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Public Policy Brief

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Trends in Job Skill Requirements, Technology, and Wage Inequality in the United States

Michael J. Handel

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Preface

Despite seven years of economic growth, a large gap exists between the wages earned by workers at the top of the earnings scale and those at the bottom. The leading explanation for this growth in wage inequality continues to be the skills-mismatch theory. This theory in part posits that gains in technology have resulted in jobs having technical skill requirements that have outpaced growth in worker skills; demand for highly skilled workers therefore rises more swiftly than that for less-skilled workers, creating upward pressure on wages for those with the most skills. In other words, technological advances have increased the number of high-skill jobs relative to low-skill jobs, but worker skills have not kept up.

The dramatic growth, beginning in the 1980s, in the use of computers in the workplace made the skills-mismatch theory plausible. During the 1980s this theory was the key explanation for increasing returns to education; as a postulate, it "explained" that minority workers' lack of skills was the cause of their relative disadvantage in the labor market. Policymakers, having accepted this theory, expressed alarm over the failure of the American educational system to provide workers with the skills needed to succeed in the new, high-tech economy. Thus, it was thought that educational programs aimed at upgrading skills would raise wages among minority and low-skill workers.

In this brief, however, Michael J. Handel examines the evidence used to support this theory and finds it lacking. The empirical data show little sign of a shortage of workers with computer skills or technical skills in general. Handel argues that it is not sufficient to show a relationship between technology and the demand for skilled workers; in order for the skills-mismatch theory to be plausible it must be shown that the rate of technological change, which would shift demand in favor of high-skill workers, accelerated during periods of increasing wage inequality. What he finds is that most of the growth of inequality actually *preceded* the slowdown in the growth of educational attainment and did not coincide with an acceleration in demand toward more skilled work. The evidence, therefore, is not strong enough to support the argument that computers or information technology have done much to alter either the skill content of work within occupations or the occupational composition of the workforce.

If Handel's analysis is correct, then policymakers may need to rethink policies aimed at closing the wage gap. His conclusions indicate that improved education and training alone will not solve the wage inequality problem; rather, the solution may require much more, such as macroeconomic policies aimed at maintaining economic growth and full employment, and labor policies (such as increases in the minimum wage) that support the earnings of workers at the lower end of the wage scale. Considering the important role that the skills-mismatch theory has played in policy development over the past two decades, it is worth reexamining so that policymakers can evaluate current strategies aimed at eliminating wage inequality and consider alternate means by which to alleviate this problem.

I trust that you will find the research contained in this brief insightful, and that it will provide some of the tools necessary for reexamining the skills-mismatch theory and those policies proposed to alleviate wage disparities. As always, I invite your comments.

Dimitri B. Papadimitriou, *President*

Is There a Skills Crisis?

A leading explanation for the recent growth of wage inequality in the United States is a widening gap between the demand for and supply of more-skilled workers. Concern about the match between worker skills and job skill requirements has a long and interesting history. In the 1970s sociologists argued that employers' excessive hiring requirements were causing American workers to obtain more education than their jobs really required (Berg 1971; Collins 1979). Economists reported that an oversupply of well-educated workers had driven the college–high school wage differential to historic lows, with moderate prospects for improvement in the 1980s and 1990s relative to earlier levels (Freeman 1976, 73 ff.). Policymakers wondered how they could make work more satisfying as the complexity of jobs at all levels failed to grow as rapidly as workers' educational levels and aspirations for meaningful work (U.S. Department of Health, Education, and Welfare 1973). Harry Braverman's controversial deskilling hypothesis raised the prospect that the skill content of most jobs was actually declining, even as individuals' educational attainment continued to rise (Braverman 1974). Despite different approaches, most analysts agreed there was a glut of high-skilled workers relative to the number of jobs that could make full use of their skills.

What a difference a decade makes. In the 1980s the balance of opinion among sociologists shifted to the view that technology was increasing the relative number of high-skill jobs, consistent with Daniel Bell's theory of an emerging information society (Bell 1976; Form 1987; Attewell 1987; Wright and Martin 1987). Policymakers were so alarmed by the failure of schools to keep up with the postindustrial economy's need for skills that they compared the education system to a national security risk (U.S.

National Commission on Excellence in Education 1983), established commissions to clarify the skills that all workers needed (U.S. Department of Labor 1991), and authorized new programs to set national occupational skill standards and improve the transition from school to work. Sociologists argued that an increasing mismatch between employer requirements and workers' skills was a principal source of minority workers' disadvantage in the labor market (Wilson 1987). Economists studying the large growth in wage inequality in the 1980s concluded that the rising payoff to education reflected a more general imbalance between the growth of the supply of and demand for skilled labor that was caused by changes in technology (Katz and Murphy 1992). The demand for skills seemed to have suddenly raced ahead of supply. In just a few years, glut seemed to have turned into serious shortage, even more remarkable since most workers in the 1980s had also been working in the 1970s.[1]

But is it true? Is the growth in inequality in the 1980s attributable to historically large shifts in job skill requirements favoring the more skilled? The dramatic growth of computers and microelectronics gives the argument plausibility, but the question resists easy answer.

A review of a large and disparate literature that tries to measure directly employer demand for skills, workers' stock of skills, and any imbalance between the two does not yield unambiguous evidence of a skills shortage any time in the last twenty years. Many employers have basic literacy requirements even for jobs filled by less-educated workers and express dissatisfaction with the quality of employees and job applicants. But it is not at all clear that their dissatisfaction is primarily with workers' level of cognitive or technical skills rather than with perceived work attitudes. Nor is it clear whether employer complaints extend beyond young workers, who are likely to acquire the desired attitudes and skills as they mature and gain job experience. The lack of clear evidence of a cognitive skills shortage persists even in the face of surprisingly low cognitive test scores among a large segment of the American workforce, though tests of high school seniors indicate there has been no meaningful change in young people's reading and math test scores since the early 1970s, contrary to popular perceptions of decline. There is little evidence that computer skills are in especially short supply, particularly among the young, despite the technology focus of much of this debate, nor is there evidence of a general shortage of other technical or high-level skills (for details see Handel 2000a).

The general problem in studying the postindustrial skills mismatch explanation of wage inequality growth is that trends in wage inequality are readily documented, but trends in job skill requirements and technology diffusion are not. Even when all the variables can be measured, there are difficulties establishing causal relationships among them. Further, it is not sufficient to show a relationship between technology and demand for more-skilled workers; to explain the exceptional growth of inequality during the 1980s, it must be shown that the rate of technological change that shifts demand in favor of high-skilled workers *accelerated* during that time, since economists generally acknowledge that technology has been raising skill requirements for a long time (Mishel and Bernstein 1994; Mishel, Bernstein, and Schmitt 1997). This has led some advocates of the skill-biased technological change thesis to suggest that the cause of the skills gap may not be a technology-induced acceleration in the demand for skill but a slowdown in the growth of educational attainment or supply of skilled workers (Katz and Murphy 1992; Autor, Katz, and Krueger 1998).

