HUMAN CAPITAL INVESTMENT, INEQUALITY AND ECONOMIC GROWTH

Kevin M. Murphy
Robert H. Topel

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Kevin M. Murphy and Robert H. Topel
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ABSTRACT

We treat rising inequality is an equilibrium outcome in which human capital investment fails to keep pace with rising demand for skills. Investment affects skill supply and prices on three margins: the type of human capital in which to invest; how much to acquire; and the intensity of use. The latter two represent the intensive margins of human capital acquisition and utilization. These choices are substitutes for the creation of new skilled workers, yet they are complementary with each other, magnifying inequality. When skill-biased technical change drives economic growth, greater inequality reduces growth.

Kevin M. Murphy
Booth School of Business
The University of Chicago
5807 S. Woodlawn Ave.
Chicago, IL 60637
and NBER
murphy@chicagoBooth.edu

Robert H. Topel
Booth School of Business
The University of Chicago
5807 South Woodlawn Avenue
Chicago, IL 60637
and NBER
robert.topel@ChicagoBooth.edu

I.   Introduction

Economists recognized the emergence of rising earnings inequality in developed economies, especially the United States, decades ago.[1] The basic facts are well known—in the U.S., wage growth of low skilled individuals stagnated after the mid-1970s, and their employment rates declined, while individuals near the top of the wage distribution enjoyed rapid and sustained wage growth. More recently the seeming permanence of this change in the income distribution has motivated a number of policy proposals meant to mitigate its impact, such as more progressive income taxation, wealth and inheritance taxes, pay regulation and greater empowerment of labor unions. We argue that most of these interventions would treat the symptom rather than the disease, exacerbating the underlying scarcity of skilled labor that is the root cause of greater inequality of labor market outcomes.

We treat rising earnings inequality as an equilibrium outcome in which endogenous human capital investment fails to keep pace with steadily rising demand for skills, driven by skill-biased technical change (SBTC) or other shifts in economic fundamentals, such as a decline in the price of capital, that favor highly skilled labor.[2] Our main focus is on the supply side, where the human capital choices of individuals and families affect the skill composition of the labor force, and hence skill prices, on three margins. The first is a choice of the type of human capital in which to invest—"skilled" or "unskilled" in our analysis—say by deciding whether to attend or complete college. We refer to this source as the extensive margin because responses to a rising demand for skills add more individuals to the ranks of skilled labor, just as the output of an industry expands by entry of new firms. Second, given choice of a skill type, an individual decides how much human capital of that type to acquire; when skill prices are high, more investment occurs. Third, for a chosen skill type and amount of human capital, an individual must also decide how intensively their skills will to be applied to the market sector, say through effort, labor supply or occupational choice. We refer to the latter two decisions as occurring on the intensive margins of human capital acquisition and utilization, similar to an expansion of output by infra-marginal firms when rising market demand increases price in a competitive

[1] Juhn, Murphy and Topel (1991); Juhn (1992); Katz and Murphy (1992). Peracchi (2001) summarizes international trends.
[2] Violante (2008), Karabarbounis and Neiman (2013).

market. All of these choices are affected by heterogeneous opportunities and abilities to acquire human capital, and each is a source of greater skill supply that can "meet" rising demand for skills and so dampen its impact on skill prices.

Among other results, we show that while investment and utilization on the intensive margins are substitutes for the creation of new skilled workers on the extensive margin, intensive margin choices are strongly complementary with each other. Greater incentives to invest in human capital, due to a higher price of skills, also raise the returns to using human capital intensively, while the opportunity to use skills intensively increases the returns to investment. Unlike the extensive margin supply elasticity, which always dampens the impact of SBTC on earnings inequality by increasing the number of skilled workers, greater elasticity of response on the intensive margins magnifies the impact of SBTC on earnings inequality because the increased per-worker supply of human capital increases the earning power of high ability workers.

We argue that these forces are important in light of the evident slowdown in educational attainment in the US, which has been especially prominent for men. When the extensive margin flow of individuals who are able to join the ranks of skilled labor slows or declines—which raises the price of skills—the incentives for the more "able" to acquire even more human capital and to apply it intensively magnify the effects of rising skill demand on overall earnings inequality. This effect is especially important in an intergenerational context, where the skills and resources of high income families beget greater human capital investment in their offspring. As James Heckman (2008) has recently put it, "Children in affluent homes are bathed in cognitive and financial resources" that reduce the costs of acquiring human capital. These resources include better inputs from parents, who are themselves more skilled, as well as financial resources, superior schools and interactions with comparably advantaged peers. All of these factors facilitate human capital investment. These "able" investors benefit disproportionately from an increase in the relative scarcity of skilled labor because they are well positioned to exploit the resulting higher returns to human capital investment and utilization. With diminished supply growth of skilled labor from the extensive margin, the incentives of advantaged investors to acquire even more human capital and to use it more intensively magnify earnings inequality.

Many view rising inequality itself as an important social problem worthy of corrective policies. We don't take a position on these concerns, but we do argue that effective policies meant to limit or reduce inequality should, if possible, attack its source, which is a relative scarcity of skilled labor. We also emphasize a less normative concern about rising earnings inequality, which is that greater inequality reduces the rate of overall economic growth that can be realized from a given rate of skill-biased technical progress. Specifically, we embed the human capital investment incentives mentioned above in a model of economic growth with both human and physical capital deepening. In our model, productivity growth accrues to human capital because physical capital is elastically supplied at a constant return. When technological progress or other economic fundamentals favor skilled labor—which has evidently been the case—the induced growth rate of overall productivity is proportional to the labor income share of skilled workers. Other things equal, greater earnings inequality reduces this share because the relative demand for skilled labor is price elastic—the elasticity of substitution between skilled and unskilled labor exceeds 1.0. This means that factors causing greater inequality *lower* the rate of economic growth associated with a given rate of SBTC, because employers substitute away from relatively expensive skilled labor.

Our analysis is motivated by several empirical facts regarding the earnings distribution and the returns to various measures of skill, which are documented in the next section. The primary fact is the well-known increase in wage and earnings inequality, which began in the 1970s for the U.S. We demonstrate that this rise in inequality is not restricted to any particular part of the wage distribution—such as the very top or the very bottom. Instead, rising inequality occurs throughout the distribution—the wages of persons at the 99th percentile increased relative to those at the 95th, but so did the wages of those at the 60th percentile relative to the 50th and at the 20th percentile relative to the 10th. Similarly, educational wage premiums also began a steady increase around 1980 and the premium associated with college relative to high school completion had roughly tripled by the late-1990s. Though less pronounced than in the United States, these changes in relative earning power of more versus less skilled individuals also occurred in other developed economies, and at about the same time.[3] These outcomes indicate that rising inequality is mainly a skill-based phenomenon and the result of changes in economic

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[3] Peracchi (2001), Edin and Topel (1997), Fredericksson and Topel (2005), Piketty (2014), Gottschalk and Smeeding (1997).

fundamentals, such as technical change that raises the relative productivities of more skilled workers or, similarly, a decline in the price of factors (such as capital) that are more complementary with skilled than unskilled labor, rather than particular institutions or policies that might have favored one group or another.

The evident increase in skill "prices" has occurred in an environment of greater relative skill abundance. For example, the average educational attainment of the workforce and the fraction of the workforce who are college graduates have increased, which again point to changes in economic fundamentals—growth in demand for skills has outpaced growth in supply, so that the relative price of skill has risen. While there is compelling evidence that individual investments in education respond to rising returns, we show most of this response involves persons who leave college before obtaining a four-year degree. This is especially apparent for men, for whom the fraction completing a four-year college education has remained roughly constant at 30 percent since 1980.

II.   Background: Rising Skill Prices and Human Capital Investment

We begin by documenting some new and old facts about rising inequality and human capital investment in the U.S., using data from the March Current Population Surveys of 1963-2013, the U.S. Censuses since 1940, and the American Community Surveys since 2001.

Figures 1A and 1B and show the magnitudes of rising wage inequality for "full-time" men and women aged 18-64 in the indicated years.[4] The figures graph average real weekly wages (deflated by the GDP price deflator for personal consumption expenditures (PCE)) at selected percentiles of the wage distribution since 1962. Figure 1A shows that real weekly wages roughly doubled for men in the 95th percentile of the wage distribution, driven by a well-known acceleration of wage growth that began in the late 1970s. In contrast, real wages of men at the 10th percentile did not grow at all, though neither did they materially decline.[5] The timing of rising wage inequality is virtually the same among women, though magnitudes are different than

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[4] We define "full time" as working at least 30 weeks during the previous year with average weekly hours of at least 30.

[5] The absence of a decline in real wages for men near the bottom of the wage distribution may due to selection, as those with the lowest skill and earnings potential leave the labor force. Then real wages at a given level of skill may be declining, but selection causes means that workers at a given percentile of the wage distribution (say the 10th) are more skilled than in the past. See Juhn, Murphy and Topel (1991, 2002) for evidence on this point.

for men—even the least skilled (lowest wage decile) women experienced rising real wages. These points are further illustrated in Figure 2, which graphs cumulative real wage growth at each percentile of the male and female wage distributions over 40 years (1972-2012).[6] Note that wage growth was monotonically increasing over the entire wage distribution, which is perhaps the key fact about rising inequality in the U.S.—the trend toward rising wage disparities was not unique to the top or bottom of the distribution, but occurred at all skill levels for both men and women.

The patterns in Figure 2 undermine theories that attribute rising inequality to an outbreak of self-dealing conspiracies or rent-seeking among the very rich, while wage growth for everyone else languished.[7] The monotonic increase in wage growth across percentiles for both men and women strongly indicates that market fundamentals favoring more skilled workers are the driving force behind rising inequality. This important fact motivates our emphasis below on demand-side changes that have increased the relative productivity of more skilled workers.

