The Payoff to Skill in the Third Industrial Revolution*

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Abstract

We develop a new approach to analyzing earnings and earnings inequality in the United States that rests on a comprehensive measurement of skill. The simple model based on this approach, which we apply to the 1979-2010 Current Population Surveys, allows us to adjudicate between competing accounts of the changing returns to cognitive, creative, technical, and social skill. We find that the recent takeoff in between-occupation inequality can be fully explained when such skills are taken into account. We also find that the returns to schooling, which have long been understood to be rapidly increasing, are in fact quite stable and have appeared to increase in conventional models only because correlated changes in workplace skills have not been parsed out. The most important trend under this specification is a precipitous increase in the wage payoff to "analytic skills" that entail synthesis, critical thinking, and deductive and inductive reasoning. The payoff to technical and creative skills, which are typically featured in discussions of the third industrial revolution, have been oversold and don't compare to this payoff to analysis. We conclude by suggesting that such skill-biased trends are driven more by institutional change than technical change.

We remain in the throes of a "third industrial revolution" that appears to be recasting the payoff to skilled labor in very fundamental ways. The two previous industrial revolutions, as defined by the introduction of steam power in the early 19th century and the mechanization of production in the mid-19th century, were characterized by bursts of both skill-biased and skill-degrading technologies. The latest revolution, by contrast, is widely understood as a mainly skill-biased one in which the supply for skilled labor just can't keep up with the demand.[1] The "canonical model" (Acemoglu & Autor 2010) of this third revolution has it that accelerating technical change (e.g., computerization) has increased the demand for skilled workers, raised the payoff to skill, and thereby generated much earnings inequality (also, Goldin & Katz 2008; Autor, Katz, & Kearney 2008). This model is expressed not just in the economic literature on skill-biased technical change (SBTC) but also in the postindustrialist literature that rests on a "knowledge theory of value" (Bell 1999, p. xvii) and, like SBTC, treats the rising demand for skilled labor as a central feature of contemporary economies.

This account is so frequently rehearsed that one forgets how little it has to say about *how* the third industrial revolution has changed the demand for and payoff to skill. What types of skills are increasingly in demand and increasingly well paid in the third industrial revolution? Is Krueger (1993) right to suggest that, at its heart, it's a *computer revolution* in which the payoff to computer use and computer knowledge is taking off and driving the rise in inequality (Cappelli & Carter 2000; Black & Lynch 2001; DiNardo & Pischke 1997)? Or are we instead in the midst of a far broader *technocratic revolution* that entails a growing payoff to scientific and other forms of technical knowledge (e.g., Bell 1973; Castells 2000; Powell & Snellman 2004; Giddens 2008; Esping-Andersen 2008)? Or is creativity rather than knowledge driving the third industrial revolution? Is Florida (2002), for example, correct in suggesting that there's a burgeoning creative economy and that the rising payoff to creative skills is the core labor market trend of our time (see also Giddens 2008)? Or are all the foregoing theories wrongly defaulting to a "knowledge theory of value" (Bell 1999, p. xvii) and overlooking the rising demand for directing, controlling, and supervising labor? Are we witnessing, in other words, a *managerial revolution* in which the globalization of markets, the complexity of the modern firm, and the "low road" strategy of intensive supervision has created an accelerating demand for oversight (e.g., Gordon 1996)?

For each of these stories about the third industrial revolution, a supporting literature has of course emerged, but such balkanized literatures are unsatisfying because the competing stories can't be convincingly assessed in isolation from one another. In all cases, they are at least partly stories about the type of labor that's increasingly in demand and that's increasingly rewarded, and a complete test accordingly requires that each type of skill is measured and that the net returns are estimated in the context of a full model of earnings. The purpose of this paper is to begin that task of developing and estimating just such a model for the U.S. case. For those who prefer some foreshadowing, we can reveal now that none of the foregoing formulations will provide a complete account of returns to skill in the third industrial revolution and that, insofar as one wants to tag recent changes with a single label, the most appealing one is the *analytic revolution*. The defining feature, we will show, of the last thirty years has been a precipitous increase in the wage payoff to jobs requiring synthesis, critical thinking, and deductive and inductive reasoning.

How is it that we still know so little about the types of skill underlying the third industrial revolution? The main source of this state of affairs is the spectacularly poor conceptualization and measurement of skill within the economics *and* sociological literatures on earnings inequality. The entire SBTC apparatus is predicated on the view that skill can be usefully treated as a unidimensional concept, that one can accordingly divide the labor force into skilled and unskilled workers, and that the third industrial revolution increased the demand for the former category and diminished the demand for the latter (see Handel 2003 for a relevant review). In most renditions of the SBTC account, it's of course appreciated that skill might be measured in continuous rather than dichotomous form, but it's still understood to be a unidimensional concept in which one simply has more or less of it. If skill is viewed in such simple terms, it's perhaps no surprise that it's typically operationalized with a measure of schooling, either a continuous measure (e.g., years of schooling) or a categorical one (e.g., high-school dropout, high-school degree, college degree). Worse yet, skill is sometimes simply equated with the residual in a conventional earnings model, the presumption being that education-based measures of skill are incomplete and that any residual variability in earnings can be attributed to unmeasured skill (see DiPrete 2007; Lemieux 2006; Autor, Katz, & Kearney 2005; Card & DiNardo 2002; Acemoglu 2002; Katz & Autor 1999; Juhn, Murphy, & Peirce 1993). If rising demands for skill are indeed so central to the third industrial revolution, one might imagine we could be bothered to measure it directly.

It would be wrong, however, to blame the poor measurement of skill entirely on this willingness to default to a unidimensional view of it. Throughout the history of the SBTC literature, there are occasional references to the need to better conceptualize skill, in fact over

15 years ago Neal (1995, p. 670) presciently argued for "directly capturing important skill specificities" (see also Card & Lemieux 1996). More recently, Acemoglu (2002, p. 13) noted that "models based on a single skill index" cannot well explain recent trends in inequality, while Kambourov and Manovskii (2009) have shown that wages increase with occupational tenure, a finding that's interpreted as "consistent with occupational specificity of human capital" (p. 63). There's ample awareness, then, within even the SBTC literature that the various types of skill are not perfect substitutes for one another and that it's accordingly important to distinguish between them. Likewise, sociologists of postindustrialism and skill (e.g., Handel 2003; Felstead, Gallie, Green, & Zhou 2007) have long been aware that skill is a multidimensional concept, yet they've been captivated by debates about whether this complicated panoply of skills evince an across-the-board trend toward upgrading; and hence discussions of trend typically revert to a unidimensional formulation. There's been little interest, moreover, in building sociological models of the changing payout to this panoply of skills (see Carbonaro 2005, 2006, 2007 for important exceptions).

The key challenge facing the field is to translate this awareness of skill unsubstitutability into a full-blown multidimensional model of earnings. Insofar as specific types of skills *have* been directly measured, the tendency has been to estimate earnings models that include just a few types, thereby leaving the analysis wide open to charges of omitted variable bias. Most famously, Krueger (1993) reported a 15% "computer wage premium" in a model that included a measure of computer skills, a result that DiNardo and Pischke (1997) later criticized because the putative computer effect could be recast as a pencil effect by substituting the measure of computer usage with one of pencil usage (see Cappelli & Carter 2000; Black & Lynch 2001).

There are of course a few two-factor models of skill. The most famous one rests on the distinction between cognitive and noncognitive skills and shows that the latter contribute substantially to wages (Heckman, Stixrud, & Urzua 2006; Heckman & Rubinstein 2001; Dunifon & Duncan 1998; Moss & Tilly 1996). The two-factor extension is an important step forward and has been very influential, yet even so it might usefully be extended by assessing whether the so-called cognitive factor is itself a composite of many correlated dimensions (e.g., creative skills, analytic skills, managerial skills). This is all to make the seemingly obvious point that one cannot well estimate the effects of particular skill types without teasing out the possibly correlated effects of other types. Although the need for a truly multidimensional model of skill thus seems obvious, it's nonetheless strangely missing from the field.

It bears noting that relevant multidimensional models have been applied in other research contexts. For example, research on occupational rent and closure often rests on models that estimate the net effects of closure in the context of multiple controls for skill (e.g., Weeden 2002), while research on the wage penalty for nurturing likewise typically conditions on a multidimensional measurement of skill (e.g., England, Budig, & Folbre 2002; Kilbourne et al. 1994). Within labor economics, there's also a relevant modeling tradition that explores the relative importance of firm-specific, industry-specific, and occupation-specific capital (esp. Poletaev & Robinson 2008). The foregoing streams of research are important for our own effort (and we'll therefore be drawing upon them), but none of them attend, as we will, to the changing returns to different types of skills.

The approach that we take here rests on the distinction between the general cognitive skills formed at school and the specialized cognitive and noncognitive skills formed in the workplace (e.g., Carbonaro 2005). We will, per convention, use schooling and experience to index general skills, but we'll depart from convention by additionally developing a new eight-factor representation of workplace skills that draws on occupational ratings from the Occupational Information Network (O*NET). As the replacement for the *Dictionary of Occupational Titles* (U.S. Department of Commerce 2000), O*NET is a rich resource that allows us to directly measure cognitive, creative, technical, and social skills within the detailed occupations of the 2000 Standard Occupational Classification. We will provide further details on our O*NET measurement of skills below (Peterson et al. 1999), but for now it suffices to note that we will measure three types of cognitive skills (verbal, quantitative, analytical), one type of creative skill, two types of technical skills (computer and science & engineering), and two types of social skills (managerial, nurturing). We review below some long-standing hypotheses about how the returns to such skills have been changing over the last 30 years.

Long-term trend in the payoff to skill

It's fitting to begin our discussion of the changing payout to skill by first laying out the main mechanisms by which such changes presumably arise. The most obvious prerequisite for any increase in the payout to a particular type of skill is that demand for that skill exceeds the supply of labor that can provide it. For example, the SBTC account features a technical change, such as the computerization of the workplace, that is then presumed to raise the demand for skilled labor well in excess of the available supply. The conventional SBTC account doesn't identify particular types of skill for which demand is increasing, and instead it presumes, if only by default, that technological change will uniformly increase demand for all types of skill (with the rise of computer-based skills simply illustrative of a broader upgrading process). The accounts reviewed below will instead focus on exogenous shifts that may increase demand in skill-specific ways.

