Title
The Impact of Technological Change on Older Workers: Evidence from Data on Computers

Author
Friedberg, Leora

Publication Date
1999-06-01

99-11

UNIVERSITY OF CALIFORNIA, SAN DIEGO

DEPARTMENT OF ECONOMICS

THE IMPACT OF TECHNOLOGICAL CHANGE ON OLDER WORKERS: EVIDENCE FROM DATA ON COMPUTERS

BY

LEORA FRIEDBERG

DISCUSSION PAPER 99-11
JUNE 1999

THE IMPACT OF TECHNOLOGICAL CHANGE ON OLDER WORKERS

Evidence from Data on Computers

Leora Friedberg

University of California, San Diego and NBER

June 1999

This paper explores the impact on older workers of new technologies that change skill requirements. Older workers, with older skills and less skills than prime-age workers, will suffer in comparison. Furthermore, if skill acquisition is costly, older workers have less incentive to acquire new skills because they have a shorter time horizon until retirement. Several data sets show that the rate of computer use is surprisingly flat over most ages but declines for the oldest workers. The evolution of computer use suggests that most workers, old or young, learn to use computers as needed, and further that older workers use computers less not because they are old, but because they are nearing retirement. In turn, we might expect older workers who do not use computers to retire sooner. In the Health and Retirement Survey non-computer users were 25% more likely to leave work between 1992 and 1996. Instrumental variables estimates, which aim to control for the impact of retirement plans on computer use, do not yield conclusive results, but they suggest that computer use lowers the retirement probability, especially for 55-59 year olds.

JEL Codes: J24, J26, O33

I would like to thank Julian Betts, João Miguel Ejarque, Larry Katz, Jim Poterba, Valerie Ramey, and seminar participants at several universities for very useful comments, Johannes Moenius and Andrew Caffrey for excellent research assistance, and the National Institute on Aging (grant # 1 R55 AG14800-01) for financial support.

Address until August 1999: National Bureau of Economic Research, 1050 Massachusetts Avenue, Cambridge, MA 02138, (617) 588-0345, fax (617) 868-2742. Permanent address: Department of Economics 0508, University of California-San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0508, (619) 534-2973, fax (619) 534-7040. Email: *lfriedbe@weber.ucsd.edu*, *lfriedbe@nber.org*.

The proportion of workers using a computer jumped from 24% in 1984 to 51% in 1997.[1] Many people have the impression that older workers find it difficult to adapt to new technologies like computers. 40% of 60-64 year old workers used a computer in 1997 – 21% below the average, even though we might expect selective retirement of non-computer users to boost observed computer use among aging workers. In this paper I argue that it is not simply age that explains why older workers use computers less. Impending retirement, which reduces the time horizon to recoup an investment in new skills, appears to play a major role. I also investigate the interaction of changing technologies with skill acquisition and retirement decisions of older workers.

The underlying premise is that new technologies alter jobs and skill requirements in jobs. While some jobs are eliminated and others made more routine, new skills and tasks will be required in many jobs as new technologies are adopted.[2] In altering production, technological change can accentuate differences across workers.

Older workers may be affected differently than prime-age workers for several reasons. First, more older workers are unskilled, so their jobs will be replaced by new technologies at a faster clip.[3] Second, if older workers' skills are of an older vintage, they will grow obsolete more rapidly than younger workers' skills. Third, both skilled and unskilled older workers deciding whether to invest in new skills complementary with new technology face a shorter time horizon to recoup the investment due to approaching retirement. For all these reasons, we might expect the earnings and employment opportunities of older workers to be harmed by new technologies. That might lead people, in turn, to retire sooner than they would otherwise.

An extensive literature documents the increasing dispersion of earnings and employment by education and by unobservables and considers the potential impact of

---

[1] Statistics for workers aged 18-64 from the Current Population Survey.

[2] Computers are replacing traditional clerical jobs (bank teller, inventory clerk, typist) and some types of production jobs. Levy and Murnane (1996) found that computers raised skill requirements in some jobs while reducing them in others in a financial firm. They also noted the increased skill required to handle the greater volume and complexity of financial transactions, itself caused by technological changes.

[3] Goldin and Margo (1992) discussed the major increase in educational attainment during the 20th century.

changing technologies.[4] That research focuses on prime-age workers. An important exception is Juhn (1992), who suggested that the rising education premium contributed to earlier retirement among low-education relative to high-education workers. Similarly, Farber (1996) found that older workers have recently experienced more job loss than they used to, though still less than young workers. Katz and Murphy (1992) documented shifts in the earnings premium for experience. They found that older low-education workers suffered less on average than young low-education workers, while older high-education workers benefited less than young high-education workers. The asymmetry by education implies an interaction of skill requirements with worker age or skill vintage.

If computers alter job skill requirements, that will affect workers of all ages. But, because older workers have less education and skills of an older vintage, on average, the impact will be sharper if new technologies are skill-biased – complementary with skilled labor and human capital while substituting unskilled labor – as much of this literature suggests. The question of skill bias is an active topic of research because technological change is difficult to observe – hence the usefulness of computer use data.[5]

Unlike many technologies, computers have altered almost all areas of production, as McConnell (1996) noted. Brynjolffson and Hitt (1997) and Lehr and Lichtenberg (1997a,b) found significant productivity gains and complementarity with skilled labor in firms that purchase more computers. Krusell, Ohanian, Ríos-Rull, and Violante (1998) argued that rising demand for skill results from declining prices for complementary capital equipment – which are largest for office information processing equipment.[6] This accords with data from Autor, Katz, and Krueger (1998) showing that the spread of computers might explain 30-50% of the increased growth in relative demand for skilled labor since

---

[4] Katz and Murphy (1992), Murphy and Welch (1992), and many others, summarized in Gottschalk (1997).

[5] Johnson (1997) and Topel (1997) reviewed supply and demand side factors, agreeing that the rising price for skill, concurrent with greater supply, implies that changing technology raised demand for skill. Berman, Bound, and Griliches (1994) found that industry investment is correlated with a more skilled labor force, though Doms, Dunne, and Troske (1997) found that the latter precedes the former in panel data. Goldin and Katz (1998) found evidence of technology- and capital-skill complementarity going back to the early 1900s.

1970. Moreover, Bresnahan, Brynjolffson, and Hitt (1999) found that firms that successfully computerize often incur substantial training, re-organization, and other adjustment costs; this supports the notion that new technologies alter skill requirements.

Bartel and Sicherman (1993) focused on the impact on older workers of technological change in the 1960-70s. Using industry data on productivity growth and on training requirements, they found support for the notion that the cost of training associated with unanticipated technological change led workers to retire early.

New data on computer use by individuals can offer insight here. I use the Current Population Survey and the new Health and Retirement Survey, described in Section I. These surveys register the diffusion of new computer technology. But also, computer use data reflect decisions by workers and firms that are important to understand. The response of workers of different ages to the spread of computers is the focus of this paper.

The age pattern of computer use, shown in Section II, is extremely flat. Computer use is virtually constant for workers up until the early 50s, so many people readily learn to use computers on the job. Computer use drops off only for the oldest workers, which suggests a key role of impending retirement. Moreover, computer use of the oldest workers lags precisely in those jobs with recent increases in computer use. Section III shows that older workers also lose ground in other facets of computerization – like computer training rates, the intensity of computer use, and home computer use.

In Sections IV and V I use the detailed information in the HRS about older workers, aged 50-62 when the survey began, to study the link with retirement. Non-computer users were 25% more likely to leave work between 1992 and 1996 than computer users. The inference may run in either direction, however. Someone lacking computer skills might face a disadvantage in the labor market and choose to retire. But also, someone *intending* to retire soon might choose not to invest in computer skills, as the data suggest, and then would be observed retiring soon.