It is also worth noting that use of the PCE deflator rather than the CPI makes some difference for gauging the magnitudes of real wage growth. It is well known that various biases in the CPI cause it to overstate increases in the cost of living, and that some of these biases are at least partially corrected by the PCE index, which is chain-weighted and which includes prices paid by a broader population of consumers as well as a different mix of goods.[8] Over short periods these differences don't matter much, but over long ones they do. Had we used the CPI, estimates of wage growth would have been slightly lower though there would be no impact on inequality because we deflated all wages by a common index. Though we do not pursue the point here, this common index assumption could be misleading in terms of calculations of relative welfare—for example, we would overstate the growth in inequality if nominal prices of goods purchased by low income households rose by less than those for high income households, which some have conjectured.[9]

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[6] For these calculations we pool individuals from the March CPS files of 1970-72 and 2010-12.
[7] See, for example, Piketty (2014) or Dew-Becker and Gordon (2005).
[8] National Research Council (2002)
[9] Broda and Romalis (2009). The importance of different price indexes for high and low skilled labor is less important on the demand side since the cost to firms of utilizing labor would be deflated by the same price index regardless of which type of labor (or other inputs) is used.

Skilled-biased technical change and other factors that affect skill demand raise the relative demand for skills, but its impact on inequality is also determined by the supply of skills—the propensity of workers, especially new workers, to acquire skills through human capital investment. Figure 3 shows the evolution of college attainment for male and female high-school cohorts from 1918 through 2003. For these calculations high-school "cohorts" are defined by the calendar year in which individuals turned 18; the typical age of high-school graduation. The figures shows that college completion rates (defined as 16 or more years of completed schooling) for pre-1935 cohorts were quite low, but then grew rapidly for the next 30 years. For men, the college completion rate peaked at 33 percent for high-school cohorts of the mid-1960s who, it should be noted, received a deferment from the Vietnam-era military draft while in college. After falling through the 1970s male college completion again exceeded 30 percent in the mid 1980s, but declined slightly thereafter. Similarly, the fraction of men who have completed some college (one year or more post high school) has also never surpassed the peak that was achieved in by cohorts from the mid-1960s. In contrast, college completion rates for women continued to grow—with some noteworthy deceleration in the 1970s—and have exceeded men's completion rates since about 1980. For cohorts reaching college age after 2000 the fraction of women completing four or more years of college reached about 35 percent, exceeding the 1960s peak of male college completion.

A key ingredient of our analysis is the response of human capital investment to an increase in the price of skills. Using college attendance and completion as our measures of investment on the extensive margin, Figures 4A and 4B show the evolution of the college/high-school wage ratio for full-time workers along with the fractions of each cohort that have some college or have completed college.[10] Note that the college wage premium for both men and women bottomed out in the late 1970s. This nadir corresponds almost exactly to the minimum of men's college participation (and coincides with an inflection point in college participation for women). After 1979 the fraction of men who had completed some college (at least one year) rises with the wage premium, suggesting substantial human capital investment in response to greater potential returns, but even this growth stalls after the mid-1980s. And note that any possible investment

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[10] For the wage calculations in Figures 4A and 4B "full time" refers to individuals aged 25-40 who worked at least 48 weeks in the previous year, with usual weekly hours of at least 30. We measure college completion rates among individuals age 23-28 for each cohort. Figures 5A and 5B indicate that reported college completion continues to rise after age 30, especially among younger cohorts for whom the returns were highest.

response is far more muted for actual college *completion*. In spite of a rough tripling of the college premium after 1979, male college completion rates are not much changed—fewer than 30 percent of men in the most recent cohorts complete college before age 30—which indicates that the supply of these skills has proven highly inelastic over the indicated time interval. The picture for women in Figure 4B is somewhat different—the 1970s decline in the college premium does seem to have slowed the growth of women's investments in schooling, but subsequent growth in the premium was associated with renewed growth in the shares of women with some college training and who have completed college.

The modal college experience is a four-year continuation of full-time schooling after high-school, culminating with graduation at age 22. Figures 5A and 5B graph college completion rates by age for 5-year high-school cohorts since 1960, showing that this prototype accounts for only about half of individuals who report completing college. For men, the fraction completing college by age 23 (the vertical line) is about 15 percent for every cohort except those of 1965 and 1970—who benefitted from the availability of draft deferments during the Vietnam War. Thus there is little evidence that rising educational premiums after 1980 caused more men to acquire a college education via the traditional route. Yet cohorts after 1980 do have higher (and rising) college completion rates—all of the increase is accounted for by rising shares of individuals who complete college at older ages. Indeed, completion rates continue to rise up to nearly age 40. The picture for women is again somewhat different. For them, each new cohort is more likely to have graduated college by age 23 than the ones before it. But as for men, college completion continues to rise after age 30, and an increasing fraction of college completion occurs after age 23. About 40 percent of the women in the youngest cohort (age 18 in 2000) had completed college by age 32, which is double the corresponding rate for the 1965 cohort.

Why did growth of male educational attainment stall, and why have men fallen behind women in terms of overall educational attainment? Whatever the core sources might be, the evidence suggests that men are simply less prepared, on average, for post-secondary education.[11] Figure 6 shows grade point averages of male and female graduating high school seniors from 1990 to 2009.[12] Though GPAs of both genders are rising—which may reflect grade inflation

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[11] See Becker, Hubbard and Murphy (2010) for some potential explanations.
[12] Source: National Center for Education Statistics, Beginning Postsecondary Students survey.

more than improved performance—the important point is that there is a substantial gap between the measured high school performance of males and females; females average about 0.2 grade points higher than males, and there is no indication that the gap has narrowed. This gender gap in high school academic performance persists in the population that continues on to college. Table 1 reports the distributions of first year college GPAs for men and women attending four-year non-profit colleges and universities, broken out by broad areas of intended study. Not only do women perform better overall, but the performance gap is at least as large in traditionally "male" majors (science, engineering and mathematics) as it is in majors with a heavier representation of female students (social sciences and humanities). For example, in the 2003-04 cohort two-thirds of women majoring in the sciences and engineering had GPAs above 3.0, compared to only 48 percent of men. The gap between the fractions of college women and men earning high GPAs also widened over time.

The model developed in the next section emphasizes that rising returns to skill increase the incentives of able individuals to invest in human capital and, once it is produced, to use human capital more intensively. Some supportive evidence on the latter point is in Figures 7A and 7B, which show average weekly hours worked by percentile of the weekly wage distribution in 1970-72 (before the increase in wage and earnings inequality) and 2010-12. For both men and women, the evidence indicates that rising returns to skill (see Figure 2) are associated with increased utilization—relative weekly hours increased in the right tail of the wage distribution, where wages increased the most.[13] For men the range of increased effort is confined to the upper half of the distribution, with monotonically larger increases in the highest percentiles. The pattern for women is similar, though only the bottom quartile of their wage distribution is associated with declining hours worked.

The data summarized above are the empirical context for our following modeling effort. Especially for men, the data suggest that human capital investment via schooling (measured by college graduation) has been unresponsive to the large increase in the educational wage

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[13] Note that hours decline in lower percentiles, especially among men. In our papers with Chinhui Juhn (1991, 2001) and in Murphy and Topel (1997) we provide evidence of declining real wages of less skilled men, many of whom have left the labor force as a result of declining opportunities. In this paper we select on individuals who worked at least 30 weeks in the previous year and whose average weekly hours exceeded 30. Thus, especially for low-wage categories, our criteria mean that (say) the first decile of the distribution is unlikely to contain a population of constant relative skill. We would overstate wage growth for a constant-skill population.

premium, which we interpret as indicating that the supply of college graduate human capital has low price elasticity during the era of rising inequality, at least on the "extensive" margin of producing a larger stock of college educated workers. Though we don't explore the issue further here, we also think it is noteworthy that much of the correspondence between rising educational premiums and completed schooling is accounted for by two sources. First, a much larger fraction of both men and women report completing *some* schooling post high-school, though they do not complete a traditional four-year program. Second, especially for men, the expansion of college graduates is due in large part to completion at older ages. Human capital from these sources is likely to be qualitatively and quantitatively different, on average, than from the relatively unresponsive margin of continued schooling after high school, culminating in a college or advanced degree. And for the range of skills that experienced sharply rising returns—the upper reaches of the distribution—the evidence is that "gainers" have magnified their advantage by applying their skills more intensively.

III.   Growth, Human Capital Investment and Inequality

We begin with a basic model of economic growth in which aggregate output at date *t* is determined by the size of the labor force *(L)*, the per-worker stocks of skilled (*S*) and unskilled (*U*) human capital embodied in *L*, physical capital *(K)*, and the state of technology (τ). Normalizing *L*=1 expresses all quantities in per-worker units, and we write output per worker as:

(1) $$Y_t = F(S_t, U_t, K_t; \tau_t)$$

Corresponding to the three inputs are three factor prices (rental rates), R_S, R_U, and R_K, all measured in real terms. Our assumption that there are only two skill types is obviously limiting, as we will note below, but it serves to make our essential points in a very simple framework while sacrificing little in terms of generality.

The driving force behind growth is technological improvement that raises output produced by given factor quantities, and determines factor prices. We assume that physical capital is elastically supplied in the long run, so that R_K is exogenously determined while R_S and R_U are endogenously determined by demand (technical change) and supply (investment in human

capital) forces specified below.[14] On the demand side, the evident long-term increase in measures of the skill premium (R_S/R_U) indicates that the effects of capital deepening and/or biased technological progress have favored skilled labor, so that one or both of the following conditions hold:

$$(2) \qquad (a) \quad \frac{\partial \left(F_S / F_U \right)}{\partial K} > 0$$

$$\qquad (b) \quad \frac{\partial \left(F_S / F_U \right)}{\partial \tau} > 0$$

where F_j denotes the marginal product of factor j. We are agnostic as to the relative contributions of (2a) and (2b). For example, (2a) could result from a declining price of physical capital combined with greater ease of substitution of capital with unskilled labor than with skilled labor ($\sigma_{KU} > \sigma_{KS}$ in the usual notation).[15] For simplicity we assume in what follows that rising relative productivity of skilled labor is generated by skill-biased technical change (SBTC), as in (2b), and R_K is assumed to be fixed.