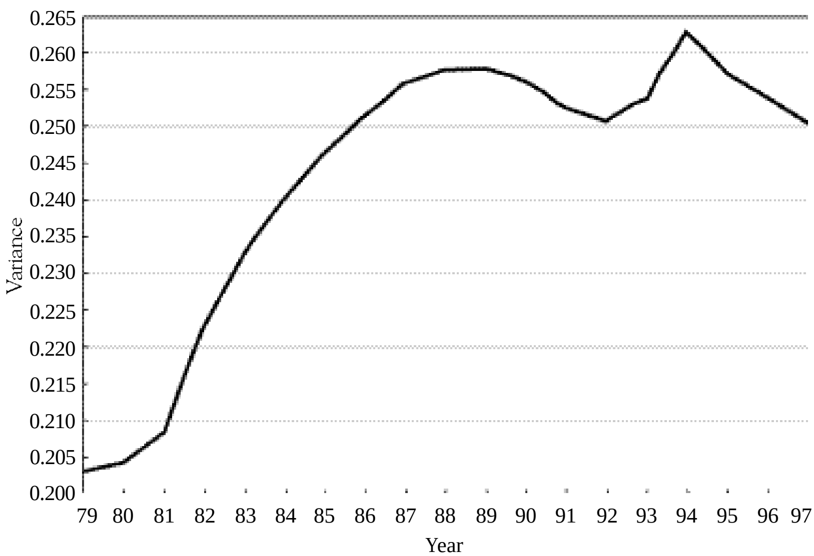
Clearly, the two versions of the skills mismatch hypothesis imply very different views of the underlying processes generating inequality growth. The demand-side explanation is consistent with the postindustrial vision in which high technology has dramatically upgraded skill requirements, while the supply-side explanation suggests no break with the past in terms of technology's effect on skill requirements, locating the cause of the skills shortage in the failure of the educational system to keep up with a secular trend in technology as it has in the past.

This policy brief examines both the supply- and demand-side explanations, giving special attention to technology's role in raising job skill requirements. It examines trends in inequality growth and various measures of skill and technology use, including workers' educational attainment, occupations' shares of the workforce, direct measures of job skill requirements, and use of computers at work. The results indicate that most inequality growth *preceded* the slowdown in the growth of educational attainment and did not coincide with an acceleration of trends toward more skilled work. Computer technology does not appear to have increased the educational requirements of jobs and there are few examples of disproportionate growth or decline in occupations likely to be sensitive to technological change. In short, the results do not suggest that inequality growth reflects the growth of a skills gap owing to either a slowdown in the growth of supply or an acceleration in demand and it is hard to find evidence that computers or information technology have done much to alter either the skill content of work within occupations or the occupational composition of the workforce.[2]

Trends in Wage Inequality and the Supply of and Demand for Education

Any explanation of trends in wage inequality will have to be consistent with the temporal pattern of inequality growth. Figure 1 shows the trend in wage inequality among wage and salary workers from 1979 to 1997, using the variance of log wages. The nonlinearity of the growth is immediately evident. About 50 percent of the growth of inequality between 1979 and 1993 occurs in the years 1981 to 1983, coinciding with the deepest recession in U.S. history since the Great Depression and prior to the greatest diffusion of computers. Inequality growth then flattens out and declines somewhat in the late 1980s and early 1990s. The large growth

Figure 1 Trends in Wage Inequality (Variance of Log Wages), 1979–97



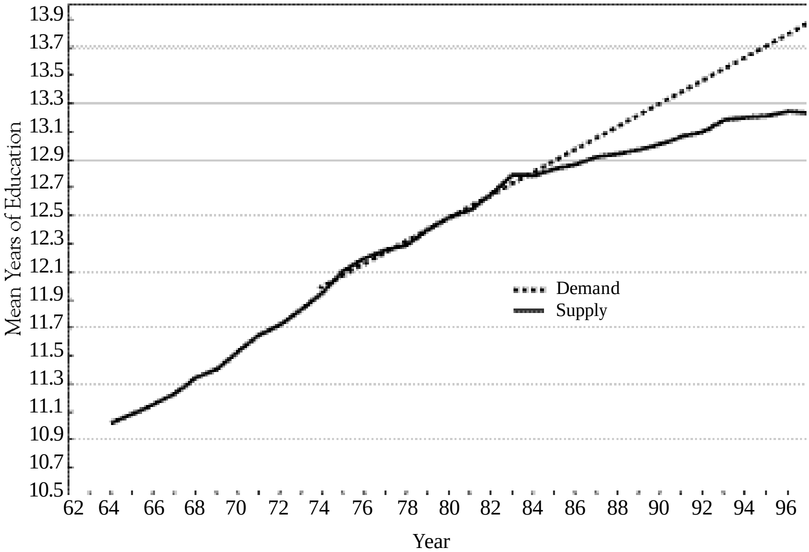
Source: Current Population Survey Outgoing Rotation Group Files.

in inequality between 1993 and 1994 may reflect a continuation of the increase visible between 1992 and 1993 but may well also reflect changes in the survey design. After 1994 inequality declines modestly.

The solid line in Figure 2 shows the trend in mean years of education. There is a nearly linear rise in workers' mean years of education between 1962 and 1983, then a slowdown in growth between 1983 and 1991 and an even flatter trend between 1992 and 1997.

As noted, Katz and Murphy (1992) suggest the skills mismatch responsible for the growth in inequality may reflect a slowdown in the growth rate of the supply of more-educated workers in the 1980s rather than any acceleration in demand. But a closer inspection of the evidence reveals problems with this supply-side explanation. If one were to assume that supply and demand were in equilibrium prior to the 1980s and demand continued to grow at a constant rate thereafter while supply growth slowed, as Katz and Murphy suggest, the trend in demand would look something like the dotted line in Figure 2, which simply extrapolates from the growth rate in the supply of educated workers for 1974 to 1979. As can be seen, a skills gap emerges, as the supply-side neoclassical explanation of rising inequality predicts.

Figure 2 Trends in the Supply of and Projected Demand for Education



Note: Assumes equilibrium during the late 1970s and constant demand growth for education. Figures for 1992–97 are imputed from categorical responses.
Source: March CPS.

The only problem is that the timing of the emergence and widening of the skills gap is inconsistent with the temporal pattern of inequality growth. In Figure 2 the skills gap is either not present or minor in the early 1980s and grows more severe as time progresses, reaching its widest point in 1997. Yet, as Figure 1 shows, inequality grew most rapidly in the early 1980s, moderated steadily as the decade progressed, and overall did not grow much in the 1990s (the sharp spike in 1994 notwithstanding) despite the flat trend in workforce education levels. The timing of inequality does not correspond to the deceleration in the growth of workers' educational attainment.

The problem for the neoclassical explanation is even more serious than Figure 2 suggests. It is well known that there was an oversupply of educated labor in the 1970s (Freeman 1976), so the demand line in Figure 2 should be drawn below the supply line in that decade, which would mean the skills gap would not emerge until even later than shown. The only way to derive a skills deficit in the early 1980s following the skills glut in the late 1970s is to assume significant acceleration in the growth of demand for skill, as Mishel, Bernstein, and Schmitt (1997) have argued is implicit in the skill-biased technological change argument. Whether technology can reasonably be argued to have had a stronger effect in the early 1980s than it did in previous decades will be considered in subsequent sections.

Some analysts might argue that the growth in wage inequality is not related to a slowdown in the growth of average educational levels, but to an increase in the inequality of educational attainment. However, inequality in years of education declined from 1962 to 1987, albeit at a somewhat decelerating rate, before flattening out (Handel 2000a). Changes in the distribution of education or human capital have not contributed to inequality growth but have had an equalizing effect until relatively recently.

The Relationship between Education and Computer Use

The skills mismatch hypothesis relies heavily on the notion that computers have increased the educational requirements of jobs. A series of regression models show that computer users do have more education than otherwise similar workers; the difference is on the order of one-half to one year, depending on the controls included in the model (Handel 2000a).[3]

But these results do not settle the issue. Firms that could afford computers may have been more able to afford more-educated workers as well. Or firms may have initially given computers to more-educated workers because they had higher status or held positions in which computers were most complementary to their tasks, such as office work. In these cases the association in the cross-sectional models between computer use and higher educational level would not imply a causal link between the two.

For example, one might find that the manager of a construction company uses a computer at work and has somewhat more education than a carpenter working for the firm. No one would attribute the educational differential to the introduction of computers into the manager's job. The educational differential long predates the introduction of computers and the differential computer use merely reflects the fact that computers are not very useful for carpentry but are very useful for office work. In this case, the association between computers and education would not reflect some additional increment of skill that computers have introduced into the workplace.