This discussion highlights the difficulty of analyzing the links between technology changes, training decisions, retirement plans – all generally unobserved – and subsequent

[6] They estimated an aggregate production function and found that capital equipment is complementary with skilled workers and substitutes unskilled workers, which implies a major role for falling equipment

retirement. Section V presents instrumental variables estimates focusing on the observed relationship between computer use and subsequent retirement. To isolate the impact of changing skill requirements, I instrument for individual computer use with average computer use of prime-age workers in the same occupation and industry. Though the instruments may not be ideal, the HRS is key because its detailed data on people and on jobs control for many other influences on retirement. The estimates, which are imprecise, imply that using a computer lowers the probability of leaving work by up to 25-30%.

In sum, computer use data suggest that impending retirement – rather than age itself – causes older workers to lag in adapting to new technologies like computers. It also appears that some who do not adapt choose retirement, but this remains difficult to pinpoint. It will be important to learn more about how the pace of technological change affects older workers as we design policies to encourage more saving and later retirement among the aging baby boom.

I. DATA

This section describes the data and previous research on computer use. Earlier studies were compelled to use industry data on computerization and technological change.[7] Recently the CPS and the HRS asked people about computer use at work. The CPS is useful because it is large, includes workers of all ages, and repeats questions about computers several times, so cohorts can be followed. The HRS offers enormous detail about older workers and will follow them as they retire.

A. Data on computer use

The Current Population Survey collects information about employment and schooling from over 150,000 people each month, yielding a sample of about 60,000 18-64 year old workers. One-quarter of the sample are asked more detail about their job and earnings. Also, monthly supplements focus on particular issues of interest. The October supplements of 1984, 1989, 1993 and 1997 asked people "Do you directly use a computer

---

prices.

[7] Bartel and Lichtenberg (1987), Bartel and Sicherman (1993), and Autor, Katz, and Krueger (1998).

at work?" and, if so, what they used the computer for.[8] The January 1991 supplement asked people about job training and specifically about training in computer skills.

The longitudinal Health and Retirement Survey began in 1992. Every two years the HRS contacts over 7,600 households with someone born between 1931 and 1941. It collects detailed information about employment, income, and other variables. The first wave asked workers how often they are required to work with computers.[9] This information on computer use, which has not been closely studied, will be well-suited for analyzing the impact of computerization on older workers as the HRS follows people into retirement. The detailed data on individual and job characteristics allow controls for other factors that may be correlated with computer use, a concern discussed below.

B. Previous research on computer use

Krueger (1993) first exploited the computer data in the CPS. Krueger included computer use in a standard wage regression and found a sharp positive effect on wages. Since computers spread mostly among educated workers, the earnings premium for computer use could account for $^1/_3$ to $^1/_2$ of the rising premium for education in the 1980s. Autor, Katz, and Krueger (1998) used industry data on computer use and investment, matched with apparent shifts in demand for educated workers. Their results suggested that the spread of computers might explain 30-50% of the increased growth in the relative demand for higher-skilled workers since 1970.

However, research by DiNardo and Pischke (1997) casts doubt on the interpretation of the computer use variable. They used a similar German data set that asked whether people use computers and also pencils, telephones, chairs, and other tools in their work. The tools used in white collar jobs – such as computers and pencils – are all associated with higher earnings. Since the ability to use a pencil does not actually raise earnings, DiNardo and Pischke concluded that computer use might also reflect other unobserved attributes of jobs and workers that are increasingly rewarded.

[8] To focus directly on computers, the 1993 supplement began with the following lead-in: "The next set of questions has to do with direct or hands on use of computers.… These questions do not refer to hand-held calculators or games, electronic video games, or systems which do not use a typewriter-like keyboard."
[9] Hurd and McGarry (1993) analyzed the effect of numerous job characteristics, including computer use, on retirement plans, as indicated by the self-assessed probabilities of working past ages 62 and 65.

As I show later, interesting differences in computer use emerge for workers of different ages. These age patterns appear informative – they would not be expected if computer use simply proxies for pencil use or other unobserved job attributes. Thus, the interpretation here is that a worker uses a computer if he or she has the skills to and if it makes him more productive. Nonetheless, a computer user might have unobserved attributes that also make him more productive. The HRS is superior to previous data sets in the level of detail about individuals and jobs potentially correlated with computer use and retirement. For example, pensions designed to induce optimal timing of retirement should vary systematically across occupations; the detailed data on pension characteristics in the HRS can control for this.

II. PATTERNS OF COMPUTER USE

This section examines the age patterns of computer use in the CPS and the HRS. I describe trends in computerization and illustrate the age profiles of computer use, which persist with controls for occupation and education. I also show how the computer use of older workers is affected as computers spread in their occupations and industries.

A. Trends in computer use

Table 1 reports computer use of workers aged 18-64 in the CPS. In 1984 24.4% of workers used a computer. Computer use rose 12.9 percentage points by 1989 and 9.3 percentage points by 1993, but only 4.0 percentage points, to 50.6%, in 1997. While this suggests that computerization has reached a plateau, computer purchases still remain strong, and I show later that the intensity of computer use has deepened.

TABLE 1: Percent Using a Computer at Work, CPS			
1984	24.4% (0.2)	Increase	% Increase
1989	37.3% (0.2)	12.9	52.7%
1993	46.6% (0.2)	9.3	24.9%
1997	50.6% (0.2)	4.0	8.6%

Sample: age 18-64, at work or with a job last week, October CPS. Computed with the 1997 final weights and otherwise the supplemental weights. Standard errors in parentheses.

Table 2 shows computer use among various demographic groups, and also the distribution of users across groups. Computer use varies significantly, especially by education and age. Nevertheless, regressing computer use in 1997 on these variables yields an $\bar{R}^2$ of 0.180, so most of the variation occurs within, rather than across, groups.[10]

Computer use is strongly correlated with education. In 1997, 75.9% of people with a college education used a computer, compared to 36.4% of people with only a high school education. Over most of the period the gulf widened between low and high education groups. Women use computers more than men – 57.3% of women and 44.8% of men used a computer in 1997. However, controlling for forty-five two-digit occupations explains virtually all of the computer use differential for women. Whites use computers considerably more than blacks and somewhat more than other races. Occupation explains 60% of the differential for blacks, but none for other races.

[10] The same tabulations appear in Krueger (1993) and Autor, Katz, and Krueger (1998). I am unable to exactly replicate the 1984 and 1989 statistics in Krueger's Table 1, but they are very similar to those here.

TABLE 2: Computer Use among Demographic Groups								
	% who use computers:				% of computer users who are:			
	1984	1989	1993	1997	1984	1989	1993	1997
All workers	24.4	37.3	46.6	50.6				
Age								
18-22	16.9	25.7	28.9	31.8	6.9	7.1	5.2	5.4
23-39	28.5	40.9	49.2	52.6	59.5	55.0	51.0	46.7
40-49	23.6	40.3	51.3	54.9	19.1	24.0	27.5	28.9
50-59	19.7	32.0	43.9	50.7	11.9	11.4	13.6	16.0
60-64	14.4	23.3	32.7	40.0	2.6	2.5	2.7	2.9
Education								
< High school	4.9	7.7	9.5	11.7	3.1	2.7	1.9	2.2
High school	18.5	28.5	34.1	36.4	29.5	27.8	26.4	24.4
Some college	31.2	44.8	53.1	56.2	29.6	31.5	33.0	32.6
College +	41.2	58.6	70.2	75.9	37.9	38.0	38.7	40.8
Race and gender								
White, male	21.6	32.9	42.3	46.3	45.1	41.6	42.9	41.9
White, female	30.5	44.9	54.8	58.9	45.0	47.9	45.7	44.9
Black, male	12.6	21.7	29.7	32.3	2.7	2.8	3.2	3.3
Black, female	22.6	33.8	43.3	47.8	4.6	4.6	4.9	5.5
Other race, male	21.2	32.7	40.1	45.0	1.4	1.5	1.7	2.1
Other race, female	24.2	41.8	46.2	53.0	1.3	1.7	1.6	2.2

CPS, see the Table 1 notes. Note that the question about educational attainment was revised after 1992.