Specifically, we assume that labor inputs S and U only appear in (1) through a single human capital aggregate $H(S,U)$. Allowing for labor-augmenting technical progress A_t, output per worker is

$$(3) \qquad Y_t = F(A_t H(S_t, U_t), K_t).$$

With competition, constant returns and capital in perfectly elastic supply at constant price R_K, the rate of growth in output per worker is determined by the growth rates of A and H:

$$(4) \qquad d \ln Y = d \ln A + d \ln H$$

which embeds capital deepening because K grows in proportion to A and H. According to (4), for a given rate of labor-augmenting technical progress the growth rate of output per worker depends only on the growth of human capital per worker—the ability to upgrade the average

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[14] It is possible to endogenize the return on capital without substantially altering our results. In particular, if we allow the return to be a function of the growth rate (as in the neoclassical growth model) then the growth impacts we discuss below would go in the same direction.

[15] E.g. Kouraboubanis and Neiman (2013), Rosen (1968).

worker's skills. Forces that limit human capital accumulation, such as the deceleration in growth of educational attainment documented above, correspondingly limit growth.

We place additional structure on *H* by assuming a constant elasticity of substitution σ between *S* and *U*:

(5)
$$H = \left[\left[\beta_S S \right]^{\frac{\sigma-1}{\sigma}} + \left[\beta_U U \right]^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

With (3) and (5), *S* and *U* are weakly separable from other factors. Then the equilibrium evolution of relative skill prices must be consistent with firms' willingness to employ the supplied stocks of skills:

(6)
$$d \ln \left(R_S / R_U \right) = \frac{\sigma-1}{\sigma} d \ln B_S - \frac{1}{\sigma} d \ln \left(S / U \right) .$$

where $B_S = \beta_S / \beta_U$. Then SBTC is represented by $d \ln B_S > 0$, which raises the relative productivity of type-S skills as in (2b) so long as $\sigma > 1$, which evidence indicates and which we shall assume in what follows. The share of *labor* income accruing to type-*S* workers is simply

$$\Phi_S \equiv \frac{R_S S}{R_S S + R_U U} = \frac{B_S^{\sigma-1} \left[R_S / R_U \right]^{1-\sigma}}{1 + B_S^{\sigma-1} \left[R_S / R_U \right]^{1-\sigma}} .$$

With $\sigma > 1$ and a given skill premium R_S / R_U, SBTC ($d \ln B_S > 0$) raises the skilled income share. But for a given state of technology B_S, a higher skill premium ($d \ln R_S / R_U > 0$) reduces the skilled share because relative demand is price elastic. This property will prove important in our examination of the relation between inequality and growth, developed below.[16]

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[16] We treat SBTC as exogenous, raising the skill premium and hence inequality so long as σ >1. Models of directed technical change allow the skill bias in technical change to be endogenous, as summarized in Acemoglu (2009). Then causality may be reversed—an increase in the proportion of skilled workers *S/U* may drive R&D toward technologies that exploit the greater abundance of skill. If the technological response is large enough, an increase in the skill ratio—say as occurred before 1980—can increase inequality. The facts seem inconsistent with this, however—the continued increase in inequality after 1980 coincides with stagnation in the growth of skills, at least as measured by educational attainment.

Condition (6) is familiar in the analysis of changing relative wages. Assume that skill biased technical progress causes the relative demand for *S* to grow at a steady rate over the long term, so $d \ln B_S$ is constant. Then changes in the factor ratio *S/U* drive the returns to skill—if demand grows faster than supply then the skill premium R_S/R_U will rise, and conversely. For example, Katz and Murphy (1992) apply (6) to the evolution of the male college-high school wage premium in the U.S. from 1963 to 1987, assuming constant relative demand growth. Their estimate of $\sigma \approx 1.4$ for the elasticity of substitution between college-trained and high school-trained labor does well in tracking the college wage premium, even well outside of the sample period they study—see Murphy and Welch (2001). Autor's (2002) review of evidence from several studies offers a somewhat higher "consensus" estimate of $\sigma \approx 2$. The only important point for what follows is that $\sigma > 1$—the relative demand for skilled labor is price elastic.

The Supply of Skills

The (inverse) demand equation (6) determines the relative rental prices of skilled and unskilled human capital for any given stocks, *S* and *U*. Our point of departure is to explicitly model behavioral responses on the supply side that determine the relative abundance of skilled human capital, *S/U*. For each skill type, we specify the supply of skills as being the result of individuals' wealth maximizing human capital investments and their choices of how a given quantity of human capital should be applied. Then both the overall quantities of skills of each type and their distributions across workers are endogenous.

We maintain the structure of (1) and (3) in which there are just two types of human capital, skilled (*S*) and unskilled (*U*)—generalizing to an arbitrarily large hierarchy of skills and associated relative prices is straightforward.[17] We think of *S* and *U* as categories of workers, such as those with and without a college education. To save on notation, it will not cause confusion to use *S* and *U* to denote both skill types and the average amounts of each type of human capital that enter the production function. For given skill prices R_S and R_U that are expected to apply over working careers individuals choose whether to be skilled or unskilled, given their backgrounds and abilities. Even with only two skill types, this setup will generate a

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[17] As is shown shortly, our two-skill setup yields a full income distribution because we assume individuals have heterogeneous abilities to acquire human capital. A multiple or continuous skill hierarchy will reinforce this effect by allowing different rates of skill-biased technical change across the endogenous skill distribution.

full income distribution because we assume that individuals have heterogeneous abilities to invest in human capital, and so they will acquire different quantities of skills and apply them in different ways.

Specifically, given choice of skill type $j \in (S, U)$, we assume that individuals make an investment choice of how much human capital, H_j, to acquire. They also choose how intensively to use their human capital, which we denote as T_j. The simplest interpretation of T that it represents simple labor supply (e.g. hours worked as in Figures 7A-B), but we view it more broadly as representing alternative opportunities to apply a given stock of skills. For example, in a world where the rental price of skilled human capital, R_S, is high, skilled (*S)* individuals may choose to apply their human capital to more remunerative though less pleasant activities, such as business occupations rather than teaching. Then T embeds a set of choices including g occupational choice, effort and initiative. The fact that changes in the intensity of skill use occur on margins other than time worked has the important empirical implication that these intensive margin responses will show up in wages and not just earnings.[18]

Let *a* represent an individual's investment abilities with c.d.f. *G(a)* in the labor force. For an individual with investment abilities *a* who has chosen to be of skill type *j*, we assume that the choices of H_j and T_j solve

(7) $$\underset{H,T}{Max}V_j(a) = R_j H_j T_j - c_j(a)\frac{H_j^{1+\theta_H}}{1+\theta_H} - \omega\frac{T_j^{1+\theta_T}}{1+\theta_T} \quad j \in (S,U).$$

The first term on the right of (7) is total earnings from supplying H_j units of human capital at intensity T_j, which is proportional to the rental price of type-*j* skill, R_j. Thus human capital supplied by an ability-*a* individual is $Z_j(a) = H_j(a)T_j(a)$. The remaining terms are the costs (disutility) of acquiring skills and applying them intensively. We assume rising marginal cost of acquiring human capital where θ_H is the constant elasticity of marginal cost with respect to H; marginal cost rises faster when θ_H is large. Greater intensity of use is also subject to rising

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[18] Some forms of utilization that we embed in *T* can be varied over short periods, such as hours worked. Others, such as occupational choice are more similar to *H,* which is the result of a forward-looking investment decision. Our model abstracts from an explicit treatment of time, however, so differences in these responses do not come into play.

marginal cost, with elasticity θ_T. The cost of acquiring human capital also depends each individual's ability to invest, *a*, through the cost shifter $c_j(a)$. Individuals differ in this ability, and we assume that higher ability individuals are better at investing:

$$\frac{dc_j(a)}{da} < 0$$

(8)

We make the natural assumption that type-*S* human capital is more costly to acquire, so $c_S(a) > c_U(a)$ for all abilities *a;* additional conditions on these costs appear shortly. We maintain the shorthand of referring to *a* as an individual's "ability" to invest, though we don't think of it as individual ability in the usual sense. In fact, in our analysis ability *a* only affects earnings indirectly by making it easier to acquire human capital, so more is acquired. We therefore interpret *a* as a broad index of advantages in acquiring human capital encompassing much more than just individual talents. For example, it can also embed family or other characteristics (educated or wealthy parents, access to better schools, and so on) that make it cheaper or easier for some individuals to acquire human capital than for others. Then greater human capital investments by one generation will reduce the average costs of investing in the next generation by shifting the distribution of *a*. For our purposes the important thing is that people differ in characteristics that make the acquisition of human capital more or less difficult.

Given a person's chosen type $j \in (S,U)$ the necessary conditions for optimal choices of *H* and *T* in (7) are instructive:

(9a) $$H_j^{\theta_H} = \frac{R_j T_j}{c_j(a)}$$

(9b) $$T_j^{\theta_T} = \frac{R_j H_j}{\omega}$$

Condition (9a) indicates that human capital *H* is more valuable when it can be used intensively (*T* is large), so more is acquired. Condition (9b) indicates that intensity of use is greater when *H* is large, so more human capital is applied. Thus *H* and *T* are strong complements because they

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are multiplied in the first term of (7). This will have important implications below. The solutions for H and T are (in logs):

(10a) $\qquad \ln H_j(a) = \dfrac{\theta_T + 1}{\theta_H \theta_T - 1} \ln R_j - \dfrac{1}{\theta_H \theta_T - 1} \ln \omega - \dfrac{\theta_T}{\theta_H \theta_T - 1} \ln c_j(a)$

(10b) $\qquad \ln T_j(a) = \dfrac{\theta_H + 1}{\theta_H \theta_T - 1} \ln R_j - \dfrac{\theta_T}{\theta_H \theta_T - 1} \ln \omega - \dfrac{1}{\theta_H \theta_T - 1} \ln c_j(a)$

The second order condition for a maximum of (7) is $\theta_H \theta_T > 1$, so both H_j and T_j are increasing with R_j and also with ability a, due to condition (8). More able investors acquire more skills (10a) and also apply them more intensively (10b), so earnings exhibit a form of increasing returns in ability.

