and "growing apart" patterns are shown in Figure 1, which compares real income growth across the family income distribution for the postwar period before and after 1973. For the pre-1973 period, real income growth was fastest near the bottom of the income distribution and slowest near the top, making the changes modestly equalizing. In sharp contrast, for 1973 to 2005 family incomes virtually stagnated for the lowest quintile but grew more than three times as rapidly for the top 5 percent as for the middle group.

Since most Americans make their living from work, it should not come as a surprise that changes in the labor market and the distribution of wages have been the driving force behind the rising disparity in the economic fortunes of American families.[2] We document the nature of rising U.S. wage inequality since 1980 and place the recent changes into a century-long historical perspective to understand the sources of change.

The widening of the wage structure that began in the early 1980s differed markedly from the wage structure changes of the early- to mid-twentieth century. Rather than expanding during the previous decades, the wage structure narrowed substantially during the first half of the twentieth century and was relatively stable during the 1950s and 1960s.

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[1] See Dew-Becker and Gordon (2005) on the changing distribution of the benefits of U.S. productivity growth.
[2] Burtless (1999) assesses the contribution of changes in the inequality of labor market earnings to rising family income inequality.

The spreading out of the wage structure since 1980 occurred in two stages. From 1980 to around 1987, wage inequality increased in a rapid and monotonic fashion. The top grew most rapidly, the middle less rapidly, and the bottom the least of all. Since the late 1980s the upper-end of the wage distribution has continued to grow rapidly relative to the middle, but the lower part has not lost out relative to the middle. These recent wage structure changes have been associated with a "polarization" of the U.S. labor market with employment shifting into high- and low-wage jobs at the expense of middle-wage positions.[3] Another key point we will make is that the majority of the increase in wage inequality since 1980 has come from rising educational wage differentials, particularly rising returns to post-secondary schooling.

Why has the wage structure widened so much since 1980? A popular explanation attributes the primary role to an increase in the rate of growth of the relative demand for more skilled workers from skill-biased technological changes and a re-organization of work driven by the spread of computer-based technologies.[4] Globalization pressures, eroding labor market institutions, and changes in the social norms that constrain pay disparities have also been offered as explanations and each appears to have played some role.[5] Our focus is on re-assessing the skill-biased technological change hypothesis in a long-run historical context.

Skill-biased technological change is not a new phenomenon. Rather, it has driven rapid secular growth in the relative demand for more-educated workers for at least a century. During most of the twentieth century the narrowing of the wage structure came about largely because the supply of skills grew faster than did the demand for skills. Growth in the relative demand for

[3] The polarization terminology is borrowed from Goos and Manning (2007) who document similar recent changes in the employment patterns for Britain and has been used for the United States by Autor, Katz, and Kearney (2006).
[4] See Autor, Katz, and Kearney (2008) and Card and DiNardo (2002) for contrasting evaluations of the role of technological change in U.S. wage structure changes.
[5] See Borjas, Freeman, and Katz (1997) on the impacts of trade and immigration; and see DiNardo, Fortin and Lemieux (1996) and Levy and Temin (2007) on institutions and social norms. Katz and Autor (1999) provide an overview of alternative approaches to modeling and measuring wage structure changes.

skills was produced largely by skill-biased technological change. Skill supply growth was due primarily to the rising educational attainment of successive cohorts. That, in turn, was fueled by increased access to public high schools and later to colleges and universities. The upshot of these changes was that the wage structure and educational wage differentials narrowed from 1915 to 1980, especially from 1915 to 1950.

Relative demand shifts favoring more-educated workers have *not* been particularly rapid since 1980. Instead, the growth of the supply of skills slowed considerably after 1980 and the wage structure, in consequence, widened. The slowdown in the relative supply of skills of the working population came about largely from the slowdown in the growth in the educational attainment of U.S. natives for cohorts born since around 1950. In contrast, the increase in unskilled immigration accounts for only a small part of the slowdown skill supply growth.

Although the overall rate of relative demand shifts for more-skilled workers does not appear to have accelerated since 1980, computerization and international trade and offshoring have changed the nature of demand shifts. Skill-biased technological change has increased the relative demand for skill in a rather *monotonic* manner across most of the past century. But computerization, a recent form of skill-biased technological change, has increased the relative demand for skill in a *non-monotonic* manner. Computers strongly complement the non-routine or abstract tasks of high-wage jobs, but they directly substitute for the routine tasks in many traditional middle-wage jobs. However, computers have little impact on the non-routine manual tasks of many low-wage service jobs. Furthermore, this pattern of demand shifts appears to have been reinforced by international offshoring. The consequence of these changes is a polarization of labor demand that has led to rapidly growing inequality in top half of distribution with little or no change in inequality in the bottom half of the distribution.

I. The Evolution of the U.S. Wage Structure

Two large and representative household data sets have been widely used to document changes in the U.S. wage structure over recent decades. The March Current Population Survey (CPS) micro-data provide reasonably comparable information for the past four decades on (prior year's) earnings, weeks worked, and full- and part-time work status. We use the March files from 1964 to 2006 (covering earnings years 1963 to 2005) to examine the evolution of weekly earnings of full-time, full-year workers (FTFY; those working 35 or more hours per week for 40 or more weeks in the year). We complement the March CPS FTFY series with point-in-time data on the hourly wages of all wage and salary workers using May CPS samples for 1973 to 1978 and CPS Outgoing Rotation Group samples for 1979 to 2006 (CPS MORG).[6]

Individual-level data from the federal population censuses on labor market earnings for the previous calendar year, weeks and hours worked, and educational attainment allow us to track wage inequality and educational wage differentials since 1939.[7] Since no national sample exists giving all parts of the wage structure before 1939, we have pieced together data from various sources to track wage structure changes from 1890 to 1940. These sources include individual-level data on earnings and educational attainment from the 1915 Iowa state census, wage distributions for manufacturing industries for 1890 to the 1940s, and occupational wage series.[8]

A. Recent U.S. Wage Structure Changes

[6] Our wage tabulations from the March CPS and CPS MORG files cover wage and salary workers aged 16 to 64 years and follow the data processing steps documented in the Data Appendix to Autor, Katz, and Kearney (2008). Autor, Katz, and Kearney (2005) and Lemieux (2006b) discuss the advantages and disadvantages of the March CPS and CPS MORG samples for measuring changes in wage inequality.

[7] Social Security Administration individual-level longitudinal annual earnings data starting in 1937 have recently become available, but these data do not include information on educational attainment or on weeks and hours worked. Kopczuk, Saez, and Song (2007) use these data to examine inequality and mobility from 1937 to 2004.

[8] See Goldin and Katz (2008) for the details on these data sets and on the wage structure from 1890 to 1940.

Wage inequality for hourly, weekly, and annual earnings has increased substantially since 1980 for men, for women, and for men and women combined.[9] The weekly earnings of the 90th percentile FTFY worker relative to the 10th percentile FTFY worker increased by 40 log points (49 percent) for both men and women from 1980 to 2005 in the March CPS. Expanded wage differentials by education, occupation, and age (or experience) and rising within-group (residual) wage dispersion have contributed to the overall rise in wage inequality. The rise in the relative earnings of college graduates and those with advanced degrees has been particularly large. The weekly earnings of those with exactly a bachelor's degree increased by 22 log points and those with post-college degrees rose by 34 log points relative to those with exactly a high school degree for FTFY workers from 1980 to 2005. An offsetting factor has been a substantial narrowing of gender wage differential since 1980. But the 90-10 log weekly wage gap for FTFY males and females combined still increased by 26 log points from 1.33 in 1980 to 1.59 in 2005.

Rising wage inequality since 1980 was *not* offset, and actually appears to have been *reinforced*, by changes in non-wage benefits and workplace amenities.[10] Although transitory earnings variation increased in the 1980s, the bulk of the rise of cross-section wage inequality was driven by relatively permanent components of earnings variation including rising returns to education.[11] Earnings inequality expanded even more if one moves beyond standard household data sets and includes the better information on the top 1 percent of the annual earnings distribution from data on tax returns.[12] But large changes in the wage distribution for the bottom 99 percent group remain.