B. Computer use and age

This section shows how computer use varies for workers of different ages. Figure 1 shows the age profile of computer use in 1997. It is striking to observe that computer use is essentially flat for workers of most ages. The proportion of computer users is virtually identical, at about 54%, from the middle 20s to the early 50s.

Figure 2 shows computer use shifting steadily upward in the age profiles from all four CPSs. The age patterns over time are similar but were a little more peaked early on; they spread out as early computer users aged. Maximum computer use was observed for 35 year olds in 1984, 39 in 1989, and 46 in 1993 – virtually the same cohort throughout.

FIGURE 1
Computer use at work by age, 1997

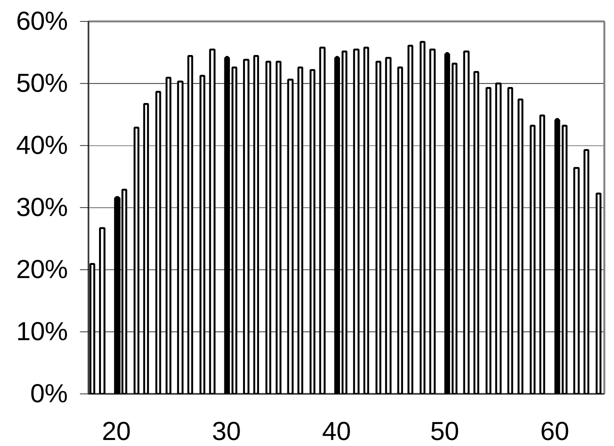
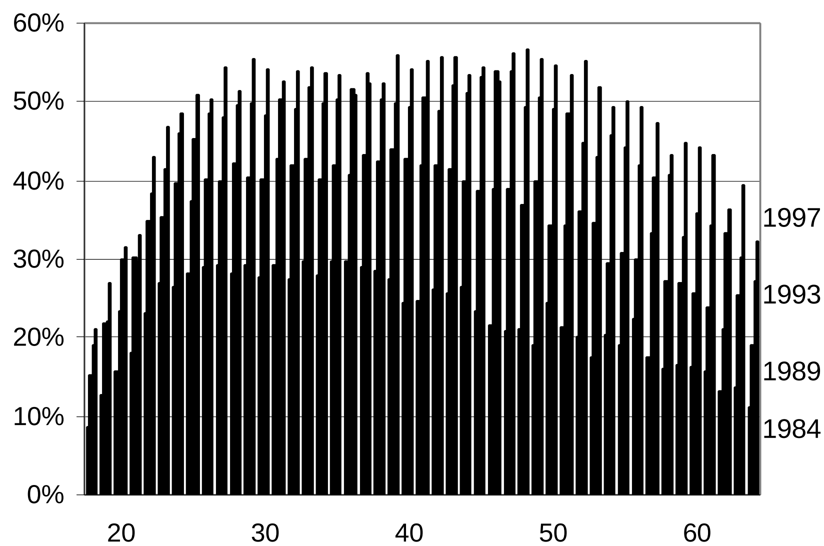


FIGURE 2
Computer use at work, by age

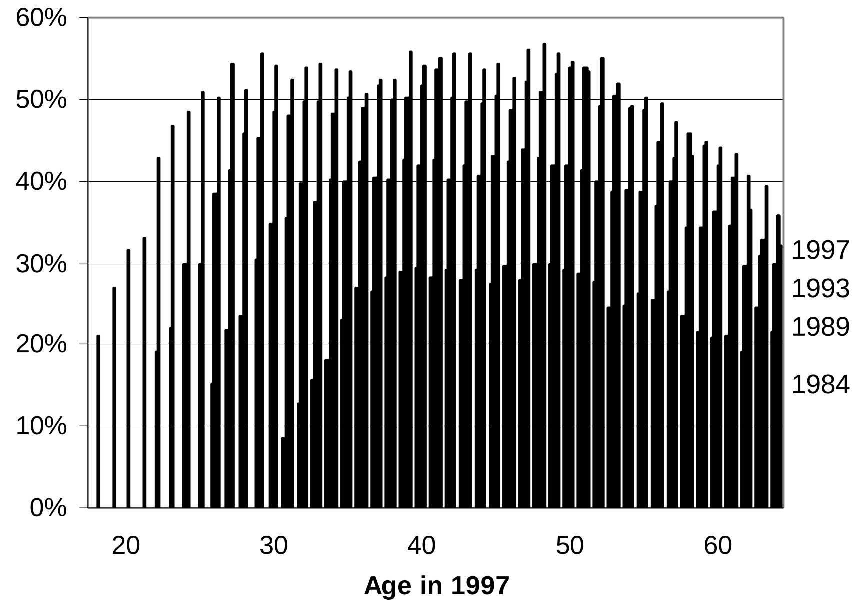


The long flat range of computer use in Figures 1 and 2 suggests that being old or many years out of school does not inhibit people from learning to use computers. Workers in their 50s in 1997 were very unlikely to have used a computer in college, for example. Thus, people acquire computer skills readily as required for their jobs, largely independent of age – except for the oldest workers.

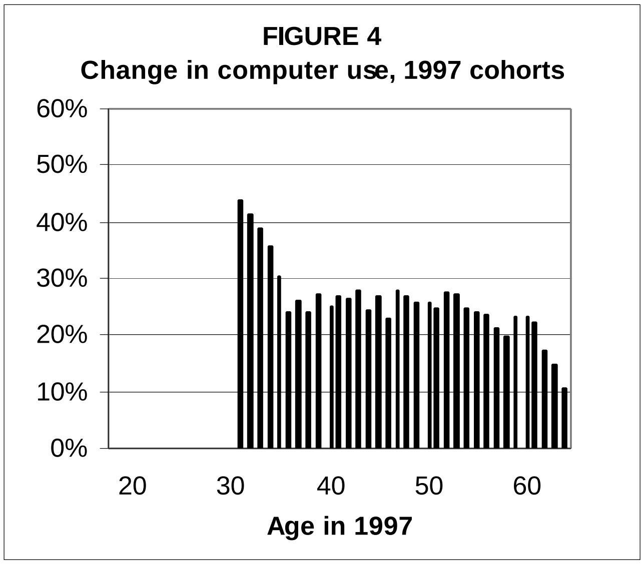
Figure 3 highlights the evolution of computer use for age cohorts in 1997. The data is rearranged to show computer use, for example, when people were 40 year olds in

1997, 36 in 1993, 32 in 1989, and 27 in 1984. This makes it apparent that today's oldest workers have recently fallen behind. People now in their 50s and 60s used computers only slightly less than younger cohorts early on. Computer use rose for all ages, but older workers today had a smaller gain and lag further behind now than they used to.

FIGURE 3
Computer use at work, by 1997 cohorts



Figures 4 shows the gains in computer use for 1997 cohorts since 1984. Young workers have rapid increases in computer use as they gain experience and as more educated youth join the labor force. Growth is then remarkably uniform for workers in the middle 30s until the 50s, but it lags for the oldest workers.



These cohort profiles suggest an alternative explanation for the age effect. Age by itself does not account for lower computer use rates of the oldest workers – nor do years since schooling, nor the obsolescence of older skills. Those backward-looking factors should generate a peaked, rather than flat, age profile. Why have the oldest workers failed to keep pace? The age profiles suggest the importance of forward-looking factors, of which the key is probably impending retirement. The decision of whether a worker (of any age) uses a computer requires an investment in training that pays off over time. Therefore, a worker's time horizon affects whether they use a computer.

Data from multiple CPSs illustrate the evolution of computer use for cohorts nearing retirement *and also* earlier. The trends for cohorts as they age support the hypothesis that impending retirement reduces the incentive to acquire new skills. Table 3 shows the increases in computer use for cohorts over time, as in Figure 4.