Now define the following price elasticities of human capital acquisition and intensity of use:

(11)
$$\eta_H \equiv \frac{\theta_T + 1}{\theta_H \theta_T - 1} > 0, \quad \eta_T \equiv \frac{\theta_H + 1}{\theta_H \theta_T - 1} > 0,$$
$$\eta \equiv \eta_H + \eta_T$$

Total human capital applied is $Z_j(a) = H_j(a)T_j(a)$, so for a person of ability a

(12a) $\qquad \ln Z_j(a) = \eta \ln R_j - \eta_H \ln c_j(a) - \eta_T \ln \omega$

and log earnings are

(12b) $\qquad \ln E_j(a) = [1 + \eta] \ln R_j - \eta_H \ln c_j(a) - \eta_T \ln \omega$

Note from the definitions in (11) that reductions in either cost elasticity (θ_H or θ_T) increase the price elasticities of human capital supplied (Z) and earnings (E=RZ).

Equations (10a-b) and (12a-b) are the solutions for human capital acquired (H), intensity of use (T), supply (Z) and earnings (E) *given* an individual's ability and choice of a skill type.

They can be inserted in (7) to obtain an expression for maximum utility that can be realized by an individual of ability a from the choice of skill type j:

$$(13) \qquad V_j(a) = R_j^{1+\eta} c_j(a)^{-\eta_H} \omega^{-\eta_T} \frac{1}{\eta_H(1+\theta_H)}$$

Given (13), an individual of investment ability a chooses a skill-type to maximize utility. That is, a person of ability a chooses to be skilled (S) if $V_S(a) > V_U(a)$, and conversely. With appropriate conditions on $c_S(a)$ and $c_U(a)$ this choice implies a cutoff level of investment ability $a*$ where only individuals with $a > a*$ choose to be type-S while those with $a < a*$ choose to be type-U. The indifference condition determining $a*$ is $V_S(a*) = V_U(a*)$, which from (13) implies $R_U Z_U(a*) = R_S Z_S(a*)$ for marginal individuals. Then earnings are monotonically increasing in ability and a marginal individual would earn identical amounts from either skill type.[19] A bit of algebra then yields:

$$(14) \qquad \ln c_S(a*) = \ln c_U(a*) + [1+\theta_H]\ln(R_S/R_U).$$

The cost of producing type-S human capital must be higher than for type-U, otherwise all would choose S because we assume $R_S > R_U$. We assume conditions on $c_S(a)$ and $c_U(a)$ so that a greater premium for type-S skill increases relative supply of S by drawing in lower a investors:

$$(15) \qquad da* = -\frac{1+\theta_H}{\kappa_S(a*) - \kappa_U(a*)} d\ln(R_S/R_U) < 0$$

$$\Leftrightarrow \ \kappa_S(a*) < \kappa_U(a*) \qquad \kappa_j(a) \equiv \frac{\partial \ln c_j(a)}{\partial a} < 0$$

An increase in the skill premium R_S/R_U "pulls in" lower ability individuals on the margin if the costs of producing type-S human capital fall more rapidly with ability than the costs of producing type-U human capital. That is, we assume that the relative cost of producing type-S human capital is smaller for more able individuals.

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[19] With a hierarchy of skill types, there will be multiple ability cutoffs and this condition will hold for each one, under the same cost conditions stated in the text.

Equations (10), (12) and (15) specify three margins by which an increase in the return to skill drives investment in human capital and so expands the relative supply of skills applied in the market. First, in (10a), an increase in R_S expands investment on the *intensive margin*—all type-S individuals $(a > a^*)$ invest more because the value of each unit of H_S is greater. Second, complementarity of H and T reinforces this response in (10b) because each unit of human capital is also applied more intensively—for example by working more or seeking opportunities to apply the larger stock of skills to more valuable uses—which further raises the return to investment. Thus total human capital applied, $Z_j(a) = H_j(a)T_j(a)$, rises by even more. These effects magnify the impact of a change in the skill premium on income inequality—the elasticity of earnings with respect to the premium is strictly greater than unity—because high ability individuals make complementary adjustments in behavior to exploit their price advantage.

The third source of skilled labor supply is the *extensive margin* determined by (14). As R_S rises relative to R_U the share of workers who choose to be type-S rises because greater returns cause individuals on the a^* margin to switch from U to S—for example, by attending college or acquiring other forms of type-S skill. The magnitude of this response depends on the distribution of investment abilities, $G(a)$ with density $g(a)$. The aggregate human capital factor ratio is:

$$\frac{S}{U} \;=\; \frac{\displaystyle\int_{a^*} Z_S(a)g(a)da}{\displaystyle\int^{a^*} Z_U(a)g(a)da} \;=\; \frac{[1-G(a^*)]\bar{Z}_S}{G(a^*)\bar{Z}_U}$$

where $\bar{Z}_S$ and $\bar{Z}_U$ are the average amounts of human capital applied by persons of each skill type. Using the solution for $Z_j(a)$ in (11) we obtain an expression for the aggregate skill ratio on the supply side.

(16) $\quad \ln(S/U) = \eta \ln(R_S/R_U) + \ln \displaystyle\int_{a^*}^{a^*} c_s(a)^{-\eta_H} g(a)d(a) - \ln \int^{a^*} c_u(a)^{-\eta_H} g(a)da$.

Now let $\lambda(a) = g(a)/[1-G(a)]$ be the hazard of G; then $\lambda(a^*)$ is the percentage increase in the type-S share per unit reduction in a^*. Displacement of (16) and substitution of

the extensive margin response from (15) yields an expression for growth in the relative supply of skilled human capital:

$$d\ln(S/U) = d\ln\Delta_S + \left[\eta + \lambda(a^*)\frac{Z_s(a^*)}{\bar{Z}_s}\frac{1+\theta_H}{[1-\Phi_S][\kappa_U(a^*)-\kappa_S(a^*)]}\right]d\ln\left(R_S/R_U\right)$$

(17)

$$= d\ln\Delta_S + \left[\eta + \xi(a^*)\right]d\ln\left(R_S/R_U\right)$$

In (17) the term $d\ln\Delta_S$ represents exogenous supply shifts that change the skill ratio over time, such as through changes in the costs and availability of schooling, skill-biased immigration, or long-term changes in the distribution of investment abilities.[20] Such long term changes may occur because of changes in the quality of schools or because increased skills acquired by one generation—higher college attendance by the baby-boom generation, for example—affect the ability to produce human capital in their offspring, "bathing" them in cognitive skills as Heckman (2008) phrased it. Then the distribution of *a* would change over time. This is related to the effects of human capital in some endogenous growth models, where a greater stock of human capital reduces the cost of producing more; see Becker et al. (1990) and the discussions in Topel (1999) and Acemoglu (2009). An important distinction is that in our analysis the complementarity is assumed to occur at the "micro" level of individuals and families, so that investment responses to a higher skill premium are heterogeneous.

The bracketed price elasticity in (17) is the endogenous supply-side response of skilled human capital (the skill ratio) to an increase in the skill premium. It includes responses on the intensive and extensive margins mentioned above. The intensive margin(s) response to a rising skill premium is $\eta = \eta_H + \eta_T > 0$: holding constant the share of the labor force that is skilled, a rising price of skill causes greater relative investment by high ability type-*S* workers (η_H), who also apply their greater skills more intensively than before (η_T). This response is stronger (η is

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[20] Formally, these supply shifts change the density $g(a)$ over abilities or changes in the costs of acquiring skills, and $d\ln\Delta_S$ may be positive or negative. For example, low skilled immigration would cause $d\ln\Delta_S < 0$ because the density $g(a)$ shifts to the left, while a more educated cohort of parents or government investments in education would cause $d\ln\Delta_S > 0$

larger) when the cost elasticities θ_H and θ_T are small; see (11). The terms making up $\xi(a^*)$ represent the supply response on the extensive margin—individuals who are drawn into the skilled labor pool by higher returns. This elasticity is greater when (i) the hazard $\lambda(a^*)$ is large, which means that persons with the potential to become skilled are abundant relative to the existing stock (i.e. there are many individuals that are close to the margin); (ii) when $Z_S(a^*)/\bar{Z}_S$ is large, so that "new" type-S workers are similar to existing ones; and (iii) when the skill premium moves the extensive margin a^* by a lot (see (15)).