Will such increases in demand yield a long-term increase in the payout to a skill? It of course depends on how the supply of the requisite labor responds. In a competitive economy, workers should respond to price signals by investing in the training needed for high-return jobs, thereby increasing the supply of labor for those jobs and driving down their wages. The temporary, "quasi-rents" generated by a transitory shortage of skilled labor will, through the usual equilibrating flows, be eliminated over time (e.g., Sϕrensen 2008). We should therefore observe wage premiums in the long term only insofar as they rest on (1) abilities that are in fixed supply and cannot be acquired through education or training, or (2) access to training, credentials, or certificates that is likewise restricted or rationed. The implication is that the quasi-rents accruing to those with high-demand skills will translate into permanent rents only when closure of some type prevents labor from meeting demand.

The case of rent on ability is well known, whereas that of rent accruing to institutional bottlenecks is less developed and bears reviewing (see Grusky & Weeden 2011). The main type of bottleneck, occupational closure, refers to the widespread practice of establishing barriers (e.g., certification) that protect incumbents against competition from others who might wish to enter the occupation or provide competing products or services (Weeden 2002; Kleiner 2006; Kleiner & Krueger 2008). This barrier sometimes take the form of an explicit or implicit decision to reserve jobs for graduates of elite institutions. Whenever an elite degree is treated as a prerequisite for entry, it prevents labor from fully responding to price signals, as the number of degrees is kept artificially low through administrative or institutional rules or practices (see Goldin & Katz 2008; Hout 2009). If high-status skills, such as analytic ones, are largely practiced in occupations reserved for graduates of elite schools (e.g., financial managers), then any increase in the demand for such skills won't trigger an immediate and corresponding increase in supply (Weeden & Grusky 2011).

The foregoing implies, then, that long-term price increases should emerge for those skills that are (a) experiencing an increase in demand, and (b) depend on an ability or type of training that is in fixed supply or otherwise rationed. Is this demand-led mechanism the only possible source of price increases? Absolutely not. In principle, the *tastes* for particular types of work activities can also shift over time, with the result that more or less workers will invest in the skills that are required for such activities. It's often suggested, for example, that women have historically had a special taste for caregiving and are therefore willing to accept relatively low earnings in exchange for the on-the-job rewards that, for them, arise when they tend children or the sick. But what happens when such tastes for caregiving become less widespread as enlightened parents and peers encourage women to develop other types of tastes? This is a classic example of a supply-driven source of rising payout: That is, employers will have no choice but to raise wages for caregiving, as there won't any longer be enough women who have a strong taste for caregiving that compensates adequately for the low caregiving wages.

We may accordingly refer to both demand-driven and supply-driven changes in the prices accruing to different types of skill. As we'll see, the available literatures on (putative) price changes in skill aren't all that well developed, and the mechanisms at work are often undiscussed or, at best, left implicit. We will nonetheless attempt to recast the available literatures in terms of the mechanisms discussed above. We'll lead off with the standard case of cognitive skills and then turn to creative, technical, and social skills. Throughout this discussion, we'll consider not just technological sources of price changes (e.g., rising computerization), but also cultural and institutional sources in the form of changing tastes, changing socialization practices, changing rates of female labor force participation, changing barriers to market entry (i.e., "globalization"), and changing ways of organizing and overseeing labor. These cultural and institutional factors can straightforwardly affect the demand for and supply of particular types of skills, yet are nonetheless overlooked in conventional stories about returns to skill in the third industrial revolution (but see Carbonaro 2005, 2006, 2007).

Cognitive skills: The SBTC account is sometimes interpreted as principally a story about rising demand for higher-level cognitive skills (see Handel 2003, p. 157). Although it's conventional to view cognitive skills of a piece and assume across-the-board rising returns, there's in fact good reason to believe that the payoff to their verbal, quantitative, and analytic components is changing in different ways. For many verbal and quantitative tasks, technology appears to have had a deskilling effect, as it's replaced tacit and intuitive skills with automated or self-acting technologies. The emergence, for example, of computer-based tax programs has clearly deskilled much accounting work, in effect reducing it to punching numbers into programs. This deskilling effect should suppress the demand for (true) quantitative skill and reduce its payoff. By contrast, analytic skills aren't nearly as vulnerable to such substitution effects, involving as they do critical thinking, problem solving, and deductive reasoning, all tasks that aren't readily routinized. Even more importantly, the demand for analytic thinking is likely increasing as innovation intensifies, capitalism becomes more complex, and markets change more quickly. The financial analyst who devises, for example, a successful new derivative stands to reap substantial returns, all the more so as markets become ever larger. The price effect of rising demand is also exacerbated by bottlenecks on the supply side. Because the plum analytic jobs are reserved for elite college graduates, the growing demand for analytic skills isn't necessarily met with a substantial increase in the supply of analytic labor, with rising returns then the necessary result. The upshot is that analytic skills are playing an entirely different role than verbal or quantitative ones and aren't usefully bundled into a unitary "cognitive" dimension. The resulting hypothesis: We anticipate a substantial takeoff in the price of analytic skills but only a weaker takeoff for verbal or quantitative ones.

Creative skills: The "creative class" includes workers in architecture, design, education, arts, music, entertainment, science, and engineering. In an increasingly prominent line of commentary, Florida (2002) has argued that this class has become an important engine of growth, that the "creative ethos" is rapidly spreading, and that there's accordingly been a demand-led increase in the price of creative labor (also see Giddens 2008; Howkins 2001). The latter claim, which is most relevant for our purposes, hasn't been developed all that rigorously, and we're therefore left mainly to infer the mechanisms behind it. Although it does seem likely that the demand for creative skills has been rising, what's unclear is whether there are any effective closure mechanisms in place to check the corresponding rise in supply. We suspect in fact that supply may now be outstripping demand. If indeed Inglehart (2008) and others (e.g., Benedikter 2001) are correct that postmaterialist values are gradually diffusing and raising interests in self-expression and autonomy, then young adults should increasingly aspire to becoming authors, artists, architects, entertainers, and other expressively-oriented workers.

This trend is revealed, for example, in General Social Survey (2011) data showing that U.S. adults increasingly insist upon "interesting work" as a "very important" job characteristic. In the last several decades, the proportion wanting such "interesting work" increased from 43.7% in 1989 to 51.0% in 1998 and then 56.8% in 2006, a trend line that at least suggests a rising supply of creative labor. As a result, the price of creative labor is arguably held in check by a rising compensating differential, and a bloated supply of postmaterialist children will continue to flood the creative sector and work for ever less because of the intrinsic rewards that creative labor provides them. This hypothesis, and it's obviously no more than that, suggests that the payoff to creative skills may not be growing quite as quickly as "creative class" theorists have suggested (see Markusen 2006; Montgomery 2005).

Technical skills: It's frequently noted that, under an SBTC account, the payout to cognitive skills should be increasing. In fact, SBTC is arguably a two-headed account, with at least some renditions of it stressing the growing payout to technical skills rather than cognitive ones. The distinction rests on whether demand is rising more quickly for (1) general verbal, quantitative, and analytic skills, or (2) more narrowly-drawn technical skills, especially those involving computers. We've suggested that an across-the-board increase in the demand for *all* generalized cognitive skills is unlikely because many technologies (e.g., tax programs, spreadsheets) have served to deskill verbal and quantitative work. It's analytic skills, then, that are likely to experience an especially strong takeoff in demand, with the price effect further strengthened by the supply bottlenecks that we've discussed. The question now at hand is whether this (partial) takeoff in the price of cognitive skills will be joined by a corresponding takeoff in the price of technical skills. As with cognitive skills, we think it's a mistake to address this question by treating technical skills as some unitary whole, given that the demand for specialized computer skills likely outstrips the demand for other science and engineering skills. This dramatic takeoff in the demand for computer skills reflects of course the increasingly central role of computer-based products and information technology in the U.S. economy (e.g., computerized diagnostic equipment, telecommunications, computer-aided design, automated inventory systems, database and network management). The resulting hypothesis is that demand in this particular sector has vastly outstripped supply and produced a sharp increase in the price of computer skill. Despite this simple expectation, a definitive estimate of the "computer premium" has proven elusive, as we lack a comprehensive model that can convincingly tease out that net premium. The existing analyses, beginning with Krueger's (1993) classic piece, are of course important and seminal but nonetheless are based on incomplete models and hence vulnerable to contamination by omitted skill variables (Black & Lynch 2001; Cappelli & Carter 2000; DiNardo & Pischke 1997).

Social skills: The SBTC account famously backgrounds discussion of trend in the premium to social skills even though such trend is likely a prominent feature of the third industrial revolution. It's been omitted from the SBTC account because trends in the "social premium" are largely responsive to institutional rather than technological shocks and hence don't fit SBTC's focus on technology as a prime mover (DiPrete 2007; Morris & Western 2008; cf. Garicano & Rossi-Hansberg 2004). There are two types of social skills that must of course immediately be distinguished, the first being high-status supervisory, motivational, and regulatory skills of the sort that managers and supervisors practice ("managerial skill"), and the second being lower-status nurturing and expressive skills of the sort that nurses, clergy, social workers, and other careworkers practice ("nurturing skill"). Although these two forms are very different in content, both would seem to be experiencing accelerating demand that can't be easily met by ratcheting up supply. The demand for managerial skill is increasing because of our "low road" strategy of motivating workers with intensive supervision (Gordon 1996) and because of an emerging global division of labor in which management and oversight is increasingly a U.S.-sited activity (whereas production and even service is carried out overseas).[2] The demand for nurturing skill has grown, by contrast, because the health care sector is burgeoning and because carework has been increasingly marketized (due to rising female labor force participation). For both types of social skills, the increases in demand haven't appeared to trigger corresponding increases in supply, and prices can therefore be expected to take off. The supply bottleneck for managers arises from a growing reliance on credential-based recruitment (e.g., the rise of the MBA), whereas the supply bottleneck for carework arises because women are now less likely to develop and pursue "tastes" for nurturing (England 2010; England & Li 2006). The low wages for carework were long underwritten by a ready supply of carework-primed women (England, Budig, & Folbre 2002), but such wages can't persist insofar as women now have new options and are socialized into more diverse tastes or preferences. The foregoing shifts in supply and demand thus work in concert and should produce increasing prices for social skills that may well match the technology-generated increases that SBTC features so prominently.

We have used the SBTC and postindustrial accounts as foils for developing a more comprehensive set of expectations about long-term trends in the returns to cognitive, creative, technical, and social skills. Although both accounts are useful starting points, they've arguably blinded us to the deskilling effects of some types of technology and to additional institutional sources of trend. We have suggested, for example, that technology may be working to suppress demand for some types of cognitive skills (i.e., verbal, quantitative), that the particular brand of market institutions that's recently emerged places a special premium on analytic skills, that previous estimates of the payoff to computer skills have been contaminated by unmeasured correlated skills, and that conventional technology-focused accounts have overlooked the forces making for a rising "social premium." The next section lays out the methods that we will use to assess these expectations.

