# HOW COMPUTERS HAVE CHANGED THE WAGE STRUCTURE: EVIDENCE FROM MICRODATA, 1984–1989*

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This paper uses Current Population Survey data to examine whether workers who use a computer at work earn a higher wage rate than otherwise similar workers who do not use a computer at work. A variety of models are estimated to try to correct for unobserved variables that might be correlated with job-related computer use and earnings. Estimates suggest that workers who use computers on their job earn 10 to 15 percent higher wages. Additionally, the expansion in computer use in the 1980s can account for one-third to one-half of the increase in the rate of return to education.

## INTRODUCTION

Several researchers have documented that significant changes in the structure of wages took place in the United States in the 1980s.[1] For example, the rate of return to education has increased markedly since 1979, with the earnings advantage of college graduates relative to high school graduates increasing from 34 percent in 1979 to 56 percent in 1991 [Mishel and Bernstein, 1992, Table B1]. In addition, wage differentials based on race have expanded while the male-female wage gap has narrowed, and the reward for experience appears to have increased. These changes in the wage structure do not appear to be a result of transitory cyclical factors.

In contrast to the near consensus of opinion regarding the scope and direction of changes in the wage structure in the 1980s, the root causes of these changes remain controversial. The two leading hypotheses that have emerged to explain the rapid changes in the wage structure in the 1980s are (1) increased international competition in several industries has hurt the economic position of low-skilled and less-educated workers in the United States (e.g., Murphy and Welch [1991]); (2) rapid, skill-biased technological change in the 1980s caused profound changes in the relative productivity of various types of workers (e.g., Bound and Johnson

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1. Excellent examples of this literature include Blackburn, Bloom, and Freeman [1990], Murphy and Welch [1992], Katz and Revenga [1989], Katz and Murphy [1992], Bound and Johnson [1992], Juhn, Murphy, and Pearce [1989], Levy [1989], Mincer [1991], and Davis and Haltiwanger [1991].



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[1992], Mincer [1991], and Allen [1991]). Unfortunately, the evidence that has been used to test these hypotheses has been mainly indirect, relying primarily on aggregate industry-level or time-series data.

This paper explores the impact of the "computer revolution" on the wage structure using three microdata sets. The 1980s witnessed unprecedented growth in the amount and type of computer resources used at work, and the cost of computing power fell dramatically over the decade. For example, in 1984 fewer than 10 percent of establishments reported that they had personal computers, while this figure was over 35 percent in 1989 [*Statistical Abstract of the United States, 1990,* p. 951]. Berndt and Griliches [1990] estimate that the quality-adjusted real price of new microcomputers fell by 28 percent per year between 1982 and 1988. Several authors who have come to view technological change as a promising explanation of changes in the wage structure have highlighted the computer revolution as the prototypical example of such technological change.[2]

It is important to stress that the effect of technological change on the relative earnings of various categories of workers is theoretically ambiguous. The new computer technology may be a complement or a substitute for skilled workers.[3] In the former case the computer revolution is likely to lead to an expansion in earnings differentials based on skill, and in the latter case it is likely to lead to compression in skill-based differentials. *This paper focuses on the issue of whether employees who use computers at work earn more as a result of applying their computer skills, and whether the premium for using a computer can account for much of the change in the wage structure.* The analysis primarily uses data from Current Population Surveys (CPS) conducted in October of 1984 and 1989. These surveys contain supplemental questions on computer use. Since CPS data spanning this time period were widely used to document the trends in wage differentials noted previously, these data sets are particularly germane. In addition to the CPS, I also examine data from the High School and Beyond

2. For example, Bound and Johnson [1992] write that one explanation "attributes wage structure changes to changes in technology, brought on in large part by the computer revolution." They conclude that this explanation "receives a great deal of support from the data."

3. See Blackburn and Bloom [1988] for an excellent discussion of how technological change can affect earnings differentials. Bartel and Lichtenberg [1987] present cost function estimates for 61 manufacturing industries that suggest that skilled labor is a complement to new technology. For related evidence see Welch [1970] and Griliches [1969].

Survey (HSBS), which contains information on achievement test scores and family background, as well as on computer use at work.

The remainder of the paper is organized as follows. Section I presents a brief descriptive analysis of the workers who use computers at work and details trends in computer utilization in the United States in the 1980s. Section II seeks to answer the question: Are workers who use computers at work paid more as a result of their computer skills? Section III addresses issues of possible omitted variable bias. Section IV analyzes the impact of computer use on other wage differentials. Finally, Section V concludes by speculating on the likely future course of the wage structure in light of the new evidence regarding the payoff to computer use.

To preview the main results, I find that workers are rewarded more highly if they use computers at work. Indeed, workers who use a computer earn roughly 10–15 percent higher pay, other things being equal. Additionally, because more highly educated workers are more likely to use computers at work, and because computer use expanded tremendously in the 1980s, computer use can account for a substantial share of the increase in the rate of return to education.

## I. Descriptive Analysis

In spite of the widespread belief that computers have fundamentally altered the work environment, little descriptive information exists concerning the characteristics of workers who use computers on the job. Table I summarizes the probability of using a computer at work for several categories of workers in 1984 and 1989. The tabulations are based on October CPS data. These surveys asked respondents whether they have "direct or hands on use of computers" at work.[4] Computer use is broadly defined, and includes programming, word processing, E-mail, computer-aided design, etc. For one-quarter of the sample, information on earnings was also collected.

Between 1984 and 1989 the percentage of workers who report using a computer at work increased by over 50 percent, from 24.6 to 37.4 percent of the work force. Women, Caucasians, and highly educated workers are more likely to use computers at work than

4. According to the interviewers' instructions, " 'Using a computer' refers only to the respondent's 'DIRECT' or 'HANDS ON' use of a computer with typewriter like keyboards." The computer may be a personal computer, minicomputer or mainframe computer. (See CPS Field Representative's Memorandum No. 89-20, Section II, October 1989.)

TABLE I
PERCENT OF WORKERS IN VARIOUS CATEGORIES WHO DIRECTLY USE A COMPUTER AT WORK

| Group | 1984 | 1989 |
|---|---|---|
| All workers | 24.6 | 37.4 |
| Gender | | |
| Men | 21.2 | 32.3 |
| Women | 29.0 | 43.4 |
| Education | | |
| Less than high school | 5.0 | 7.8 |
| High school | 19.3 | 29.3 |
| Some college | 30.6 | 45.3 |
| College | 41.6 | 58.2 |
| Postcollege | 42.8 | 59.7 |
| Race | | |
| White | 25.3 | 38.5 |
| Black | 19.4 | 27.7 |
| Age | | |
| Age 18–24 | 19.7 | 29.4 |
| Age 25–39 | 29.2 | 41.5 |
| Age 40–54 | 23.6 | 39.1 |
| Age 55–65 | 16.9 | 26.3 |
| Occupation | | |
| Blue-collar | 7.1 | 11.6 |
| White-collar | 33.0 | 48.4 |
| Union status | | |
| Union member | 20.2 | 32.5 |
| Nonunion | 28.0 | 41.1 |
| Hours | | |
| Part-time | 23.7 | 36.3 |
| Full-time | 28.9 | 42.7 |
| Region | | |
| Northeast | 25.5 | 38.0 |
| Midwest | 23.4 | 36.0 |
| South | 23.2 | 36.5 |
| West | 27.0 | 39.9 |

*Source.* Author's tabulations of the 1984 and 1989 October Current Population Surveys. The sample size is 61,712 for 1984 and 62,748 for 1989.

men, African Americans, and less-educated workers. Furthermore, the percentage gap in computer use between these groups grew between 1984 and 1989. For example, in 1984 college graduates were 22 points more likely to use computers at work than high school graduates; in 1989 this differential was 29 points.