The Supply of Human Capital and Equilibrium Inequality

The bracketed terms in (17) determine the aggregate supply elasticity of relative skills, *S/U*. The demand elasticity for *S/U* is σ, the elasticity of technical substitution between the skill aggregates. We can insert (17) into (6) to obtain an expression for the evolution of the skill premium in terms of demand and supply shifters and the behavioral responses of buyers and sellers:

(18a) $$d \ln \left(R_S / R_U \right) \;=\; \frac{1}{\sigma + \eta + \xi(a^*)} \left[[\sigma - 1] d \ln B_S - d \ln \Delta_S \right]$$

The bracketed term measures growth in net demand for skilled human capital; the skill premium and hence earnings inequality will be rising if growth in relative demand for skill induced by SBTC, $[\sigma - 1] d \ln B_S$, outpaces the exogenous growth in relative supply, $d \ln \Delta_S$. Equation (18a) is a market equilibrium framework for thinking about the determinants of a rising skill premium, which in our analysis is the driving force behind observed increases in wage and income inequality. But the skill premium is not a direct measure of earnings inequality because of the magnifying effects of human capital investment and utilization responses discussed above. To see this, consider two fixed levels of ability $a_S > a^*$ and $a_U < a^*$; for example, at fixed percentiles (say 90 and 10) of the earnings distribution. Then the earnings ratio between these ability levels is

$$\frac{E_S(a_S)}{E_U(a_U)} = \left[\frac{R_S}{R_U} \right]^{1+\eta} \left[\frac{c_S(a_S)}{c_U(a_U)} \right]^{-\eta_H}$$

Using (18a),

$$(18b) \qquad d \ln \left(E_S(a_S) / E_U(a_U) \right) \; = \; \frac{1+\eta}{\sigma + \eta + \xi(a^*)} \left[[\sigma - 1] d \ln B_S - d \ln \Delta_S \right]$$

Comparison of (18a) and (18b) illustrates the important distinction between sources of human capital supply response and their implications for earnings inequality. Specifically, greater supply elasticity on the extensive margin $(\xi(a^*))$ mitigates inequality because more workers choose to *become* skilled in response to a rising skill premium, just as entry by new sellers dampens the impact of rising product demand on price in a competitive industry. In contrast, greater supply elasticity on the intensive margins $(\eta = \eta_H + \eta_T)$ *magnifies* earnings inequality (when $\sigma + \xi(a^*) > 1$) because infra-marginal individuals respond to a higher skill premium by investing in more skills and applying them more intensively, which increases earnings disparities between high and low ability individuals. In our view, this distinction is especially important in light of the long term "stall" in college completion rates among men, which was documented above. The failure of supply from the extensive margin to keep pace with rising demand for skill raised the skill premium, and so created the incentive for the more able to benefit even more, in proportion to the elasticity η. This has magnified the impact of SBTC on earnings inequality.

When growth in the supply of skilled labor on the extensive margin is sufficient to keep the skill premium from rising, inequality between individuals of differing abilities will remain unchanged since the intensive margin responses will be neutral across skill groups. But when growth in supply on the extensive margin is insufficient to maintain a fixed skill premium, supply responses on the intensive margin come into play. These responses mitigate the impact of the supply changes on skill prices by increasing the relative supply of the skill type with the rising relative price. However, these same responses exacerbate the impact on inequality since they further increase earnings for the skill group that experienced a rising relative price. When interpreted at the level of families, this magnifying effect on inequality can play out over generations.

IV.   Inequality and Growth

Our analysis above indicates a central role for the supply of human capital, on differing margins, in determining equilibrium inequality. The next step is to incorporate these outcomes into the model of economic growth given by (4), repeated here:

(19) $$d \ln Y = d \ln A + d \ln H$$

Recalling that Φ_S is the labor income share of skilled workers, displacement of (5) yields:[21]

$$d \ln H = \Phi_S [d \ln B_S + d \ln S] + [1 - \Phi_S] d \ln U$$

(20)

$$= \Phi_S \left[d \ln B_S + d \ln \Delta_S \right] + \eta \left[\Phi_S d \ln R_S + [1 - \Phi_S] d \ln R_U \right]$$

All factor prices are measured in real terms and capital is in perfectly elastic supply ($d \ln R_K = 0$) so productivity growth accrues to human capital because of induced capital deepening:

(21a) $$\Phi_S d \ln R_S + [1 - \Phi_S] d \ln R_U = d \ln A + \Phi_S d \ln B_S$$

or

(21b) $$d \ln R_U = d \ln A + \Phi_S \left[d \ln B_S - d \ln(R_S / R_U) \right]$$

Using condition (21a) in (20) eliminates price terms, yielding a simple expression for the growth rate of the human capital aggregate:

(22) $$d \ln H = \eta [d \ln A + \Phi_S d \ln B_S] + \Phi_S [d \ln B_S + d \ln \Delta_S]$$

According to (22), aggregate human capital per worker grows for two basic reasons. First, technical progress ($d \ln A + \Phi_S d \ln B_S$) raises both skill prices and induces skill acquisition and utilization by both S and U workers, with common supply elasticity η. Second, SBTC ($d \ln B_S$)

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[21] Terms in (20) involving the change in the skilled/unskilled ability cutoff a^* vanish because marginal workers are indifferent between choosing type S or U.

and supply shifts ($d \ln \Delta_S$) raise H by directly increasing the effective amount of type-S human capital. These effects are proportional to the skilled (S) share of labor income, Φ_S.

The final step is to use (22) in (19), obtaining an expression for growth in output per worker:

(23) $\qquad d \ln Y \; = \; [1+\eta]d \ln A + \Phi_S \left[[1+\eta]d \ln B_S + d \ln \Delta_S \right]$

Contemporaneous changes in the skill premium $d \ln(R_S / R_U)$, given by (18), are second order and so they do not appear directly in either (22) or (23). Thus it might appear that factors causing greater income inequality are also of second order importance for economic growth. Yet (23) draws an important distinction between the effects of labor-augmenting but skill-neutral technical progress ($d \ln A$) and skill-biased changes in technology ($d \ln B_S$) and supply ($d \ln \Delta_S$) on economic growth. Skill-biased technical progress and exogenous supply growth increase overall productivity growth by augmenting the relative supply of skilled human capital. This human capital deepening impacts overall productivity growth in proportion to the labor income share of the affected skill group, Φ_S, which is endogenous. From the definition of the skilled labor income share:

(24) $\qquad \dfrac{d\Phi_S}{d \ln(R_S / R_U)} = [1-\sigma][1-\Phi_S]\Phi_S < 0 \quad \Leftrightarrow \quad \sigma > 1$

With $\sigma > 1$, the skilled income share declines as the skill premium R_S/R_U increases because relative demand for skilled human capital is price elastic. So, for a given rate of change in skill-biased technology B_S, *greater inequality reduces economic growth* because a higher skill premium induces substitution away from skilled human capital, which is a source of productivity growth in our model.

How important is inequality as an impediment to productivity growth? The calculation isn't straightforward because we do not observe a direct estimate of the change in R_S/R_U over time; instead we observe changes in relative wages, which include the behavioral responses of human capital investment and utilization represented by the elasticity $\eta = \eta_H + \eta_T$. To get a

very rough (and probably conservative) estimate of the effect, consider the labor supply responses of high-wage individuals, as graphed in Figures 7A and 7B. Treating η_T as a pure labor supply (hours) response and using the data from Figures 7A and 7B, Table 2 shows estimates of the ratio

$$\hat{\eta}_T = \frac{\Delta \ln(T)}{\Delta \ln(W)}$$

for various intervals in the upper half of the male and female wage distributions. The implied elasticity is largest in high percentiles, where wage gains and hours increases were the biggest. Near the top of the respective distributions the estimates for men and women are remarkably similar, about .09 for both. If η_H is of similar magnitude then a (very) rough estimate is $\eta \approx .20$.

We use the college/high school wage premium as an index for changes in R_S/R_U over time. According to Figures 4A and 4B, this premium increased by about 50 log points after its 1979 nadir. Using $\eta \approx .20$ implies $\Delta \ln(R_S / R_U) = .50/1.2 = .42$. According to (18), this increase would have been mitigated if the endogenous supply of skilled workers had been highly elastic (if $\xi(a^*)$ had been large) or if exogenous supply growth of skilled human capital $(d \ln \Delta_S)$ was sufficient to offset rising demand. So assume counterfactually that these effects had been large enough to maintain the skill premium at its 1979 level. Then R_S/R_U would be 42 log points lower than it was. Productivity growth in the U.S. has averaged slightly more than two percent per year since 1979, so $d \ln Y = d \ln A + \Phi_S \left[[1 + \eta] d \ln B_S + d \ln \Delta_S \right] \approx .02$ per year. Assume further that $d\ln A = 0$, which means that all productivity growth has been due to SBTC and growth in supply. Defining skill groups in terms of efficiency units of college-educated and high-school educated workers yields $\Phi_S \approx 0.60$, so the bracketed growth rate of human capital is $d \ln H \approx 3.3$ percent per year. With $\sigma \approx 2$, as discussed above, (24) implies that the skilled income share would be $0.4 \times 0.6 \times 0.42 = 10.1$ percent higher—call it $\hat{\Phi}_S = 0.70$. Then, had inequality not increased in response to SBTC, the growth rate of labor productivity would be $d \ln H \times [\hat{\Phi}_S - \Phi_S] =$

.033×.101=.0033 per year higher than it was. Over 10 years this reduction in inequality would increase productivity by about 3.4 percent.[22]

V.   Conclusion

Over the past 40 plus years there has been a substantial rise in wage inequality for both men and women in the United States. When viewed in the context of a labor market equilibrium in which skill prices are determined by the interaction of supply and demand, much of the recent history has a simple explanation—rising relative wages for more skilled workers reflect the fact that the demand for skilled labor has outpaced growth in the supply of skilled labor. For purposes of understanding the evolution of inequality it is important to distinguish multiple dimensions on which the relative supply of skilled labor responds to a rise in its relative price. Different margins have very different effects on inequality. Investments on the extensive margin mitigate the impact of rising demand on the skill price and thereby mitigate the resulting rise in inequality. In contrast, while investments on intensive margins—by which we mean greater skill accumulation by those that with the ability and background to become skilled as well as more intensive application of skills in producing market income—also mitigate the rise in the skill price, these investments magnify the growth in inequality because they increase the quantity of human capital each skilled worker employs in the market.

This contrast is particularly important for the U.S. after 1980. The evidence indicates that the human capital supply response on the extensive margin has fallen far short of what would be required to prevent the skill price (measured by, say, the college premium) from rising. The rising skill premium then leads to more investment on the intensive margin and magnifies the growth in inequality. The shortfall of investment on the extensive margin therefore not only contributes to inequality directly by driving up the price of skill but also sets in motion supply responses on the intensive margins that cause further growth in inequality. This suggests that the failure to "produce" a sufficient number of high skilled workers has contributed both directly and indirectly to the observed rise in inequality. The consequences of these behavioral responses are

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[22] These calculations assume that all of the growth in productivity is generated by technical change that augments skilled labor. To the extent that productivity growth is accounted for by technical change that augments a mix of unskilled and skilled labor the growth effects would be smaller.

likely to be even broader since slower growth in skilled labor will be associated with slower rates of economic growth when technical progress augments skilled labor.