Measuring skill and its determinants

The foundation to any credible estimate of the payout to skill is a strong individual-level model of earnings. We estimate our earnings model with microdata from the monthly outgoing rotation group supplement of the 1979-2010 Current Population Surveys (CPS-ORG). Although CPS-ORG data are available for each year from 1979 to 2010, the 1994 and 1995 surveys are unusable because allocated wages, which must be excluded from the analysis, aren't readily identified in those surveys.[3] We include all non-military wage and salary workers between the ages of 16 and 65 who are currently working and for whom a valid occupation and employment status code is available. We do not exclude part-time workers and instead include a control for part-time status. After imposing all restrictions, our surveys contain on average 65,939 men and 62,710 women per year, yielding a total of 1,978,175 men and 1,881,294 women (making for a grand total of 3,859,469).

Throughout the analyses presented here, earnings are measured as hourly wages. In the CPS-ORG data, workers who indicate that they are paid on an hourly basis are asked to report their usual hourly wages, and workers who indicate some other pay periodicity report their usual weekly wages. We follow here the conventional practice of calculating hourly wages for non-hourly workers by dividing weekly wages by the number of hours usually worked at the main job. We then convert hourly wages into constant 2005 dollars using the Personal Consumption Expenditures Price Index (see McCully, Moyer, & Stewart 2007). When wages have been truncated by the BLS to maintain confidentiality (i.e., "topcoding"), we have proceeded by multiplying such wages by 1.4, as is conventional (e.g., Card & DiNardo 2002). We then model logged hourly wages as a function of race, gender, sector, region, marital status, work experience, employment status, and education. These variables, which are presented in Table 1, are operationalized in standard ways, as reported in the stub to that table. This table further reports the means and standard deviations (where appropriate) for each of the variables.[4]

The centerpiece of our effort is a comprehensive measurement of workplace skill using occupation-level data from the Occupational Information Network (O*NET). The O*NET data, which includes both analyst and incumbent ratings of occupational skills, is a new resource designed to build on and extend the *Dictionary of Occupational Titles* (DOT). The "analyst ratings" of occupations are just the long-standing DOT expert ratings of occupational skills, but O*NET analysts have recoded them into the highly detailed occupations defined by the 2000 Standard Occupational Classification System (SOC). These ratings pertain, therefore, to occupational skills when the DOT was last updated, which for most occupations was in 1977 but for a small subset was in 1991. The O*NET archive also provides a new “incumbent database” with more recent evidence on occupational skills. These ratings were developed by identifying organizations that employ workers in targeted occupations, randomly sampling those workers, and then distributing a detailed survey of the occupational skills required in their jobs. This survey was designed to be consistent with the DOT analyst survey and hence the two ratings are nominally comparable, with the analyst ratings pertaining to occupational skills in 1977 (and in some cases 1991) and the incumbent ratings pertaining to occupational skills in the 2000s (see Peterson et al. 1999).[5] Although some incomparabilities may arise because the DOT ratings were completed by analysts and the O*NET ratings by incumbents, we have developed methods to purge those incomparabilities (which will be discussed below). The ratings on each skill variable range from 0 (low skill) to 6 (high skill) and are reported by O*NET as occupational means (averaged across all raters).

We have used the O*NET databases to build an eight-factor representation of workplace skill (see Felstead, Gallie, Green, & Zhou [2007] for a related scheme; also, Howell & Wolff 1991). The approach that we’re proposing stands or falls on the claim that we’ve captured the core nonmanual skills that, at least potentially, underlie the third industrial revolution. Because “skill” is such a sprawling cultural construction, we well appreciate that this is an ambitious claim, if nothing else one that we hope will trigger efforts by others to extend it. At minimum, our model is an improvement relative to (1) those that presume that skills are exclusively formed in schools, and (2) those that measure workplace skills unidimensionally in terms of computer usage.

As shown in Table 2, each of the eight factors captures a form of cognitive, creative, technical, or social skill, and each is measured as a composite based on two to fifteen indicators. The resulting loadings, which are also presented in Table 2, are based on a confirmatory factor analysis of the O*NET skills for the 494 occupations in the SOC scheme. These estimates come from a model that constrains the loadings for the incumbent and analyst skills to be equal (a constraint that ensures that the factors are constructed identically over time and are thereby nominally comparable).

The O*NET database is an important resource because its repeated measurements of occupational skill allow us to represent possible within-occupation changes in skill requirements (see Autor, Levy, & Murnane 2003; Spenner 1988). Until now, repeated measurements of skill haven't been available, and it's simply been assumed that the skill content of occupations is unchanging (Howell & Wolff 1991), an assumption that has of course been subjected to some criticism. Although the O*NET data provide an opportunity to address this issue, their most obvious limitation is that any observed changes in skill may in part reflect the switch from analyst to incumbent coding. It's plausible, for example, that incumbents tend to exaggerate the importance of highly desirable skills, a bias that could then create the appearance of skill upgrading across the two skill ratings. This possible bias suggests a purging strategy in which we first identify occupations for which any skill change is highly implausible and then compare the analyst and incumbent ratings for those occupations. If we're indeed willing to stipulate that the true skill level is unchanged for such occupations (based on qualitative accounts of those occupations), this approach allows us to identify and estimate the size of the "incumbency" bias and then apply it to calibrate the incumbent and analyst scores. We've thus proceeded by selecting, for each of the eight skill dimensions, a subset of occupations that are unlikely to have experienced skill changes in the last 30 years. The following simple regression can then be estimated for those occupations:

$$IN_i = \alpha + \beta(AN_i) + \varepsilon_i \qquad (1)$$

where i indexes the occupations (for each type of skill) presumed to have no true change in skill level, IN_i refers to the incumbent score for the i^{th} occupation, and AN_i refers to the analyst score for the i^{th} occupation.[6] We next applied our estimate of α and β (for each skill type) to convert the 1977 analyst ratings into the same metric as the incumbent ratings. The final step is to assume that change is linear and therefore interpolate to secure purged occupational skill scores for all years between 1979 and 2010.

The foregoing analyses are of course complicated by virtue of changes in the SOC occupational scheme in the 1983, 1992, and 2003 CPS-ORG surveys. The O*NET ratings are only available for 2000 SOC codes, yet the CPS-ORG data are coded into simpler precursor schemes for all years prior to 2003. How, then, can we assign skill ratings to occupations appearing in these precursor schemes? This problem is easily addressed because the Bureau of Labor Statistics (BLS) has double-coded the occupations of a subset of respondents (see Weeden 2005). With the double-coded results in hand, we can identify the subset of 2000 SOC occupations into which the incumbents of precursor occupations would have been coded, thereby allowing us to calculate the rating for a precursor occupation as a simple weighted average of the ratings for the constituent 2000 SOC occupations. We've relied on this approach throughout the analyses described above.

The means for each of the eight skill factors are presented in Table 3 (as averages across all CPS-ORG years). As might be anticipated, generalized cognitive skills (verbal, analytic, nurturing) have the highest average scores, while more specialized skills (science and engineering, quantitative, computing) have the lowest. In Table 4, we list the occupations that rank highest on each of the skill factors, a list that again reveals largely predictable and reassuring results, such as high quantitative scores for mathematicians, high creative scores for architects, and high nurturing scores for clergy. The correlations between the skill factors, presented in Table 5, are only moderately strong and quite inconsistent with the standard presumption that a single dimension underlies the skill space.[7] In Table 6, it's further revealed that the corresponding skill measurements for 1977 and 2008 are strongly intercorrelated, a result that implies that intra-occupational change in skill is glacial. The lowest correlation, .789, is found for the computing factor, which is hardly surprising given that computing has transformed many (but not all) occupations over the last 30 years. The other correlations all imply rather more stability. The implication: If a major upgrading in skill is to be found, it will either be confined to computing alone or be driven by changes in the mix of occupations rather than within-occupation changes in skill content.

Trends in the revealed demand for skills

But all of the foregoing is mere stage-setting. The first results of real substantive interest, presented here in Figure 1, speak to the types of skills that are becoming more or less prominent in the third industrial revolution. The data points of Figure 1 have been calculated by attaching our eight occupation-level factor scores to CPS-ORG microdata and then fixing the

1979 starting point at one (for all factors). The trends revealed here are driven by changes in the skill content of occupations as well as by economy-wide changes in the mix of occupations.

The first conclusion of interest is that, with but one exception (i.e., science and engineering), we find an across-the-board upgrading in cognitive, creative, technical, and social skills. Although an overall trend of upgrading is hardly surprising, it is nonetheless striking that the trend is so far-reaching as to cut across nearly all types of skills. The rate of upgrading is at the same time quite variable. It's especially notable that cognitive skills, which have long been featured in discussions of skill upgrading, are growing at a comparatively slow rate over the last three decades (with a total increase of just 3.6, 5.0, and 5.8 percent for verbal, quantitative, and analytic skills respectively). The suppressed growth for verbal and quantitative skills is consistent with our previous suggestion that new computer technologies (e.g., tax programs) may have a deskilling and demand-reducing effect for some quantitative and verbal skills.

What types of skills are, by contrast, taking off at an especially fast pace? The rising demand for computer skills is of course prominent (see Figure 1c) and stands in sharp contrast to the flat trend line for other technical skills (i.e., science and engineering). In the introduction, we characterized the SBTC literature as two-headed, with some commentators focusing on the growing demand for generalized cognitive skills and others focusing on the growing demand for more specific and technical computer skills. When skill is represented in unidimensional terms, it's easy of course to conflate these two dimensions, indeed one can do so without even appreciating the conflation. However, when the conceptual distinction *is* properly made, it reveals an especially sharp takeoff in computer skills, just as the computer-focused variant of SBTC would evidently have it.

The latter result is accordingly quite consistent with at least one strand of the SBTC account. By contrast, the account is more vulnerable on the matter of managerial skills, which are shown here to be in increasingly high demand (Figure 1d). This takeoff in managerial skills has not, to our knowledge, been much remarked upon in SBTC circles (cf. Piketty & Saez 2006; Autor 2010), although it has of course long been featured in the literature on managerial capitalism (see Mizruchi 2007 for a review). But even the latter literature hasn't always anticipated results as striking as those of Figure 1d. In fact, some commentators have pointed out that new monitoring technologies (e.g., software-based supervision in call centers) can replace many types of supervisorial labor, thus attenuating the demand for mid-range managerial skill (e.g., Garicano & Rossi-Hansberg 2004; Milgrom & Roberts 1990). The results of Figure 2d imply that, even if such suppression has occurred, it hasn't undermined one of the most prominent forms of upgrading of our time. We can conclude that, by the metric of revealed demand, the third industrial revolution is as much a social revolution as a technical one (see Jackson 2006, 2007 for a related conclusion).