Surprisingly, workers age 40–54 are more likely to use computers at work than workers age 18–25, and the growth in computer use between 1984 and 1989 was greatest for middle-aged workers.

A linear probability regression of a computer-use dummy on experience and its square, education, and demographic variables indicates that the likelihood of using a computer increases with experience in the first fifteen years of experience, and declines thereafter.

Tabulations of the 1989 CPS show that relatively few employees (less than 5 percent of employees) use computers in the agriculture, construction, textile, lumber, and personal services industries, whereas computer use is widespread (exceeding 60 percent of employees) in the banking, insurance, real estate, communications, and public administration industries. The October CPS does not contain information on employer size, but a 1989 establishment survey by the Gartner Group found that computer use is not strongly related to establishment size for establishments with more than twenty employees [*Statistical Abstract of the United States, 1990,* p. 951]. And the growth in personal computers per worker between 1984 and 1989 was not strongly related to establishment size for establishments with more than twenty employees.

## II. Computer Use and Wages

I have estimated a variety of statistical models to try to answer the question: Do employees who use computers at work receive a higher wage rate as a result of their computer skills? I begin by summarizing some simple ordinary least squares (OLS) estimates. The analysis is based on data from the October 1984 and 1989 CPS. The sample consists of workers age 18–65. (See Appendix A for further details of the sample.)

My initial approach is to augment a standard cross-sectional earnings function to include a dummy variable indicating whether an individual uses a computer at work. Let $C_i$ represent a dummy variable that equals one if the $i$th individual uses a computer at work, and zero otherwise. Observation $i$'s wage rate $W_i$ is assumed to depend on $C_i$, a vector of observed characteristics $X_i$, and an error $\epsilon_i$. Adopting a log-linear specification,

$$(1) \qquad \ln W_i = X_i\beta + C_i\alpha + \epsilon_i ,$$

where $\beta$ and $\alpha$ are parameters to be estimated. Section III considers the effect of bias because of possible correlation between $C_i$ and $\epsilon_i$.

Table II reports results of fitting equation (1) by OLS, with varying sets of covariates ($X$). In columns (1) and (4) a computer-use dummy variable is the only right-hand-side variable. In these

TABLE II
OLS REGRESSION ESTIMATES OF THE EFFECT OF COMPUTER USE ON PAY
(DEPENDENT VARIABLE: ln (HOURLY WAGE))

| Independent variable | October 1984 | | | October 1989 | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Intercept | 1.937 | 0.750 | 0.928 | 2.086 | 0.905 | 1.094 |
| | (0.005) | (0.023) | (0.026) | (0.006) | (0.024) | (0.026) |
| Uses computer at work (1 = yes) | 0.276 | 0.170 | 0.140 | 0.325 | 0.188 | 0.162 |
| | (0.010) | (0.008) | (0.008) | (0.009) | (0.008) | (0.008) |
| Years of education | — | 0.069 | 0.048 | — | 0.075 | 0.055 |
| | | (0.001) | (0.002) | | (0.002) | (0.002) |
| Experience | — | 0.027 | 0.025 | — | 0.027 | 0.025 |
| | | (0.001) | (0.001) | | (0.001) | (0.001) |
| Experience-squared ÷ 100 | — | −0.041 | −0.040 | — | −0.041 | −0.040 |
| | | (0.002) | (0.002) | | (0.002) | (0.002) |
| Black (1 = yes) | — | −0.098 | −0.066 | — | −0.121 | −0.092 |
| | | (0.013) | (0.012) | | (0.013) | (0.012) |
| Other race (1 = yes) | — | −0.105 | −0.079 | — | −0.029 | −0.015 |
| | | (0.020) | (0.019) | | (0.020) | (0.020) |
| Part-time (1 = yes) | — | −0.256 | −0.216 | — | −0.221 | −0.183 |
| | | (0.010) | (0.010) | | (0.010) | (0.010) |
| Lives in SMSA (1 = yes) | — | 0.111 | 0.105 | — | 0.138 | 0.130 |
| | | (0.007) | (0.007) | | (0.007) | (0.007) |
| Veteran (1 = yes) | — | 0.038 | 0.041 | — | 0.025 | 0.031 |
| | | (0.011) | (0.011) | | (0.012) | (0.011) |
| Female (1 = yes) | — | −0.162 | −0.135 | — | −0.172 | −0.151 |
| | | (0.012) | (0.012) | | (0.012) | (0.012) |
| Married (1 = yes) | — | 0.156 | 0.129 | — | 0.159 | 0.143 |
| | | (0.011) | (0.011) | | (0.011) | (0.011) |
| Married*Female | — | −0.168 | −0.151 | — | −0.141 | −0.131 |
| | | (0.015) | (0.015) | | (0.015) | (0.015) |
| Union member (1 = yes) | — | 0.181 | 0.194 | — | 0.182 | 0.189 |
| | | (0.009) | (0.009) | | (0.010) | (0.010) |
| 8 Occupation dummies | No | No | Yes | No | No | Yes |
| $R^2$ | 0.051 | 0.446 | 0.491 | 0.082 | 0.451 | 0.486 |

*Notes.* Standard errors are shown in parentheses. Sample size is 13,335 for 1984 and 13,379 for 1989. Columns (2), (3), (5), and (6) also include three region dummy variables.

models the (raw) differential in hourly pay between workers who use computers on the job and those who do not is 31.8 percent (exp(0.276)-1) in 1984, and 38.4 percent (exp(0.325)-1) in 1989. In columns (2) and (5) several covariates are added to the regression equation, including education, potential experience and its square, gender, and union status. Including these variables reduces the computer premium to 18.5 percent in 1984 and to 20.6 percent in

1989.[5] Even after including these covariates, however, the computer dummy variable continues to have a sizable and statistically significant effect on wages, with $t$-ratios of 21.3 in 1984 and 23.1 in 1989.

It is not clear whether occupation dummies are appropriate variables to include in these wage regressions because computer skills may enable workers to qualify for jobs in higher paying occupations and industries. For example, one would probably not want to control for whether a worker is in the computer programming occupation while estimating the effect of computer use on earnings. Nevertheless, columns (3) and (6) include a set of eight one-digit occupation dummies. These models still show a sizable pay differential for using a computer at work. In 1989, for example, employees who use computers on the job earn 17.6 percent higher pay than employees who do not use computers on the job, holding education, occupation, and other characteristics constant. If 44 two-digit occupation dummies are included in the model in column (6) instead of the 8 one-digit occupation dummies, the computer-use wage differential is 13.9 percent, with a $t$-ratio of 15.5.