Finally, as should be obvious, our analysis indicates that efforts to combat inequality by capping the returns to skill or otherwise artificially compressing the wage distribution will reduce human capital investment and utilization. In turn, this exacerbates the underlying scarcity of skills that is the root cause of rising inequality and reduces economic growth. Our analysis points to remedies to the inequality problem that lie on the supply side, specifically in policies that encourage or enable the acquisition of skills or encourage the immigration of highly skilled individuals. Expanding supply in these ways is unlikely to have much impact in the extreme right-tail of the earnings distribution, where the nature of skill-biased technical change has produced the "superstar" effects described by Rosen (1981). Yet most of the welfare implications of rising inequality and skill scarcity are at lower altitudes, where changing factor proportions can play a significant role in mitigating inequality.

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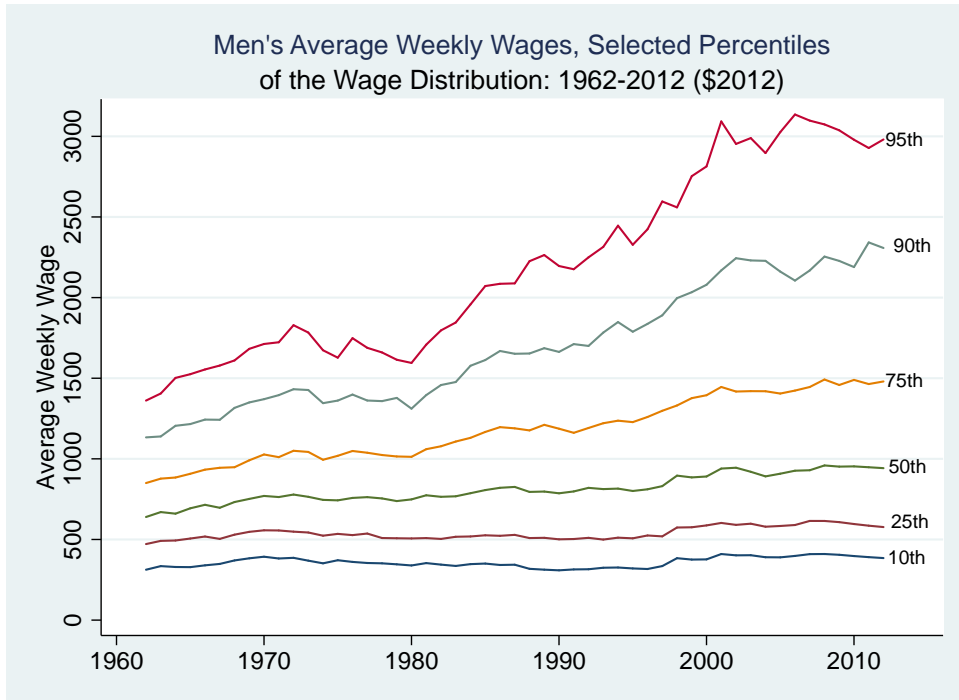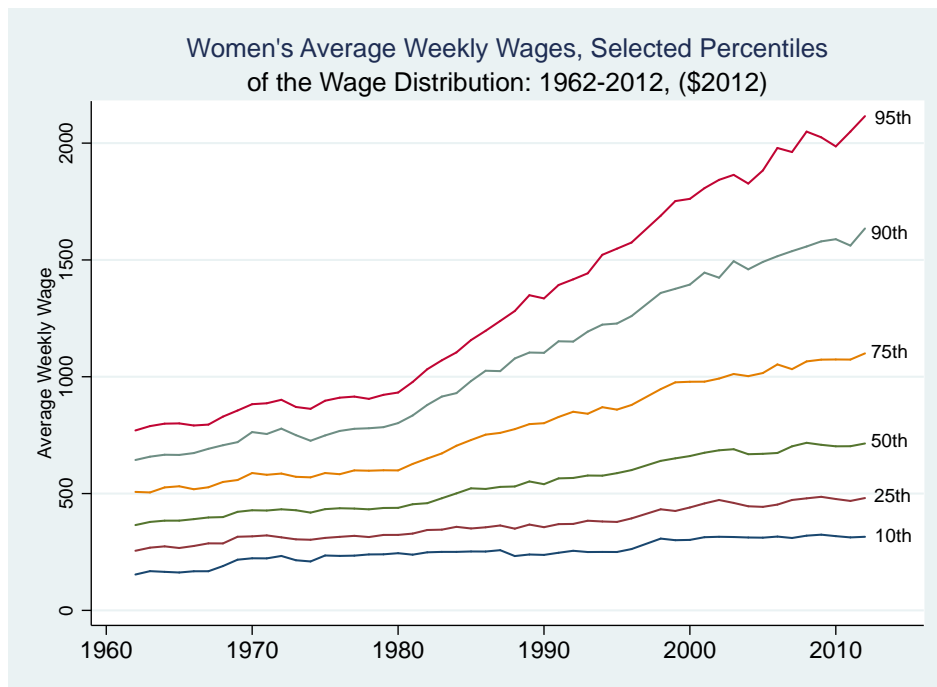
Figure 1A

Men's Average Weekly Wages, Selected Percentiles
of the Wage Distribution: 1962-2012 ($2012)

Figure 1B

Women's Average Weekly Wages, Selected Percentiles
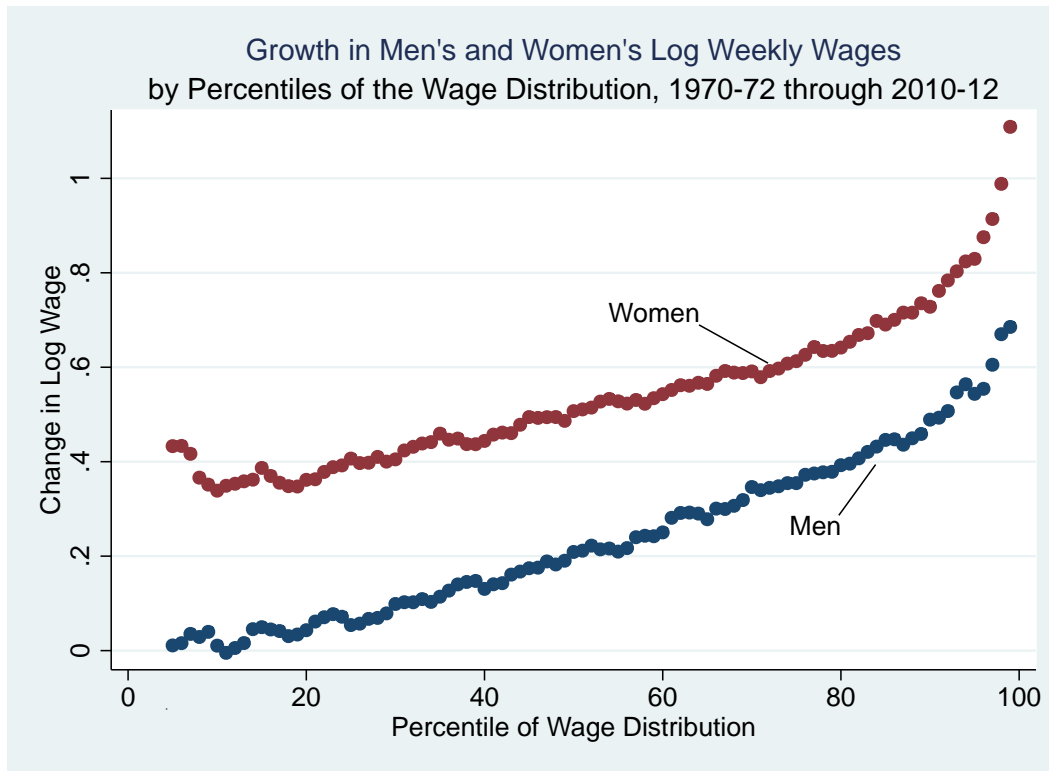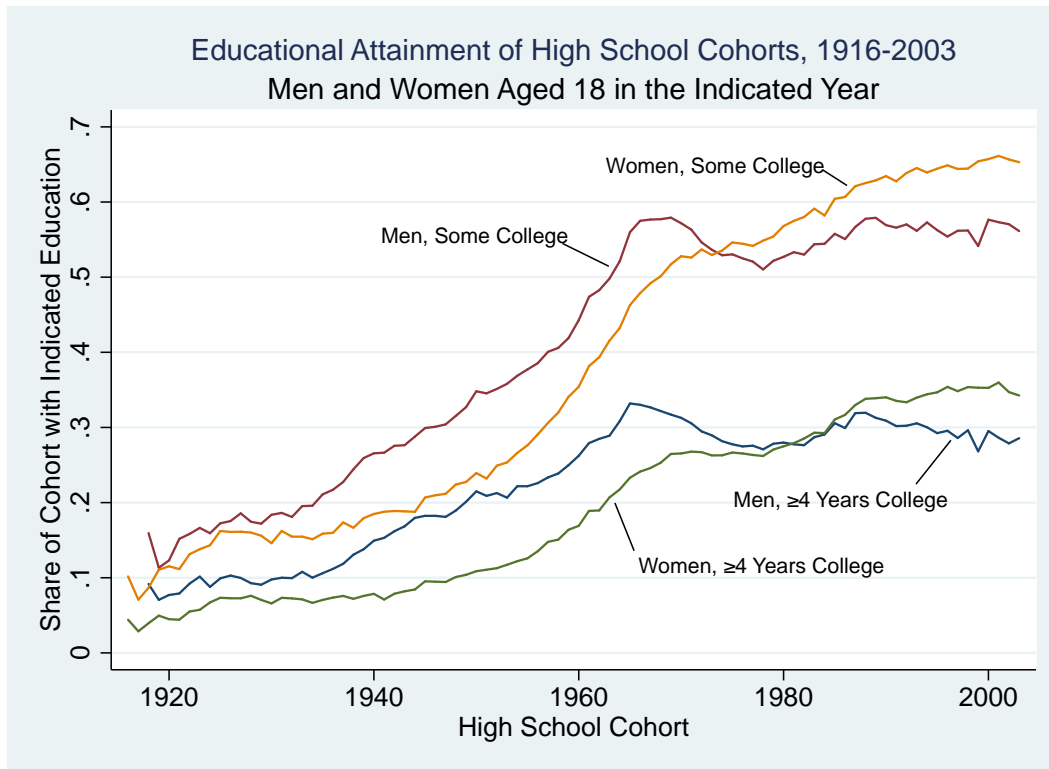of the Wage Distribution: 1962-2012, ($2012)

Notes: Authors' calculations from March Current Population Surveys, 1963-2013. Samples are individuals aged 18-64 who worked more than 30 weeks and more than 30 hours per week during the indicated calendar years.

