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The Computer Evolution

Since the introduction of the IBM PC in 1981, desktop computers have become a standard fixture in most workplaces. Through their ubiquity and impact on how work is done, personal computers (PCs) arguably have transformed the workplace. At the same time, the use and impact of PCs varies across worker groups with different educational and skill levels. As a result, an extensive body of research suggests that the spread of computers, or perhaps increased workplace emphasis on skills that are closely related to computer use, has altered the distribution of wages as well. This process has been marked not so much by abrupt change as by slow and steady change—it is an "evolution" rather than a "revolution."

In this *Economic Letter*, we use data from five special surveys, covering the period 1984–2001, to examine two key aspects of the computer evolution: the spread of PCs at work and the evolving wage differentials between individuals who use them and those who do not. Although the spread of computers has been relatively uniform across labor force groups, the wage returns associated with computers tilted sharply in favor of the highly educated at the end of our sample frame. This finding appears consistent with the increase in trend productivity growth that occurred around the same time.

Computers and workers

By the middle to late 1980s, the rapid expansion of computer power embodied in PCs, combined with software that enhanced the overall ease of PC use and application to common business tasks, suggested to researchers and casual observers alike that computers were playing an increasingly important role in the determination of worker productivity and wages. In the first systematic analysis of the impact of computer use on wages, Krueger (1993) used data for the years 1984 and 1989 to estimate standard wage regressions that included controls for computer use at work. As such, his estimates reflect wage differences between workers who use and do not use computers, adjusted for other observable differences across such workers that are systematically related to wages as well (age, educational attainment, sex, etc.). His results suggested that workers who used computers earned about 10%–20% more than workers who did not. Moreover, Krueger found that differences between highly educated and less educated workers in the incidence of and returns to computer use could account for 40%–50% of the increased return to education during the 1980s.

Krueger's analysis tied in well with earlier work regarding the contribution of technological change to increased dispersion in the U.S. wage distribution. Since then, wage gaps have widened even further, intensifying the research focus on how equipment like computers can alter the wage distribution by altering the demand for workers with the skills to use such equipment effectively. In a notable recent piece, Autor, Levy, and Murnane (2003) argue that increased computer use can explain most of the increase in nonroutine job tasks, hence the advanced skill content of jobs, during the 1970s, 1980s, and 1990s, and as such can explain most of the increased relative demand for college-educated workers. Although Autor et al. do not directly address the question of computer effects on earnings, their results indirectly suggest that rising computer use also explains a substantial portion of the rising wage gaps between highly educated and less educated workers over these three decades.

PC diffusion and wage effects

Given these existing findings about computer use, skill demand, and wages, an updated assessment of the returns to computer use is in order. To do so, we use the School Enrollment and the Computer and Internet Use Supplements to the federal government's Current Population Survey (CPS). The CPS covers about 60,000 households each month; the resulting sample of individuals serves as a primary source of information on U.S. employment, unemployment, and income patterns. The supplements we use were conducted in 1984, 1989, 1993, 1997, and 2001 (Krueger's work relied on the first two of these). In these sur-

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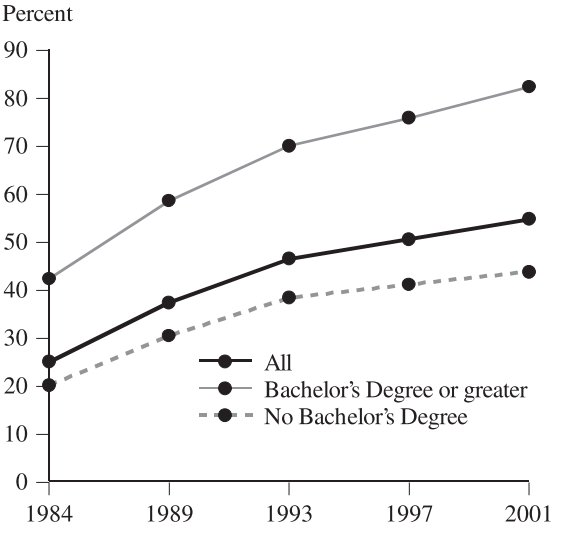
veys, the respondents were asked about computer use at home, work, and school. Although the exact content of the supplements changed over time (for example, Internet use was first addressed in 1997), the question about computer use at work has been essentially unaltered. We rely on samples of about 60,000 employed individuals in each survey to calculate rates of computer use at work; of these, information on wages and related variables is provided for a bit under one-fourth of the sample (about 12,000–14,000 individuals). We restrict the analysis to individuals age 18 to 65.

Figure 1 shows the time series of computer use rates for college graduates, nongraduates, and the combined population. Although the level of computer use is significantly higher for workers with a bachelor's degree (82.3% in 2001) than for those without it (42.7%), the diffusion over time has been relatively uniform across these groups. Additional tabulations show a similar pattern of diffusion when the sample is broken down into narrower educational groups or by additional characteristics such as gender, race, age, geography, and occupation. In percentage terms, we find the sharpest increase in computer use at work for groups with low initial use, including older workers, part-time workers, blue-collar workers, and workers without a high school degree. Moreover, the diffusion of computer use at work slowed after 1993. These patterns are consistent with common models of technology diffusion, in which individuals and firms with the most to gain adopt the new technology first and the rate of diffusion slows as the group that has not yet adopted it shrinks.