*A. Employer Characteristics*

Although I am mainly concerned about bias because of omitted employee characteristics that are correlated with computer use at work, it is possible that characteristics of employers are correlated with the provision of computers and the generosity of compensation. Such a relationship might exist in a rent-sharing model, in which employees are able to capture some of the return to the employer's capital stock. Unfortunately, there is only a limited amount of information about employer characteristics in the CPS. However, if 48 two-digit industry dummies are included in a model that includes two-digit occupation dummies and the covariates in column (6), the computer-use wage differential is 11.4 percent, with a $t$-ratio of 13.0.[6]

Information on employer size is not available in the October CPS, but two findings suggest that the computer differential is not merely reflecting the effect of (omitted) employer size. First, establishment-level surveys do not show a strong relationship

5. The computer differential is about the same for men and women. For example, in 1989 the coefficient (and standard error) for computer use is 0.197 (0.012) for men and 0.185 (0.011) for women.

6. Results for 1984 are similar: the wage differential falls to 11.3 percent if 44 occupation dummies are included, and to 9.0 percent if 48 two-digit industry dummies are included.

between computer use and establishment size (e.g., Hirschorn [1988]). Second, in a recent paper Reilly [1991] uses a sample of 607 employees who worked in 60 plants in Canada in 1979 to investigate the relationship between establishment size and wages. Reilly estimates wage regressions including a dummy variable indicating access to a computer. Without controlling for establishment size, he finds that employees who have access to a computer earn 15.5 percent ($t = 5.7$) higher pay. When he includes the log of establishment size, the computer-wage differential is 13.4 percent ($t = 3.9$).

Finally, I have estimated the model in column (5) separately for union and nonunion workers. The premium for computer use is 20.4 percent ($t = 23$) in the nonunion sector, and just 7.8 percent ($t = 4.3$) in the union sector. Since unions have been found to compress skill differentials (see Lewis [1986] and Card [1991]), this finding should not be surprising. However, if one believes that the premium for work-related computer use is a result of employees capturing firms' capital rents rather than a return to a skill, it is difficult to explain why the premium is so much larger in the nonunion sector than in the union sector.

### *B. Computer Premium over Time*

The results in Table II indicate that, if anything, the estimated reward for using a computer at work increased slightly between 1984 and 1989. For example, based on the models in columns (3) and (6), between 1984 and 1989 the computer (log) wage premium increased by 0.022. The standard error of this estimate is 0.011, so the increase is on the margin of statistical significance. There is certainly no evidence of a decline in the payoff for computer skills in this period.

This finding is of interest for two reasons. First, given the substantial expansion in the supply of workers who have computer skills between 1984 and 1989, one might have expected a decline in the wage differential associated with computer use at work, *ceteris paribus*. The failure of the wage differential for computer use to decline suggests that the demand for workers with computer skills may have shifted out as fast as, or faster than, the outward shift in the supply of computer-literate workers. This hypothesis is plausible given the remarkable decline in the price of computers and the expansion in uses of computers in the 1980s.

A second reason why the slight increase in the wage differential associated with computer use is of interest concerns the effect of possible nonrandom selection of the workers who use computers. Companies are likely to provide computer training and equipment first to the workers whose productivity is expected to increase the most from using a computer. This would pose a problem for the interpretation of the OLS estimates if these workers would have earned higher wages in the absence of computer use. The large increase in the number of workers who used computers at work between 1984 and 1989 is likely to have reduced the average quality of workers who work with computers, which would be expected to drive down the average wage differential associated with computer use. However, the slight *increase* in the computer wage premium between 1984 and 1989 suggests that nonrandom selection of the workers who use computers is not the dominant factor behind the positive association between computer use and wages.

The other variables in Table II generally have their typical effects on wages, and their coefficients are relatively stable between 1984 and 1989. One notable exception is the rate of return to education, which increased by 0.6 percentage points between 1984 and 1989, even after holding computer use constant. And the black-white wage gap increased, while the wage gap between whites and other races declined in these years.

*C. Specific Computer Tasks*

The 1989 CPS asked workers what tasks they use their computer for. Respondents were allowed to indicate multiple tasks. Table III presents estimates of the coefficients on the specific computer tasks for a wage regression that also includes the covariates listed in column (6) of Table II (including occupation dummies). Importantly, the regression includes a dummy that equals one if the individual used a computer for *any* task at all, as well as dummies for the specific tasks. Thus, the coefficients on the specific tasks should be interpreted as indicating the additional payoff associated with a specific task relative to any computer use at all.

Interestingly, these results show that the most highly rewarded task computers are used for is electronic mail, probably reflecting the fact that high-ranking executives often use E-mail. On the other hand, the results indicate a negative premium for individuals who use a computer for playing computer games. In fact, the −0.11 coefficient on computer games virtually negates the 0.145 coefficient for using computers at all. This result is signifi-

TABLE III
THE RETURN TO VARIOUS USES OF COMPUTERS, OCTOBER 1989[a]
(DEPENDENT VARIABLE: ln (HOURLY WAGE))

| Use of computer at work | Proportion | Coefficient (std. error) |
|---|---|---|
| Uses computer at work for any task[b] | 0.398 | 0.145 (0.010) |
| Specific Task[c] | | |
| Word processing | 0.165 | 0.017 (0.012) |
| Bookkeeping | 0.100 | −0.058 (0.013) |
| Computer-assisted design | 0.039 | 0.026 (0.020) |
| Electronic mail | 0.063 | 0.149 (0.016) |
| Inventory control | 0.102 | −0.056 (0.013) |
| Programming | 0.077 | 0.052 (0.031) |
| Desktop publishing or newsletters | 0.036 | −0.047 (0.021) |
| Spread sheets | 0.094 | 0.079 (0.015) |
| Sales | 0.060 | −0.002 (0.016) |
| Computer games | 0.019 | −0.109 (0.026) |
| $R^2$ | | 0.495 |

a. The sample and other explanatory variables are the same as in column (6) of Table II.
b. The computer use dummy variable equals one if the worker uses computers for any of the ten enumerated tasks or for any other task.
c. The dummy variables for any specific computer task, and the dummy variable for any computer use, are not mutually exclusive.

cant because it suggests that using a computer for nonproductive activities does not enhance earnings. If the positive premium associated with computer use documented in this paper were reflecting characteristics of employers, such as ability to pay, we would expect workers who use computers exclusively for playing games to also have a large positive premium; this clearly is not the case.

## III. IS THE COMPUTER WAGE DIFFERENTIAL REAL OR ILLUSORY?

A critical concern in interpreting the OLS regressions reported above is that workers who use computers on the job may be abler workers, and therefore may have earned higher wages even in the absence of computer technology. Further, the finding that the computer wage differential is attenuated when covariates are included in the OLS regressions suggests that important variables may be omitted that are positively correlated with both computer use and earnings. I have tried four empirical strategies to probe whether the computer pay differential is a real consequence of computer use or is spurious.