Figure 2

Growth in Men's and Women's Log Weekly Wages
by Percentiles of the Wage Distribution, 1970-72 through 2010-12

Notes: See notes to Figures 1A & 1B

Figure 3

Educational Attainment of High School Cohorts, 1916-2003
Men and Women Aged 18 in the Indicated Year

Note: Figure shows the fraction of individuals that turned 18 in the indicated years with either some college (at least 1 year of post-secondary schooling) or with at least 4 years of college.
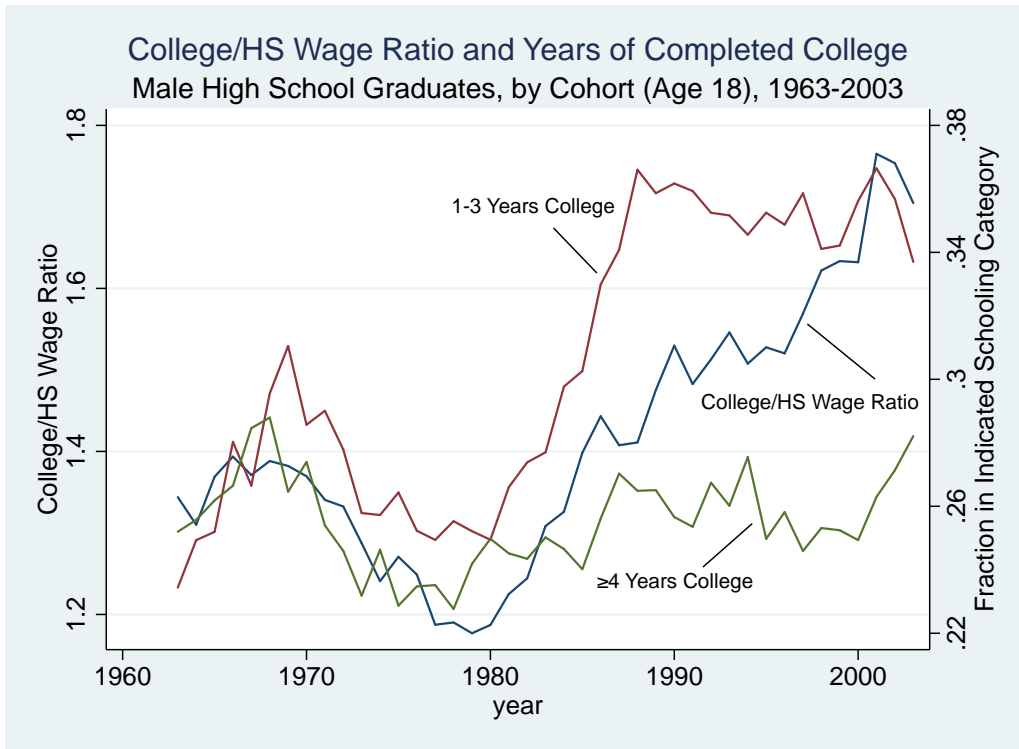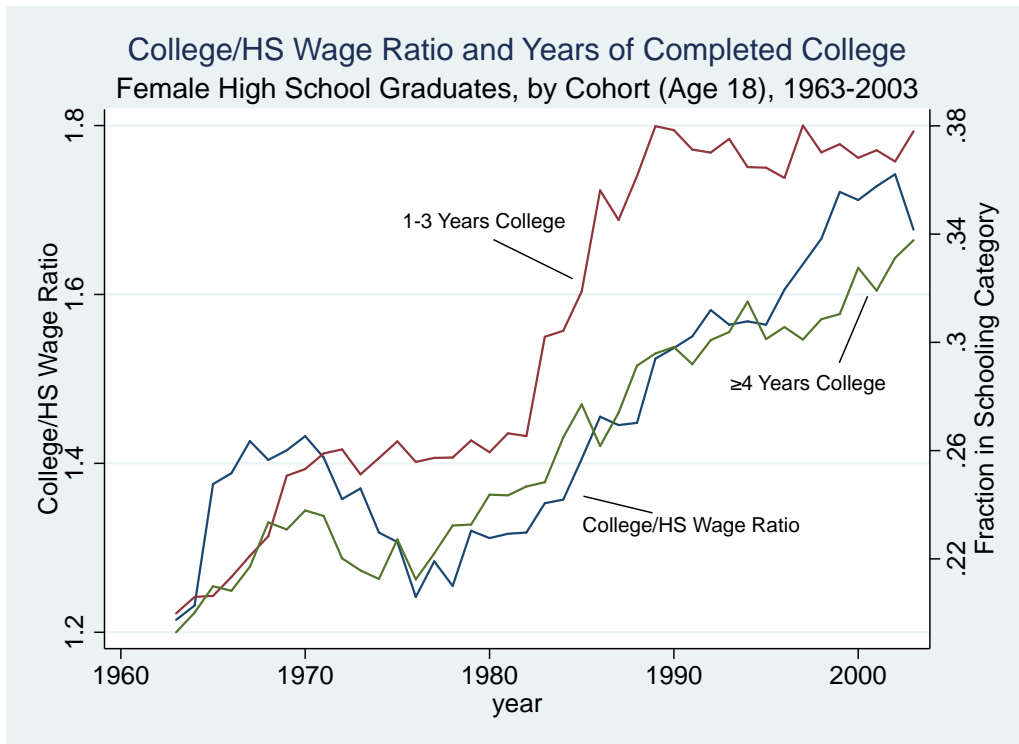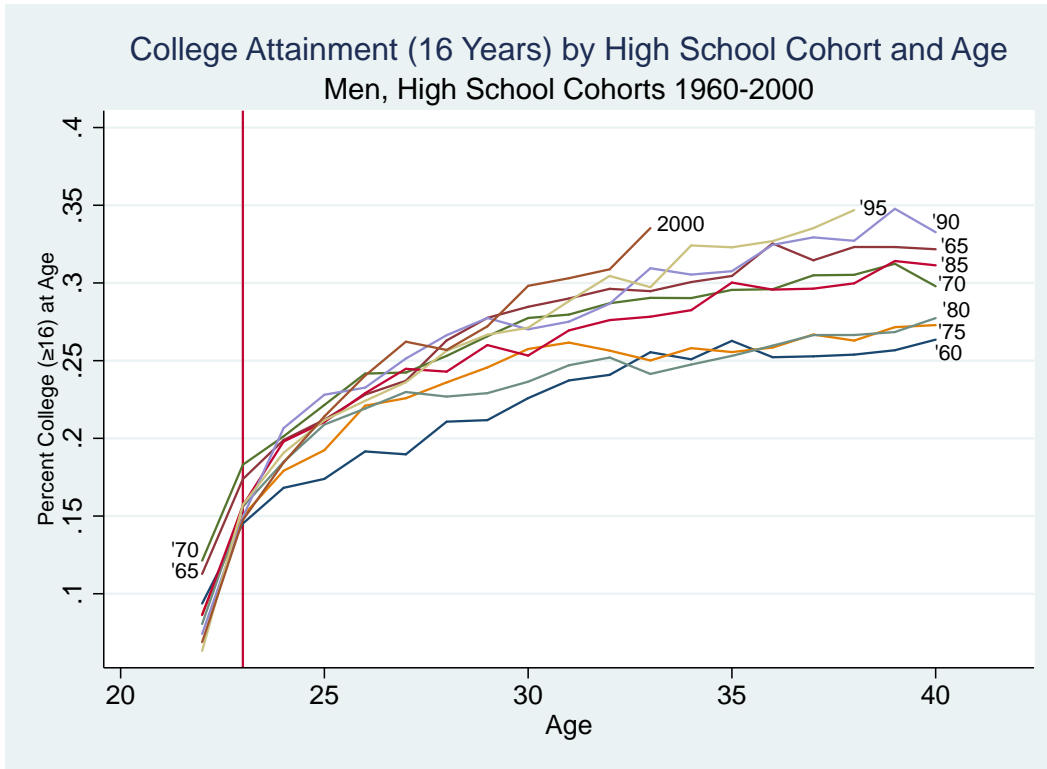
Figure 4A

College/HS Wage Ratio and Years of Completed College
Male High School Graduates, by Cohort (Age 18), 1963-2003

Figure 4B

College/HS Wage Ratio and Years of Completed College
Female High School Graduates, by Cohort (Age 18), 1963-2003

Figure 5A

College Attainment (16 Years) by High School Cohort and Age
Men, High School Cohorts 1960-2000

Figure 5B

College Attainment (16 Years) by High School Cohort and Age
Women, High School Cohorts 1960-2000