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[9] See Autor, Katz and Kearney (2008), Katz and Autor (1999), Lemieux (2006b, 2007), and Mishel, Bernstein, and Allegretto (2007) for more comprehensive descriptions of recent U.S. wage structure changes.
[10] See Hamermesh (1999) and Pierce (2001).
[11] See, for example, Kopczuk, Saez, and Song (2007).
[12] See Piketty and Saez (2003, 2007) who document that the share of wage income accruing to the top 1 percent of tax units increased from 6.43 percent in 1980 to 11.62 percent in 2005.

The timing and the key components of the recent rise in U.S. wage inequality are shown in Figure 2. Three aspects of wage inequality are displayed for the March FTFY weekly sample covering 1963 to 2005 (Panel A) and for the CPS MORG hourly wage sample covering 1973 to 2006 (Panel B): the 90-10 overall log wage differential (for males), the 90-10 residual log wage differential (for males), and the college-high school log wage differential (for males and females combined). The three measures of inequality rose rapidly and in tandem during the 1980s and then grew more slowly (or flattened) in the 1990s and 2000s. But the college wage premium increased substantially in the 1960s when residual inequality was quiescent, and it declined in the 1970s when residual inequality increased (March CPS) or was flat (CPS MORG). Thus, the rise in wage inequality has not been a unitary phenomenon.

All three measures of hourly wage inequality from the CPS MORG display large increases in the first-part of the 1980s but, in contrast to the March CPS FTFY series, residual inequality stopped growing after the mid-1980s for hourly wages in the CPS MORG. The greater increase in wage inequality since the mid-1980s for full-time weekly wages in the March CPS than for hourly wages in the CPS MORG partly reflects an increasingly positive covariance of weekly hours and hourly wages even among full-time workers and likely reflects the growing importance of performance pay (such as annual bonuses), which is presumed to be better reported in the March CPS earnings measure.[13]

B. Divergent Upper- and Lower-Tail Wage Inequality

Underlying the rapid growth of overall wage inequality in the 1980s followed by deceleration in the 1990s is a divergence in inequality trends in the upper-half and bottom-half of

[13] Lemieux, MacLeod, and Parent (2007) document the rising incidence of performance pay and its role in rising wage inequality in the upper 20 percent of the wage distribution.

the wage distribution. The divergence is shown in Figure 3, which compares the evolution of the 90-50 and 50-10 log hourly wage differentials for all workers across the past three decades.

Substantial increases in wage inequality occurred in both the upper-half (90-50) and lower-half (50-10) of the distribution from 1979 to 1987 expanding the 90-10 log wage differential by 18 log points. But the trends in upper-half and lower-half wage inequality diverged after 1987 with upper-half wage inequality continuing to rise steadily and lower-half wage inequality ceasing to rise (and actually contracting by 4 log points from 1987 to 2005).[14]

To show more precisely where in the wage distribution the divergence of upper- and lower-tail wage inequality has occurred, we plot cumulative log hourly real wage growth by wage percentile for 1974 to 1988 and for 1988 to 2005 in Figure 4. An almost linear spreading out of the wage distribution (from the 4th to the 96th percentile) is apparent from 1974 to 1988, driven by changes in the first half of the 1980s, whereas wage growth has polarized since 1988. The 1988 to 2005 line shows modestly faster wage growth near the bottom than in the middle of the distribution and a continued spreading out of the wage distribution in the top quintile.[15]

C. Contribution of Increased Returns to Education to Rising Wage Inequality

Expanded educational wage differentials have been a key component of the rise in wage dispersion since 1980. How much of the overall rise in wage inequality is due to increased returns to schooling? An intuitive approach to answering the question is as follows. We first use our 1980 and 2005 CPS MORG samples to estimate a modified Mincerian human capital earnings regressions with log hourly wages as the dependent variable run on a linear spline in years of schooling with break points after 12 and 16 years of schooling; a quartic in experience; race, region, and gender dummies; and interactions of gender and the experience quartic. The

[14] Autor, Katz, and Kearney (2008) document similar patterns of divergence of upper-half and lower-half wage inequality trends after 1987 for men and women separately and for both hourly and weekly earnings.
[15] The post-1988 polarization is somewhat larger for the male wage distribution.

component of recent increases in U.S. male wage inequality.[17]

D. Long-Run U.S. Wage Inequality Changes

How does the large recent expansion of wage inequality and educational wage differentials fit into the longer-term evolution of the U.S. wage structure? We use the Integrated Public Use Micro-samples from the 1940 to 1970 decennial censuses (Census IPUMS) to extend our March CPS series on overall male FTFY weekly wage inequality (from Figure 2, panel A) back to 1939. The extended series on the male 90-10 log weekly wage differential from 1939 to 2005 is plotted in Figure 5.

The growth of wage inequality since the late 1970s was preceded by a substantial narrowing of the wage structure during the "Great Compression" of the 1940s when the male 90-10 log weekly wage gap decreased by 35 log points and then by a period of little change in wage inequality during the 1950s and 1960s.[18] Also plotted in Figure 5 is a relatively homogeneous series for 1937 to 2004 from Social Security Administration earnings history data on annual earnings inequality (the Gini coefficient) for male commerce and industry workers constructed by Wojciech Kopczuk, Emmanuel Saez, and Jae Song.[19] The time series pattern is similar to the Census/CPS weekly wage inequality series but reveals that the great narrowing of wages in the 1940s continued until 1953 although it was sharpest during World War II. Both series indicate the surge in wage inequality during 1980s undid the changes of the Great Compression and that male earnings inequality is higher today than at any time at least back to the 1930s.

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[17] Lemieux (2006a) using a formal variance decomposition finds that higher returns to post-secondary education explain 55 percent of the rise of male log hourly wage variance from 1973-5 to 2003-5. Firpo, Fortin, and Lemieux (2007) using a non-parametric decomposition find that rising education returns can explain .067 (or 54 percent) of a .125 rise in the male 90-50 log hourly wage gap and over 100 percent of increased wage variance for 1988 to 2005.
[18] See Goldin and Margo (1992) on the "Great Compression."
[19] Kopczuk, Saez, and Song (2007).

We use the Census IPUMS data to examine educational wage differentials back to 1940 and link the results to data we collected from the 1915 Iowa state census to create a consistent measure of education returns back to 1915. Figure 6 plots the college and high school graduate wage premiums from 1915 to 2005. The wage compression of the 1940s was partially driven by large reductions in educational wage differentials. The college and high school wage premiums were exceptionally high in 1915 when white-collar workers (even ordinary clerks) were considered a "non-competing" group. A high school education was, at the time, the ticket to most white-collar and top blue-collar jobs, and high school graduates were a more elite class than college graduates are today.[20] Educational wage differentials narrowed substantially from 1915 to 1940. The college wage premium today has come full circle to its level in 1915, but the high school wage premium is much lower today than in the early twentieth century.

Although we do not have nationally-representative samples to measure the full wage structure prior to the end of the 1930s, we have uncovered a wide range of data on different parts of the wage structure for 1890 to 1940. All of our sources indicate a substantial narrowing of the wage structure from 1910 to 1940 especially during the World War I period of the late 1910s. Overall earnings dispersion among manual workers in manufacturing, occupational wage differentials between skilled and less skilled manual workers, and white-collar to blue-collar wage differentials as well as the direct estimates of educational wage differentials in Figure 6 all show large declines from the early twentieth century to 1940.[21] We conclude that wage inequality and wage differentials by occupation and education shrank substantially during the first half of twentieth century.

[20] See Goldin and Katz (2000, 2008) on education returns, occupational wage differentials, and non-competing groups in the early twentieth century. Goldin and Katz (2008, table 1.2) find that 14.6 percent of the Iowa work force had at least a high school degree in 1915 and that under 12 percent of the U.S. work force had a high degree in 1915 as compared with 30 percent having a college degree in 2005.

[21] See Goldin and Katz (2008, chapter 2).

The U.S. wage structure has followed the progression: narrowing to widening to polarizing. A substantial narrowing occurred from 1910 to 1950 and relative stability characterized the 1950s and 1960s. A sharp monotonic widening ensued in the 1980s and the wage structure has polarized since the late 1980s. Even though educational wage differentials and overall wage inequality do not always move closely together in the short run (such as during parts of the 1970s), changes in education returns have played a major role in declining wage inequality in the first half of the twentieth century and rising wage inequality over the last three decades. In fact, our estimates imply the majority of the increase in U.S. wage inequality since 1980 can be accounted for by increased returns to education (dominated by large increases in returns to college and post-college schooling). Thus, an understanding of the driving forces behind long-run changes in the educational wage differentials is essential to understanding recent U.S. wage structure changes.