There is also the issue of interpreting the magnitude of the association, even assuming the observed association is causal. If one accepts that a worker who uses a computer must have an additional one-half to one year of education compared to an otherwise similar worker, this implies about a 3 to 8 percent wage premium for computer use operating through enhanced educational requirements alone, not counting any direct effect on wages through computer-specific human capital. The low end of this range, which is the more probable, does not seem large enough to account for much of the observed growth in inequality, though if one accepts the high end and adds some large wage effect for computer use itself (e.g. Krueger 1993), then the situation is less clear.

Despite the problems in determining causality or judging magnitudes, it is useful to note that the educational upgrading effect of computers is not likely, even by relatively generous estimates, to exceed one year of education, which at least provides an upper bound and a caution for those who would see computers as dramatically upgrading the educational requirements of work. Even in the most favorable case, computers are not typically leading to the replacement of workers who have a high school education with workers who have a four-year or even a junior college education.

Of course, some people use computers for much more complicated tasks than do others and the small magnitude of the overall educational differential may be due to a failure to distinguish between jobs that require a large increment in education when computers are introduced and jobs in which the computer tasks are sufficiently simple that little educational upgrading is necessary. This is another situation that is not so simple. Workers using computers for inventory and invoice functions have *less* education (about 0.2 fewer years) than otherwise similar workers. Workers using the Internet, spreadsheets, and word processing programs have the greatest educational advantage (about 0.3 years) over otherwise similar workers, while workers using computers for programming or computer aided design are little different from otherwise similar workers. This does not reflect one's expectations regarding the relative skill requirements of these different tasks. In short, specific computer tasks do not seem to be reliably related to educational differentials (see also DiNardo and Pischke 1997; Handel 1999).

To address the problem of causality, cross-sectional analyses can be replaced with analyses of the relationship between changes in the educational composition of occupations and changes in the level of computer use within occupations between 1984 and 1997.[4] These models predict that if an occupation went from having no computer users to 100 percent computer users, the mean education of workers in the occupation would increase by 0.2 years, well below even the lower-bound estimate of one-half year mentioned above.

When years of education is broken into five categories (less than high school, high school degree, some college, college degree, and postgraduate), the analyses suggest that a 25 percentage point increase in computer use within occupations, about average for the period 1984 to 1997, was associated with a 2.7 percentage point decline in the share of workers with a high school degree and a 1.1 percentage point increase in workers with a college degree within an occupation. By comparison, the actual share of workers with a high school degree declined by 6.7 percentage points and the share of workers with a college degree increased 5.3 percentage points during this period, suggesting that any increase in educational requirements occasioned by the spread of computers was easily absorbed.

However, further analyses suggest that even these associations do not reflect a causal connection between computer use and occupations' educational requirements. When changes in educational levels within occupations for 1971 to 1976 are related to changes in computer use within occupations for 1984 to 1997 the results are remarkably similar (Handel 2000a). It appears that the growth of computer use at a later point in time is as good a predictor of educational upgrading in the past as it is a predictor of contemporaneous educational upgrading within occupations! In other words, occupations that increased their computer use most in the 1980s were already upgrading educational levels for other reasons in the early 1970s, prior to the diffusion of computers. This suggests that the association between changes in computer use and skill upgrading is not a causal relationship. The same occupations that upgraded in the 1980s and 1990s, when computers diffused rapidly, had upgraded educational levels long before then.

Trends in Major Occupational Groups' Shares of the Workforce

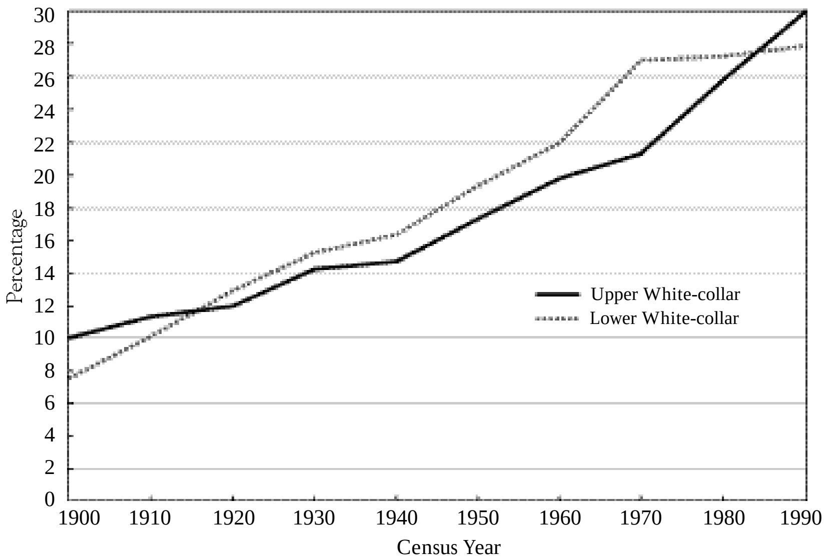
Although workers' educational attainment is the principal measure of job skill requirements within economics, most sociologists would consider occupation to be a better indicator of the nature of jobs rather than the personal characteristics of those filling them. This section examines whether there is evidence of occupational upgrading and, more importantly, whether any such trend accelerated over the course of the 1980s in a fashion that might explain inequality growth and suggest a role for technology.

In general, the data do not suggest acceleration of demand shifts throughout most of the 1980s and 1990s, but there was a sharp decline in the share of blue-collar workers in manufacturing in the early 1980s, when inequality rose sharply. The absence of a similar trend in later years calls into question explanations based on adoption of high technology and suggests a greater role for macroeconomic and trade policies in this sharp drop.

It is useful to begin with a long view. Figures 3 and 4 present trends in the share of the workforce for five highly aggregated occupational groups from 1900 to 1990. Despite changes in occupational codes, there is a reasonable degree of comparability across decades at this level of aggregation.

Figure 3 shows that not only did the share of the highest skill group, upper white-collar workers (managers, professionals, technical workers) grow substantially, from 10 percent of the workforce in 1900 to 30 percent in 1990, but this increase accelerated, with the fastest growth between 1970 and 1990. However, there is no difference in the growth rate between the 1970s and the 1980s, and more recent data do not indicate any change in the 1990s. In short, there would seem to be little about demand for upper white-collar workers in the 1980s that would make it distinctive from adjacent decades such that it might explain the

Figure 3 Trends in Upper and Lower White-collar Workers as a Percentage of the Workforce



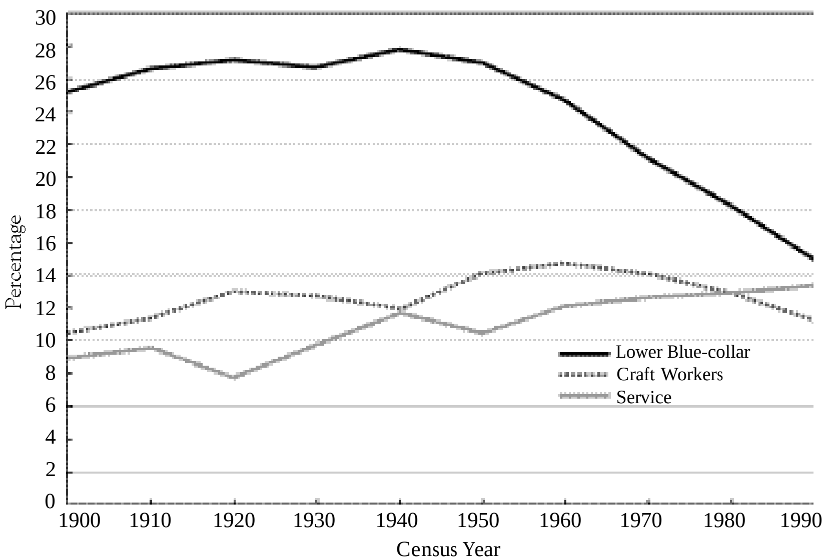
Source: Decennial census.

growth in inequality. However, the continued increase in the upper white-collar share when their relative wages were presumably rising may be evidence for an acceleration in underlying demand.