### *A. Computer Use at Home and at Work*

The 1984 and 1989 October CPS surveys collected information on computer use at home as well as at work. This enables a more general specification of the wage equation. In particular, I have estimated parameters of the following log-wage equation:

$$\ln W = X\beta + C_w\alpha_1 + C_h\alpha_2 + C_w \cdot C_h\alpha_3 + \epsilon, \tag{2}$$

where $C_w$ is a dummy variable that equals one if a worker uses a computer at work and zero otherwise, $C_h$ is a dummy variable that equals one if a worker uses a computer at home and zero otherwise, and $C_w \cdot C_h$ is an interaction term between computer use at home and at work.

Workers who possess unobserved characteristics that are associated with computer use at home may be selected by employers to use computers at work on the basis of those same characteristics. In this case, controlling for whether workers use a computer at home would capture at least some of the unobserved heterogeneity that is correlated with computer use at work. If the positive association between computer use at work and earnings is spuriously reflecting a positive correlation between the tendency to use computers and unobserved earnings capacity, one would expect $\alpha_2$ to be positive and $\alpha_3$ to be negative. On the other hand, workers with extremely high earnings capacity may use computers at both home and work, so $\alpha_3$ may be positive. In either case, holding constant the effect of home computer use should reduce any bias in $\alpha_1$ due to omitted factors that are associated with computer use more generally.

Table IV presents OLS estimates of equation (2) using CPS data for 1984 and 1989. The results suggest that computer use at work is the main determinant of earnings, not computer use generally. For example, in 1989 individuals who used a computer *for work only* earned approximately 18 percent more per hour than those who did not use a computer at all, whereas individuals who used a computer *at home only* earned 7 percent more than those

TABLE IV
THE RETURN TO COMPUTER USE AT WORK, HOME, AND WORK AND HOME
(STANDARD ERRORS ARE SHOWN IN PARENTHESES.)

| Type of computer use | October 1984 (1) | October 1989 (2) | Percent of sample, 1989 (3) |
|---|---|---|---|
| Uses computer at work | 0.165 | 0.177 | 39.8 |
| | (0.009) | (0.009) | |
| Uses computer at home | 0.056 | 0.070 | 12.5 |
| | (0.021) | (0.019) | |
| Uses computer at home and work | 0.006 | 0.017 | 8.6 |
| | (0.029) | (0.023) | |
| Sample size | 13,335 | 13,379 | |

*Notes.* The table reports coefficients for three dummy variables estimated from log hourly wage regressions. The other explanatory variables in the regressions are education, experience and its square, two race dummies, three region dummies, dummy variables indicating part-time status, residence in an SMSA, veteran status, gender, marital status, union membership, and an interaction between marital status and gender. Covariates are the same as in columns (2) and (5) of Table II.

who did not use a computer at all.[7] On the other hand, individuals who used a computer *at home and at work* earned about 9 percent more than individuals who used a computer at work only. Results are similar for 1984.

Some workers may use computers at home infrequently (e.g., because the home computer is mainly used by a spouse), so home computer use may not reflect "serious" computer use. To examine this issue further, the models in Table IV were reestimated for subsamples of women and men who were unmarried. For these samples, however, the results are strikingly similar to those in Table IV, again suggesting that computer use at work influences earnings and not characteristics that are associated with computer use generally.[8]

### *B. Estimates for Narrow Occupations*

As a second approach, I limit the CPS sample to homogeneous groups of workers. The largest narrowly defined occupational group in the CPS is secretaries. In 1984 some 46 percent of secretaries used computers at work; by 1989 this figure rose to 77 percent. Not surprisingly, three-quarters of the secretaries who report using computers on their job use computers for word

7. The effect of home computer use on pay may be biased upwards because some individuals may use computers at home for work-related tasks.

8. For unmarried men, $\alpha_1 = 0.186$, $\alpha_2 = 0.013$, and $\alpha_3 = 0.064$. For unmarried women, $\alpha_1 = 0.192$, $\alpha_2 = 0.010$, and $\alpha_3 = 0.067$. In both samples, only $\alpha_1$ is statistically significant at the 5 percent level.

TABLE V
OLS WAGE REGRESSION ESTIMATES FOR SECRETARIES
(DEPENDENT VARIABLE: ln (HOURLY WAGE))

| Independent variable | October 1984 (1) | October 1989 (2) |
|---|---|---|
| Intercept | 1.387 | 1.208 |
| | (0.019) | (0.180) |
| Uses computer at work (1 = yes) | 0.059 | 0.093 |
| | (0.024) | (0.030) |
| Years of edcuation | 0.014 | 0.035 |
| | (0.008) | (0.008) |
| Experience | 0.009 | 0.024 |
| | (0.003) | (0.004) |
| Experience-squared ÷ 100 | −0.007 | −0.047 |
| | (0.008) | (0.009) |
| Black (1 = yes) | −0.079 | 0.065 |
| | (0.012) | (0.053) |
| Other race (1 = yes) | −0.095 | 0.065 |
| | (0.080) | (0.074) |
| Part-time (1 = yes) | −0.321 | −0.160 |
| | (0.031) | (0.034) |
| Lives in SMSA (1 = yes) | 0.159 | 0.152 |
| | (0.024) | (0.025) |
| Female (1 = yes) | 0.090 | 0.146 |
| | (0.166) | (0.127) |
| Married (1 = yes) | 0.422 | −0.027 |
| | (0.219) | (0.027) |
| Married*Female | −0.387 | — |
| | (0.220) | |
| Union member (1 = yes) | 0.016 | 0.046 |
| | (0.040) | (0.046) |
| $R^2$ | 0.256 | 0.222 |

*Notes.* Standard errors are shown in parentheses. Sample size is 751 for 1984 and 618 for 1989. Regressions also include three region dummy variables. Mean (standard deviation) of the dependent variable for column (1) is 1.86 (0.36), and for column (2) is 2.08 (0.34).

processing. Table V contains estimates of wage regressions for samples of secretaries in 1984 and 1989. The wage premium for secretaries who use computers on the job is 6 percent ($t$ = 2.5) in 1984 and 9 percent ($t$ = 3.1) in 1989. If the sample is further restricted to secretaries with exactly a high school education, the wage premium is 9.2 percent ($t$ = 3.3) in 1984 and 8.6 percent ($t$ = 2.1) in 1989.[9]

9. These results complement Conant's [1963] earlier finding of a positive correlation (0.24) between a secretary's wage rate and typing speed in Madison, Wisconsin. Typing accuracy was also positively correlated with wages.

The large premium secretaries appear to receive for using a computer accords with two additional pieces of evidence on the value employers place on computer skills. First, I conducted a small phone survey of temporary employment agencies in New York City, San Francisco, Cleveland, and Dallas, and asked several questions concerning the computer use and pay of the secretaries they place. One hundred and forty-one temporary agencies were contacted, and at least partial responses were received from 83 (58.9 percent) agencies.[10] Interestingly, 84 percent of surveyed firms currently give job applicants a written or hands-on test of computer skills. One of the questions we asked the placement firms was: "In your experience, are employers willing to pay secretaries more if they have computer skills than if they don't have computer skills?" Ninety-eight percent of agencies responded yes.