Trends in the price of skills

The next objective that we take on is to tease out trends in the payoff to cognitive, creative, technical, and social skills. We care about such trends because they speak to (2) who's getting ahead in the third industrial revolution, (2) the types of skills for which supply bottlenecks might be in play, and (3) the sources of the takeoff in inequality. We will evaluate the evidence on payoffs in light of the expectations outlined in the introduction.

We proceed by way of estimating a hierarchical linear model (e.g., Raudenbush & Bryk 2002). This model takes the following form:

$$\ln Wage_{ij} = \beta_{0j} + \sum_{p=1}^{P} \beta_p X_{pij} + r_{ij}$$

$$\beta_{0j} = \gamma_{00} + \sum_{s=1}^{S} \gamma_s Z_{sj} + \mu_{0j} \qquad (2)$$

where i refers to individuals, j refers to occupations, p indexes the variables in the individual-level equation (and P refers to the number of such variables), s indexes the variables in the occupation-level equation (and S refers to the number of such variables), and X_{pij} and Z_{sj} are the p^{th} and s^{th} variables in the individual-level and occupation-level equations.

The individual-level model is intended to remove compositional differences across occupations and thus allow the true effects of skills on wages to be revealed. These compositional differences, if left uncontrolled, could of course bias our estimates of returns on skill. There are many ways in which such bias could play out. The returns to creativity, for example, may be overestimated in the absence of a control for metropolitan residence, with such bias arising because (1) creative skills are in heaviest demand in metropolitan areas (e.g., screenwriters in Hollywood), and (2) labor is paid a premium in metropolitan areas (a premium that may be interpreted either as a causal effect or as reflecting omitted measures of human capital among metropolitan workers). This type of bias could create an artifactual trend in the price of creativity insofar as creative occupations are increasingly practiced in metropolitan areas (or insofar as the effect of metropolitan residence on earnings has changed).

It's likewise the case that individual-level effects may be biased when they're estimated in models that don't take workplace skill into account. This possibility is arguably most troubling in assessing the individual-level returns to schooling. Because a conventional estimate of such returns ignores the effects of workplace skills, this estimate can be understood as a weighted combination of (1) the effects of the educational skills themselves (i.e., the "direct effect"), and (2) the extent to which the educational credential propels its recipients into workplaces that then provide further training for which there is further payoff (i.e., the "allocative effect"). It's of course possible that skill-biased technical change could operate by increasing either the direct or allocative effect. If a particular technical change expresses itself by raising the returns to certain occupations that are mainly staffed by the well-educated (e.g., an increased demand for computer programming), then one would expect the rising payoff to express itself via the allocative effect. If, however, it operates by opening up new opportunities for some, but not all, occupational incumbents (e.g., new computing software that's disproportionately exploited by well-educated programmers), then the rising payoff will be expressed as a direct effect. The SBTC approach has never accorded much of a role to occupations (but see Acemoglu & Autor 2010) and hence is predisposed to direct effects, whereas the postindustrialist variant has a more sociological, occupation-emphasizing heritage and hence is predisposed to allocative effects (see Carbonaro 2005, 2006, 2007; Barone & van de Werfhorst 2011).

Which of these two approaches is on the mark? The results of Figure 2a and 2b, which provide the first estimates of trend in the direct and allocative effects of education, make it clear that the direct effect is increasingly comparatively slowly.[8] As shown in Figure 2a, the total effect of college increases from .55 to .76 from 1979 to 2010, whereas the direct effect only increases from .32 to .38 over the same period. The trend in the high-school premium (see Figure 2b) is less dramatic but is again driven mainly by an increase in the allocative effect. We can conclude that the payoff to schooling is rising mainly because it allocates workers into increasingly well-paid occupations. This result, which is consistent with a sociological account of the third industrial revolution, makes it clear that much hinges on understanding trends in the effects of workplace skills. Although such trends have been largely ignored in the literature, in fact it's where most of the change is to be found

The remainder of the individual-level coefficients, which we've presented in Figures 3a to 3d, is of less interest for our purposes. These figures reveal a host of well-known trends, including the declining penalty to being a woman, the declining penalty to residing in the South, and the increasing returns to experience in the 1980s. We won't discuss Figure 3 in any further detail because we regard our individual-level variables mainly as nuisance controls applied for the purpose of securing unbiased estimates of workplace skill. It's nonetheless important to bear in mind that the occupational effect on wages (i.e., β_{0j}) is net of the effects represented in Figures 2 and 3.

The estimates for workplace skill are presented in Figure 4. The first and most important conclusion coming out of this figure is that the payoff to workplace skill is *not* increasing in any simple across-the-board fashion. Of our 8 skill measures, the payout for only four is increasing (analytical, computer, managerial, nurturing), while the payout for three is decreasing (quantitative, analytical, creative), and the payout for one is stable (S&E). This result is inconsistent with postindustrial or SBTC accounts that treat skill in an undifferentiated fashion and imply that the payout for all skills should be rising. If one wishes to explain the rise of inequality through skill bias, it surely doesn't help that some skills have a diminishing payoff (i.e., converging to zero) and are therefore introducing ever less heterogeneity into the wage distribution. The steady increase in the *demand* for most skills is of course consistent with a postindustrial or SBTC account (see Figure 1). However, because such changes don't reliably translate into a rising payoff, any account of the takeoff in inequality has to be more complicated than the standard commentary has it.

Although skill is treated in undifferentiated ways by most SBTC and postindustrial theorists, there are also variants of these accounts that imply an especially prominent takeoff in the payout to cognitive skills (e.g., Bell 1979) or computer skills (e.g., Krueger 1993). The results in Figures 4a and 4b suggest that we cannot salvage these more delimited accounts. In Figure 4a, we find that the payout to verbal and quantitative skills is actually decreasing, a result that's consistent with the somewhat anemic demand for such skills revealed in Figure 1a. By contrast, the payout to computer skill is increasing (see Figure 4c), but it's not a very steep increase and can hardly figure prominently in explaining the takeoff in inequality. The upshot is that neither a generic or delimited version of SBTC receives much support in Figure 4.

There's just one type of cognitive skill for which the payout is indeed taking off. As Figure 4a reveals, the rising returns to analytic skill are quite spectacular, indeed the increase is far in excess of that for any other workplace skill. We aren't aware of an SBTC or postindustrialist account that singles out analytic skill in a way consistent with this result. In fact, both Bell (1999) and Gouldner (1979) place rather more emphasis on the rise of purely technical knowledge, as do many SBTC analysts (e.g., Krueger 1993). Why, then, are analytic skills the unexpected winner over the last three decades? We've already suggested that the demand for analytic skills may be increasing because (1) they require intuitive problem solving that can't easily be substituted with computer programming or software (unlike quantitative and verbal skills), and (2) the accelerating "creative destruction" of modern capitalism places a growing premium on innovation, problem solving, and rapid response to changing market conditions (e.g., Schumpeter 1942; Castells 2000). On the supply side, elite university credentials are now required for virtually all analytic positions, yet such credentials are rationed rather than sold in some profit-maximizing fashion. The resulting supply-demand imbalance should bring about rising returns of the sort revealed in Figure 4a.[9]

The case of creative skill provides an instructive contrast. Although analytic and creative skills are both in increasingly high demand (see Figures 1a and 1c), the payout to creative skills is, unlike that for analytic skills, rapidly deteriorating. As Figure 4c shows, in fact there's been a long-standing wage penalty to creative skills, a penalty that speaks to the widespread taste for creative work and an associated willingness to forego earnings for the privilege of holding a creative job. The more striking result of Figure 4c, however, is that this wage penalty is growing ever larger, even as the demand for creative work increases and even as some commentators (e.g., Florida 2002) celebrate the rise of a creative economy. What drives the decline? It's long been argued that the postmaterialist turn (e.g., Inglehart 2008) is creating a burgeoning class of would-be dancers, journalists, poets, sculptors, creative writers, artists, and all manner of associated creative types. The simple hypothesis here, and it's obviously no more than that, is that late industrialism creates a reserve army of workers who are captivated by creative work and hence drive down wages (despite the rising demand for such labor).

The SBTC and postindustrial accounts also haven't attended much to the rising demand for social skills, an omission that arises because this development is again driven by institutional forces (e.g., the growing marketization of carework), not the conventionally privileged technical ones (cf. Garicano & Rossi-Hansberg 2004). We've already shown that the demand for social work, both in its managerial and nurturing forms, has taken off in the third industrial revolution (Figure 1d). In Figure 4d, we now show that the payoff to managerial and nurturing skills are also increasing, albeit from very different bases. The penalty to nurturing skill was once quite substantial, but over the course of thirty years that penalty diminished by a full 61.3 percent. The premium to managerial skill started off, by contrast, from a small positive base and has risen by 78.2 percent from 1979 to 2010. These results suggest that increases in demand haven't triggered corresponding increases in supply. In the introduction, we speculated that a supply bottleneck for managers arises from a growing reliance on credential-based recruitment, whereas a supply bottleneck for carework arises because women are now less likely to develop and pursue "tastes" for nurturing (Grusky & Weeden 2011). As England (2010) has noted, gender-typed tastes have evolved in very asymmetric fashion, with women adopting characteristically male tastes without men in turn adopting characteristically female tastes. This asymmetric pattern to change is likely responsible in part for a burgeoning supply bottleneck for nurturing skill and consequent higher prices for that skill.

The foregoing trends are summarized in Figure 5. The bars presented here index the effect on wages of a standard deviation increase in each of the eight skills. For example, a standard deviation of analytical skill raised wages by 9.0 percent in 1979 and 21.7 percent in 2010, an increase in the payout that's far in excess of that observed for any of the other workplace skills. The trends in the returns to social skill are less striking but also substantial, with the premium for a standard deviation of managerial skill doubling from 3.6 to 7.2 percent, and the penalty to a standard deviation of nurturing skill declining from 9.4 to 3.9 percent. The wage penalty for a standard deviation of creative skill has, by contrast, increased from 7.3 to 13.8 percent. We turn next to considering how these trends, which haven't been well appreciated in the literature, require us to revise our understanding of the takeoff in earnings inequality.