Figure 3 also shows that the share of lower white-collar workers (sales, clerical) rose throughout the century until 1970, from 7.5 percent to roughly 28 percent of the workforce, but essentially stopped growing between 1970 and 1990. More recent data suggest a decline between 1983 and 1997 of a bit more than 1 percentage point, and the diffusion of computer technology is a plausible candidate for a factor in this decline.

Figure 4 shows that the share of craft workers remained relatively constant during the century, fluctuating between roughly 11 and 14 percent, although there was a modest decline, without acceleration, between 1970 and 1990. However, the share of lower blue-collar workers (operatives, transport operators, laborers) declined consistently and markedly in the postwar period from a high of roughly 28 percent in 1940 to a low of less than 15 percent in 1990, but, again, the trend in the 1980s does not look very different from the 1970s.

Figure 4 Trends in Craft, Lower Blue-collar, and Service Employment as a Percentage of the Workforce



Source: Decennial census.

Figure 5 Trend in the Share of Blue-collar Workers in Manufacturing 1962–1997

Note: Break in series between 1982 and 1983.
Source: March CPS.

Interestingly, annual employment data indicate that almost all of the decline in the lower blue-collar share since 1980 occurred prior to 1985. Between 1965 and 1985 the share of lower blue-collar workers declined by an average 0.42 percent per year, while the rate for 1985 to 1997 was 0.11 percent per year. That flatness does not reflect the decline of manufacturing's overall share of the workforce. The contrast between the rates of decline in the two periods for lower blue-collar workers within manufacturing, 0.52 percent and 0.05 percent, is even more stark, even though it is within manufacturing that one might expect technology to have the greatest effect. Within-industry shifts are often used as measures of technological change. However, as Figure 5 shows, the steep decline in the share of lower blue-collar workers within manufacturing virtually halted by 1985. From that year onwards there is essentially random variation around a constant level. If automation and computer-controlled processes were making lower blue-collar workers redundant in unprecedented numbers, there is no evidence for it in these figures.

Some have raised the possibility that the relative stability of the blue-collar share within manufacturing after 1985 reflects the decline in these workers' relative wages, which made them relatively more attractive than when they were better paid (Eli Berman, Boston University, personal communication). If the share of blue-collar employment is stable in the face of declining relative wages, then presumably underlying demand for these workers is still falling. However, the relative stability of lower blue-collar employment in manufacturing after 1985 does not correspond to any marked change in the hourly wages of lower blue-collar workers relative to other workers in manufacturing (see Handel 2000a, Figures 10 and 11).

The rapid decline in the demand for blue-collar workers occurred during the early 1980s, prior to the widespread diffusion of computer or other advanced microelectronics, suggesting that the recession and trade deficits of the early 1980s, rather than an upsurge in factory automation and consequent labor displacement, were responsible for the observed trends. Further, the correspondence of this trend with the growth in inequality in the early 1980s suggests the importance of the decline of blue-collar manufacturing work for inequality growth, long emphasized by Bluestone and Harrison (1983; Harrison and Bluestone 1988), rather than the emergence of an information economy.

Figure 4 also shows that the share of workers in low-skill service occupations has grown modestly from about 9 percent (1900) to a little over 13 percent (1990), but the growth in this occupational group does not seem sufficiently large to account for much of the growth in wage inequality, despite frequent statements of concern.

By contrast, the share of workers in farm occupations (not shown in figure) fell from 37.5 percent in 1900 to 2.5 percent in 1990, by far a larger change than in any other group examined here. Although this decline is little noticed in the long-running sociological debate on skills, clearly, skill trends over the course of the twentieth century depend more on this decline and how one evaluates the skill level of declining farm occupations than on any other single trend (cf. Braverman 1974, 381; Spenner 1983, 825). However, the change in the share of farm occupations has been slight since 1965 and is not relevant to the study of the growth of inequality in the 1980s and 1990s.

Summarizing the figures for the nonagricultural workforce and making allowance for the difficulty of rank ordering the lower white-collar occupational group with respect to craft and lower blue-collar occupations, one can say with reasonable confidence that the trend has been one of general upgrading of job skill levels, but trends in the 1980s and 1990s do not appear upon initial inspection to have accelerated—despite the growth of information technology—in marked contrast to trends in wage inequality.

Trends in the Growth of Occupations Potentially Sensitive to Technological Change

Trends in the composition of employment by aggregated occupational group can give some indication of the direction and pace of skill shifts and the role of technology. For example, the trend for blue-collar manufacturing workers does not suggest that factory automation has displaced large numbers of less-skilled workers. However, the use of broad occupational groups is limiting. One can examine the possible effects of technological change on the occupational distribution in a more detailed fashion using finer occupational categories that one might suspect a priori to be especially sensitive to technological change. Technology can alter the demand for skill by altering the skill content within occupations or by adding workers at the top of the occupational skill hierarchy or eliminating them at the bottom, for example as a result of automation.

Table 1 presents trends in different detailed occupations' share of the workforce or of certain industries and annual rates of change for specific years between 1971 and 1997. The first two rows present trends for scientists, engineers, and technicians. If information technology were increasing the skill requirements of work by adding workers at the top, one would expect the shares of these workers to rise; if the rising share were related to inequality growth in the 1980s, one would expect acceleration in that decade. The data indicate that the shares of workers in these two groups grew steadily, but remained relatively small; their growth accelerated only modestly in the 1980s and 1990s, but was rapid during the recessionary period of the early 1980s. Despite much talk of the growth of knowledge workers, most upper white-collar workers are not in highly technical occupations and growth rates remain relatively low.

Rows 3 and 4 indicate that despite the visible and dramatic growth of the importance of computers in the economy, computer systems analysts/

Table 1 Trends in the Percentage Share of Specific Occupations Potentially Sensitive to Technological Change, 1971–1997

Occupation	Percentage Share[1]					Annual Rate of Change		
	1971	1979	1982	1983	1997	1971–79	1979–82	1983–97
Scientific/Technical Workers								
Scientist/Engineer	2.62	2.69	3.15	3.15	3.91	0.01	0.15	0.05
Technicians	2.68	2.82	3.21	3.28	3.52	0.02	0.13	0.02
Computer Workers								
Systems Analysts[2]	0.10	0.28	0.35	0.32	1.16	0.02	0.02	0.06
Programmers	0.25	0.36	0.47	0.40	0.56	0.01	0.04	0.01
Retail Trade Workers								
Cashiers (percent of grocery workers)	17.79	24.30	25.08	29.60	28.96	0.81	0.26	–0.05
Clerks (percent of retail and wholesale workers)	2.21	1.60	1.83	1.56	1.40	–0.08	0.08	–0.01
Clerical Workers								
All clericals	17.19	18.24	18.46	16.85	14.12	0.13	0.07	–0.20
Manager/Clerical Ratio	1.45	1.47	1.57	1.58	2.22	0.00	0.03	0.05
All clericals (percent of banking and insurance)	52.96	53.62	50.76	50.04	39.66	0.08	0.95	0.74
Secretaries	3.63	4.11	4.07	4.16	2.28	0.06	–0.01	–0.13
Manager/Secretary Ratio	6.86	6.53	7.11	6.38	13.75	–0.04	0.19	0.53
Tellers (percent of bank workers)	20.62	25.33	23.62	19.78	18.03	0.59	–0.57	–0.13
Postal Clerks (percent of postal workers)	37.52	36.06	39.28	34.56	33.50	–0.18	1.07	–0.08
Telephone Workers [3]								
Operators	21.35	14.36	12.51	6.82	3.94	–0.87	–0.62	–0.21
Installer/Repairer	31.86	30.91	28.44	26.34	17.41	–0.12	–0.82	–0.64
Auto Workers [3]								
Assemblers	14.95	18.60	14.66	15.90	20.42	0.46	–1.31	0.32
Welders/Painters	6.95	8.29	5.61	3.97	7.59	0.17	–0.89	0.26

Notes: All figures weighted by hours worked in previous week. Unless otherwise indicated, all figures are percentages of total workforce.