To estimate the effect of computer use on wages, we use a regression model similar to Krueger's (1993). The model controls for observable characteristics that are systematically related to wages, including age, education, race, sex, marital status, veteran status, union status, part-time status, and geographic location (region and urban/rural residence), allowing us to isolate the effect of computer use on wages independent of the influence of these other characteristics. Given the potentially important interaction between computer use and education level, we also allow for separate estimates of the return to computer use for individuals who have attained at least a college degree versus those who have not. After applying an appropriate mathematical transformation based on the logarithmic regression function, we obtain the estimated percentage effect of computer use on wages.

Figure 2 plots how the estimated return to computer use at work has changed over time. For the full sample of workers, the return to computer use reached

Figure 1
Computer use at work

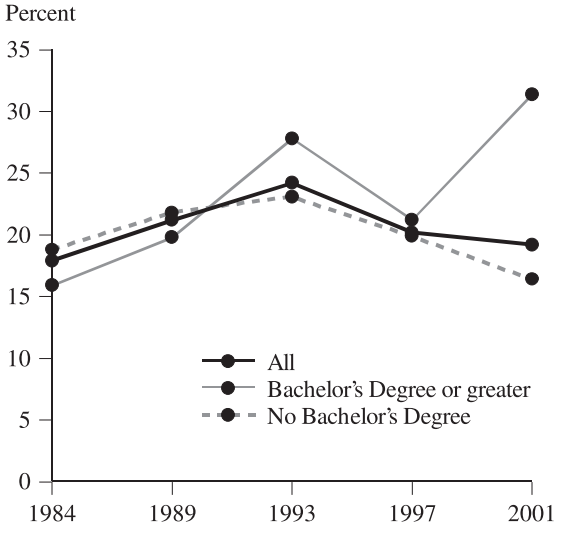


Note: Authors' tabulations of CPS computer use supplement data.

a peak in 1993, with a 24.2% wage advantage over otherwise similar workers. The estimated return to computer use for the full sample declined to 19.2% in 2001. However, the return for individuals with a college or graduate degree increased dramatically during the last period, reaching 31.4% in 2001. This sharp change is surprising, as it conflicts with the general expectation, based on economic reasoning, that the return to scarce skills (those needed for computer use) should decline as that skill becomes less scarce. As shown in Figure 1, only about one in five college-educated workers did not use computers at work in 2001, which suggests that the skills needed to use computers are far from scarce among the highly educated.

Although the spread of computer skills suggests that the wage returns to computer use should decline, this argument ignores the possibility that production technology is changing rapidly and in ways that support increased rewards for workers with the skills needed for effective use of critical technologies such as computers. Available evidence suggests that rapid expansion of information technology capital (mainly computers and software) in the workplace accounts for a substantial portion of the increased growth in labor productivity during the period 1996–2001 (see for example Oliner and Sichel 2003). While computers make some tasks easier and reduce required skill levels, many advances in computer technology have enabled increasingly sophisticated applications that require complex analytical and evaluative skills. A leading reason to attend college is to acquire such skills. It appears that these skills commanded an increasing premium as workplace computer use intensified

Figure 2
Wage returns to computer use



Note: Authors' estimates.

between 1997 and 2001, enabling college-educated workers to capture the largest benefits from the spread of computers in the workplace during this period.

Implications

Our findings confirm that workers who use computers earn more than otherwise similar workers who do not. We also find that this effect has been especially large for highly educated workers in recent years. Some researchers, however, have questioned whether the computer effect on wages is fundamentally meaningful in an economic sense. For example, DiNardo and Pischke (1997) have shown that workers who use simple office tools like pencils earn a wage premium similar to that estimated for computer users. This suggests the possibility that the estimated effect of computer use on wages reflects unobserved aspects of skilled workers and their jobs, such that these workers would earn higher wages even if they did not use computers. In other words, DiNardo and Pischke argue that computer use does not have an independent "causal" impact on wages but instead serves as a mediating or auxiliary factor, reflecting related skills that are more fundamental than the direct ability to use a computer.

Nevertheless, an abundance of evidence regarding close relationships among the use of advanced technology and the demand for and wages of skilled workers suggests an important causal role for computers and the skills needed to use them. In that regard, an emphasis on "causal" impacts may be misplaced. For many jobs, effective performance requires computer use, which suggests a close relationship between computer use and critical job skills. In technical parlance, the ability to use a computer probably is not a "sufficient" condition for earning high wages, but it is increasingly a "necessary" condition.

Overall, we interpret the evidence as suggesting that direct computer skills or skills that closely relate to computer use command a substantial premium in the labor market, especially in conjunction with a college degree. It remains to be seen whether the recent increase in returns to computer use for highly educated individuals will continue. However, the trend over the past few years suggests that U.S. productivity growth remains on (or even above) the accelerated growth path that was established during the late 1990s. Going forward, it is likely that these productivity gains will be largely reflected in wage gains for highly educated individuals who use computers, much as was the increase in the relative return to computer use for these individuals during the period 1997–2001.

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