Figure 6

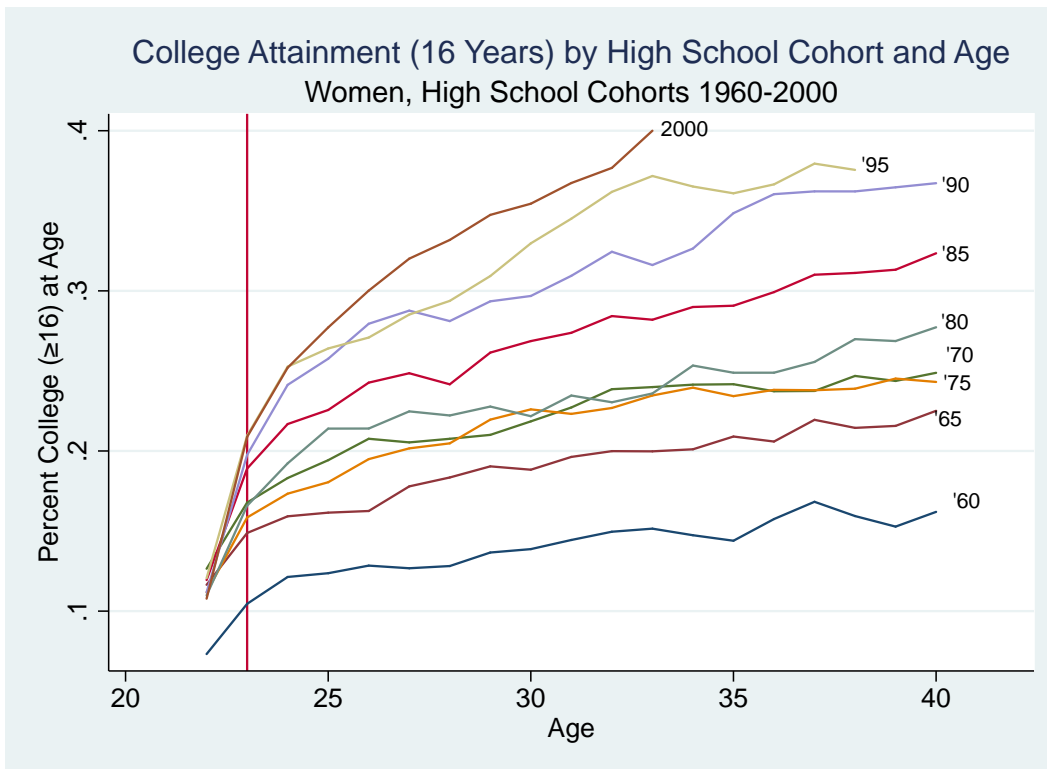**Grade Point Averages of Graduating High School Seniors**
1990-2009

Source: National Center for Education Statistics.

Figure 7A

Average Weekly Hours Worked, by Percentile of Wage Distribution
Men, 1970-72 & 2010-12

Figure 7B

Average Weekly Hours Worked by Percentile of the Wage Distribution
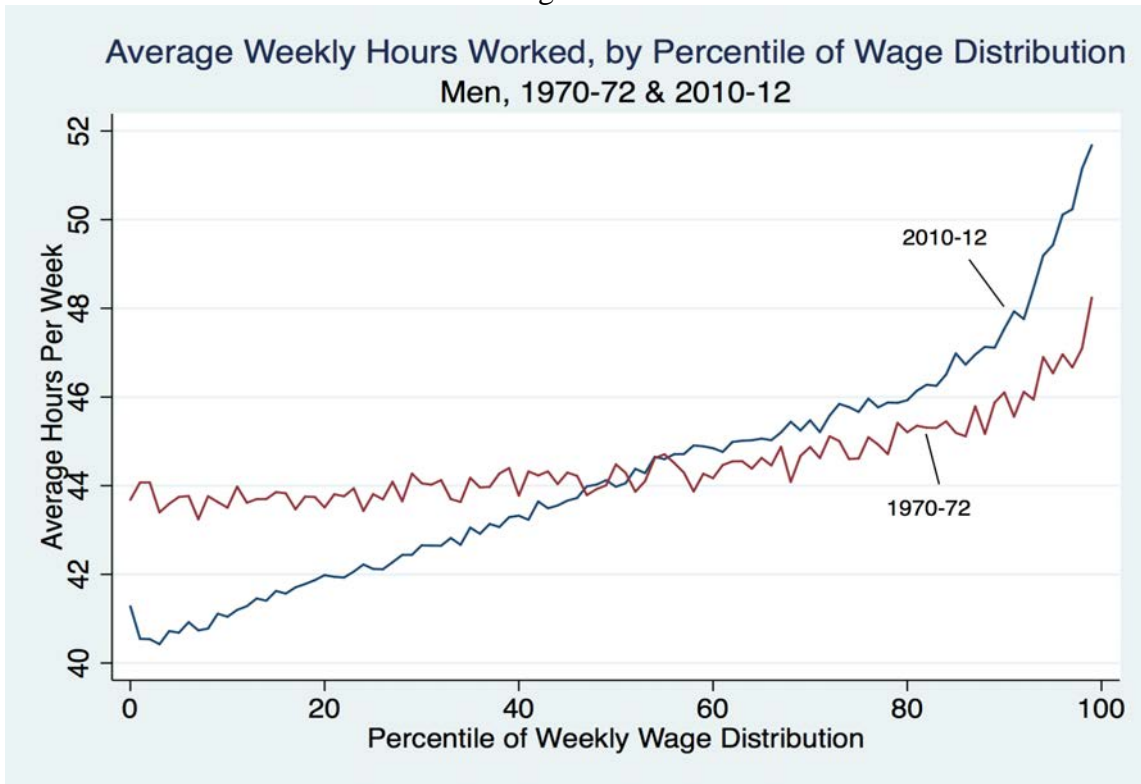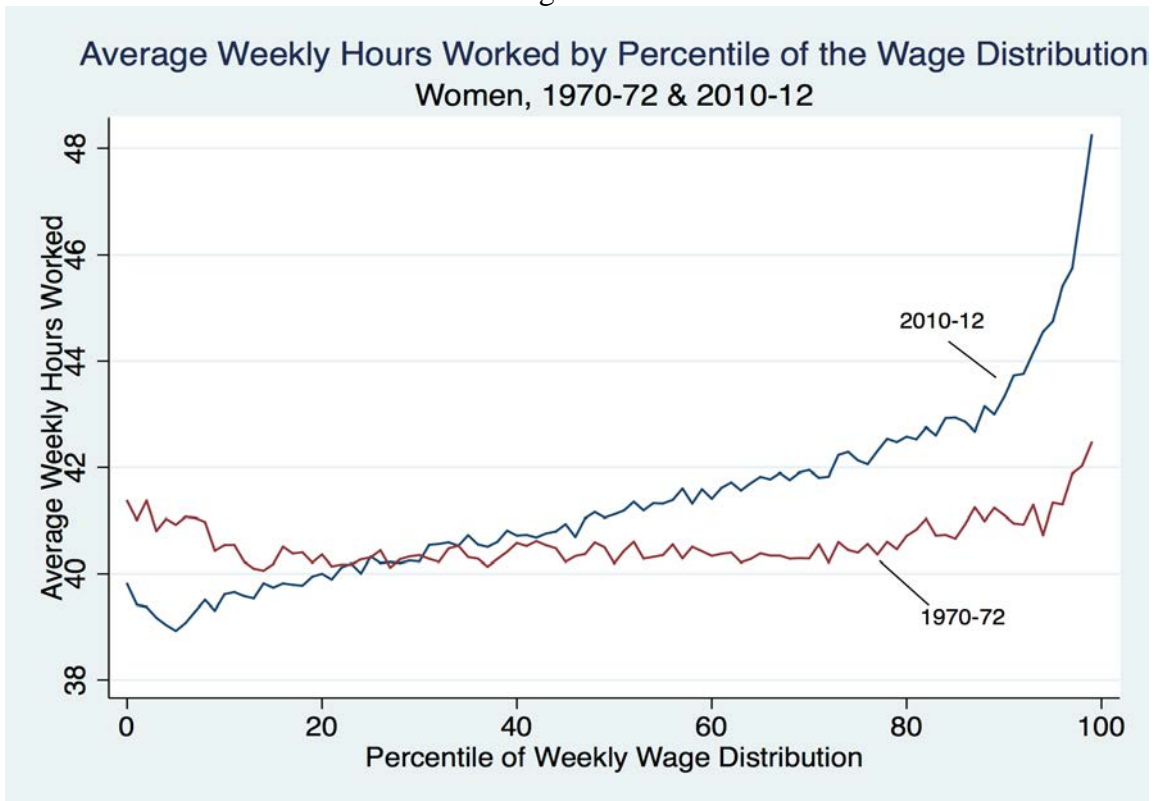Women, 1970-72 & 2010-12

Table 1
Distributions of Grade Point Averages
First Year Students at Four-Year Colleges and Universities
1995-96 & 2003-04, by Intended Major

Academic Year & Major	Gender (%)	First Year Grade Point Average (Share of Students in Range)				
		< 2.0	2.0-2.49	2.5-2.99	3.0-3.49	3.5+
1995-1996						
Math & Science	Male (62.5)	19.0	21.2	23.0	20.3	16.5
	Female (37.5)	12.5	14.3	21.3	27.2	24.7
Social Science & Humanities	Male (38.4)	17.7	19.1	24.0	20.0	19.2
	Female (62.6)	16.1	14.1	22.5	27.4	19.9
2003-2004						
Math & Science	Male (63.9)	12.1	13.2	26.6	21.4	26.7
	Female (36.1)	4.0	9.8	19.7	30.2	36.3
Social Science & Humanities	Male (38.1)	11.6	15.1	18.8	28.3	26.3
	Female (61.9)	6.9	9.0	20.8	28.8	34.5

Source: National Center for Education Statistics, Beginning Postsecondary Students Surveys.

Table 2

Wage Elasticities of Average Weekly Hours, 1970-72 through 2010-12
By Intervals of the Male and Female Weekly Wage Distributions

	Wage Percentiles				
	46-55	**55-65**	**66-75**	**76-85**	**86-95**
Men	-.008	.046	.054	.057	.092
	(.011)	(.007)	(.008)	(.006)	(.007)
Women	.040	.060	.074	.080	.091
	(.003)	(.003)	(.002)	(.004)	(.007)

Note: Calculated from data underlying Figures 7a and 7b. See text for description of calculations.