[1] The choice of specific years in the left panel reflects the change in occupational coding schemes between 1982 and 1983, which fortunately is not a large problem in many cases here, and the desirability of isolating changes in the early 1980s, which was a period of abrupt change in wage inequality, as noted earlier. All figures are weighted by hours worked as well as by CPS sample weights. All figures for the years shown have been checked against plots for the entire period to insure that conclusions are not substantively affected by choice of period endpoints.

[2] The Systems Analysts category also includes Computer Scientists.

[3] These percentages represent the share of the occupation within this industry only, not as a share of all workers.

Source: March CPS.

computer scientists and programmers represented less than 2 percent of the workforce as recently as 1997. While the growth of systems analysts and computer scientists did accelerate in the late 1980s, they remain a small group and the share of programmers, surprisingly, does not seem to have accelerated for most of the period covered here.[5]

The first four rows of Table 1 are high-skilled occupations that might be expected to expand with the growth in high technology. Clearly, rather than accelerating dramatically in the 1980s, the growth of these occupations has been rather steady over time. The remaining rows are occupations, most of them less-skilled, that many have argued are being eliminated by the impressive spread of computer and microelectronic technology. Danziger and Gottschalk (1995, 141) express the conventional wisdom that beginning in the 1980s, firms

> substituted computers and more-skilled workers for lower-skilled workers whose tasks could now be performed more efficiently with computers. Insurance companies could lay off file clerks . . . checkout clerks no longer had to enter prices in the cash register. Inventory control was simplified and reordering could be done automatically. In these and other ways, technology (or automation) decreased the value of the skills of workers with lower levels of education and increased demand for workers with more education.

In this passage, Danziger and Gottschalk link the labor-displacing effect of computers to the growth of wage inequality. The examples they cite and others they do not mention, such as bank tellers, have much common-sensical appeal. However, trends in these occupations have rarely been examined systematically.

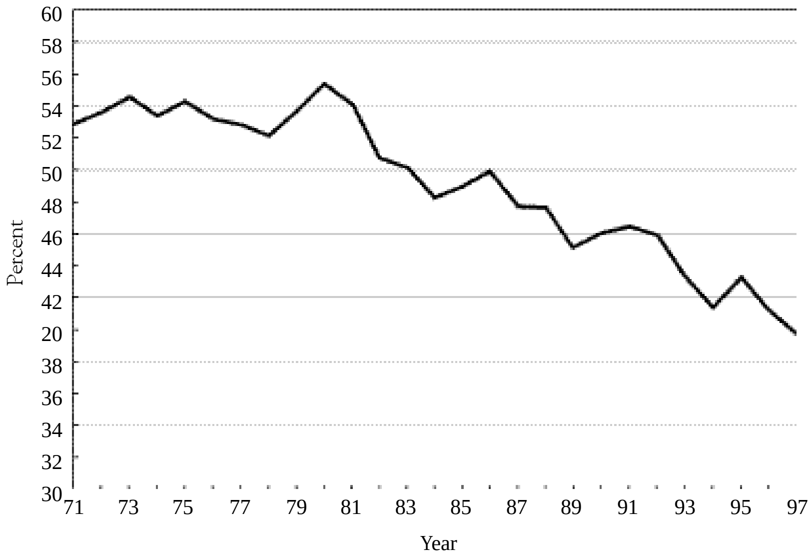
In the section of Table 1 on the share of occupations in retail industries, Row 5 presents trends in the percentage of grocery store workers who are cashiers—the checkout clerks who are most likely to use scanners rather than entering prices manually. Cashiers grew as a percentage of grocery workers in the 1970s and then declined modestly after 1983, consistent with the scanner story. A plot of the data for all years (not shown) indicates that the trend was flat from 1983 to 1991 and the decline somewhat uneven thereafter. One can say that at most, scanners might have stopped the growth in the cashier share evident in the 1970s, but there seems to have been very little actual decline, even after nearly two decades of scanner diffusion. This is not to say that scanners may not have had an effect on productivity, by speeding customer throughput or generating more readily used information for inventory and planning databases. It is merely to say that there has been little decline in employment as a result, though growth has clearly halted.[6]

Danziger and Gottschalk also refer to the computerization of inventory control, which presumably reduces the need for shipping, stock, and inventory clerks to keep track of stock. However, Row 6 in Table 1 indicates that the share of clerks in retail and wholesale declined more rapidly in the 1970s than in the 1980s and 1990s.[7] These data, combined with those for cashiers, do not suggest that, although highly visible, computer and microelectronic technologies have displaced much labor in retail.

The next section of the table deals with clerical work. As a share of all workers, clerical workers as a group grew during the 1970s and declined steadily after 1983. This series is rather strong evidence that the century-long increase in the clerical employment share has ended, though the full data series indicates the most dramatic declines were from 1986 to 1989 and especially from 1992 to 1997, after the large increase in wage inequality. The ratio of managers and professionals to clerical workers (Row 8), a measure of "clerical productivity" since most clerical workers support the work of managers and professionals, increased sharply from 1992 to 1997, though less dramatic increases are evident as early as the 1970s. In the absence of more detailed information, it is unclear whether to ascribe the growth in this ratio to technology or to more general cost-cutting policies on the part of employers. Even so, the ratio's sharp growth in the 1990s is at least consistent with a role for computer technology in reducing demand for clerical work, but the growth does not coincide with the period of inequality growth.

A stronger case for the possible impact of information technology on clerical employment is the trend in clerical workers as a percentage of workers in finance and insurance (Row 9). Clerical tasks in these industries are highly repetitive and routine and these industries have long been leaders

Figure 6 Trends in the Share of Clerical Workers as a Percentage of Workers in Finance and Insurance Industries 1971–1997

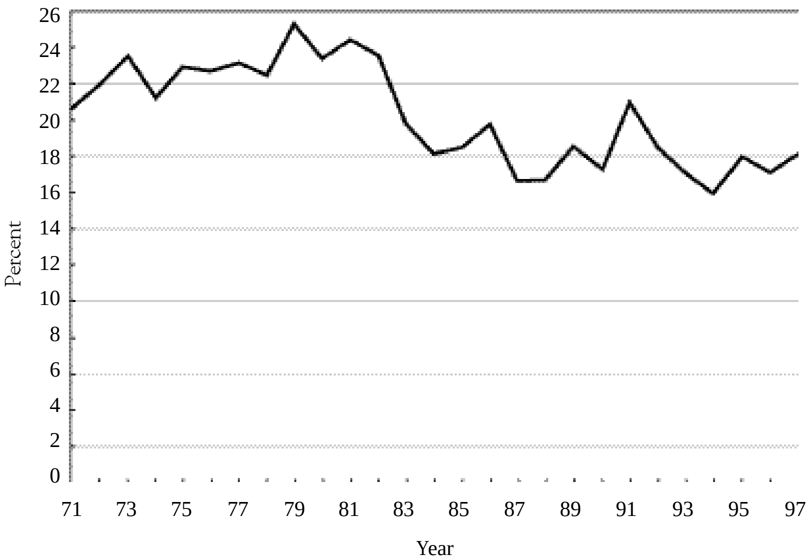


Note: Average n=2,787.
Source: March CPS.

in adopting computer applications for office automation. After remaining steady as a share of finance and insurance employment in the 1970s, the clerical share for these industries falls more sharply than for any other occupation in the table. Figure 6 shows that the decline was consistent throughout the 1980s and 1990s.[8] Danziger and Gottschalk's hypothesis that computers have automated the work of file clerks in this sector seems well supported. This occupational group clearly shows the pattern one would expect if information technology were driving shifts in skill demand through changes in the occupational composition of employment. Unfortunately for the skill-biased technological change hypothesis, it is one of the few occupational groups to show such a clear pattern.