The influence of approaching retirement is most apparent for the oldest workers in 1993, in the middle rows. People aged 60-64 in 1993 kept close to younger workers earlier, from 1984 to 1989; their computer use rose 8.9 percentage points, compared to 12.9 for those aged 45-49. From 1989 to 1993, however, the oldest lagged behind; their gain was 4.1 percentage points, compared to 11.4 for the younger workers.

Thus, the oldest workers in 1993 failed to keep up with younger workers as they neared retirement, though they had previously acquired computer skills at a similar rate.

The changes from 1993 to 1997 are smaller overall, muting the potential age effect, which is not surprising as computers stop spreading and existing computer users age.[11]

TABLE 3: The Spread of Computers among Older Cohorts

	Change in the rate of computer use by the same cohorts, across years			
	45-49	50-54	55-59	60-64
Cohorts in 1989:				
change 1984-89	13.2	12.5	8.8	4.9
Cohorts in 1993:				
change 1984-89	12.9	12.6	11.8	8.9
change 1989-93	11.4	8.7	7.1	4.1
Cohorts in 1997:				
change 1984-89	13.9	13.3	12.2	11.0
change 1989-93	8.2	11.2	8.5	6.2
change 1993-97	3.9	1.5	1.8	1.5

This table reports the increase in computer use across CPSs for various cohorts. For example, computer use for 45-49 year olds in 1989 rose by 13.2 percentage points between 1984 and 1989.

To sum up, age influences computer use – but not simply because "old dogs can't learn new tricks." The evolution of computer use as cohorts age suggests the importance of impending retirement, which reduces the gains from costly skill acquisition. This is reinforced by evidence presented later that the effect is strongest in occupations with recent increases in computer use. The next subsection shows that occupation and education differences by age do not explain the age pattern of computer use.

C. Controlling for occupation and education

The impact of occupation and education on computer use may explain the age profiles. Occupational differences in computer use are enormous.[12] Table 4 shows that computer use in 1997 was most prevalent (70-80%) among professionals, managers, and clerical workers; moderate among sales workers; and much lower (25% or less) among

[11] It is clear that computer usage *per se* will grow less interesting in years to come. Still, new technologies will continue to be introduced and change skill requirements.

[12] Computer use in 45 two-digit occupations ranged from 4% to 97%. Still, the coefficient of variation of across occupations is almost identical at the one and two-digit occupation levels.

craftsmen, operatives, laborers, and service workers. Computer use rose more for those with high initial rates of computer use in 1984, so the gulf across occupations widened.

TABLE 4: Occupational Computer Use and Age Structure

	% using a computer, by occupation				% in each occupation		
	1984	1989	1993	1997	23-49	50-59	60-64
All	24.4	37.3	46.6	50.6			
Professional & technical	38.1	54.4	65.7	73.1	19.8	20.0	17.2
Managers & administrators	42.5	61.8	73.7	78.7	15.2	17.4	16.0
Sales	23.9	35.5	49.8	55.8	10.8	11.8	12.7
Clerical	47.4	66.8	77.4	78.6	14.2	14.1	14.4
Craftsmen	10.1	15.2	23.5	25.3	11.6	10.3	8.5
Operatives	5.8	9.6	15.7	18.6	10.9	10.5	10.6
Laborers	3.2	6.6	11.7	12.8	5.5	4.6	6.7
Service	6.0	9.8	15.1	16.8	12.0	11.4	13.9

The last three columns show data for 1997. Aggregated from CPS data. See the Table 1 notes.

Table 4 also shows how people's occupations varied by age in 1997. For example, 19.8% of people aged 23-49 worked in professional and technical jobs, compared to 17.4% of people 50-59 and 16.0% of people 60-64. These occupational differences might account for some of the difference in computer use by age.

The link between computer use and education is also strong, as was seen in Table 2. Between 1984 and 1993 less educated workers lagged educated workers in each cohort, and older workers with high or low education lagged younger workers. Computer use among the high-school educated rose from 18.2% in 1984 to 27.2% in 1993 for workers aged 60-64 and from 19.5% to 37.4% for workers aged 33-49. Computer use among the college-educated rose from 31.5% to 53.7% for workers aged 60-64 in 1993 and from 44.8% to 71.4% for workers aged 33-49.

Table 5 reports regressions of computer use in 1993 that control for age differences in occupation and education. The estimated coefficients on the age dummies alone reflect the age profile of computer use from Figure 2. Computer use was 11-19 percentage points lower for 60-64 year olds relative to 23-59 year olds. With 45 occupation dummies included, most of the age coefficients change only a little, and the age

18-22 coefficient swings over 10 percentage points and becomes positive. With education and occupation dummies in the last column, the differential for older workers shrinks by only $^1/_4$ to $^1/_3$.[13] Age differences in occupation and education do not account for much of the computer use differential.

TABLE 5: Adding Occupation and Education Controls

	Dependent variable: do you use a computer at work?			
Age, relative to 60-64				
18-22	-0.039 (0.012)	0.067 (0.010)	omitted	omitted
23-39	0.165 (0.011)	0.153 (0.009)	0.107 (0.010)	0.128 (0.009)
40-49	0.185 (0.011)	0.141 (0.009)	0.144 (0.010)	0.118 (0.009)
50-59	0.112 (0.012)	0.083 (0.010)	0.085 (0.011)	0.076 (0.009)
Education, relative to < high school				
high school	-	-	0.132 (0.005)	0.109 (0.007)
some college	-	-	0.259 (0.006)	0.202 (0.007)
college +	-	-	0.350 (0.006)	0.278 (0.008)
Occupation dummies	no	yes	no	yes
Constant	0.327 (0.010)	0.761 (0.023)	-0.001 (0.011)	0.553 (0.024)

Sample: workers aged 18-64 in the October 1993 CPS. Occupation dummies represent 45 detailed two-digit occupation codes. Supplemental weights are used. Standard errors are in parentheses.

Education dummies also remain large and significant when occupation dummies are included, so more educated people within occupations use computers more. This might arise because they learn to use computers more easily, because their productivity of computer use is greater, and/or because occupations are not defined finely enough.

Differences in computer use can be further decomposed into those arising across versus within occupations. This involves regressing computer use on occupation dummies for a reference cohort. The estimated occupational coefficients are combined with the occupational distribution of a comparison cohort to predict their computer use, if they had the same within-occupation computer use of the reference cohort.[14]

---

[13] The estimates with education dummies omit 18-22 year olds; their rate of computer use is not representative, since many are still in school.

[14] The difference between computer use of the reference cohort and the prediction for the comparison cohort arises from differences in computer use across occupations; the difference between predicted and actual computer use of the comparison cohort arises from differences in computer use within occupations.

The results, in Appendix Table 1, show that almost all of the computer use deficit of older cohorts arose within occupations. For example, 1993 computer use was 51.0% for the prime-age cohort and 32.7% for 60-64 year olds. The within-occupation difference accounts for 14.6 of the 18.3 percentage point gap, while the difference in cohort occupation explains the rest. A decomposition over time shows that most of the evolution in computer use also occurred within occupations. 20.2 percentage points of the increase for the prime-age cohort occurred within occupations, and 2.5 occurred as people moved into high computer use occupations. For 60-64 year olds, 13.5 points were gained within occupations, and 0.6 were *lost* as people moved into lower computer use occupations.

Overall, these results suggest that within-occupation and within-education differences in computer use are the major factor behind age differences in computer use. Further, within-occupation increases in computer use were smaller for older cohorts, who failed to move into computer intensive occupations as prime-age workers did.

D. The spread of computers in jobs

Computer use varies enormously across occupations, as Table 4 showed. The rate at which computers spread in different jobs also varies – some jobs had high rates of computer use early on, while others had major increases in recent years.[15] The pattern of computerization has an important effect on older workers.

Table 6 shows regressions of individual computer use on both levels and changes in average use in the person's occupation and industry. Not surprisingly, average computer use in someone's occupation, and its interaction with the industry average, is the key determinant of whether they use a computer.