We also asked the placement firms: "What is the typical hourly pay rate a secretary is paid who does not have computer skills?" and: "What is the typical hourly pay rate a secretary is paid who is otherwise identical but does have computer skills?" The mean hourly rate for a secretary with computer skills was \$12.77 (standard error = \$0.43), and the mean hourly rate for a secretary without computer skills was \$9.14 (standard error = \$0.25). The difference in the mean log wage for computer versus noncomputer use in this sample is 0.33 (standard error = 0.02), which is much greater than the estimated log-wage differential for computer use derived for secretaries using CPS data.

Last, we asked the employment agencies whether they provide computer training to the workers they place, and who pays for the training. Some 62 percent of employment agencies responded that they provide up-front training for the workers they place. And in 96 percent of the instances in which training is provided, the employment agency pays for the training. In the remaining 4 percent the employee pays for training; none of the firms responded that the firm where the worker is placed pays for training. The finding that employment agencies pay for computer training for temporary employees is quite surprising because the training is likely to be of general use. Moreover, this phenomenon differs from on-the-job training since temporary workers cannot pay for training by taking a lower initial wage because they receive the training before they

10. Employment agencies in the survey were selected from the yellow pages of the phone books for these four cities. The survey was conducted in August 1991, and the questions were addressed to "someone who is knowledgeable about placement." More information on the sample frame and questionnaire is available on request.

start work, and they are under no obligation to subsequently work. The fact that temporary agencies seem to find it profitable to provide computer training to the workers they place suggests there is a substantial return to computer skills.

Second, a survey of 507 secretaries employed by large firms conducted by Kelly Services [1984, p. 13] provides some additional evidence on whether employers truly pay a wage premium to secretaries with computer skills. This survey found that 30 percent of secretaries received a pay raise as a result of obtaining word processing skills.

Although the estimated wage premium for secretaries who use computers at work based on CPS data may appear to be large by economic standards (e.g., at least as important as one year of additional schooling), it does not seem implausible given this external evidence. In fact, the phone survey of temporary employment agencies suggests that the CPS may underestimate the premium for computer use. From a practical perspective, the large wage differential for secretaries who are proficient at operating computers suggests that public-sector training programs might profitably concentrate on providing trainees with computer skills.

I have estimated the computer wage differential for six additional white-collar occupations.[11] To summarize these results, the estimated computer differential ($\alpha$ in equation (1)) and standard error for these occupations in 1989 are 0.137 (0.035) for managers, 0.101 (0.044) for registered nurses, 0.060 (0.038) for school teachers, 0.185 (0.046) for sales supervisors, $-0.052$ (0.073) for sales representatives, and 0.089 (0.062) for bookkeepers. Further analysis indicates that the computer premium tends to be smaller in three-digit occupations that have a greater proportion of workers using computers.

### *C. Estimates Based on the High School and Beyond Survey*

To control for a more comprehensive set of personal characteristics, I have examined data from the High School and Beyond Survey. This longitudinal data set contains information on computer use, achievement test scores, and school performance for individuals who were high school sophomores or seniors in 1980.

11. The occupations were selected on the basis of sample size: three-digit occupations with 180 or more observations were selected. (Elementary school, secondary school, and special education teachers were combined.) The regressions included the same variables as in column (5) of Table II. See Appendix A for further details.

The 1984 wave of the survey asked about earnings and work experience. I restricted the sample to workers with exactly a high school education because anyone with additional schooling would not have spent much time in the labor market by 1984. Further description of the sample and variables is provided in Appendix B.

Unfortunately, the computer use question in the HSBS is not ideally suited for my purposes. Information on computer use at work was collected only in the 1984 wave of the survey. In that year individuals were asked whether they *ever* used a computer on a job. Some individuals may have used a computer on an earlier job but not on their present job. Consequently, computer use and earnings are not perfectly aligned. Nevertheless, the HSBS provides another data set with which to examine the robustness of the effect of computer utilization at work on earnings.

Table VI presents several OLS estimates of the effect of computer use at work on wages using the HSBS. The first column simply reports the difference in the mean log wage rate in 1984 for workers who have used a computer at work and those who have not. The differential of 0.11 log points is lower than the estimate derived from the October 1984 CPS. Column (2) adds several demographic variables, column (3) adds several variables measuring the kind of high school the individual attended, and column (4) adds the worker's self-reported high school grade point average, a composite test score measuring reading and mathematics skills, and additional background characteristics (e.g., parents' education). Including these variables has little effect on the magnitude of the wage premium for work-related computer use.

Interestingly, in the HSBS data there is a statistically significant, positive association between a worker's propensity to use a computer at work and both his achievement test score and grade point average. For example, a one–standard deviation increase in the cognitive test measure is associated with a 2.7 percentage point increase in the likelihood of computer use at work.[12] A possible concern about the estimates in column (4) is that the test score variable has a negative effect on earnings. To explore this further, in other estimates I have used workers' 1982 achievement test score, which is available only for sophomores, as an instrumental variable for their 1980 test score. However, these estimates

12. The association between "recreational" computer use (i.e., computer use that is unrelated to work or school) and test scores is even higher. For example, a one–standard deviation increase in the test score raises the probability of recreational computer use by 9.6 percentage points.

TABLE VI
OLS LOG WAGE REGRESSIONS USING THE HIGH SCHOOL AND BEYOND SURVEY

| Independent variable | Mean [SD] | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|---|
| Uses computer at work | 0.19 | 0.109 | 0.114 | 0.110 | 0.110 | 0.097 |
| | [0.39] | (0.015) | (0.015) | (0.015) | (0.015) | (0.017) |
| Used computer at home | 0.20 | — | — | — | — | −0.026 |
| | [0.40] | | | | | (0.017) |
| Used computer at home and work | 0.05 | — | — | — | — | 0.057 |
| | [0.24] | | | | | (0.034) |
| Female | 0.52 | — | −0.102 | −0.102 | −0.104 | −0.105 |
| | [0.50] | | (0.014) | (0.014) | (0.014) | (0.014) |
| Black | 0.14 | — | −0.056 | −0.060 | −0.070 | −0.070 |
| | [0.34] | | (0.018) | (0.019) | (0.020) | (0.020) |
| Other race | 0.27 | — | −0.014 | −0.009 | −0.014 | −0.014 |
| | [0.44] | | (0.014) | (0.015) | (0.016) | (0.016) |
| Married | 0.25 | — | 0.083 | 0.095 | 0.091 | 0.090 |
| | [0.43] | | (0.022) | (0.022) | (0.022) | (0.026) |
| Married*Female | 0.16 | — | −0.059 | −0.065 | −0.064 | −0.063 |
| | [0.36] | | (0.028) | (0.028) | (0.028) | (0.028) |
| Union member | 0.13 | — | 0.100 | 0.102 | 0.101 | 0.102 |
| | [0.33] | | (0.018) | (0.018) | (0.018) | (0.018) |
| Senior in 1980 | 0.44 | — | 0.142 | 0.139 | 0.133 | 0.133 |
| | [0.50] | | (0.022) | (0.021) | (0.022) | (0.022) |
| Native born | 0.93 | — | −0.034 | −0.020 | −0.032 | −0.031 |
| | [0.25] | | (0.024) | (0.024) | (0.024) | (0.024) |
| Academic high school | 0.36 | — | — | −0.041 | −0.028 | −0.027 |
| | [0.48] | | | (0.015) | (0.016) | (0.016) |
| General high school | 0.37 | — | — | −0.024 | −0.021 | −0.021 |
| | [0.48] | | | (0.015) | (0.015) | (0.015) |
| Urban high school | 0.24 | — | — | 0.015 | 0.016 | 0.016 |
| | [0.43] | | | (0.014) | (0.014) | (0.014) |
| 9 region dummies for high school | — | No | No | Yes | Yes | Yes |
| Parents' education (10 dummies) | — | No | No | No | Yes | Yes |
| 1980 achievement test score, (/100) | 0.50 | — | — | — | −0.179 | −0.169 |
| | [0.09] | | | | (0.090) | (0.091) |
| Grade point average (/100) | 0.81 | — | — | — | 0.047 | 0.049 |
| | [0.75] | | | | (0.093) | (0.093) |
| Disciplinary problem | 0.13 | — | — | — | 0.018 | 0.018 |
| | [0.33] | | | | (0.018) | (0.018) |
| Disability limits work | 0.06 | — | — | — | −0.051 | −0.051 |
| | [0.24] | | | | (0.025) | (0.025) |
| $R^2$ | | 0.011 | 0.076 | 0.092 | 0.099 | 0.099 |