The share of secretaries in the workforce (Row 10) begins to decline around 1983 and falls consistently thereafter. Similarly, the ratio of managers and professionals to secretaries (Row 11) is flat for the 1970s, rises significantly between 1983 and 1991, and then accelerates dramatically after 1992. There is some question as to whether the decline in the secretarial share is real or an artifact of changing categorization, with more of these workers being assigned to the residual "clerical workers, not elsewhere classified" category (Autor 1995). Given the overall decline in

Figure 7 Trends in the Share of Tellers as a Percentage of All Workers in Banking 1971–1997



Note: Average n=1,075.
Source: March CPS.

the share of clerical workers, it is not clear that this is a reasonable supposition, but in any case, whether the relative decline of secretaries is genuine or not, the timing is not consistent with the pattern of inequality growth.

Row 12 of Table 1 gives trends in tellers as a percentage of all workers in banking. The rapid spread of automated teller machines (ATMs) would seem to make this occupation an ideal candidate for obsolescence. In fact, the data in the table and in Figure 7 show no such strong trend, but at best a one-time drop in the teller share in the early 1980s. There is some modest growth in the teller share during the 1970s, a large drop between 1982 and 1983 (which may reflect either genuine change or occupational coding changes) and a modest overall decline over the next 14 years.[9] Census data for 1980 and 1990, which are less subject to the changes in occupational codes than the annual data in Table 1, and a 1970 Census extract coded using both the 1970s and 1980s occupational codes suggest that the observed decline between 1982–1983 may be genuine rather than an artifact of the changes in occupational classification schemes. If so, the share of tellers declined from an average of about 23 percent from

1971 to 1982 to an average of about 18 percent from 1983 to 1997, mostly within the space of a single year in the early 1980s. The timing of the decline coincides with both the recession and the growth of inequality, but the flatness of the trend for most of the 1980s and 1990s casts some doubt on a technology explanation. While it is possible that ATMs had such an abrupt impact, the trend, unlike that for all clerical workers within banking and insurance, does not correspond to intuition about the effects of automation on the composition of employment. There is certainly no evidence in Figure 7 that ATMs have rendered the teller occupation obsolete. This finding is consistent with sector studies of tellers within banking (Larry Hunter, Wharton School, personal communication).

Like clerical tasks in banking and insurance, back office work in the U.S. Postal Service is a highly standardized, high-volume operation. In principle, this makes it ideal for automation on a large scale. Nevertheless, rather surprisingly, Row 13 indicates that postal clerks have not declined much as a share of all postal workers in the last 25 years.[10] Further, the 1980s and 1990s do not seem to differ from the 1970s in this regard.

The telephone industry has been substituting electrical and electronic equipment for labor in a highly visible fashion since its inception. Indeed, the transistor was invented by Bell Labs, so it is not surprising that microelectronics have replaced switchboard operators and other workers over time. Table 1, Row 14 indicates that operators declined from over 21 percent of all telephone workers to less than 4 percent between 1971 and 1997.[11] What is interesting is that the rate of decline was faster in the 1970s than in the 1980s and 1990s.

Telephone installers and repairers are another substantial fraction of all employment in the industry and have likely been affected by improvements in telephone switching equipment. The share of these workers declined by nearly half from 1971 to 1997, from 32 percent to 17.5 percent (Row 15). The rate of decline for this group did accelerate in the mid 1980s and 1990s relative to the 1970s when calculated on the basis of the years shown in Table 1. However, a plot of the full series, along with Census figures from 1960 to 1990, casts some doubt on this result.

Finally, Table 1 shows trends for the percentage of workers in the auto industry who are assemblers (Row 16) and welders or painters (Row 17). The auto industry is the leader in the use of industrial robots, and welders and painters are believed to be most strongly affected. Figures for assemblers are presented for comparative purposes, since automation efforts are widely recognized to have failed in auto assembly (John Paul MacDuffie, Wharton School, personal communication). Rather surprisingly, although the shares of both groups declined for a few years in the early 1980s, their shares have increased somewhat since then.[12] Of course, robots may be displacing labor in large firms but that displacement may be offset by increased outsourcing to more labor intensive subcontractors. Nevertheless, there seems to be no overall effect of robots or automation on the employment of either assemblers, welders, or painters in the auto industry, using these data. Census data do suggest a modest decline in the share of welders and painters in the auto industry, but there is little difference between the rate of decline from 1970 to 1980 and the rate from 1980 to 1990.

It should be noted that most of the preceding has dealt with office jobs, many of which are predominantly staffed by women. Indeed, computers are primarily an office, rather than a factory, technology and might be expected to have less impact among men in the lower part of the occupational structure. The fact that this group has experienced the most severe wage losses in the last two decades may be another clue that technology is less important than commonly believed.

Trends in Direct Measures of Job Skill Requirements

While the broad occupational categories examined above are useful rough measures of job skill requirements, a more fine-grained measure is desirable. This section uses previously unexamined individual-level data on job skill requirements and occupation-level data applied to a long time series. The results show that job skill requirements have increased in the last several decades, but there is little evidence of recent acceleration in mean job skill requirements. These findings are consistent with the notion that job skill requirements have risen at a consistent but modest rate over time (Spenner 1979).

Table 2 Trends in Formal Education Requirements 1969–1986

Education Required	SWC/QES		PSID		Annual Rate of Change	
	1969	1977	1976	1985	1969–77	1976–85
Grades 0–8	25.700	14.700	25.100	11.700	–1.400	–1.500
Grades 9–11	10.500	6.700	1.900	1.500	–0.500	–0.000
High School, High School +VocationalEducation, Some College	47.200	61.000	50.400	56.300	1.700	0.700
B.A.	10.200	10.600	17.100	23.400	0.100	0.700
Post-grad	6.600	7.000	5.500	7.100	0.100	0.200
Mean	2.620	2.880	2.760	3.130	0.030	0.040
Coeff. of Variation	0.444	0.352	0.422	0.317	–0.012	–0.012
N	1,033	861	3,250	4,509		

Notes: For comparability, samples are restricted to workers over age 25 working at least 20 hours per week. Figures in top part of table are percentages. Means and c.v. calculated by taking ordinal codes as numeric. All figures calculated using sample weights.
Sources: Tabulations are made using data from the Survey of Working Conditions (1969), Quality of Employment Survey (1977), and Panel Study of Income Dynamics (1976, 1985).

Individual-Level Measur es

The advantages of individual-level skill measures are clear. Job skill requirements vary both within and between census occupational groupings and only individual-level measures capture both. Occupation-level measures can be used for charting skill shifts that result from changes in the occupational composition of the workforce, but necessarily wash out all within-occupation variation at any one time and over time if jobs are not subsequently rerated.

The individual-level measures are survey responses to questions asking the level of formal education the respondent needed for his or her job and the time it takes the average person to learn the job. These variables are referred to as “education required” and “training time.” Measures are drawn from two different series of surveys, the first covering 1969, 1972, and 1977, and the second covering 1976 and 1985.[13] There are some comparability problems across the series; this calls for caution in splicing the two together and makes the results necessarily tentative. However, they are worth examining together because they are the only sources of data for representative samples for the period 1969 to 1985, allowing comparison of job skill trends prior to and during the period of greatest inequality growth.

Table 2 gives a percentage breakdown of workers' responses to the education required question and annual change rates.[14] For simplicity, figures for 1972 are not presented here (see Handel 2000b). The table tells an interesting story. Fully one-quarter of respondents in 1969 reported that their jobs require eight years of education or less. The figure is over one-third when those with jobs requiring grades 9–11 are added. These numbers drop substantially by 1977, with almost all of the decline occurring by 1972. Strangely, the Panel Study on Income Dynamics (PSID) figures for 1976 show a much greater concentration in the lowest education required group than the Quality of Employment Survey (QES) for 1977, but the decline in the share reporting no need for any high school falls by roughly the same amount. In fact, adding the first two rows of the right panel of Table 2 shows that the eight-year QES series and the nine-year PSID series show almost exactly the same trend rates in the shift of jobs out of these two lowest skill categories, –1.9 and –1.5 percentage points per year respectively. For this reason the discussion concentrates on trend rates irrespective of level differences.