Skill and inequality

We've made much of the failure of both the SBTC and postindustrial accounts in characterizing how skill payouts are changing. The main failures, as we've stressed, involve (1) misrepresenting the third industrial revolution as a purely technical response to rising computer use, (2) misunderstanding that only some cognitive skills, in particular analytic ones, have experienced sharply increasing payoffs, and (3) misappreciating the important role of social skills in the third revolution. The simple conclusion: We haven't done a good job of identifying the types of skills that are playing a leading role in the contemporary economy. The inveterate SBTC theorist might nonetheless point out that, even if there's been some misunderstanding of the types of skills in play, it's still appropriate to characterize the third industrial revolution as driven by changes in the supply and demand for skill. Is this fallback claim indeed on the mark? We turn next to the question of whether long-run changes in the payoff to skill and the distribution of skill are crucial in understanding rising inequality.

In addressing this question, it should be recalled that rising earnings inequality is increasingly driven by the between-occupation component of inequality, although the within-occupation component is also growing at a slower rate. This result is now well established (e.g., Weeden, Kim, DiCarlo, & Grusky 2007; Mouw & Kalleberg 2010; Acemoglu & Autor 2010). The one discrepant piece of evidence, an unfortunately influential piece by Kim and Sakamoto (2008), can be attributed to a mishandling of missing values and doesn't in the end challenge the general result (see Mouw & Kalleberg 2010). This research stream thus implies that the task of explaining the rise in between-occupation inequality is important because it underlies the overall rise in inequality. The purpose of the next set of analyses is to build on this result by asking whether (1) the between-occupation component to inequality can be explained in terms of workplace skill, and (2) the growth in that component is attributable to the changing payoff to and distribution of workplace skill.

The answer to these questions is provided in Figure 6. The upper line of Figure 6, which graphs the residual variance when all measures of workplace skill are omitted from the occupation-level equation, depicts the now well-known increase in the between-occupation component to earnings inequality (an increase that, as shown here, persists even after all individual-level controls are in place). The bottom line of Figure 6 reveals the extent to which this residual variance declines when our full model, now including the eight workplace skill measures, is estimated. The results from this decomposition reveal that our measures of workplace skill account for a rapidly growing share of between-occupation inequality. Indeed, while the explained share of between-occupation inequality stood at only 40.0 percent in 1979, it steadily increased to 61.4 percent by 2010. It follows that the striking growth in between-occupation inequality over the last three decades is entirely due to the changing payout to and distribution of skill. In fact, the unexplained residual variance is gradually growing smaller over time, even while the total residual variance is growing larger. The implication is that our skill-based account of rising between-occupation inequality proves to be a full and complete account.

We don't of course mean to suggest that our skill-based account is the same as the conventional SBTC skill-based account. Far from it. We've emphasized that the SBTC account falls short by virtue of misunderstanding (1) the way in which the payout to skill is changing, and (2) the way in which such changes are driven in part by institutional sources (as opposed to narrowly technological ones). It's nonetheless striking that the task of explaining the rise in between-occupation inequality devolves completely to the task of explaining changes in the payout to skill and the distribution of skill.

Although we can account for the takeoff in between-occupation inequality, we can't likewise explain the growth in within-occupation inequality (given that our model is based on occupation-level measures of skill). As shown in Figure 7, the total residual variance under our full multilevel model continues to rise, a result that entirely reflects the growing residual variance at the individual level. This result is of interest because it calls into question the frequent SBTC claim that rising inequality is attributable to the changing returns to unmeasured skill. It's very clear from Figure 7 that the residual variance continues to rise even though we've now measured skill quite comprehensively. By virtue of this result, the burden of proof should shift to those who would like to claim a yet larger role for skill, a claim that should now be documented by identifying exactly what the omitted measures are and bringing them into the model.[10] It's indefensible to continue to assume that the residual pertains wholly to unmeasured skill in light of the persistently large residual even in a model in which skill is quite comprehensively measured.

Conclusions

The starting point for this paper has been the seemingly obvious premise that any theory of inequality that rests fundamentally on the concept of skill would do well to measure that concept carefully. It's unfortunate that the postindustrial and SBTC theories, both still very popular, have carried on for so long without attending much to the concept of skill underlying them (cf. Heckman, Stixrud, & Urzua 2006; Heckman & Rubinstein 2001). The appeal of a new measurement model is, we appreciate, inherently limited and doesn't of course match that of a new theory or ingenious statistical test, but nonetheless we've reached a point in which meaningful headway can't be made without taking measurement more seriously. The practice of simply equating skill with schooling, while perhaps acceptable in the early tests of SBTC, should have long ago been superseded by an explicit and comprehensive measurement protocol. The rising payoff to schooling has been interpreted variously as support for a strikingly wide range of theories that, at least implicitly, refer to skill in multidimensional terms. Although the need for a properly multidimensional model of skill seems obvious in this context, the field has nonetheless preferred time and again to project all manner of theories on the unidimensional trend.

We've therefore turned to developing a framework that refers not only to general skills learned in school but also to more specialized cognitive, creative, technical, and social skills acquired in the workplace. The latter types of skill, while frequently referenced in the literature, have nonetheless been ignored in quantitative models of earnings, an omission we've sought to rectify. The first conclusion to be reached on the basis of our models is that there's much to appreciate in both SBTC and postindustrial accounts. However much sociologists like to debunk, there's no denying that some of our results are quite consistent with the conventional wisdom on the third industrial revolution, indeed in some cases our new measurement framework has merely allowed that conventional wisdom to better reveal and express itself. Most notably, we've reported here a rising demand for nearly all types of skill, including an especially sharp takeoff in the demand for creative skills, computer skills, and social skills. Although the rate of upgrading is less dramatic for some of the skills featured in the SBTC or postindustrial accounts (e.g., cognitive skills), the main conclusion to be emphasized is that we're experiencing upgrading of the sort that's long been suspected but never been entirely verified (save by treating rising educational investment as prima facie evidence). This brute fact of steady and across-the-board upgrading for a wide variety of cognitive, technical, creative, and social skills is an important backdrop to the third industrial revolution. To be sure, it's conjoined with a recently resurgent skill polarization (e.g., Autor & Dorn 2011; Esping-Andersen 2008), but it's important to be clear on the first moment of a distribution before turning to the second.

The second point of consistency, and again it's a fundamental one, is that changes in the payout to and distribution of skill are central to explaining the takeoff in income inequality. Over the last three decades, there's been a striking increase in between-occupation inequality, an increase that we can now completely and fully explain with our eight-factor measurement of skill (in conjunction with a conventional individual-level model of earnings). It follows that the SBTC and postindustrial accounts are on the mark in looking to skill for an explanation of rising inequality. As we'll discuss subsequently, the SBTC account isn't as useful in explaining *why* the returns to skill are changing, but it's important to give it credit for identifying skill as a key mediating variable, at least in explaining rising between-occupation inequality.[11] We're assuming, of course, that the SBTC faithful would regard our multidimensional representation of skill as a sympathetic revision of the account, a revision that simply entails recognizing that new technologies and institutions may be complementary with particular types of skill rather than with skill per se. If this revision is indeed accepted, we can conclude that the third revolution has an SBTC feel to it, founded as it is on skill upgrading and a skill-based takeoff in inequality.

The main problems with the conventional accounts arise when we look more closely at the *types* of skills that underlie the third industrial revolution. In all of our models, we've distinguished between the skills learned in school and those learned in the workplace, a distinction that proves to be fundamental in understanding the sources of the takeoff in inequality. The core result in this regard: The takeoff in income inequality is a consequence of changing returns to workplace skills rather than, as is typically supposed, changing returns to skills learned or selected for in school. When workplace skills are included in our models, the trend in the education premium flattens out, the implication being that there's no dramatic increase in the payoff to education within similarly-skilled occupations. If two workers with different levels of education enter the same occupation (or enter different occupations with the same skill levels), the better-educated worker will of course earn more but the extent of that within-occupation premium has not increased much over the last 30 years. We simply cannot understand the takeoff in inequality without refocusing our attention on the parameters that *are* changing rather than those that, by virtue of omitting workplace skills, have only appeared to be changing.

What do we find when the focus thus shifts to trends in workplace skills? In turning to this question, it has to be appreciated that there isn't any dominant narrative about the changing pattern of workplace skills, in fact the cacophony of voices on this particular question hasn't been as well appreciated as it should be. The most popular account, however, focuses on the "computer revolution" and the associated rising payoff to computer use and knowledge (esp. Krueger 1993). We've found that this account is but a partial one. The payout to computer skill is indeed increasing (see Figure 4c), but it's not a very steep increase and can hardly figure prominently in explaining the takeoff in between-occupation inequality. This result speaks to the obvious point that the net effect of computer skill can't be convincingly estimated without a comprehensive model of skill that parses out all potentially contaminating skills (see Black & Lynch 2001; Cappelli & Carter 2000).

We also considered two accounts that are motivated more by the postindustrialist literature than the SBTC literature. The classic postindustrial vision of Bell (1999), as updated by Esping-Andersen (2008) and others (e.g., Giddens 2008), emphasizes a "technocratic revolution" that raises the payout to various scientific and technical skills. This view garners little support in our full model. As Figure 4c reveals, the payoff to science and engineering skill is strikingly flat, in fact by the end of our three-decade times series it's been overtaken by the payoff to computer skills. We next examined the currently more fashionable version of postindustrialism emphasizing the payoff to creative skills rather than more narrowly technical ones (e.g., Florida 2002; Giddens 2008). The argument here, so far as it's laid out, is that contemporary capitalism is defined by a creative revolution that raises the marginal product of and payoff to creative labor. We again find little support for this hypothesis. To the contrary, there's a net penalty to creative skill, a penalty that's actually growing in size over the last three decades. Here again, our suspicion is that "creative class" accounts have rested on a conflation of soft creative labor (e.g., writing novels) with hard analytic labor (e.g., marketing derivatives), a conflation that we've identified and resolved by operationalizing the dimensions and fitting the full model.[12]

We've suggested so far that the third industrial revolution is not a computer revolution, not a technocratic revolution, and not a creative revolution. What type of revolution is it? The most striking result from our model is that rewards are increasingly going to those who engage in critical thinking, problem solving, and deductive reasoning. The payout to a standard deviation of such "analytic skill" was already large in 1979, but it increased by a factor of 2.41 over the course of the next 31 years (see Figure 5). The return to managerial skill also increased rapidly and, by 2010, was higher than that of any other skill except analytical. It follows that there are two roads to getting ahead in the third industrial era, the first being problem solving, innovation, and critical thinking (i.e., the "intellectual road"), and the second being direct authority and supervision (i.e., the "command road"). The payoff to technical skill (e.g., computer use), which is typically featured in discussions of the third industrial revolution, has been oversold and simply doesn't compare to the payoff to analysis and command.