*Notes.* Standard errors are shown in parentheses. Sample size is 4,684. Regressions also include age, age-squared, and a constant. The mean [SD] of log hourly earnings is 1.59 [0.41]. Sample consists of workers with exactly a high school education. See Appendix B for further information on the sample.

continue to show a negative relationship between achievement test scores and wages.

The 1984 wave of the HSBS also inquired about individuals' "recreational" use of computers; that is, whether they have used a computer outside of work and school. I have used this information to estimate equation (2) for the HSBS sample, where "home" computer use denotes "recreational" use. These results are reported in column (5). Similar to the estimates from the CPS, the results indicate that computer use at work is an important determinant of earnings, whereas computer use at home does not significantly affect earnings.

### *D. Occupational Level*

The characteristics of workers and employers in an occupation are likely to change slowly over time. By contrast, some occupations adopted computers extremely quickly in the 1980s. As an alternative approach to measuring the payoff to computer use, I have estimated the relationship between the growth in wages and the growth in computer use at the occupational level. Specifically, I used the 1984 and 1989 October CPSs to calculate the proportion of workers who use a computer at work for 485 three-digit occupations, and I used the 1984 and 1989 outgoing rotation group files of the CPS to calculate the mean log wage for the same set of occupations. I then regressed the change in mean log wage on the change in computer use. The coefficient estimates, with standard errors in parentheses, are as follows:

$$\Delta \overline{\ln W_j} = \underset{(0.004)}{0.152} + \underset{(0.029)}{0.105}\, \Delta \overline{C_j} \qquad R^2 = 0.03, \tag{3}$$

where $\Delta\overline{\ln W_j}$ is the growth in mean log hourly earnings in occupation $j$ and $\Delta\overline{C}_j$ is the growth in the proportion of workers who use computers at work in occupation $j$.[13] The equation was estimated by weighted least squares, using the number of workers in occupation $j$ in 1989 as weights.

These results indicate that computer growth is positively associated with wage growth in an occupation. If an occupation moved from no computer use in 1984 to 100 percent computer use in 1989, wages are estimated to rise by 10.5 percent. Although this figure is somewhat lower than the amount implied by the micro

13. Qualitatively similar estimates are obtained if the change in the mean education for workers in the occupation is included as well.

estimates in Table II, it still indicates a substantial payoff to computer use.

## IV. The Effect of the Computer Revolution on Other Wage Differentials

The previous sections tentatively establish that workers who use computers on their jobs earn more as a result of their computer skills. A natural question to raise is *what effect has the proliferation of computers at work had on the relationship between earnings and other variables, such as education.* This issue is particularly relevant because computer use, and the expansion of computer use, has not been uniform across groups. Here I only estimate the direct effect of holding computer use constant on other earnings differentials; potentially important spillover effects of computer use on noncomputer users (e.g., the effect on his or her boss of a secretary using a computer) are not taken into account.

To explore the effect of computer use on other wage differentials, Table VII presents OLS estimates of wage equations in 1984 and 1989, with and without including the computer-use dummy variable. Columns (2) and (5) simply reproduce estimates in Table II. Columns (3) and (6) report an alternative specification, which includes both a computer dummy and an interaction between the computer dummy and years of education. This specification indicates that the computer differential is greater for more highly educated workers.

Notably, the table shows that the rate of return to education increased by one point between 1984 and 1989 if the computer dummy is not included in the regressions. If the computer dummy is included in the equation, the return to education increased by 0.6 points, so nearly 40 percent of the increase in the return to schooling can be attributed to the expansion in computer use.

I have examined the effect of computer use on the return to education in several other samples. These results are summarized in Tables VIII and IX. First consider Table VIII, which reports estimates of the rate of return to education (times 100), with and without including a dummy indicating computer use at work. The first subsample is private sector workers.[14] Between October 1984 and 1989 the conventional OLS estimate of the return to education

14. Katz and Krueger [1991] find that the increase in the return to education was much greater for private sector workers than for public sector workers.

TABLE VII
OLS REGRESSION ESTIMATES OF THE EFFECT OF COMPUTER USE ON PAY
(DEPENDENT VARIABLE: ln (HOURLY WAGE))

| Independent variable | October 1984 | | | October 1989 | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Uses computer at work | — | 0.170 | 0.073 | — | 0.188 | 0.005 |
| (1 = yes) | | (0.008) | (0.048) | | (0.008) | (0.043) |
| Computer use*Education | — | — | 0.007 | — | — | 0.013 |
| | | | (0.003) | | | (0.003) |
| Years of education | 0.076 | 0.069 | 0.067 | 0.086 | 0.075 | 0.071 |
| | (0.001) | (0.001) | (0.002) | (0.001) | (0.001) | (0.002) |
| Experience | 0.027 | 0.027 | 0.027 | 0.027 | 0.027 | 0.027 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| Experience-squared ÷ 100 | −0.042 | −0.041 | −0.042 | −0.044 | −0.041 | −0.042 |
| | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) |
| Black (1 = yes) | −0.106 | −0.098 | −0.099 | −0.141 | −0.121 | −0.122 |
| | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) | (0.013) |
| Other race (1 = yes) | −0.120 | −0.105 | −0.106 | −0.037 | −0.029 | −0.032 |
| | (0.020) | (0.020) | (0.020) | (0.021) | (0.020) | (0.020) |
| Part-time (1 = yes) | −0.287 | −0.256 | −0.256 | −0.261 | −0.221 | −0.221 |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| Lives in SMSA (1 = yes) | 0.123 | 0.111 | 0.111 | 0.148 | 0.138 | 0.138 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Veteran (1 = yes) | 0.043 | 0.038 | 0.039 | 0.027 | 0.025 | 0.029 |
| | (0.011) | (0.011) | (0.011) | (0.012) | (0.012) | (0.012) |
| Female (1 = yes) | −0.140 | −0.162 | −0.160 | −0.142 | −0.172 | −0.168 |
| | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) | (0.012) |
| Married (1 = yes) | 0.162 | 0.156 | 0.156 | 0.169 | 0.159 | 0.158 |
| | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) | (0.011) |
| Married*Female | −0.171 | −0.168 | −0.168 | −0.146 | −0.141 | −0.139 |
| | (0.015) | (0.015) | (0.015) | (0.015) | (0.015) | (0.015) |
| Union member (1 = yes) | 0.167 | 0.181 | 0.181 | 0.164 | 0.182 | 0.182 |
| | (0.009) | (0.009) | (0.009) | (0.010) | (0.010) | (0.010) |
| $R^2$ | 0.429 | 0.446 | 0.446 | 0.428 | 0.451 | 0.452 |
| Mean-squared error | 0.168 | 0.163 | 0.163 | 0.176 | 0.169 | 0.169 |