The share of middle-skill jobs, those requiring a high school degree or some college, increases somewhat faster between 1969 and 1977 than between 1976 and 1985. The share of high-skill jobs, those requiring a college degree, rises more rapidly in the later period, though the differences are not dramatic. The growth of the share of jobs requiring a postgraduate degree is roughly equal across the two series. In general, the decline in very low-skill jobs, those requiring no high school education, is more noticeable in both series than the growth in high-skill jobs.

To obtain a summary measure of the trends, the categorical education required variable can be treated as numeric in order to calculate means (Row 6) and a measure of the inequality of job skill requirements, the coefficient of variation (Row 7). Although the ordinal nature of the measure argues for caution in interpreting means, the growth rates in the mean are similar for the two series, 0.03 (1969 to 1977) and 0.04 (1976 to 1985), and are identical for the measure of inequality (coefficient of variation). Overall, then, there seems to be little difference

Table 3 Trends in the Percentage Under- and Overeducated, 1969–1985

	Percentage			Annual Rate of Change			
Year	Undereducated	Match	Overeducated	Undereducated	Match	Overeducated	N
1969	18.7	57.1	24.2				1,032
1972	21.1	57.3	21.7	0.80	0.07	–0.83	979
1977	19.8	52.5	27.8	–0.26	–0.96	1.22	857
1976	15.3	49.7	35.1				3,240
1985	17.6	53.5	28.9	0.26	0.42	–0.69	4,489

Note: Sample is all workers over age 25 working at least 20 hours per week. Undereducation is defined as (own education–job educational requirements) < 0 and overeducation is defined as (own education–job educational requirements) > 0.
Source: 1969: Survey of Working Conditions. 1972 and 1977: Quality of Employment Surveys. 1976 and 1985: Panel Survey of Income Dynamics

between the two series in the rate of growth in the level of formal education required by jobs or the rate of decline in the inequality of educational requirements.

Since the critical issue in the wage inequality debate is the extent to which the skill requirements of jobs and workers are mismatched, Table 3 gives the percentage of workers whose education is less than, equal to, or greater than the requirements of their jobs and annual change rates. If the growth of wage inequality is due to a skills mismatch, one might expect to see some increase in the number of workers with less education than their job requires and corresponding decline in workers with more education than their job requires, reversing the growth of overeducated workers in the 1970s when large numbers of college graduates entered the workforce.

Table 3 shows that the number of undereducated workers grew by 2.4 percentage points from 1969 to 1972, fell by 1.2 percentage points from 1972 to 1977, and then grew by 2.3 percentage points from 1976 to 1985. The trend is in the direction predicted by the skills mismatch hypothesis but neither the absolute change nor the annual change rate suggests that the growth in undereducation from 1976 to 1985 was especially large. Indeed, the annual change rate was much higher between 1969 and 1972, when inequality was not growing.

The percentage of overeducated workers declined by 2.5 percentage points from 1969 to 1972, grew by 6.1 percentage points from 1972 to 1977, confirming the impression of a growth in overeducation during this period, and then declined by 6.2 percentage points from 1976 to 1985. Again, the direction of the trend supports the skills mismatch hypothesis, but the magnitude suggests more a return to the status quo ante than a dramatic break with the past. The growth in undereducation and decline in overeducation from 1976 to 1985 seem to be pretty much part of the usual ebb and flow of these numbers.

Table 4 Trends in Estimated Training Times in Months

	1976	1985
Training Times		
Mean	20.0	20.0
(standard deviation)	(25.5)	(25.9)
Median	9.0	8.0
Coeff. of Variation	1.28	1.29
Percentage Breakdown		
≤ 1 month	23.1	22.5
> 1–3 months	13.3	12.3
> 3–6 months	12.2	14.2
> 6 months – 1 year	16.2	16.3
> 1–2 years	11.0	11.2
> 2 years	24.3	23.5
	Medians	
Education Required		
Grades 0–8	2	2
Grades 9–11	1	1
High School	6	6
High School and Vocational Education	—	12
Some College	12	12
College Degree	24	24
Postgraduate	36	24
Occupation		
Manager/Professional	24	24
Sales/Clerical	6	6
Craft	24	24
Lower Blue-collar	2	2
Service	2	2

Note: Samples are household heads and spouses working at least 20 hours per week. The figures change little when the PSID samples are expanded to include all workers regardless of hours worked. Sample sizes are about 4,600 (3,600 for tabulations using occupation) (Column 1) and about 5,480 (5,380 for tabulations using occupation) (Column 2).
Source: PSID76, PSID85.

In short, though differences in the data series suggest some caution in splicing them together, there is little that suggests extraordinarily rapid upgrading in job educational requirements in the more recent period, during which inequality grew, compared to earlier periods, during which inequality was relatively stable. Likewise, there is little evidence that the nature of job–worker matches deteriorated notably during the period of high inequality growth compared to earlier periods.

The second individual-level skill measure is training time or the time it takes the average person to learn the respondent's job, which is only available for the PSID series. The average training time is about 20 months and the median is about 8 to 9 months (Table 4). The raw trends between 1976 and 1985 for mean and median are flat, and there is also little change in the inequality of job training times (coefficient of variation). A fuller percentage breakdown into different categories of training time required does little to alter this picture. For example, about a quarter of all jobs in both 1976 and 1985 could be learned in less than a month. In most cases, jobs that require more formal education have longer median training periods, but within educational levels there is little change in job training time between 1976 and 1985, even for jobs requiring a great deal of education. (The large change for postgraduates reflects a clustering of cases around the median; the means show no meaningful change.)

The situation is the same for trends in median training time within broad occupational groups. The training times for the groups make intuitive sense; for example, lower blue-collar and service workers require two months to learn their jobs and craft workers have a two-year apprenticeship. However, there is no difference of any kind over time.

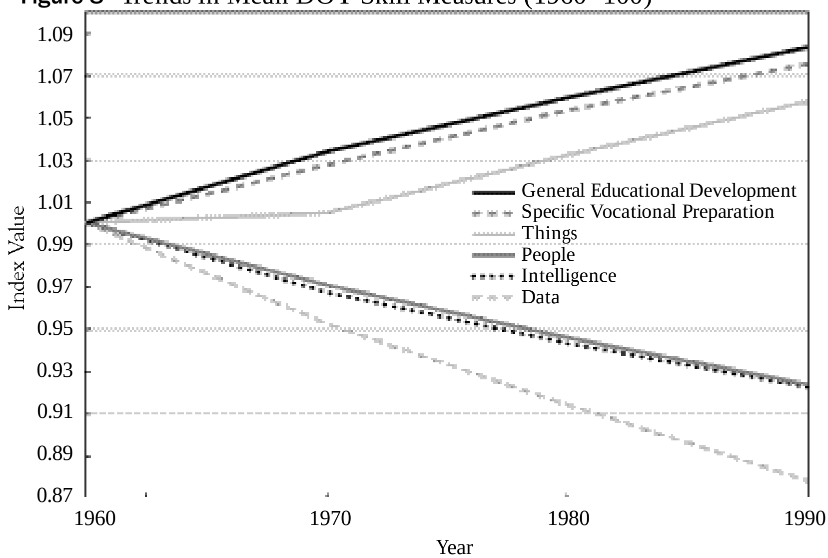
If there is any series that would seem to confirm Spenner's (1979) thesis of little or no change in skill requirements, it is this one. This is the period during which upper and lower white-collar jobs experienced a surge of computer use. However, there is no increase in training time for these jobs even though few workers could have learned to use computers in school this early in the diffusion process. If the appearance of computers in the workplace in large numbers dramatically increased job training requirements, there is little evidence of it here.