We suspect that scholars have become fixated on computers because of the presumption that technical change is the main force behind the changing payoff to skill. The evidence from our models suggests that, contrary to this view, the real driving force is skill-biased institutional change rather than skill-biased technical change. The role of institutions in generating skill-biased change is twofold. First, the changing demand for skill often originates in institutional change rather than technical change, an obvious example of this process being the effects of rising female labor force participation on the demand for childcare, nursing, and other nurturing skills. As women increasingly enter the formal economy, many types of formerly domestic work are gradually marketized, and the demand for nurturing skills accordingly increases. Likewise, the rising demand for managerial work partly reflects our institutional commitment to "low-road" supervisory forms of organization, while the growing demand for analytic labor reflects the accelerating "creative destruction" of modern capitalism and the associated premium on innovation, problem solving, and rapid response to changing market conditions. These institutional changes would not appear to be simple reactions to technical change. When the world is nonetheless viewed through the blinders of technical change, the result is stories about the rising payoff to technical skill that ignore how broader institutional developments have also changed the demand for analytic and social skills.

But it's not simply that institutional change often drives the demand for skill. Even more importantly, our institutions also affect how labor responds to changes in demand, in particular whether labor can take advantage of rising prices for particular skills by acquiring them. If the labor market doesn't allow workers to freely flow to such opportunities, then the price of some skills can remain high for protracted periods of time. We've laid out many examples of such supply bottlenecks. The price of analytic labor, for example, remains unusually high because analytic positions are typically only open to workers with elite educational credentials, and such credentials are rationed out by major private universities rather than freely sold on the market

(Grusky & Weeden 2011). The supply bottleneck for nurturing skill is partly attributable, by contrast, to an emerging commitment among enlightened parents, teachers, and peers to draw out and cultivate a broader range of talents among girls and young women (see England 2010).

We don't of course mean to set up some disciplinary horse race in which sociologists root for the institutional horse and economists for the technical one. Although we're all prone to some amount of disciplinary flag-bearing, obviously what matters most is ensuring that the lens through which the third industrial revolution is viewed are a full and complete one. The ruthlessly technical lens misses in particular the rise of a new fast-moving form of capitalism in which market conditions change rapidly, stock markets become difficult to fathom, product cycles become shorter, and the payoff to inspired and insightful analysis is accordingly ratcheted up. It doesn't hurt, moreover, that the winners of this analytic contest have access to increasingly global markets and are therefore increasingly big winners. The financial analyst who devises, for example, a successful new insurance product stands to reap substantial returns from a market that's now virtually global. With a few important exceptions (Frank & Cook 1996; Saez 2009), the inequality literature has ignored the role of globalization in opening up new opportunities for the privileged, preferring instead to focus on how it harms the less privileged by weakening unions and exposing them to competition from foreign workers (see Western & Rosenfeld 2011). The rising return to analytic labor suggests that globalization may be a many-headed Hydra that increases inequality not just by undermining returns at the bottom of the class structure but also by affording new opportunities to collect marginal product and rent at the top.

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Endnotes

[1] This is not to gainsay the equally important evidence of recent polarization in labor demand. For example, Autor and Dorn (2011) report evidence of rapid growth in both high-skilled *and* low-skilled jobs, thus creating an increasingly bimodal distribution of skill. This new development is an important counterpoint to the long-standing and continuing growth in demand for skilled labor.

[2] The increasingly high pay of managers may also be attributed to new institutional practices (e.g., linking pay to stock performance) that allow them to more easily extract rent (Bebchuk & Wiesbach 2009; DiPrete, Eirich, & Pittinsky 2010; Grusky & Weeden 2011; cf. Murphy & Zabojnik 2008, Gabaix & Landier 2008).

[3] Wages are allocated according to the worker's major occupational group. Because our analysis is based on detailed occupations, allocated wages are likely to introduce non-trivial biases, and we have therefore included only those CPS surveys for which workers with allocated wages can be identified and omitted.

[4] We've also experimented with models that measure the effects of education more exhaustively. We've estimated, for example, a model that fits effects for years of schooling, a high school degree, a college degree, and a postgraduate degree (in the individual-level model of Equation (2)). Because this specification changed the results only trivially, we've opted throughout to present our results in terms of the more economical specification of education (that only includes effects for high school and college degrees).

[5] The O*NET surveys were first administered in 2001 but were designed to be distributed on a rolling basis and hence continued through 2008.

[6] For ease of presentation, we've suppressed here our decision to estimate such regressions separately within each major social class (i.e., managerial, professional, service, sales, construction, production), a decision that was made because of possible class differences in how skills are evaluated. If the service worker, for example, has a greater interest in exaggerating nurturing skills than does the production worker, this will generate class differences in our estimates of α and possibly β.

[7] In the regression analyses described below, we've also experimented with a unidimensional specification (in which all O*NET measures in Table 2 load on a single skill factor), and we've found that it explains far less of the between-occupation variability in earnings than our eight-factor specification.

[8] We have estimated the total college and high school effects by omitting the second equation in Equation (2) and replacing β_{0j} with β_0 in the individual-level equation. The net effects come directly from the model of Equation (2).

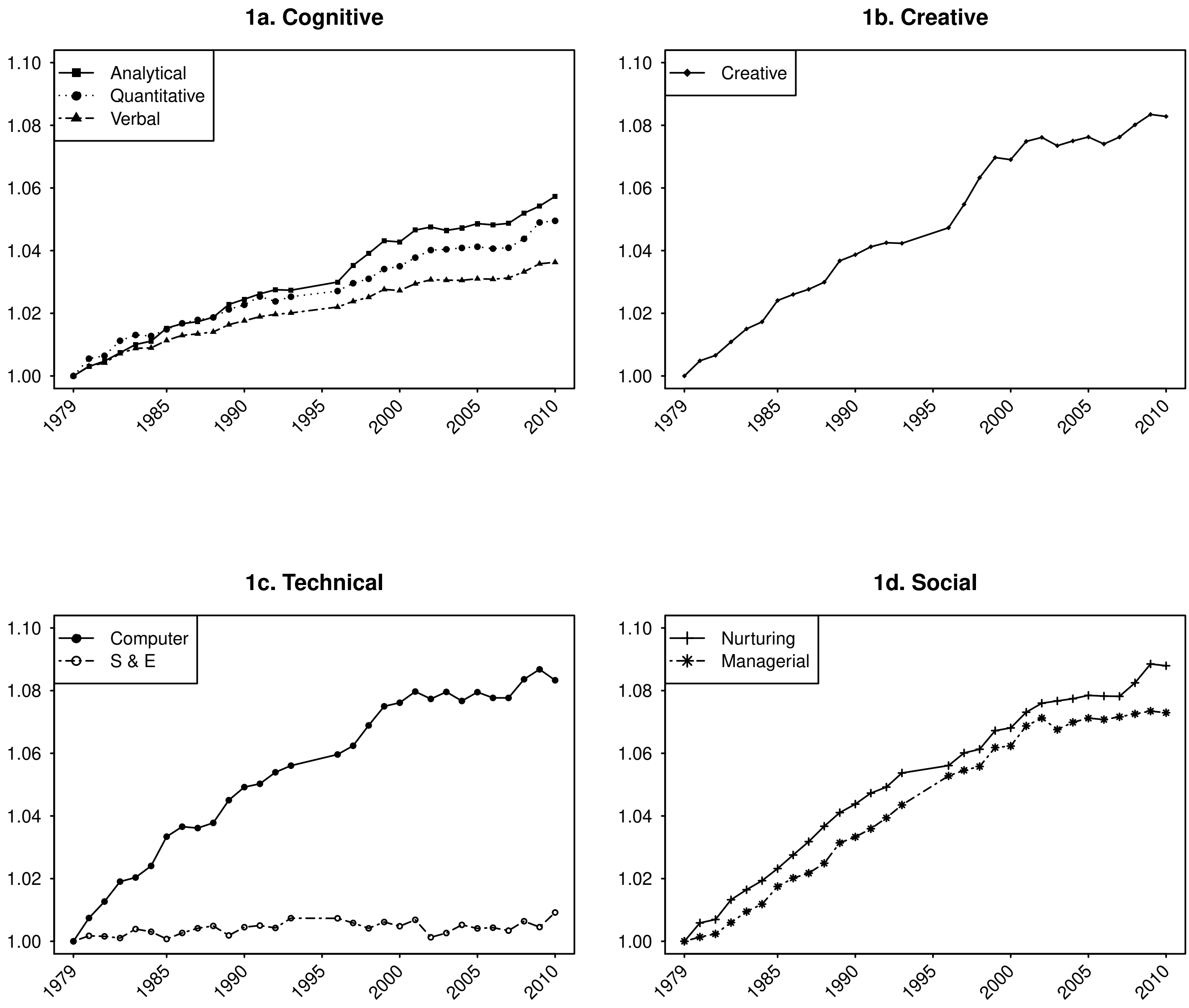
[9] Although the skeptic might attribute this trend to a growing effect of intelligence on earnings (Herrnstein & Murray 1994), the available evidence suggests that the net effect of intelligence is in fact quite small once schooling is controlled (Hauser 2010; see also Ashenfelter & Rouse 2000; Cawley, Heckman, Lochner, & Vytlacil 2000).

[10] The obvious next step in this regard would be to incorporate measures of "noncognitive skill" (e.g., Heckman, Stixrud, & Urzua 2006; Heckman & Rubinstein 2001). Although it's likely that some of the residual variance in Figure 7 can be explained with individual-level measures of noncognitive skill, it's also possible that such measures will work mainly to allocate individuals to occupations of different skill types.

[11] Although within-occupation inequality has also increased during this period (albeit at a slower rate), our model cannot of course explain that increase because it measures skill at the occupational level.

[12] In defense of the "creative class" hypothesis, it bears noting that we're imposing a more delimited definition of creative labor than some scholars might prefer, indeed we suspect that many would consider analytic labor as just another form of creative labor. We aren't opposed to such relabeling (as the label that's affixed to the phenomenon is quite irrelevant). The results that we've secured here simply make it clear that, insofar as analytic and creative labor *are* distinguished, it's the analytic component that's experiencing the takeoff in returns.