II. The Race between the Supply of and Demand for Skills, 1915 to 2005

We model changes in educational wage differentials using the conceptual framework of a race between the supply of skills (driven by changes in the educational attainment of the work force) and the demand for skills (driven by skill-biased technological change).[22] We apply this approach to understand the evolution of the college wage premium from 1915 to 2005.

Our illustrative framework starts with a CES production function for aggregate output *Q* with two factors, skilled workers (S) and unskilled workers (U):

$$Q_t = \left[\alpha_t (a_t L_{S_t}^{\rho}) + (1-\alpha_t)(b_t L_{U_t}^{\rho})\right]^{\frac{1}{\rho}} \tag{1}$$

[22] The notion that long-run changes in the wage structure are an outcome of a race between education and technology is further developed in Goldin and Katz (2007, 2008) and dates back to Tinbergen (1974) and Freeman (1975). We follow the specific analytical framework and empirical methods developed by Katz and Murphy (1992).

where L_{S_t} and L_{U_t} are the quantities employed of skilled labor and unskilled labor in period t, a_t and b_t represent skilled and unskilled labor augmenting technological change, α_t is a time-varying technology parameter that can be interpreted as indexing the share of work activities allocated to skilled labor. The production function parameter ρ is related to σ_{SU}, the aggregate elasticity of substitution between skilled and unskilled labor, such that $\sigma_{SU} = \frac{1}{1-\rho}$. Skill-neutral technological improvements raise a_t and b_t by the same proportion. Skill-biased technological changes involve increases in (a_t / b_t) or in α_t. We focus on the college/high school divide so that skilled workers (S) are "college equivalents" (college graduates plus half of those with some college) and unskilled workers (U) are "high school equivalents" (those with 12 or fewer years of schooling and half of those with some college).

Under the assumption that college and high school equivalents are paid their marginal products, we can use equation (1) to solve for the ratio of the marginal products of the two skill groups yielding a relationship between relative wages and relative skill supplies in t given by:

$$\ln\left(\frac{w_{S_t}}{w_{U_t}}\right) = \frac{1}{\sigma_{SU}}\left[D_t - \ln\left(\frac{L_{S_t}}{L_{U_t}}\right)\right] \qquad (2)$$

where D_t depends on the skill-biased technological change parameters and indexes relative demand shifts favoring college equivalents and is measured in log quantity units.[23] The terms in brackets in equation (2) show how the evolution of the college wage premium depends on a race between the relative demand for and supply of skills. The aggregate elasticity of substitution between college and high school equivalents (σ_{SU}) is the key parameter determining how much changes in skill supplies affect the college wage premium. The greater is σ_{SU}, the smaller is the

[23] $D_t = (1/\sigma_{SU})\ln[\alpha_t /(1-\alpha_t)] + (\sigma_{SU} - 1)\ln(a_t / b_t)$.

impact of shift in relative supplies on wages and the greater must be fluctuations in demand shifts (D_t) for any given time series of relative wages to be consistent with a given time series of relative quantities.

How important have been skill supply and skill demand shifts in the evolution of the college wage premium series from 1915 to 2005 as shown in Figure 6? We directly measure the college wage premium and the relative supply of college equivalents, assume a plausible value for σ_{SU}, and then use equation (2) to generate an implied time series of relative demand shifts (D_t). A large literature using national time series data and regional panel data provides estimates of extended versions of equation (2) with demand shifts proxied by smooth time trends and cyclical variables or more direct measures of technology (capital-intensity) variables. These studies find strong negative impacts of the growth in college relative supply on the college wage premium and estimates of σ_{SU} in the range of 1 to 2.5.[24] Our preferred model estimated on national data for 1914 to 2005 with demand shifts given by smooth time trends and an allowance for institutional wage-setting in the 1940s indicates that a 10 percent increase in relative skill supplies reduces the college wage premium by 6.1 percent implying $\sigma_{SU} = 1.64$.[25] We also find little evidence that σ_{SU}, measured in this manner, has changed much over the last century.

The large increase in the log college wage premium from 0.313 in 1950 to 0.618 in 2005 (see Figure 6) occurred at the same time the relative supply of college workers greatly increased. The college graduate share of full-time equivalent employment increased from 7.8 percent in 1950 to 31.8 percent in 2005 and the college equivalent share increased from 12.4 percent to

[24] Katz and Autor (1999) review much of this literature.

[25] See table 8.2 of Goldin and Katz (2008). Autor, Katz, and Kearney (2008) uncover almost identical estimates of σ_{SU} for a variety of specifications of time trends estimated on data for 1963 to 2005.

46.2 percent.[26] Rapid secular growth in the relative demand for college workers is needed to reconcile a rising college wage premium with these large increases in college relative supply. Long-run shifts in the industrial and occupational mix of employment toward more education-intensive sectors and jobs have played an important role in rapid secular growth in the relative demand for skills.[27]

Furthermore, substantial indirect and direct evidence suggests skill-biased technological change has been the primary contributor to rising relative demand for skills. The relative employment of more-skilled workers has increased rapidly within detailed industries and individual establishments in recent decades despite sharp increases in their relative wages.[28] The adoption of new technologies (and associated organizational changes), more R&D, and greater capital-intensity of production have been strongly associated with a higher utilization of more-skilled workers in firms and industries. Evidence of technology-skill complementarity has been associated with the electrification of the factory in the early twentieth century and the introduction of computer-based technologies more recently.[29]

Changes in the college wage premium and in the relative supply and demand for skilled (college equivalent) workers are given in Table 1 for selected periods from 1915 to 2005 assuming $\sigma_{SU} = 1.64$.[30] The college wage premium wound up in about the same place in 2005 as it started in 1915. Thus, supply and demand forces kept pace over the long run each growing at

[26] These tabulations use the 1950 Census IPUMS and 2005 CPS MORG for the work force aged 18 to 65 years.
[27] See, for example, Autor, Katz, and Krueger (1998), Goldin and Katz (1998), and Juhn and Murphy (1995).
[28] See Dunne, Haltiwanger and Troske (1997) and Autor, Katz, and Krueger (1998). Foreign outsourcing of less-skilled jobs is another possible explanation for this pattern but large within-industry shifts towards more skilled workers have been pervasive even in sectors with little or no observed international trade or outsourcing activity.
[29] See Goldin and Katz (1998, 2008) on skill-biased technological change in the early twentieth century, Griliches (1969) on capital-skill complementarity in the mid-twentieth century, and Doms, Dunne, and Troske (1997) and Bartel, Ichniowski and Shaw (2007) for more recent evidence on technology adoption and skill utilization.
[30] We measure skill supplies in efficiency units taking into account systematic differences in productivity (wages) by age, sex, and education within each skill aggregate and adjusting for changes in the age-sex-education group composition of hours worked within each skill aggregate.

about 2.9 percent per year on average. Supply growth substantially outstripped demand growth from 1915 to 1980. This pattern was reversed beginning in 1980. Although our estimates imply faster growth in the relative demand for college workers since 1950 than in the first half of the twentieth century, they do not imply particularly fast demand growth from 1980 to 2005 and suggest a slowdown in demand growth since 1990.

The implied negative relative demand growth in the 1940s is probably picking up strong institutional interventions in wage setting during World War II and a surge in unionization. Similarly, some of the rapid implied demand growth in the 1950s may reflect a partial unraveling of these institutional forces. The fast skill demand growth in the 1980s may also reflect a weakening of wage-setting institutions that had supported the earnings of non-college workers, such as the steady erosion of the real value of the federal minimum wage from 1981 to 1990 and the steep decline in unionization.

A key message from Table 1 is that a sharp slowdown in skill supply growth rather than a persistent acceleration in demand growth has been the driving force behind the large rise in the college wage premium from 1980 to 2005. The relative supply of college workers increased by 3.89 percent per annum from 1960 to 1980 and the college wage premium did not rise. But college relative supply increased at just 2.26 percent per annum from 1980 to 2005 and the college wage premium increased by 0.90 percent per annum. Relative demand growth was similar on average from 1960 to 1980 as well as from 1980 to 2005 when a deceleration in relative supply growth occurred that more than fully explains the post-1980 rise in the college wage premium.