*Notes.* Standard errors are shown in parentheses. Sample size is 13,335 for 1984 and 13,379 for 1989. Regressions also include three region dummy variables and an intercept.

in the private sector increased by 0.96 points. However, if computer use is held constant, the return to education is estimated to have increased by 0.56 points. Thus, it appears that increased computer use can "account" for 41.6 percent (=100 · (0.96 − 0.56)/0.96) of the increase in the return to education in the private sector.

Turning to the other samples, the return to education increased by less for women than for men between 1984 and 1989.

TABLE VIII
THE EFFECT OF COMPUTER USE ON THE RETURN TO EDUCATION, 1984–1989

| Sample | Excluding computer dummy | | | Including computer dummy | | | Percent of change accounted for by computer use |
|---|---|---|---|---|---|---|---|
| | 1984 | 1989 | Change | 1984 | 1989 | Change | |
| All workers | 7.577 | 8.596 | 1.019 | 6.899 | 7.537 | 0.638 | 37.4 |
| | (0.144) | (0.147) | | (0.146) | (0.150) | | |
| Private sector | 7.918 | 8.882 | 0.964 | 7.059 | 7.620 | 0.561 | 41.8 |
| | (0.172) | (0.171) | | (0.173) | (0.175) | | |
| Men | 7.073 | 8.335 | 1.262 | 6.236 | 7.011 | 0.775 | 38.6 |
| | (0.192) | (0.200) | | (0.200) | (0.211) | | |
| Women | 8.526 | 9.051 | 0.525 | 8.033 | 8.266 | 0.233 | 55.6 |
| | (0.220) | (0.216) | | (0.219) | (0.216) | | |
| All workers | 8.279 | 9.966 | 1.687 | 7.391 | 8.694 | 1.303 | 22.8 |
| age 25–34 | (0.338) | (0.338) | | (0.340) | (0.346) | | |
| All workers | 7.101 | 8.158 | 1.057 | 6.626 | 7.118 | 0.492 | 53.5 |
| age 45–54 | (0.467) | (0.500) | | (0.471) | (0.499) | | |

*Notes.* Dependent variable is log hourly wage. Standard errors are in parentheses. The returns to education have been multiplied by 100. Covariates include experience and its square, two race dummies, SMSA, veteran status, gender, current marital status, gender–marital status interaction, union membership, and three region dummies.

TABLE IX
THE EFFECT OF COMPUTER USE ON THE RETURN TO EDUCATION, 1984–1989
INTERACTIVE SPECIFICATION

| Sample | Excluding computer dummy | | | Including computer dummy and computer*education | | | Percent of change accounted for by computer use |
|---|---|---|---|---|---|---|---|
| | 1984 | 1989 | Change | 1984 | 1989 | Change | |
| All workers | 7.577 | 8.596 | 1.019 | 6.917 | 7.422 | 0.505 | 50.5 |
| | (0.144) | (0.147) | | (0.183) | (0.191) | | |
| Private sector | 7.918 | 8.882 | 0.964 | 7.117 | 7.449 | 0.332 | 65.5 |
| | (0.172) | (0.171) | | (0.217) | (0.209) | | |
| Men | 7.073 | 8.335 | 1.262 | 6.263 | 6.944 | 0.681 | 46.0 |
| | (0.192) | (0.200) | | (0.217) | (0.250) | | |
| Women | 8.526 | 9.051 | 0.525 | 8.031 | 7.890 | −0.141 | 126.9 |
| | (0.220) | (0.216) | | (0.219) | (0.216) | | |
| All workers | 8.279 | 9.966 | 1.687 | 7.368 | 8.504 | 1.236 | 32.7 |
| age 25–34 | (0.338) | (0.338) | | (0.340) | (0.414) | | |
| All workers | 7.101 | 8.158 | 1.057 | 6.585 | 7.200 | 0.615 | 41.8 |
| age 45–54 | (0.467) | (0.500) | | (0.496) | (0.558) | | |

*Notes.* Standard errors are in parentheses. The returns to education have been multiplied by 100. Covariates include experience and its square, two race dummies, SMSA, veteran status, gender, currently married dummy, gender-marital status interaction, union member dummy, and three region dummies.

Holding computer use constant accounts for over half the increase in the return to education observed for female workers, and nearly 40 percent for male workers. Also, it appears that although the return to education increased by more for younger workers than for older workers, controlling for computer use accounts for a larger share of the increase for older workers.

Table IX reports results with and without including both a computer-use dummy and an interaction term between computer use and years of education. Specifically, I estimate the equation,

$$\ln W_i = X_i\beta + E_i\rho + C_i\alpha + C_i \cdot E_i\gamma + \epsilon_i, \tag{4}$$

where $\ln W_i$ represents the log hourly wage rate, $E_i$ education, $C_i$ a computer-use dummy variable, and $X_i$ a set of covariates. I am interested in the question, what would the return to education be if computer use remained constant at its 1984 level. This is given by $\rho + \gamma \cdot 0.246$, where 0.246 is the proportion of workers who used computers in 1984.

Because $\gamma > 0$ for most subsamples and has increased over time (compare columns (3) and (6) of Table VII), the specification that includes the interaction between the computer-use dummy and education tends to account for a somewhat greater share of the increase in the return to education. For example, the augmented specification accounts for 50.5 percent of the increase in the return to education for the entire sample, and nearly two-thirds of the increase for private sector workers. For women, increases in computer use appear to account for more than the total observed increase in the return to education. For older workers, however, the wage differential for using a computer declines with education ($\gamma < 0$), so more of the increase in the return to education for this sample is accounted for by computer use in the dummy variable specification in Table VIII.

## V. Conclusion

This paper presents a detailed investigation of whether employees who use computers at work earn a higher wage as a consequence of their hands-on computer use. A variety of estimates suggests that employees who directly use a computer at work earn a 10 to 15 percent higher wage rate. Furthermore, because more highly educated workers are more likely to use computers on the job, the estimates imply that the proliferation of computers can account for between one-third and one-half of the increase in the rate of return to education observed between 1984 and 1989. Although it is unlikely that a single explanation can adequately account for all the wage structure changes that occurred in the 1980s, these results provide support for the view that technological change—and in particular the spread of computers at work—has significantly contributed to recent changes in the wage structure.