The results also show that the *recent change* in computer use matters – but only for older workers. Suppose someone aged 60-64 in 1993 works in an occupation and industry where 50% of prime-age workers have used a computer since 1984; that worker has a 54% chance of using a computer. This is not surprising since the person has probably spent a long time in the job and thus using a computer. On the other hand, if computer use in the job jumped from 10% to 30% to 50% between 1984 and 1993, the worker has only a 14% chance of using a computer. A worker aged 50-59 has a 59% chance of using a computer in the first case, but only a 26% chance in the second. The same pattern arises in 1997 for occupations that computerized since 1989.

TABLE 6: Individual Computer Use and the Spread of Computers

	Dependent variable: do you use a computer at work?					
Average computer	Age in 1993 CPS:			Age in 1997 CPS:		
use in the same:	23-49	50-59	60-64	23-49	50-59	60-64
Occupation	0.823	0.723	0.528	0.751	0.728	0.805
	(0.022)	(0.054)	(0.104)	(0.024)	(0.054)	(0.116)
change 1993-97	-	-	-	0.113	-0.108	-0.441
				(0.070)	(0.151)	(0.244)
change 1989-93	0.028	-0.390	-0.897	-0.036	-0.217	-0.551
	(0.067)	(0.145)	(0.239)	(0.068)	(0.145)	(0.217)
change 1984-89	-0.012	0.123	-0.020	-0.031	-0.112	-0.315
	(0.050)	(0.134)	(0.250)	(0.054)	(0.127)	(0.293)
Industry	0.375	0.426	0.164	0.239	0.158	0.083
	(0.027)	(0.059)	(0.109)	(0.025)	(0.052)	(0.087)
change 1993-97	-	-	-	-0.012	0.042	0.029
				(0.014)	(0.031)	(0.059)
change 1989-93	-0.120	-1.001	-0.707	0.304	0.653	0.147
	(0.085)	(0.193)	(0.369)	(0.067)	(0.149)	(0.294)
change 1984-89	-0.228	-0.382	-0.407	-0.107	-0.026	0.414
	(0.051)	(0.128)	(0.266)	(0.054)	(0.113)	(0.233)
Occupation *	0.099	0.154	0.556	0.266	0.304	0.260
Industry	(0.036)	(0.077)	(0.135)	(0.038)	(0.079)	(0.152)
Constant	-0.085	-0.019	0.057	-0.083	-0.089	-0.108
	(0.007)	(0.016)	(0.026)	(0.009)	(0.020)	(0.034)
R^2	0.365	0.304	0.288	0.370	0.312	0.310

The right-hand side variables are levels and changes of average computer use for workers aged 23-49 in 45 occupations and 50 industries. Supplemental weights are used. Huber-White standard errors in parentheses.

These results reinforce the key role of the decision to acquire computer skills. The evolution of the age profiles showed earlier that the oldest workers fall behind only as they

[15] Examples of high computer-use occupations in 1984 include engineers and some managers and clerical jobs. Teachers, public administrators and health workers had major increases in computer use since 1984.

approach retirement age. Here, the pattern of computerization shows that the oldest workers fall behind only when computers use grows important in their jobs.

E. Computer use in the HRS

The Health and Retirement Survey asked workers in the first wave how frequently they use a computer on the job. As Table 7 shows, 48.9% of 50-59 year olds and 41.9% of 60-62 year olds used a computer at least some of the time in 1992. The age, education, and occupational characteristics of computer users are about the same as the CPS. The overall rates are higher, perhaps because the HRS focuses on frequency of use and also lacks the careful lead-in defining computer use. Over half of users report using the computer most or all of the time, with identical intensity of use for ages 50-59 and 60-62.

TABLE 7: Percent Using a Computer at Work, 1992 HRS

	Age 50-59	Age 60-62
Among those who work	48.9% (0.7)	41.9% (1.6)
Among users, % using a computer:		
all of almost all of the time	40.5	40.3
most of the time	20.1	20.1
some of the time	39.3	39.6

% using a computer all or almost, most or some of the time (question F82g). Sample: age-eligible, workers (N=6660). Computed with person level analysis weights. Standard errors in parentheses.

III. MORE ON COMPUTER USE OF OLDER WORKERS

This section presents more data on computer use. The January 1991 CPS on job training asked about computers. The October CPS asked what people use computers for at work and at home. Along each of these dimensions, computer use of older workers lags.

A. Computer use and job training

Table 8 reports data from the January 1991 CPS on computer skills and on job training. This information offers insight about the relationship between job training and age, which might reflect the same interaction between skill acquisition and retirement decisions. Among workers aged 18-64, 50.9% used a computer at least occasionally. The age profile of computer use is familiar – it peaks at 55.8% for 40-49 year olds and drops to 34.8% for 60-64 year olds.[16] The frequency of use among computer users was high, but older workers reported less everyday use, 72.7% for ages 60-64, versus 77.5% for ages 23-39. Computers users were extremely likely to consider their computer skills adequate, but older users and non-users were less satisfied with their skills.

TABLE 8: Computer Use, January 1991 CPS

	All	18-22	23-39	40-49	50-59	60-64
% using a computer	50.9	37.1	53.6	55.8	45.4	34.8
% users using computer less than once/wk	9.2	8.9	8.7	9.8	9.6	10.5
once or more/week	14.1	13.8	13.9	14.2	14.6	16.9
everyday	76.8	77.3	77.5	76.0	75.8	72.7
% who feel their computer skills are good enough for the current job:						
computer users	88.4	93.6	89.1	86.8	86.6	85.8
non-computer users	59.2	71.4	59.6	57.3	54.4	51.9
% who got any training in the current job	42.6	25.1	43.1	48.8	42.8	34.7
of those, % trained in computer skills	32.7	21.9	32.1	35.4	34.3	29.4

Data: Supplement to the January 1991 CPS. Sample: Workers aged 18-64. Computed with the final weights.

Lastly, of the 42.6% receiving some training in their current job, 32.7% were trained in computer skills. Overall, 13.9% of workers received training in computer skills, but only 10.2% of 60-64 year olds did.[17] The lower training rate for older workers remains even with controls for occupation, occupational tenure, and employer tenure. Older workers receiving training were a little less likely to be trained in computer skills.

B. What workers use computers for

CPS questions about what people use computers for shed light on the role of computers at work. The appendix lists a classification of over twenty specific uses into

---

[16] The age differentials are almost identical to the CPS computer supplements, though computer use rates are higher here, as in the HRS. More statistics about job training appear in the Appendix.

[17] In order of frequency, the types were technical skills, computer-related skills, managerial skills, other, remedial skills. 25.9% of computer users, and 1.6% of non-users, got computer training in their current job.

broad tasks. For example, word processing, databases, and spreadsheets are classified as common applications. People reported a greater number of tasks over time, especially since 1993. The average number of specific uses rose from 4.0 to 4.6, even though the number of categories dropped from 22 to 16. Thus, computer functions continue to evolve, even while the rate of use has stabilized. Common applications remain the most popular task, reported by 71% of computers users in 1997. Next most common are accounting tasks (bookkeeping, inventory control).[18] As e-mail grew more popular, communication tasks rose from 31% in 1989 to 47% in 1997.

TABLE 9: Broad Tasks Reported by Computer Users

	% of users who use a computer for each task, each year and by age in 1997							
Broad tasks	1989	1993	1997	18-22	23-39	40-49	50-59	60-64
common applications	60	64	71	54	72	73	73	68
accounting tasks	45	45	66	71	68	66	63	61
communication tasks	31	39	47	31	48	49	49	44
analysis	25	26	27	13	28	29	26	21
graphics tasks	22	25	26	15	27	27	26	22
programming	19	13	15	10	16	16	13	11
sales tasks	16	16	22	23	24	21	20	21
instruction	15	16	-	-	-	-	-	-
games	5	6	-	-	-	-	-	-
other	18	19	13	10	12	14	14	14
don't know	6	6	-	-	-	-	-	-
average # broad tasks	2.6	2.7	2.9	2.3	2.9	2.9	2.8	2.6
average # specific uses	3.6	4.0	4.6	3.4	4.7	4.7	4.4	4.0

CPS, see Table 1 notes and the Appendix for details. A dash means the category was not asked in the CPS.