Technology, we conclude from Table 1, has been racing ahead of education in the recent period because educational growth has been sluggish, *not* because the rate of skill-biased technical change has accelerated. What drove rapid relative skill supply growth for most of the twentieth century and what accounts for the post-1980 slowdown in skill supply growth?

National skill supplies can change because of shifts in the education distribution of the native-born work force and because of immigration. Immigration was a major source of U.S. labor force growth in the early twentieth century, became much less important with the imposition of immigration restrictions in the 1920s, and has surged in recent decades after immigration reform in 1965. The foreign born share of the U.S. work force declined from around 21 percent in 1915 to 5.4 percent in 1970 before rising 15.1 percent in 2005.[31] Immigrants had considerably less schooling than U.S. born workers in the early twentieth century. Recent waves of immigrants have a bimodal education distribution relative to the U.S. born. Immigrants are disproportionately found among those that have no high school education and, at the same time, among those who have greater than a college degree.[32]

The relative supply of skilled (college equivalent) to unskilled (high school equivalent) workers can be decomposed into native born and immigrant components as follows:

$$\log\left(\frac{L_{S_t}}{L_{U_t}}\right) = \log\left(\frac{N_{S_t}}{N_{U_t}}\right) + \left[\log\left(1+\frac{M_{S_t}}{N_{S_t}}\right) - \log\left(1+\frac{M_{U_t}}{N_{U_t}}\right)\right] \quad (3)$$

where N_{j_t} (M_{j_t}) = supply of U.S. born (immigrant) workers in skill group *j* in year *t* and $L_{j_t} = N_{j_t} + M_{j_t}$.[33] The first term of the right side of the equation (3) is the native contribution to the log skill supply ratio. The second term, in brackets, is the immigrant contribution.

We use equation (2) to assess contributions of the U.S. born and immigrants to changes in skill supplies in columns (3) and (4) of Table 1. The decline in the immigrant share of the

[31] These estimates are from tabulations using the 1910, 1920 and 1970 Census IPUMS and 2005 CPS MORG.
[32] See Goldin and Katz (2008, table 8.5).
[33] This decomposition approach follows Borjas, Freeman, and Katz (1997).

work force modestly contributed to relative skill supply growth from 1915 to 1970 and the recent surge in unskilled immigration has played a small role in the slowdown of skill supply growth.

But long-run skill supply growth has been dominated by growing educational attainment of the U.S. born. The post-1980 slowdown in skill supply growth has resulted mainly because of a slower growth in the education of the U.S. born. The rate of growth of the relative supply of college equivalents declined by 1.62 percent per year from 3.89 percent per year for 1960 to 1980 to 2.27 percent per year for 1980 to 2005. Of that decrease in the growth rate of the relative supply of college equivalents, 1.40 percent per year (86 percent of the total) was due to the slowdown in the relative supply of the college educated among native-born Americans. Only 0.22 percent per year (14 percent of the total) was due to immigration.

Changes in the growth of relative skill supplies of the U.S. born can arise from changes in the growth of the educational attainment of successive birth cohorts and from changes in the size of entering cohorts from baby booms and baby busts. The main source of rising national skill supplies from 1915 to 1980 was the rapidly increasing educational attainment of successive cohorts of the U.S. born. Similarly, the main factor in the slowing of skill supply growth since 1980 has been slower growth in the educational attainment of post-1950 cohorts of the U.S. born. These trends are shown in Figure 7 which plots the mean years of schooling (measured at age 30) for the 1876 to 1980 birth cohorts of U.S natives.

Educational attainment increased rapidly for the 1876 to 1950 birth cohorts. The growth of educational attainment accelerated with the high school movement in the 1910s and thus for those born starting around 1900. For those born in the United States in the first half of the twentieth century, each generation had about two more years of schooling than their parents. Educational attainment increased by 4.67 years (or 0.93 years per decade) from 8.49 for those born in 1900 to 13.16 years for those born in 1950. In contrast, those born in 1975 have only 0.74 more years of schooling (0.30 years per decade) than their parents' generation born in 1950.

We next decompose the growth of relative skill supplies of the U.S. born into educational attainment growth across cohorts and changes in cohort size.[34] This exercise implies that of the total decline in the growth rate of the domestic college supply of 1.4 percent per year (3.83 – 2.43) from 1960-80 to 1980-2005 (col. 3 of Table 1), almost 70 percent (0.97 percent per year) was due to the slowdown in the growth of educational attainment across successive birth cohorts. In fact, the deceleration in the growth rate of educational attainment of the U.S. born explains a 0.59 percent per year increase in the college wage premium (assuming σ_{SU} = 1.64) out of the actual increase of 0.90 percent per year from 1980 to 2005.

Thus, the slow growth of educational attainment for the U.S. born after 1950 is the largest source of the post-1980 increase in the college wage premium. In contrast, accelerated growth of educational attainment from increased access to public high schools starting around 1910 was the major factor in the narrowing of the high school wage premium from 1915 to 1940.[35]

The differences in skill supply growth in the early twentieth and twenty-first centuries raise the question of whether we have reached an upper bound for educational attainment so that technology must race ahead of education and lead to further expansions in inequality. We do not think so. Other OECD nations currently have achieved far higher secondary school graduation rates than the United States and some have even passed us in four-year college completion rates.[36] Perhaps more convincing is that the returns to further educational investments continue

[34] The methodology is analogous to that based on equation (3) for decomposing overall relative skill supply growth into immigrant and native-born components and uses data on skill supplies by single year of age birth cohorts.
[35] See Goldin and Katz (2007, 2008) for a supply-demand analysis of the high school graduate wage premium.
[36] OECD (2006) reports the U.S. high school graduation rate in 2004 at 75 percent as opposed to 83 percent among European Union nations. The U.S. was in the bottom third of 26 OECD nations in the high school graduation rate in 2004. The U.S. also ranked only seventh out of the 20 richest OECD nations in secondary school completion

to be substantial from marginal expansions in financial aid and in access to college as well as from recent increases in state compulsory schooling requirements.[37]

III. The Polarization of the U.S. Labor Market

The U.S. wage distribution spread out monotonically and rapidly from 1979 to 1987, but it has subsequently polarized. A strong, persistent rise in upper-tail wage inequality and a slight reversal of inequality growth since 1987 in the lower half of the distribution are apparent (see Figures 3 and 4). The polarization pattern can also be observed in educational wage differentials. The wage gap between post-college educated and college educated workers has continued to expand rapidly since the late 1980s while the wage gap between high school graduates and dropouts has stopped growing.[38]

A more nuanced view of skill biased technological change directly examines how rapid price declines in computer technology affect the demand for job tasks and serves to explain many details of the recent wage polarization. David Autor, Frank Levy and Richard Murnane (ALM) have amassed evidence consistent with a task demand framework in which computerization has non-monotone impacts on the demand for skill.[39] Changes in the organization of work associated with computerization raise the demand for the cognitive and interpersonal skills (called "abstract tasks") used by educated professionals and managers and reduce the demand for the clerical and routine analytical and mechanical skills (called "routine

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among 25 to 34 year olds in 2004 even after including GED recipients as secondary school completers. The OECD data also indicate that U.S. is at about the OECD average for four-year college completion rates among young cohorts trailing 12 nations.

[37] See Card (2001) and Oreopoulos (2007).

[38] See Autor, Katz and Kearney (2008) and Lemieux (2007).

[39] See Autor, Levy, and Murnane (2003). Autor, Katz, and Kearney (2006) extend the ALM framework and show that declining computer prices may initially lead to monotonically increasing shifts in skill demand (if low end routine tasks are easier to computerize than high end routine tasks) followed by non-monotonic shifts favoring the top and bottom at the expense of the middle of the wage distribution.

tasks") that comprised many middle-educated white collar and manufacturing production jobs. Computerization has probably had little direct impact on the demand for the non-routine manual skills (called "manual tasks") used in many low-skilled service jobs (such as some health aides, security guards, and cleaners) and in many jobs in the building trades.[40]

The ALM framework suggests that computerization has led to changes in the organization of work that have raised the demand for higher-educated workers, depressed the demand for "middle-educated" workers, and left the lower echelons of the wage distribution, in the in-person service sector, comparatively unscathed. The indirect effects of computerization in reducing the communication and coordination costs that facilitate international outsourcing are likely to have reinforced this pattern.