Occupation-Level Measures

Most studies use direct measures of job skill requirements drawn from the *Dictionary of Occupational Titles* (DOT) (1977), a government publication with ratings of skill demands that has been used to produce ratings of job complexity for narrowly-defined census occupations. Although the DOT skill measures cannot capture all the variation of individual-level measures, they can be combined with census data to generate a longer and fuller time series than the individual-level measures.

Six DOT skill measures are used here. The first, General Educational Development (GED), is a six-point scale rating the formal educational requirements of an occupation. The second, Specific Vocational Preparation (SVP), is a nine-point scale rating the time required to learn an occupation exclusive of schooling without specific vocational content. There are three six- to eight-point scales rating the level of complexity at which the worker functions in relation to Data, People, and Things. The sixth, Intelligence, is a measure of required worker aptitude and uses a four-point scale indicating the percentile range of the

Figure 8 Trends in Mean DOT Skill Measures (1960=100)



Note: Declining scores for Things, People, Intelligence, and Data mean increasing skill.
Source: Decennial Census Microdata.

population from which members of the occupation are drawn. Except for GED and SVP, lower numbers indicate higher levels of skill.

Figure 8 shows trends in the six measures for 1960 to 1990 using census data. GED and SVP slope upward, indicating increasing mean educational requirements and training times. Data, People, and Intelligence slope downward, also indicating increasing skill requirements. By contrast, Things slopes upward, indicating an increasing prevalence of jobs with lower manual skill requirements. However, Things is the only one that suggests much acceleration in skill upgrading. In fact, all of the others indicate that skill upgrading was marginally more rapid in the 1960s than subsequently and least rapid in the 1980s. Similarly, when DOT scores are combined with CPS data from 1968 to 1997 there is little evidence that changes in occupational composition are leading to more rapid upgrading of job skill requirements now than in previous decades (see Handel 2000b).

Policy Implications

The preceding findings cast strong doubt on claims that the growth of wage inequality in the last twenty years is due to a skills shortage, whether driven by an acceleration in the demand for skill arising from the diffusion of advanced information technology or a deceleration in the growth of the supply of skilled labor.

The heavy concentration of inequality growth in the recession years of the early 1980s does not coincide with the slowdown in the growth of workers' educational attainment, which diverges most strongly from earlier growth patterns in the late 1980s and 1990s. The flatness of both the supply of educated workers and wage inequality in the 1990s casts further doubt on the supply-side explanation.

Though the occupational composition shifted in favor of more skilled workers during the period of inequality growth, this is true for previous decades as well, when inequality did not grow dramatically, and there is no evidence of any acceleration in the trend. Similarly, though direct measures of job skill requirements from individual-level surveys and the DOT indicate a shift toward more skilled jobs, the trend is a steady, secular one, unlike the sharp growth of inequality in the early 1980s.

The evidence for a causal relationship between computer use and educational requirements is questionable and there are few examples of disproportionate growth or decline in occupations likely to be sensitive to technological change. In short, it is hard to find evidence that information technology has done much to alter either the skill content of work within occupations or the occupational composition of the workforce, leaving the demand-side explanation with little support.

The most powerful factors affecting wages would seem to be the recession and trade deficits of the early 1980s, which coincided with the most dramatic growth in wage inequality and the most noticeable change in occupational composition: the sharp decline in blue-collar manufacturing workers in the early 1980s. The modest decline in inequality during the expansion of the 1990s also suggests the importance of macroeconomic forces. It appears that the skill requirements of postindustrial technology have had far less influence on wages than the state of the overall economy.

The clearest policy implication of this research is the need to maintain growth and low unemployment. The least affluent workers bear most of the burdens of recession, and severe shocks, such as the deep recession of the early 1980s, have the power to reshape the wage structure. When the structure is changed, relative wage losses for those in the lower part of the distribution are not reversed when the business cycle turns upward; they persist for decades. Government can perform its greatest service to workers by maintaining tight labor markets and avoiding policies that are sharply recessionary. In addition, government can support wages at the lower end of the distribution with policies to reverse the decline of institutional protections that has continued since the economic crisis of the early 1980s. Such policies include maintaining the real value of the minimum wage and supporting protections for unions that preserve some balance between the bargaining power of workers and management.

None of the preceding should be taken to imply that policy should ignore the education and training of workers. Workforce development is critical for improving productivity and product quality. Apprenticeships, school-to-work programs, and tuition assistance deserve active support. Subsidies for brief computer and other general technical training are likely to have positive returns. The provision of such training to disadvantaged and displaced workers can help overcome market imperfections. The point is not that education and training are unimportant; they have always been good ideas. However, they are not enough. The recent growth in inequality does not have its origins in the growth of a gap between worker skills and job skill requirements and inequality is unlikely to be reduced by skill development initiatives alone. A decline in inequality requires macro policies to maintain growth and full employment and minimum wage and labor policies that directly support wages in the lower part of the wage distribution.

Notes

1. For instance, about 78 percent of household heads and spouses employed in 1985 reported at least nine years' actual work experience in the Panel Study of Income Dynamics (author's tabulations). Although this figure does not include young adults in the labor force who still lived with their parents, it gives a general sense of the overlap between the workforces in the mid 1980s and the mid 1970s.

2. The material in this policy brief is drawn from two working papers, where more detailed description of data, methods, and results may be found (see Handel 2000a, 2000b).

3. The differential is roughly one year when controlling for age, female, black, part-time status, marital status and its interaction with female, region, and three-digit industry. When controls for one-digit occupation are added, the estimated differential is cut roughly in half. The models are estimated separately using cross-sectional data from the October CPS supplements for 1984, 1989, 1993, and 1997. For details see Handel (2000a).

4. More formally, this model can be written as

   $$\Delta Ed_i = \alpha + \beta * \Delta C_i + \varepsilon_i$$

   where

   ΔEd_i = average annual change in mean years of education within occupation *i* or annual change in percentage share of an education group (e.g. high school graduates) within occupation *i*

   ΔC_i = average annual change in the percentage of computer users within occupation *i*

   ε_i = error term

   See Handel (2000a) for further details.

5. Although the computer equipment industry employs workers of all skill levels, it is worthwhile to note that this industry never accounted for as much as 1 percent of total employment. Between 1971–1985, the computer hardware industry share of employment rose from 0.27 percent to 0.85 percent, before falling to 0.57 percent in 1997.

6. Average sample size for grocery stores is 1,460. Census figures for 1980 and 1990 do suggest a decline in the share of cashiers within grocery stores, from about 30 percent to about 26 percent, though this is still well above the level in 1970 (20 percent).

7. Average sample size for wholesale and retail industries in the March CPS is 12,302.

8. Average sample size for banking and insurance in the March CPS is 2,787.

9. Average sample size for banking in the March CPS is 1,075.

10. Average sample size for the postal industry in the March CPS is 489.

11. Average sample size for the telephone industry in the March CPS is 682.

12. Average sample size for the auto industry in the March CPS is 650.

13. The data are from the Survey of Working Conditions (SWC) (1969), Quality of Employment Surveys (QES) (1972, 1977), and the Panel Study of Income Dynamics (PSID) (1976, 1985). Despite the difference in name, the SWC is part of the same data series as the two QES surveys.

    The exact items for the SWC/QES are "What level of formal education do you feel is needed by a person in your job?" (education required). For the PSID the items are "How much formal education is required [these days—1985] to get a job like yours?" (education required) and "On a job like yours, how long would it take the average new person to become fully trained and qualified?" (months) (training time).

    In addition, household heads in the PSID were re-asked the skill questions in 1978. This information was used to estimate individual-level reliabilities in a separate validation exercise in Handel (2000b). For more details on the sample and analyses that follow see Handel (2000b).

14. There is a significant noncomparability issue for this item in both data series. The SWC (1969) and the PSID85 allowed respondents to say that their jobs required high school plus vocational education, but none of the other surveys included this option. Since it is unclear how many of these respondents would have replied either "high school" or "some college" had this option not existed, all comparisons aggregate figures for those choosing any of the three options.

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