The pattern of computer tasks by age are similar, but the oldest and youngest use computers less intensively. People aged 23-49 used computers for an average of 4.7 specific functions, while people aged 60-64 reported 4.0 tasks, 14% less.

[18] The large increase in 1997 reflects the addition of a new category, "customer records and accounts".

C. Computer use at home

Information about computer use at home is reported in Table 10. The rate of home use rose sharply from 19% in 1993 to 33% in 1997 for 18-64 year olds. In 1997 56% of people who used a computer at work also used one at home, compared to 23-25% of those who did not use a computer or who did not work.

TABLE 10: Computer Use at Home

	All	18-22	23-39	40-49	50-59	60-64
	% who use a computer at home, of people who use a computer at work					
1989	23	16	22	30	23	17
1993	34	27	33	40	35	25
1997	56	50	54	64	56	46
	% who use a computer at home, of people who work but do not use a computer					
1989	7	11	6	8	4	3
1993	11	16	11	12	8	5
1997	25	26	23	29	22	15
	% who use a computer at home, of people who do not work					
1989	7	11	8	8	4	3
1993	13	18	14	14	10	7
1997	23	30	25	25	17	14

CPS, see the Table 1 notes. 1984 statistics are omitted because computer use was very low.

Computer use at work, family structure, and education are the strongest predictors of home computer use.[19] The age profile of home use is more peaked than work use because of the correlation between having children and a computer. Controlling for children, the home use age profile is roughly flat and begins to drop off around age 55. This reinforces earlier conclusions that older workers use computers less intensively.

IV. COMPUTER USE AND RETIREMENT

The age profiles showed that computer use does not vary for workers of most ages but lags for the oldest workers. That suggests that retirement reduces the value of

[19] Someone using a computer at work is 12.6 (0.4) percentage points more likely to use a computer at home, controlling for education, gender, number of children, labor force status, and age. These are in line with results from Goolsbee and Klenow (1999), who used data from consumer market research surveys.

acquiring computer skills, or any other productive skills. The rest of this paper analyzes the interaction of computer use and retirement using longitudinal data from the HRS.[20] Computer users in the HRS were more likely to continue working than non-computer users. The inference may run in either direction, however, since skill acquisition and retirement plans are determined endogenously.

A. Data on retirement

Table 11 shows data from the first three waves of the HRS. 75.6% of 50-62 year olds working in wave 1 were still working four years later in 1996.[21] Computer users were significantly more likely to continue working. 78.4% were working two years later, compared to 73.0% of non-computer users – so non-users were 25% more likely to leave work. The rates of retirement are very similar in each two year period between waves, and also in the year following the 1989 CPS. The next subsection introduces a stylized model to account for this relationship.

TABLE 11: Computer Use and Retirement, HRS

% working in… who are still working in…:	1992 → 96	1992 → 94	1994 → 96
Workers aged 50-62 in 1992	75.6% (0.6)	85.1% (0.5)	83.8% (0.5)
computer users	78.4% (0.8)	87.0% (0.6)	85.9% (0.7)
non-computer users	73.0% (0.8)	83.3% (0.6)	81.7% (0.8)

See the Table 7 notes. Sample: people who were age-eligible, working for pay in wave 1 (question F2), and answer the computer use question (F82g); N=6097 in first column.

B. The skill acquisition and retirement decisions

The interaction between costly skill acquisition and retirement decisions depends on changing technologies and skill requirements and is difficult to observe. I will focus

[20] The 1989 and 1991 CPS can be matched to form a one year panel, but matching is not straightforward. It may introduce selection bias on retirement, though Peracchi and Welch (1994) argued that match failure is not correlated with participation changes after controlling for age, gender, and initial participation status.

[21] As in much of the retirement literature, I use the objective measure of exit from employment, rather than self-reported retirement. 12% of people who report being retired as their first answer about their "current employment situation", in question FA1 of wave 2, also report working for pay.

here on the implications for the observable relationship between computer use and retirement. The discussion is meant to apply to computer skills but is stated in general terms about training. Suppose the benefits from training, which accrue either to the employee or employer, are realized over time. The employee will get trained (T=1) if the present value B(T) of the expected benefit exceeds the cost C(T) incurred today:

$$T(Y_R^{\ E}) = 1 \text{ if } B(T) = \sum_{t=1}^{Y_R^{\ E}} \frac{E[b_t(T)]}{(1+r)^t} > C(T) \qquad (1)$$

The per-period benefits of training are discounted at interest rate r and may be uncertain because, for example, future technologies could make current skills obsolete. The time horizon is the expected retirement date $Y_R^{\ E}$.[22] Retirement has little effect when distant but reduces the benefits of training as it nears, so $\partial T(Y_R^{\ E})/\partial Y_R^{\ E} \geq 0$. This hypothesis is supported by the lag in computer use as cohorts age, shown in Table 3.[23]

The training decision depends on many factors imperfectly observed, at best:

$$T = f^T(P^T, F^T, Y_R^{\ E}) \qquad (2)$$

The costs and benefits depend on personal characteristics P (skill, ability to learn), firm characteristics F (the productivity of training, earnings), and the expected retirement date $Y_R^{\ R}$. The expected retirement date depends on related variables:

$$Y_R^{\ E} = f^E(P^E, F^E) \qquad (3)$$

Here, relevant personal characteristics include health, assets, and leisure preferences; and firm characteristics include earnings and retirement benefits. Training will alter F^E and P^E and thus could modify retirement plans. One point of writing down (2) and (3) is to make clear the difficulty of estimating the interaction between training and retirement plans, which, along with many of their determinants, are at best imperfectly observed.

To continue, the worker retires at some point (R=1), in response to several factors:

---

[22] $Y_R^{\ E}$ is in the worker's information set. If the firm makes the training decision, it must infer $Y_R^{\ E}$; in that case, the firm will underinvest, relative to the efficient outcome, in the skills of workers who plan to retire late because workers cannot credibly convey their private information about retirement plans.

[23] Regressing computer use on retirement plans reported in the HRS does not reveal $\partial T(Y_R^{\ E})/\partial Y_R^{\ E}$. Reported retirement plans depend on the earlier training decision and will be considered later in the same framework as actual retirement.

$$R = f^R(Y_R{}^E, T(Y_R{}^E, \bullet), \Delta P^E, \Delta F^E) \quad (4)$$

Retirement depends on the earlier retirement plans expressed in (3); on whether the person actually got trained as determined in (2); and on changes since then, either due to training or to other factors, in the variables determining expected retirement.

The discussion suggests two testable hypotheses. One hypothesis is that $dR/dT \leq 0$ in the reduced form – someone with training is less likely to retire. The raw data in Table 11 confirms this hypothesis. Two factors might explain the reduced form relationship, though. First, training improves earnings and employment opportunities; and second, the training decision reflects earlier retirement plans, which influence actual retirement. Thus, we observe non-computer users retiring early because they lack computer skills *and* because they intended to retire early and did not get computer skills.

Therefore, the key hypothesis is $\partial R(T)/\partial T \leq 0$, computer use induces a worker to delay retirement.[24] This hypothesis can be tested in two distinct ways. One approach is to model and estimate (2)-(4) explicitly, which does not seem feasible since many relevant variables are unobserved. The other approach is to instrument for T, whether a person was trained or uses a computer. A valid instrument is correlated with computer use but otherwise uncorrelated with intended and actual retirement. The instrument identifies the delay in retirement directly attributable to computer use; it amounts to asking whether exogenously training someone, or giving them a computer and productive computer skills, will lead them to delay retiring.