The computerization task demand hypothesis for wage polarization is substantially a demand-side phenomenon induced by rising relative demands for high- and low-skill tasks. An implication is that employment demand growth (and employment growth) should have been monotonically rising in the skill distribution in the 1980s and been non-monotonic (lowest in the middle) since the late 1980s.

Figure 8 plots the share of total hours worked in the U.S. economy by occupation skill percentile for 1980 to 1990 and 1990 to 2000. Occupations are ranked in the skill distribution by mean years of schooling in 1980. During the 1980s employment shares declined substantially at the bottom of the skill distribution, and employment growth increased continuously when moving up the skill distribution. In contrast, employment growth polarized in the 1990s: the most rapid employment growth was in the highest-skill jobs, declines in employment shares occurred for middle-skill jobs, and flat or even rising employment shares occurred in the lowest-

[40] The interpersonal and environmental adaptability demanded by these manual tasks, particularly for many in-person services, have proven difficult to computerize to date. The in-person aspect of many service jobs using such manual tasks also serve to insulate them from international offshoring.

skill occupations. The polarization of employment growth since 1990 represents a sharp break in a long-line of successive technological advances that have generated monotonically rising demand by skill level since at least 1940.[41] Furthermore, Figure 8 shows that the mean gap in employment share growth rates between "college jobs" (those in the top half of the skill distribution) and "non-college jobs" (those in the bottom half) shrank from the 1980s to the 1990s in a manner consistent with the slowdown in relative demand growth for college equivalents from the 1980s to the 1990s found in Table 1.

The computer task demand hypothesis also has implications concerning within-group shifts in skill demand and wage inequality by education group. Computers are strong complements to the abstract tasks of college graduates in top-end professional and management positions whereas they substitute for the routine tasks of lower-end college graduates in middle management and certain professional positions. Computers substitute for manufacturing production and administrative jobs often found in the upper-half of the non-college wage distribution, but have little direct impact on lower-end service jobs for non-college workers. The implication is that we should find strongly rising within-group wage inequality for college graduates since the late 1980s and possibly even declining within-group wage inequality for high school workers. In fact, that is exactly what is found in the CPS wage data.[42]

IV. Conclusions

The U.S. wage structure has evolved across the last century: narrowing from 1910 to 1950, relatively stable in the 1950s and 1960s, rapidly widening in a monotonic fashion during

[41] For example, Juhn and Murphy (1995) examine the relative demand for occupation-industry cells (ranked by skill in terms of average wage percentiles) and find labor demand growth monotonically rising in skill for 1940 to 1980.
[42] Autor, Katz, and Kearney (2005) and Lemieux (2006b) document rising within-group wage inequality for both male and female college graduates from 1988 to the early 2000s and little change or declining within-group wage inequality for high school workers over the same period.

the 1980s, and polarizing since the late 1980s. The majority of the large increase in U.S. wage inequality since 1980 is accounted for by expanded educational wage differentials dominated by sharply increased returns to post-secondary schooling. Rising wage inequality among the college educated is the other major contributor to recent increases in U.S. wage dispersion.

Skill-biased technological change has generated rapid secular growth in the relative demand for more-educated workers for at least the past century. But rapid increases in the supply of skills from rising educational attainment of the U.S. work force more than kept pace with relative skill demands for most of the twentieth century and served to reduce educational wage differentials and narrow the wage structure. A sharp decline in relative skill supply growth driven by a slowdown in the growth of the educational attainment of successive cohorts of the U.S. born has been the largest contributor to the surge in the college wage premium since 1980.

The economic returns to completing high school today appear substantial and the economic benefits to college and post-college schooling are at historically high levels. But the educational attainment of American youth is not rising as rapidly as it did over much of the twentieth century. Although college enrollment rates among new high school graduates have been rising since the early 1980s in response to high college returns, the traditionally-measured U.S. high school graduation rate (not including GEDs) has been stagnant for three decades and the share of young adults completing four-year college degrees has risen only modestly for post-1950 birth cohorts (especially for males).[43] After leading the world in education for most of the twentieth century, U.S. young adults are now in the middle of the pack in the OECD in terms of education attainment.[44] Expanding the educational attainment of U.S youth requires increasing

[43] See Goldin and Katz (2008) for a detailed documentation and analysis of trends in U.S. high school graduation rates and in college enrollment and graduation rates as well as of policies to increase educational attainment.
[44] The OECD (2006) reports that the United State ranked 11th for males and 10th for females out of 30 countries in its summary measure of educational attainment (mean years of schooling) for 25 to 34 year olds in 2004.

the college readiness of children from poor and disadvantaged backgrounds and assuring the financial access to higher education of the college ready.[45]

The polarization of the U.S. wage structure since the late 1980s has been accompanied by a polarization of employment growth. U.S. employment has bifurcated into high-wage and low-wage jobs at the expense of traditional middle class jobs. Changes in task demand from the adoption of computer-based technologies have been a major source of this shift in the pattern of skill demands. The growth of international offshoring is likely to have reinforced these changes in skill demands. A key uncertainty with respect to future U.S. wage structure developments concerns the longer run impacts on skill demands and worker bargaining power from increased international economic integration and greater offshoring opportunities. Top-end knowledge jobs are likely to benefit from growing international markets and foreign offshoring is unlikely to be able to substitute for in-person services and for construction jobs.[46] The returns to abstract skills from college and post-college training are likely to remain high and demands are likely to grow for interpersonal (soft) skills found in in-person services.

Our education system will need to be better positioned to produce individuals with abstract and interpersonal skills. A complementary approach would be to try "professionalize" the growing work force of in-person service workers and to develop labor market institutions to enhance the bargaining clout of such workers. Such policy changes are first steps toward shifting America from its current path of increasingly "growing apart" back to a trajectory of shared prosperity.

[45] See Heckman and Krueger (2003) for different perspectives on the problems with the U.S. education and training system and on the effectiveness of alternative human capital policies.
[46] See Blinder (2007) and Levy and Murnane (2006) on how offshoring may affect the U.S. labor market.

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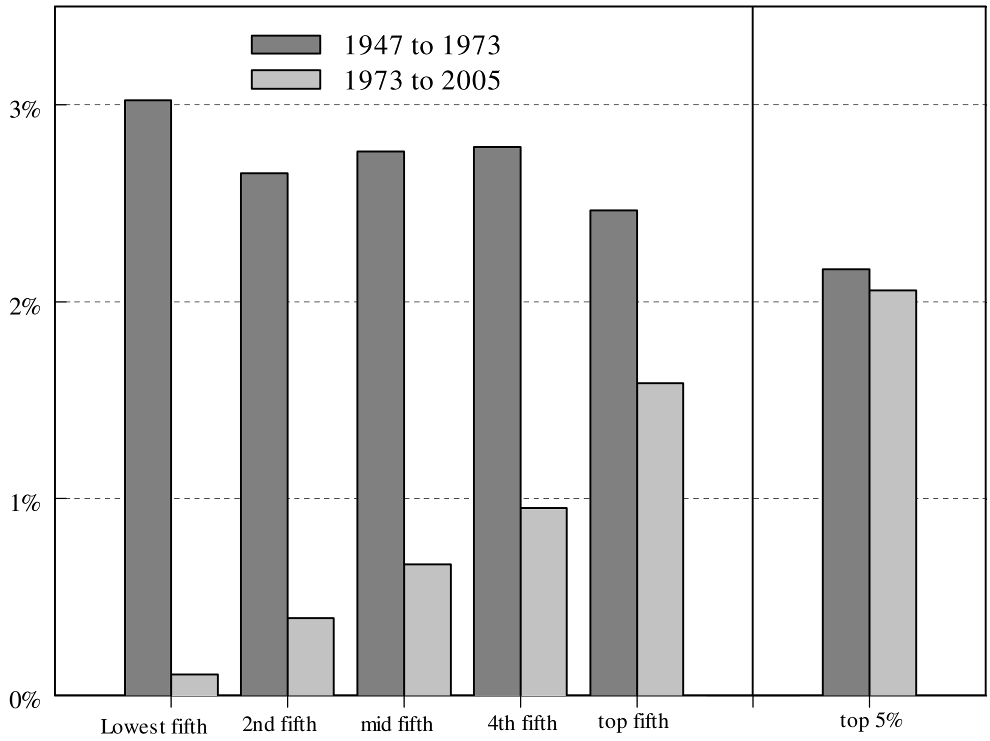
Table 1
Changes in the College Wage Premium and the Supply and Demand for College Educated Workers: 1915 to 2005 (100 × Annual Log Changes)