One frequent objection to this conclusion is made by Blackburn, Bloom, and Freeman [1991]: "U. S. productivity during the 1980s showed only sluggish growth, not the rapid advance one might expect if technological change were the chief cause of the changing structure of wages." Although there may be some merit to this view, there are two reasons to question its importance.

First, Siegel and Griliches [1991] find a positive relationship between total factor productivity growth and the prevalence of computers across industries.

Second, technological change may cause changes in the distribution of earnings without a dramatic effect on aggregate productivity growth or aggregate wage growth. For example, suppose that the advent of computers has increased by 10–15 percent the productivity of workers who use them, but has not changed the productivity of other workers at all. And suppose that the computer premium is a return to *general* human capital. Because roughly 35 percent of workers directly use a computer on the job, we would only expect average wage growth of 3.5 to 5.3 percent from the spread of computers. Furthermore, since the growth in computers was gradual over a period of at least a decade, the annual increment to aggregate productivity and income due to computers could easily be masked by other factors.

An important question is whether the wage structure changes observed in the last decade will persist in the future. The estimates in this paper suggest that, at least in part, the evolution of the wage structure is tied to future developments in technology. In the five years between 1984 and 1989, there was nearly a 50 percent increase in the percentage of workers who use computers on the job, yet the estimated payoff to using a computer at work did not fall. An obvious explanation for this finding is that employers' demand for computer-literate workers increased even faster than the supply of such workers in the 1980s. On the other hand, a measure of caution should probably be used in interpreting these results in terms of shifts in both supply and demand curves because, with only two observations, movements in both supply and demand are capable of explaining any observed pattern of changes in prices and quantities.

Nevertheless, it seems reasonable to speculate that the supply of workers who are proficient at operating computers is likely to continue to increase in the future. For example, data from the 1989 October CPS indicate that over half of all students in the United States are given training on computers in school. At the same time it would seem unlikely that the demand for computer-literate workers will continue to expand as rapidly as it has in the past decade. If these conjectures hold, one would expect that the wage differential for using a computer at work will fall in the future. On the other hand, there is little evidence that the value of computer skills has declined in recent years. Thus, computer training may, at least in the short run, be a profitable investment for public and private job training programs.

## Appendix A: CPS Data Sets

The CPS data used in Table I are from all rotation groups of the October 1984 and 1989 CPS. The CPS data used in the rest of the paper are limited to the outgoing rotation groups because only these individuals are asked about their weekly wage. The sample is further restricted to individuals between age 16 and 65 who were working or who had a job but were not at work. The "usual hourly wage" is the ratio of usual weekly earnings to usual weekly hours. Individuals who earned less than $1.50 per hour or more than $250 per hour are deleted from the sample.

The weekly wage variable in the 1984 CPS is top coded at $999, whereas the weekly wage in the 1989 survey is top coded at $1,923. To make the wage variables comparable over time, I calculated an estimate of the mean log hourly wage for individuals who were topcoded in 1984 as follows. I first converted the wage data in the October 1989 CPS into 1984 dollars using the GNP deflator. Using the deflated 1989 CPS, I then calculated the mean log hourly wage rate for individuals whose weekly earnings equaled or exceeded $999. This figure (3.27), was assigned to each individual who was topcoded in the 1984 CPS. If the shape of the wage distribution remained roughly constant between 1984 and 1989, this procedure should circumvent problems caused by changes in topcoding over time.

The "uses computer at work" dummy equals one if the employee "directly" uses a computer at work (item 48). The computer may be a personal computer, minicomputer, or mainframe computer. The "uses computer at home" dummy equals one if the individual "directly" uses a computer at home (item 53). The "married" dummy variable equals one if the worker is currently married. The "part-time" dummy variable equals one if the worker usually works less than 35 hours per week. "Potential experience" is age minus education minus six.

The sample of secretaries used in Table V consists of individuals with three-digit census occupation code (COC) 313, 314, or 315. The following table lists the sample size and census occupation code used for the other samples described in subsection III.B.

| Occupation | COC | Sample size |
|---|---|---|
| Manager | 19 | 757 |
| Registered nurse | 95 | 264 |
| Teacher | 156–158 | 456 |
| Sales supervisor | 243 | 341 |
| Sales representative | 259 | 188 |
| Bookkeeper | 337 | 242 |

The wage data used to estimate equation (3) are from all outgoing rotation groups of the 1984 and 1989 CPS files. Computer utilization for three-digit occupations is derived from all rotation groups of the 1984 and 1989 October CPS files.

## APPENDIX B: HIGH SCHOOL AND BEYOND SURVEY SAMPLE

The High School and Beyond Survey consists of a base-year survey conducted in 1980, and follow-up waves conducted in 1982, 1984, and 1986. The sample used here consists of individuals who were sophomores or seniors in 1980 and who graduated from high school by 1986, but did not receive any additional education. The sample is further restricted to individuals who responded to all waves of the survey, were employed in 1984, earned between \$1.50 and \$100 per hour, and had valid responses to the computer-use questions. Many of the variables used in the analysis, such as race and sex, are defined in a standard fashion and are not described here. For a detailed description of the HSBS, including the sample design, questionnaire, and tabulations of variables, see Sebring et al. [1987].

The variable "used computer at work" is derived from the 1984 survey wave. If the worker reports ever having used a computer at work, he or she is assigned a one for the computer-use dummy variable. Computer use may involve using a microcomputer, minicomputer, or mainframe computer. The variable defined as "used computer at home" equals one if the worker used a computer terminal, microcomputer, minicomputer, or mainframe computer for "recreational" purposes (i.e., nonwork- and nonschool-related use).

The hourly wage rate pertains to the worker's current job as of 1984, and is derived from the reported pay schedule and reported weekly hours. The variable called "Senior in 1980" equals one for individuals who were high school seniors in 1980, and zero for individuals who were sophomores in 1980. The variable called "union member" indicates whether the worker was a member or active participant in a union, farm, trade, or professional association in 1985 or 1986. There are three categories for high school types in the survey: general, academic, and vocational. Vocational high schools are the omitted dummy category. "Urban" measures whether the worker attended a school in an urban area.

Parent's education consists of five dummy variables for the mother and for the father, indicating whether each parent's education is missing, high school, some college, college, or postcollege. (Less than high school is the base group.) In 1980 all students were given a 73-minute cognitive test of vocabulary, reading, and mathematics. A student's score on the 1982 test is the variable called "achievement test score." The sophomores were given a similar test again in 1982. "Grade point average" is the student's self-reported grade point average in 1982. "Disciplinary problem" is a dummy variable that indicates whether a student reports having had a disciplinary problem in high school in the last year. "Disability limits work" is a dummy variable that equals one if a student reports having a physical disability that limits the kind or amount of work that he or she can do on a job, or that effects his or her chances for more education.

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## [Footnotes]

[1] **The Structure of Wages**
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