The instrument I use here is average computer use by prime-age workers in the same occupation and industry. High computer use in that job signals that computers are productive relative to training costs, so even older workers near retirement are more likely to get trained. Average computer use for prime-age workers, who are far from retirement, should not be otherwise correlated with an older worker's retirement plans. It must also be uncorrelated with other factors influencing retirement. I use the detailed HRS data to control for many attributes of workers and jobs in order to reduce the scope

[24] Later on, training could actually encourage retirement through an income effect. However, this is inconsistent with what we observe – that computer users retire later, as do more educated workers for whom a similar argument might be made. Furthermore, it is not obvious how to identify separate income and substitution effects of computer use.

for omitted variable bias; occupation and industry explain little of the additional variation in retirement behavior after including these controls.

V. INSTRUMENTAL VARIABLES ESTIMATES

Computer users in the HRS are less likely to retire, but two factors may explain this: lack of computer skills makes workers less attractive, and early retirement plans diminish the value of acquiring computer skills. This section uses average computer use by prime-age workers in the same type of job as an instrument for individual computer use by older workers to isolate the impact of computer use on retirement.

A. The first stage: Computer use

Table 12 reveals a strong effect of average computer use of prime-age workers on older workers in the same occupation and industry.[25] In the first column without covariates, occupational computer use has a major impact, particularly in industries with high use. The second column reports the first-stage regression with other worker and job controls. The occupation and industry effects diminish a little but still account for most of the explained variation. The estimates imply that an increase in average computer use from 40% to 50% makes a worker 8.8 percentage points more likely to use a computer.

TABLE 12: First Stage Estimates

	Dependent variable: the person uses a computer		
Average occupational computer use	0.580** (0.064)	0.412** (0.064)	0.326** (0.078)
change, 1993-97	-	-	-0.476** (0.185)
Average industry computer use	0.109* (0.061)	-0.028 (0.065)	-0.284** (0.100)
change, 1993-97	-	-	-1.053** (0.326)
Occupation*industry average	0.569** (0.120)	0.548** (0.118)	0.466** (0.120)
R^2	0.288	0.355	0.358
Includes other covariates?	no	yes	yes

Independent variables: average computer use of workers age 23-49 in the same occupation and industry, 1993 CPS. Samples and other covariates are the same as IV-4 (second column) and IV-5 (third column) in Table 14. Huber-White standard errors in parentheses. Significance at the 95% (**) or 90% (*) confidence level is noted.

[25] Average computer use in the CPS is aggregated to match the 17 occupation and 13 industry codes reported in the HRS public release.

The third column adds the change in average computer use to account for the pressure of rapid computerization. As in the CPS, older workers are much less likely to use computers in jobs with increasing computerization. The magnitude differs, at least in part because the HRS aggregates occupation and industry codes. The ongoing changes in computer use between 1993 and 1997 matter more than changes between 1989 and 1993, which is reasonable if workers respond promptly to changing technological demands.[26]

B. OLS estimates: Retirement

The OLS estimates in Table 13 add a series of covariates in sequence. The estimates start with computer use and age, to control for potentially spurious effects of age on retirement.[27] Then other demographic controls are added, and finally numerous job and worker characteristics reported only in the HRS.

The main results focus on whether someone working when first observed in 1992 is still working four years later.[28] Regression OLS-1 shows that the positive effect of computer use on work persists when controlling for age. OLS-2 has demographic controls standard in a labor supply model. Educated workers are much more likely to continue working, as typically found in the literature. Married men and single women are also more likely to keep working.[29] Controlling for education in OLS-3 reduces the computer use effect, not surprising as more educated workers are much more likely to use a computer. Including computer use reduces the college education coefficient slightly.

[26] 1993-97 changes in computer use have a small insignificant effect in the 1993 CPS as in Table 6, but they matter more when occupation and industry codes are aggregated.
[27] In fact, age has little effect on computer use when the full set of covariates are included.
[28] The estimates here are from a linear probability model but are very similar from a probit.
[29] Women retire sooner than men, and, estimated separately, the computer use coefficient is a bit higher.

TABLE 13: OLS Estimates				
	Dependent variable: the person is still working, 1992 → 96			
	OLS-1	OLS-2	OLS-3	OLS-4
Uses a computer	0.035**	-	0.014	0.022*
	(0.012)		(0.013)	(0.014)
Education:	-	0.060**	0.059**	0.070**
high school		(0.018)	(0.018)	(0.019)
some college	-	0.083**	0.080**	0.087**
		(0.019)	(0.020)	(0.022)
college +	-	0.120**	0.114**	0.126**
		(0.019)	(0.021)	(0.023)
Also includes	age	age, demographic variables		age, demographic, +
Sample size	5748	5783	5748	5152
	the person is still working 1992 → 94			
Uses a computer	0.028**	-	0.017*	0.012
	(0.010)		(0.011)	(0.011)
	the person is still working 1994 → 96			
Uses a computer	0.027**	-	0.010	0.020
	(0.011)		(0.012)	(0.013)

Linear probability estimates, Huber-White standard errors in parentheses, computed with person-level analysis weights. Demographic variables: race, sex, marital status. Full set of coefficients from OLS-4 reported in Appendix Table 4. Significance at 95% (**) or 90% (*) confidence levels noted. Sample: workers age 50-62 in wave 1; and in OLS-4, with hourly earnings between $1 and $100.

OLS-4 adds numerous individual and job characteristics which only appear in the HRS. For example, I include controls for the usual retirement age a worker reports in his job; the pension plan type and eligibility age; and whether the worker has retiree health insurance. It is important to include these sorts of job and personal controls that influence retirement and could be correlated with computer use. Moreover, it is interesting to get a glimpse of what we will learn as the HRS sample continues to age and retire.

Adding these variables in OLS-4 raises the computer use coefficient. It is significant with 90% confidence and implies that computer users are 2.2 percentage points, or 8.3%, more likely to be working four years later.[30] The magnitudes are similar in each two year period, but the HRS variables have a greater impact in the later two years. Most of the HRS variables have the expected signs, and many are significant. For example, someone older than the defined benefit pension plan's early retirement age is 12.1 percentage points less likely to continue working. Someone with health insurance from an employer is 6.0 percentage points more likely to continue working, but someone with retiree health insurance is 7.6 percentage points less likely.

Since the instruments used to explain computer use vary only by occupation and industry, it is important to understand how occupation and industry characteristics affect retirement. Included in OLS-3, occupation dummies are jointly significant at a 92% confidence level and industry dummies at 82%. With the detailed HRS controls in OLS-4, it drops to 84% and 70% respectively, below conventional levels of significance. The HRS, therefore, and the usual retirement age and pension plan variables in particular, help to capture crucial job attributes correlated with retirement. The remaining influence of occupation and industry, while not negligible, is no longer statistically significant.

C. Instrumental variables estimates: Retirement

Table 14 reports the outcome of instrumenting with occupation and industry average computer use. As before, IV-3 includes demographic controls, while IV-4 and IV-5 add the rich controls from the HRS. IV-4 instruments with average computer use in the same job, and IV-5 adds the change in computer use, as in Table 12.

---

[30] Among the new variables, pension plan characteristics and the usual retirement age in particular raise the computer use estimate. All OLS-4 coefficient estimates are shown in Appendix Table 4.

TABLE 14: Instrumental Variable Estimates			
	Dependent variable: the person is still working, 1992 $\rightarrow$ 96		
	IV-3	IV-4	IV-5
Uses a computer	0.057*	0.071*	0.066*
	(0.030)	(0.037)	(0.036)
Education:	0.051**	0.061**	0.062**
high school	(0.020)	(0.020)	(0.020)
some college	0.064**	0.072**	0.074**
	(0.023)	(0.024)	(0.024)
college +	0.089**	0.107**	0.109**
	(0.026)	(0.026)	(0.026)
Also includes	age, demographic	age, demographic, +	
Instruments	average computer use		average computer use, change in computer use
Sample size	5713	5152	5152
	Dependent variable: the person is still working, 1992 $\rightarrow$ 94		
Uses a computer	0.031	0.033	0.027
	(0.027)	(0.031)	(0.031)
	Dependent variable: the person is still working, 1994 $\rightarrow$ 96		
Uses a computer	0.056**	0.069**	0.064**
	(0.028)	(0.033)	(0.033)

See the Table 13 notes. Instruments: occupation and industry average computer use for prime-age workers, reported in Table 12. Significance at least at 95% (**) or 90% (*) confidence levels noted.