		Relative Supply			
	Relative Wage (1)	Overall Relative Supply (2)	Native-Born Component (3)	Immigrant Component (4)	Relative Demand (σ_{SU} = 1.64) (5)
1915-40	-0.56	2.82	2.57	0.25	1.90
1940-50	-1.86	2.69	2.48	0.21	-0.36
1950-60	0.83	3.23	3.02	0.21	4.60
1960-70	0.69	2.86	2.72	0.14	4.00
1970-80	-0.74	4.91	4.94	-0.02	3.69
1980-90	1.51	2.69	2.85	-0.16	5.18
1990-2000	0.58	2.26	2.35	-0.09	3.21
1990-2005	0.50	1.99	2.15	-0.16	2.81
1940-60	-0.51	2.96	2.75	0.21	2.12
1960-80	-0.02	3.89	3.83	0.06	3.85
1980-2005	0.90	2.27	2.43	-0.16	3.76
1915-1980	-0.38	3.19	3.01	0.18	2.57
1915-2005	-0.02	2.94	2.85	0.08	2.90

Sources: The underlying data are from tables 8.1 and 8.6 of Goldin and Katz (2008) and are derived from the 1915 Iowa State Census, 1940 to 2000 Census IPUMS, and 1980 to 2005 CPS MORG samples.

Notes: The "relative wage" is the log (college/high school) wage differential, which is the college wage premium. The underlying college wage premium series is plotted in Figure 6. The relative supply and demand measures are for college "equivalents" (college graduates plus half of those with some college) relative to high school "equivalents" (those with 12 or fewer years of schooling and half of those with some college). Relative skill supplies are measured in efficiency units. The native-born and immigrant relative supply columns decompose the overall relative skill supply growth into the native-born and immigrant contributions using equation (3) in the text. The log relative demand measure (D_t) is based on equation (2) in the text and is given by $D_t = \ln(L_{S_t} / L_{U_t}) + \sigma_{SU} \ln(w_{S_t} / w_{U_t})$ under the assumption that σ_{SU} = 1.64.

Figure 1: Annual Growth Rate of Real Income across the Family Income Distribution: 1947 to 1973 versus 1973 to 2005

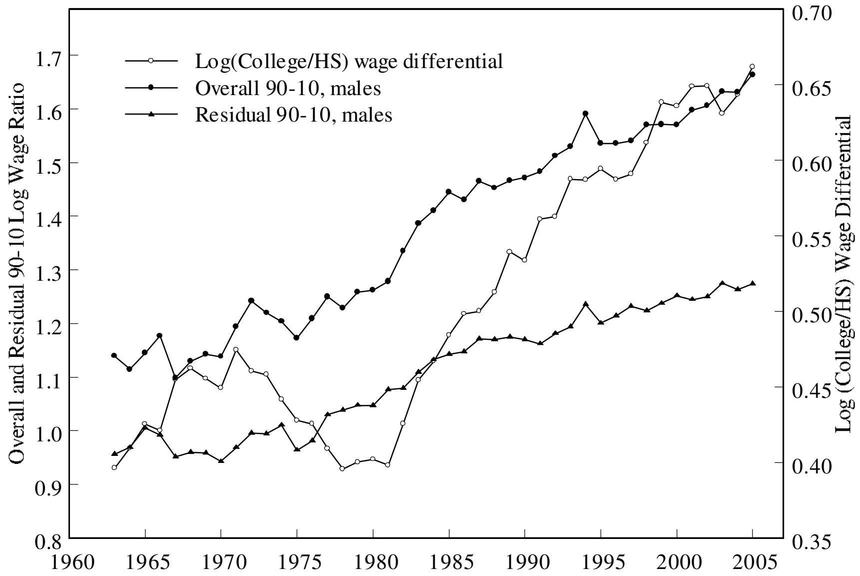


Source: U.S. Census Bureau, Historical Income Tables, table F3, http://www.census.gov/hhes/www/income/histinc/f03ar.html, updated September 15, 2006.

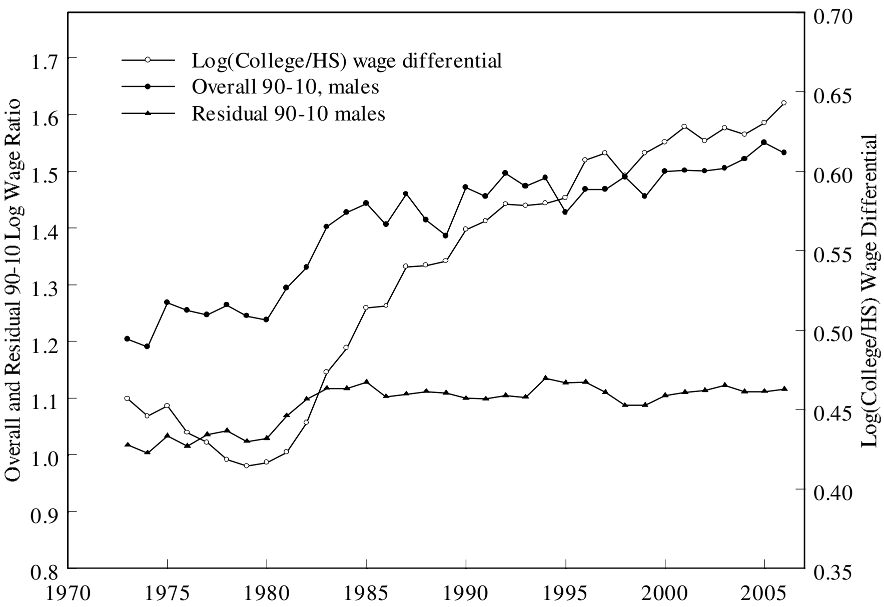
Notes: The figure plots the annual percentage growth rate in mean real family income by quintile and for the top 5 percent of families for 1947 to 1973 and 1973 to 2005. Incomes are converted to constant dollars using the Consumer Price Index Research Series (CPI-U-RS). The income concept used is the official U.S. Census Bureau measure of pre-tax, post-transfer money income.

Figure 2: Three Measures of Wage Inequality: College/High School Premium, Male 90/10 Overall Inequality, and Male 90/10 Residual Inequality