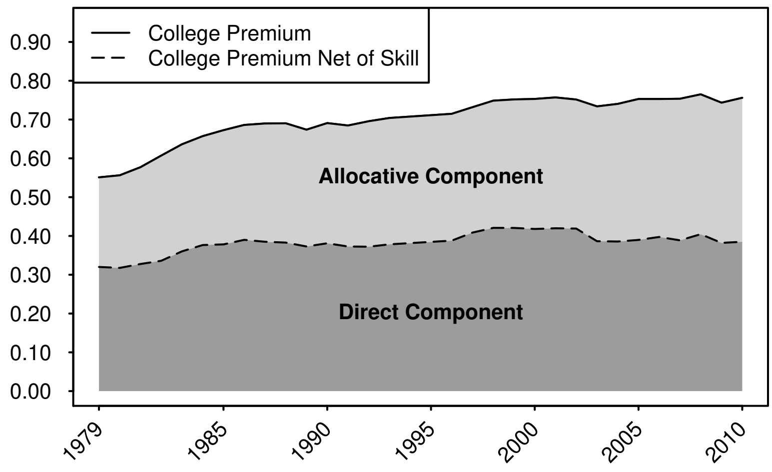
Figure 1. Trends in Revealed Demand for Skill



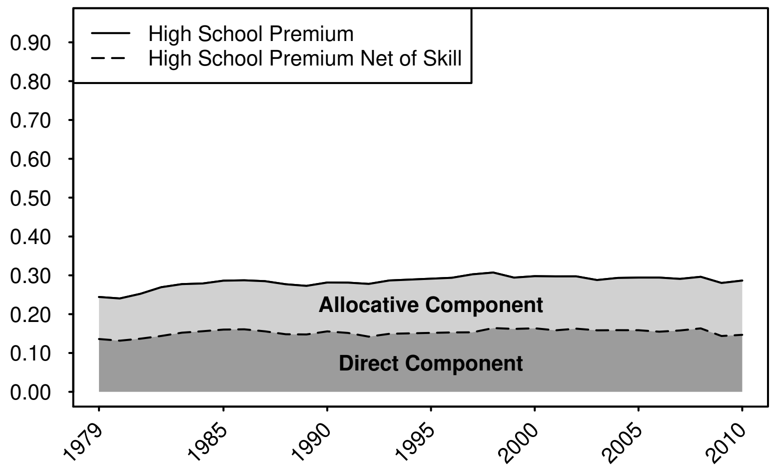
Source: 1979–2010 Current Population Surveys (CPS–ORG) with appended Occupational Information Network skill ratings.
See Table 2 for description of skill factors.

Figure 2. Decomposing the Education Premium into Direct and Allocative Components

2a. College



2b. High School



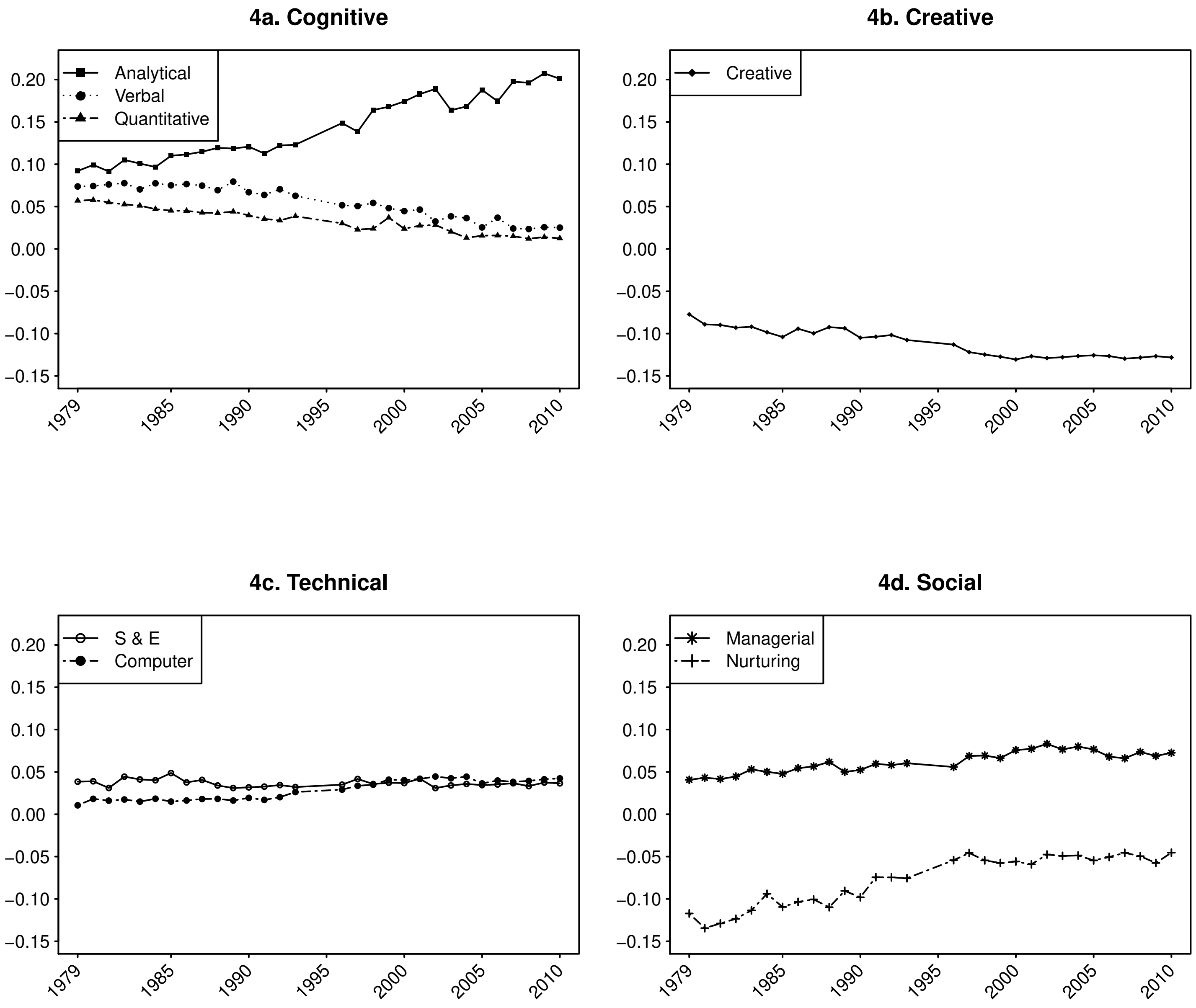
Source: 1979−2010 Current Population Surveys (CPS−ORG).

Note: The college and high school effects are estimated by omitting the second equation in Equation (2) and replacing β_{0j} with β_0 in the individual−level equation. The net effects come directly from the model of Equation (2).

Figure 3. Wage Effects of Individual–level Variables

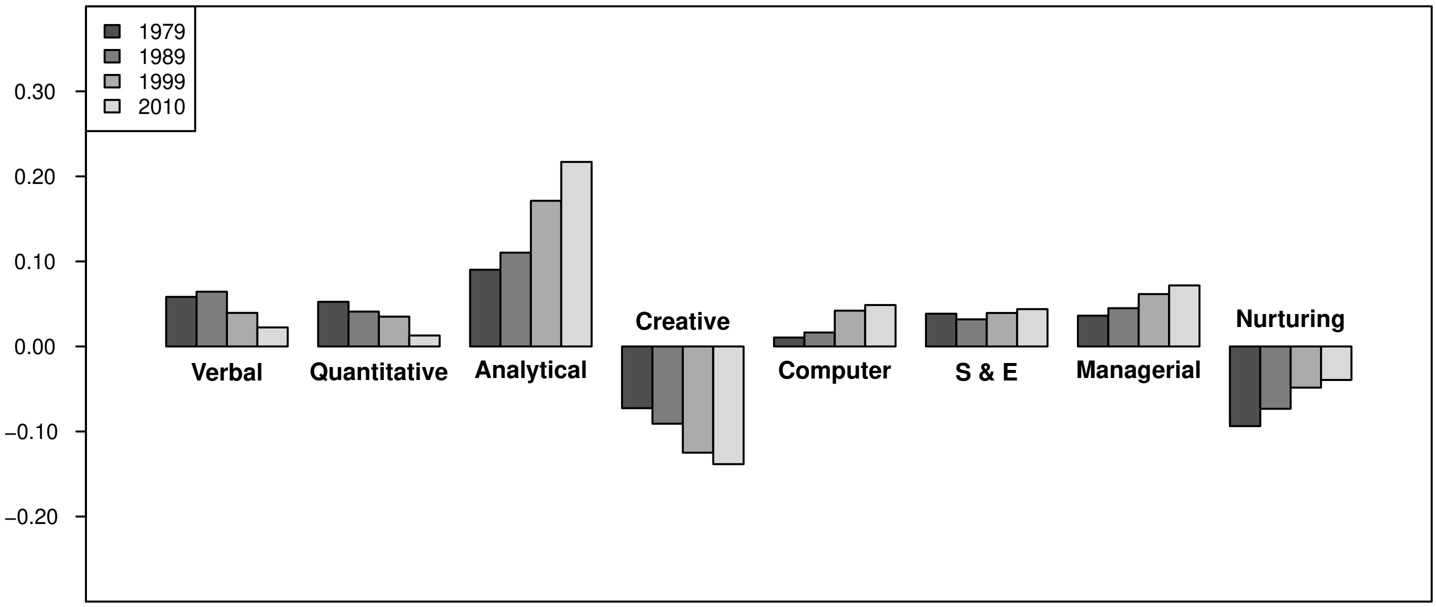
Source: 1979–2010 Current Population Surveys (CPS–ORG).
Note: Estimated from the model of Equation (2). The experience coefficient is multiplied by 10 for ease of presentation.

Figure 4. Wage Payoff to Workplace Skills



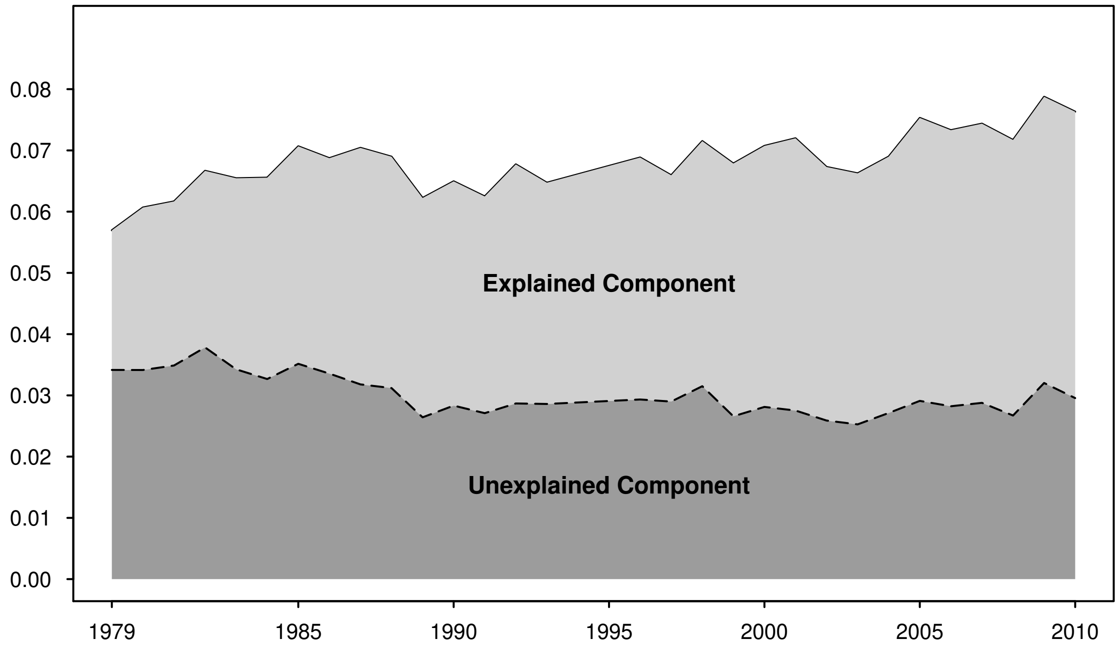
Source: 1979–2010 Current Population Surveys (CPS–ORG).
Note: Estimates are from the model of Equation (2).