Panel A: March CPS Full-Time Weekly Earnings, 1963 to 2005

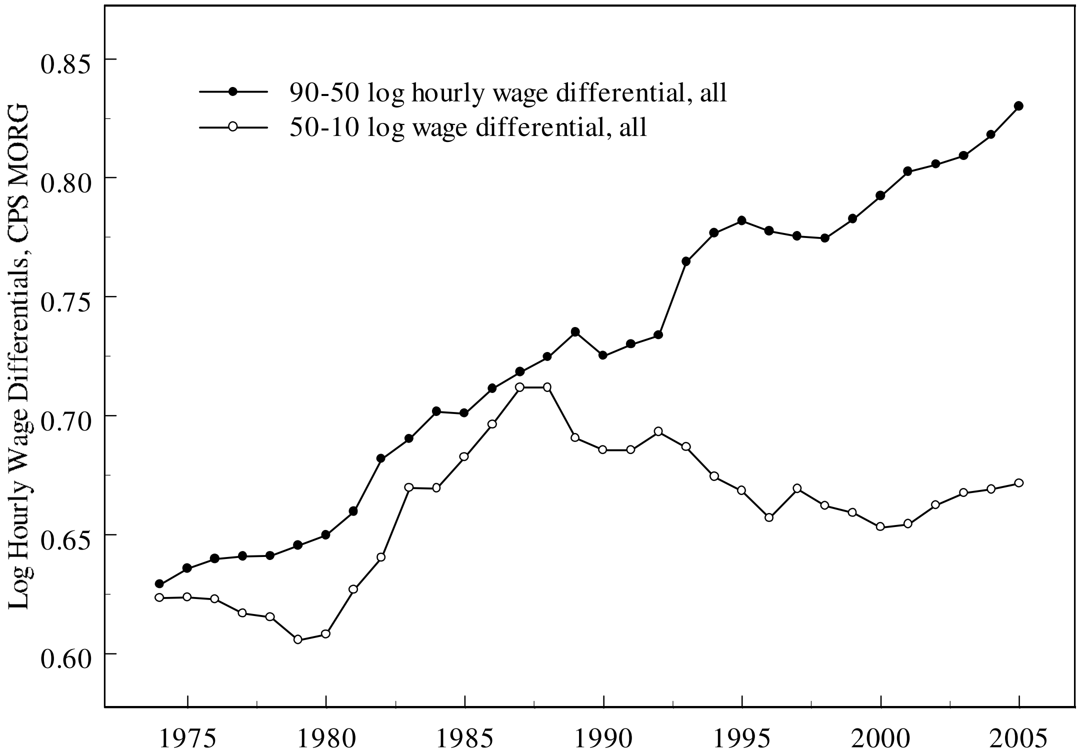


Panel B: CPS MORG Hourly Earnings, 1973 to 2006



Sources and Notes to Figure 2: Autor, Katz, and Kearney (2008, figure 2) with panel B updated to 2006. The 90-10 residual log wage differential uses the wage residuals from separate regressions in each year of log wages on a full set of age and schooling dummies and interactions among the schooling dummies and a quartic in age. The college-high school log wage differential is a fixed-weighted average of the wage differential between those with at least a B.A. degree (16 or more years of schooling) to those with exactly a high school degree (12 years of schooling) estimated separately each year by sex for four different experience groups.

Figure 3: Log Hourly Wage Differentials, 90-50 and 50-10: 1974 to 2005 (three-year centered moving averages), Males and Females Combined

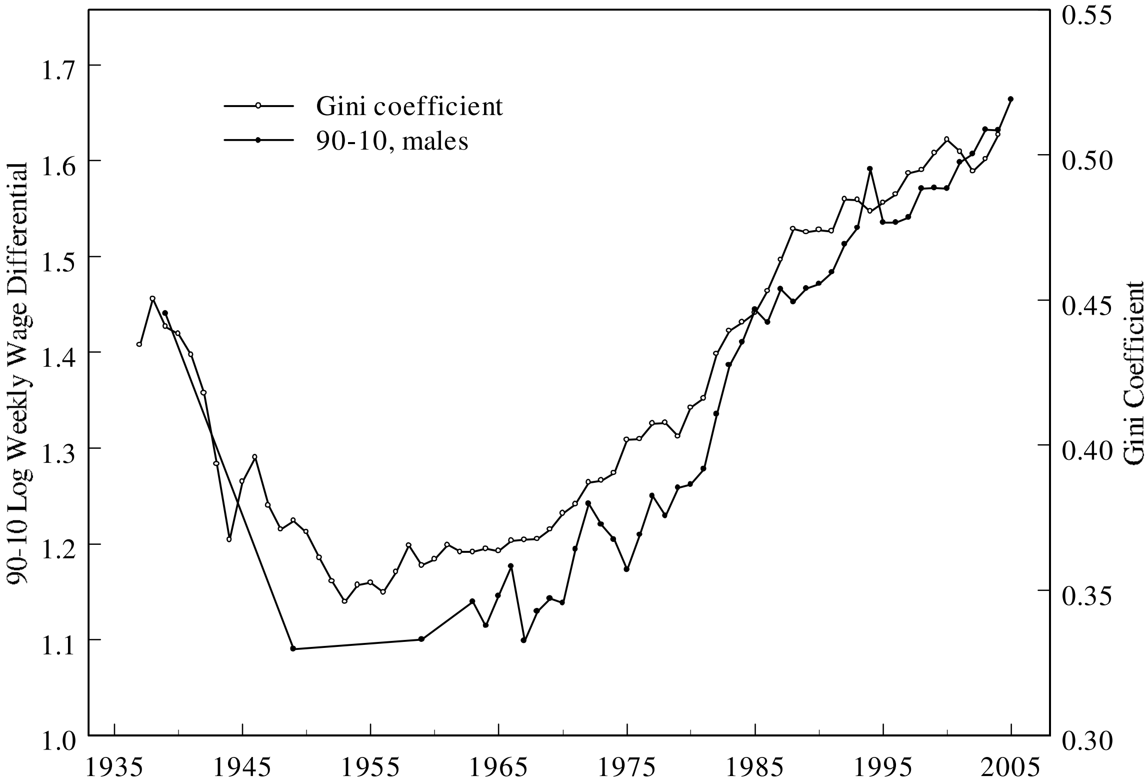


Source: 1973 to 2006 CPS May/MORG files.

Figure 4: Changes in Log Real Hourly Wages by Percentile for Two Periods: 1974 to 1988 and 1988 to 2005 (three-year centered moving averages)

Sources: 1973 to 1975 CPS May files and 1987 to 1989 and 2004 to 2006 CPS MORG files.

Figure 5: Male Wage Inequality, Gini and 90-10: 1937 to 2005

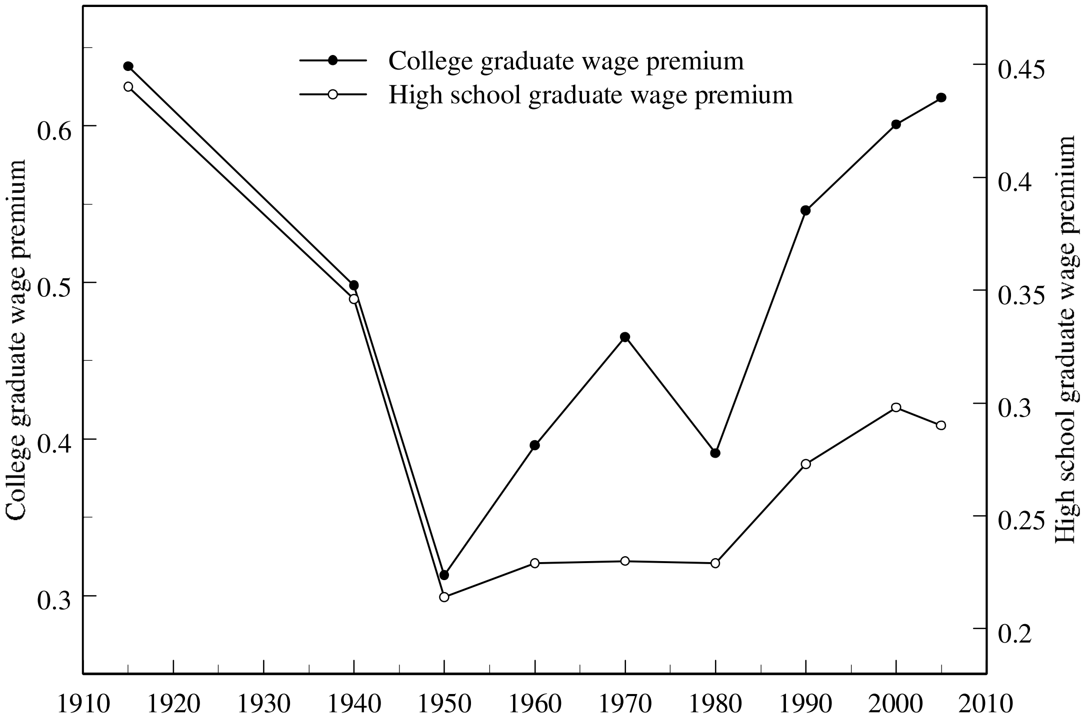


Sources and Notes:

Male 90-10 Log Weekly Wage Differential: Census IPUMS for 1940 to 1970 (covering earnings years 1939 to 1969) and the March CPS samples for 1964 to 2006 (covering earnings years 1963 to 2005) for male FTFY wage and salary workers. The Census IPUMS samples cover males 18 to 64 years old and the March sample cover males 16 to 64 years old. The 1963 to 2005 plotted numbers are directly from the March CPS and the 1939 to 1959 plotted numbers are scaled so that the 1969 to 1979 change in the 90-10 log weekly wage differential in the graph equals the actual 1969 to 1979 change in for the Census IPUMS.

Male Gini Coefficient: The plotted series is the Gini coefficient for the annual earnings of male commerce and industry workers for 1937 to 2004 from the Social Security Administration earnings history data constructed and documented by Kopczuk, Saez, and Song (2007) and posted at http://www.columbia.edu/~wk2110/uncovering/.

Figure 6: College Graduate and High School Graduate Wage Premiums: 1915 to 2005

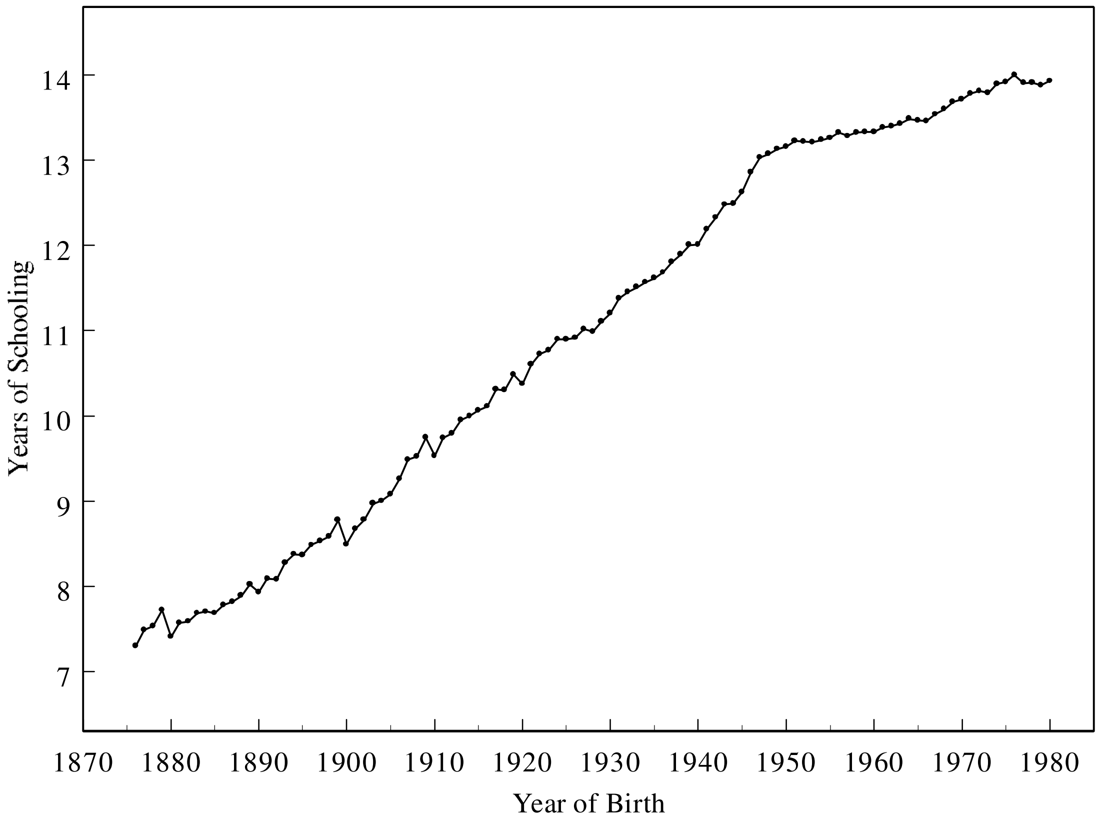


Source: Figure 1 of Chapter 8 and Appendix Table A8.1 of Goldin and Katz (2008).

College Graduate Wage Premium: The plotted series is a weighted average of the estimated college (exactly 16 years of completed schooling or bachelor's degree) and post-college (17+ years of schooling or a post-baccalaureate degree) log wage premium relative to high school graduates (those with exactly 12 years of completed schooling or a high school diploma) for the year given. The weights are the employment shares of college and post-college workers in 1980. We use estimates for 1940 to 1980 from the Census extended back to 1915 using the 1915 to 1940 change for Iowa. We extend the series to 1990, 2000, and 2005 by adding the changes in the log (college/high school) wage differentials for 1980 to 1990 for the CPS, 1990 to 2000 from the census, and 2000 to 2005 from the CPS to maintain consistency in the coding of education.

High School Graduate Wage Premium: The plotted series is for the log (high school/eighth grade) wage differential. We use the 1940 to 1980 Census estimates for the United States. To maintain data consistency, we then extend this series backwards to 1915 using the 1915 to 1940 change for Iowa and forward to 2005 using the 1980 to 1990 change from the CPS MORG, the 1990 to 2000 change from the February 1990 CPS to the 2000 CPS MORG, and the 2000 to 2005 change from the CPS MORG.

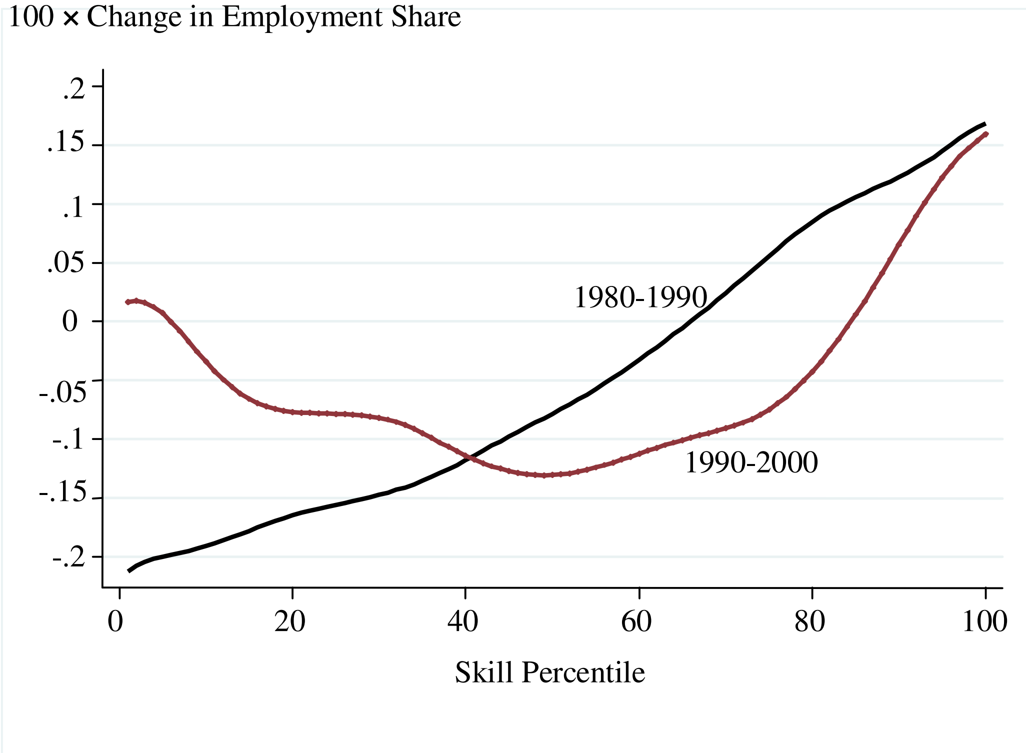
Figure 7: Mean Years of Schooling by Birth Cohorts, U.S. Native Born: 1876 to 1980



Sources: 1940 to 2000 Census of Population Integrated Public Use Micro-data Samples (IPUMS) and 2005 CPS MORG.

Notes: The figure plots the mean years of completed schooling by birth cohort adjusted to 30 years of age for the U.S. born. The log of the mean years of schooling for a birth cohort-year cell is the dependent variable in the age-adjustment regression that includes a full set of birth-cohort dummies and a quartic in age as covariates. The age-adjustment regression is run on birth cohort-census year cells, pooling all the IPUMS for 1940 to 2000. The samples include all U.S. born residents aged 25 to 64 years. For further details on the method and data processing see Goldin and Katz (2008, figure 1.4).

Figure 8: Changes in Occupation Employment Shares for 1980 to 1990 and 1990 to 2000 by Occupational Skill Percentile



Source: Autor, Katz and Kearney (2008, Figure 11A) based on Census IPUMS 5% samples for 1980, 1990, and 2000 for those currently employed in the civilian labor force ages 18 to 64.

Notes: The figure plots changes in employment shares by 1980 occupational skill percentile (based on mean years of schooling in the occupation in 1980) using a locally weighted smoothing regression (bandwidth 0.8 with 100 observations).