Figure 5. Wage Effects for a Standard Deviation Increase in Workplace Skill



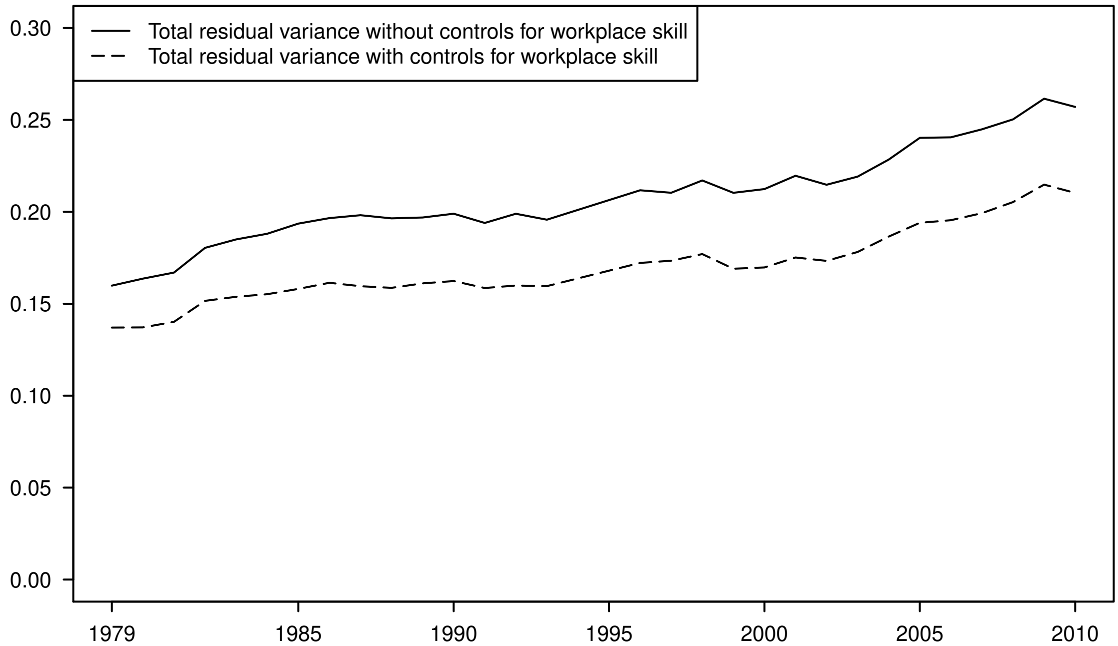
Source: 1979−2010 Current Population Surveys (CPS−ORG).
Note: Estimates are from the model of Equation (2).

Figure 6. Decomposing the Between−Occupation Residual Variance into Explained and Unexplained Components



Source: 1979−2010 Current Population Surveys (CPS−ORG)
Note: The upper line depicts the variance of V_{0j} in Equation (2) after omitting the workplace skill regressors, and the lower line depicts the variance of V_{0j} in Equation (2) with those regressors included.

Figure 7. Total Residual Variance With and Without Controls for Workplace SKill



Source: 1979–2010 Current Population Surveys (CPS–ORG).
Note: The upper line depicts the total residual variance from the model of Equation (2) after omitting the workplace skill regressors, and the lower line depicts the total residual variance with those regressors included.

Table 1. Means and Standard Deviations of Individual-Level Variables

Variable		Mean	S.D.
Wage	Natural log of hourly wage	2.60	0.60
Race	Black	0.08	-
	Hispanic	0.09	-
Gender	Female	0.49	-
Sector	Manufacturing industry	0.17	-
	Public sector	0.18	-
Spatial	Metropolitan	0.75	-
	South	0.29	-
Demographic	Not married	0.40	-
	Work experience	18.91	12.41
	Part time worker	0.18	-
Education	College degree or higher	0.26	-
	High school degree	0.60	-

Source: 1979-2010 Current Population Surveys (CPS-ORG).
Notes: Means and standard deviations are averaged across the survey years. "White" is the omitted category for race, and "high school dropout" is the omitted category for education. Work experience is calculated as Age-(Years of Schooling)-5.

Table 2. Indicators and Weights for Workplace Skill Factors

Indicators and Weights		Indicators and Weights	
<u>**Cognitive**</u>		<u>**Creative**</u>	
Verbal		***Creative***	
Oral comprehension	0.117	Originality	0.310
Written comprehension	0.116	Thinking creatively	0.244
Oral expression	0.116	Innovation	0.259
Written expression	0.119		
Reading comprehension	0.114	<u>**Technical**</u>	
Active listening	0.110	***Computer***	
Writing	0.115	Programming	0.231
Speaking	0.112	Computers and electronics	0.277
		Interacting with computers	0.312
Quantitative			
Mathematical reasoning	0.317	***Science and Engineering***	
Number facility	0.280	Operations analysis	0.114
Mathematics	0.288	Technology design	0.163
		Engineering and technology	0.140
Analytical		Design	0.123
Fluency of ideas	0.101	Mechanical	0.145
Problem sensitivity	0.108	Physics, Chemistry, Biology	0.088
Deductive reasoning	0.119		
Inductive reasoning	0.120	<u>**Social**</u>	
Critical thinking	0.114	***Managerial***	
Active learning	0.108	Management of financial resources	0.125
Learning strategies	0.111	Management of material resources	0.141
Problem identification	0.108	Management of personnel resources	0.138
Information gathering	0.104	Admin and Management	0.153
Information organization	0.105	Developing and building teams	0.117
Synthesis and reorganization	0.120	Directing and motivating subordinates	0.124
Idea generation	0.115		
Idea evaluation	0.118	***Care Work***	
Implementation planning	0.104	Service orientation	0.490
Solution appraisal	0.104	Assisting and caring for others	0.405

*Source: Occupational Information Network (O*NET).*
Note: The weights have been constrained to sum to one for each factor.

Table 3. Means of Occupational-Level Variables

Variable	Mean
Cognitive	
Verbal	3.54
Quantitative	2.57
Analytical	3.30
Creative	2.73
Technical	
Computer	2.57
Science & engineering	2.09
Social	
Managerial	2.73
Nurturing	3.19

*Source: 1979-2010 Current Population Surveys (CPS-ORG) with appended Occupational Information Network (O*NET) skill ratings.*
Note: Means are averaged across the survey years.

Table 4. Top-Ranked Occupations for Each Skill Type

Skill Type	Examples of Top-Ranked Occupations
Cognitive	
Verbal	Chief Executives, Economists, Lawyers, Technical Writers, Education Administrators, Judges, Magistrates, & Other Judicial Workers, Psychologists, Advertising & Promotions Managers
Quantitative	Mathematicians, Nuclear Engineers, Aerospace Engineers, Financial managers, Statisticians, Economists, Actuaries, Financial Examiners
Analytical	Medical Scientists, Nuclear Engineers, Chief Executives, Computer Scientists & Systems Analysts, Chemical Engineers, Engineering Managers, Financial Managers, Economists, Physicians & Surgeons, Computer Software Engineers
Creative	
Creative	Architects, Aerospace Engineers, Marketing & Sales Managers, Dancers and Choreographers, Musicians & Singers, Mathematicians, Artists & Related Workers, Chemical Engineers, Writers & Authors
Technical	
Computer	Computer Software Engineers, Computer Hardware Engineers, Computer Scientists & Systems Analysts, Computer Programmers, Database Administrators, Network & Computer Systems Administrators, Network Systems & Data Communication Analysts, Computer & Information Systems Managers, Electrical & Electronics Engineers
Science and Engineering	Aerospace Engineers, Nuclear Engineers, Engineering Managers, Chemical Engineers, Civil Engineers, Agricultural Engineers, Petroleum Engineers, Industrial Engineers, Electricians, Architects, Engineering Technicians
Social	
Managerial	Chief Executives, Education Administrators, Natural Sciences Managers, Industrial Production Managers, Advertising & Promotions Managers, Marketing & Sales Managers, Financial Managers, Producers & Directors, Engineering Managers
Nurturing	Clergy, Licensed Practical & Vocational Nurses, Social Workers, Counselors, Recreational Therapists, Registered Nurses, Directors, Religious Activities & Education, Social & Community Service Managers, Personal & Home Care Aides

Table 5. Correlation Matrix of Workplace Skill Factors

	Verbal	Quantitative	Analytical	Creative	Computer	S & E	Managerial	Nurturing
Verbal	1							
Quantitative	0.42	1						
Analytical	0.63	0.52	1					
Creative	0.36	0.37	0.52	1				
Computer	0.46	0.42	0.39	0.18	1			
S & E	0.02	0.37	0.54	0.22	0.45	1		
Managerial	0.49	0.34	0.56	0.32	0.27	0.14	1	
Nurturing	0.48	0.01	0.22	0.29	0.05	-0.24	0.38	1

*Source: Occupational Information Network (O*NET). See Table 2 for description of skill factors.*

Table 6. Correlation of 1977 and 2008 Workplace Skill Factors

Skill Factor	***Correlation***
<u>Cognitive</u>	
Verbal	0.92
Quantitative	0.88
Analytical	0.84
<u>Creative</u>	
Creative	0.81
<u>Technical</u>	
Computer	0.79
Science & Engineering	0.90
<u>Social</u>	
Managerial	0.83
Nurturing	0.81

*Source: Occupational Information Network (O*NET). See Table 2 for description of skill factors.*