The estimated computer use effect remains large in each specification and implies that computer use directly causes people to delay retirement. The point estimate in IV-4 implies that using a computer makes someone 7.1 percentage points, or 26.5%, more likely to continue working, a strong effect. With the relatively large standard errors, we cannot reject that the IV estimates are different from OLS. Adding additional instruments in IV-5 – the change in average computer use in the same occupation and industry – incorporates extra information about pressure to use a computer or alternatively to retire. The estimate falls by a little less than 10% and remains statistically significant. Instrumenting has little effect on the other variables in the model.

When estimated separately, the computer use effect grows with age. The coefficients are 0.012 (0.046) for ages 50-54, 0.089 (0.058) for 55-59, and 0.208 (0.136) for 60-62, though they are not statistically different. In contrast, the OLS estimates are quite similar across ages. The differences in the OLS and IV estimates suggest a shift in the relationship. Retirement plans affect computer use endogenously for younger non-computer users, while older non-users retire sooner because they do not use a computer. While occupation and industry effects matter somewhat for ages 60-62, they are highly insignificant for younger workers.[31] Thus, the estimate for 55-59 year olds, which implies that computer use reduces the likelihood of retiring by 32.8%, is the strongest result.

The computer effect is strong in the later two years, 1994 to 1996, and smaller for 1992 to 1994. This differs from the OLS results, which were very similar across time. The differences reflect year or selection effects, rather than aging, because restricting the samples to the same ages in each period still yields different results.[32]

Another piece of evidence comes from information about retirement plans. As with actual retirement, computer use should lead to later planned retirement, and also someone who intends to retire later would be more likely to get computer skills. On average, workers aged 50-62 plan to retire in 7.7 years. Regressing this variable on computer use yields a coefficient of 0.372 (0.134), so computer users plan to work significantly longer. Instrumenting with occupation and industry average computer use yields a coefficient of 0.676 (0.313).[33] Thus, using a computer causes a delay in planned retirement of two-thirds of a year, or 9.0%.

The conclusion that computer use makes it more attractive to continue working is driven by people in high computer use jobs, who are much more likely to use computers; and it persists with other controls for the tradeoffs between work and retirement. The IV

[31] Joint significance tests for occupation and industry dummies in OLS, as in the previous section, have confidence levels under 50% for ages 50-54 and 55-59. They are borderline significant for ages 60-62, so in that case the instruments may reflect other influences on retirement. This is discussed in the next section.

[32] Year effects mean that technology or something else changed between waves 2 and 3. Selection effects mean that people still working in wave 2 behave differently than people who retired. Another explanation might be cohort effects if cohorts behave differently as they retire, but these cohorts are quite close together.

[33] This estimation replicates OLS-4 and IV-4, with details reported in the appendix.

estimates are larger, not smaller, than the OLS estimates, however, evidently because some non-computer users in high-computer use jobs retire later than non-users in low-computer use jobs; thus, omitted variable bias may remain. The next section addresses concerns about identification.

D. Are the instruments valid?

The average computer use instruments are only valid if other occupation and industry characteristics associated with retirement are uncorrelated with computer use or else included in the retirement regression. Various job attributes – computerization, physical demands, contracting arrangements, and others – affect retirement. Moreover, people sort into jobs based on their own abilities and preferences about retirement. The rich set of HRS variables do evidently control for many of these job attributes. This section details additional strategies to assess the robustness of the instruments.

- The influence of unrestricted occupation and industry effects in the basic retirement regression gives some insight about the scope for omitted variable bias. As noted earlier, occupation and industry dummies have a statistically insignificant impact on retirement when the HRS controls are included in the OLS estimation, and a negligible impact for people in their 50s. In the first stage regression, in contrast, occupational computer use plays a major role. Industry computer use adds little explanatory power, which raises the possibility of using occupational computer use alone as an instrument, while including unrestricted industry effects in the main regression.[34] The resulting estimate rises slightly to 0.077 (0.041) for the full time period. The coefficients still grow with age, and for ages 55-59, for example, the estimate of 0.092 (0.062) is almost the same.[35] With occupation effects contributing little to the main regression, these estimates add to our confidence that the identifying variation in computer use does not reflect other occupational characteristics associated with retirement.
- Another strategy is to add more variables to capture factors correlated with computer use and retirement. The HRS asks workers who are not self-employed, "Do you make

[34] In the first stage, including only the occupational average yields an R^2 of 0.273, compared to 0.288 when also including the industry average and their interaction.
[35] The estimates are 0.041 (0.052) for ages 50-54 and 0.164 (0.151) for ages 60-62.

decisions about the pay and promotion of others?" This variable can indicate how managerial responsibility – an attribute correlated with computer use – influences retirement. Included in OLS-4, pay and promotion responsibility has an effect of a similar magnitude as computer use, which remains strong. Included in IV-4, it lowers the computer use effect for the non-self employed about 10%, from 0.075 (0.039) to 0.066 (0.040), just significant at 90%.[36]

- Other questions – like those about how often a job requires physical effort or dealing with other people, or involves intense concentration or high stress – do not significantly affect retirement and do not reduce the explanatory power of computer use.
- Another approach is to go to other sources for data on occupation and industry characteristics. I tried including average training rates in occupations and industries from the January 1991 CPS, discussed earlier, with little effect on the estimates.[37]
- I also assembled data on retirement rates from an earlier time period. The personal computer was introduced in 1981. Before then, computers will have had little effect on retirement – yet, industry retirement patterns from the CPS were quite similar to today. Including controls from an earlier period will kill the estimated computer use effect if they proxy for omitted job characteristics that persist today.[38] When measures of occupation and industry retirement from the 1970s are included in OLS-4, the coefficient on computer use is 0.019 (0.014). When they are included in IV-4, the coefficient of 0.057 (0.040) is somewhat lower than before.[39] This implies that part of the variation in average computer use does reflect other factors influencing retirement. Nevertheless, the estimate remains

[36] The coefficient on the new variable is 0.031 (0.017) in OLS, 0.025 (0.018) in IV. It is not obvious whether to control for self-employment in general, since it is probably endogenous with computer use and retirement. Although computer use among the self-employed is only 31.0%, self-employed computer users are even more likely to continue working than non-self-employed computer users.

[37] I tried including controls for average training rates in computers or of any type, by occupation and industry, for ages 23-49 and 60-64. Although we might expect computer training or any training for 60-64 year olds to raise computer use and delay retirement, the signs of the estimated training effects bounce around. They have little effect on the computer use estimate, whether included in the main regression or used as instruments. The focus in the CPS on formal training, and also on any training received in the current job rather than within a specific time frame, may explain the unsatisfactory results.

[38] The measures are described in the appendix. Industry retirement patterns in the late 1970s and the 1990s have a correlation coefficient of 0.679. Occupation patterns in the 1990s, though, are not tightly related to the late 1970s or to the early 1980s, when occupation codes match up more closely.

[39] The estimated coefficient on industry retirement rates from the 1970s is positive and small.

large though imprecisely measured, suggesting that computer use has an independent effect on retirement.

The results in this section suggest that the instruments reflect to some degree other occupation and industry characteristics related to retirement. Nevertheless, after introducing several measures of other attributes, the estimated computer use effects remain closer to the original result than to zero, especially for 55-59 year olds. Though these estimates are not precise, the results suggest that computer use has an independent influence on retirement.

VI. CONCLUSION

A large body of research has investigated the nature of technological progress and its recent impact on the employment and earnings of different types of workers. Changes in technology, especially if they are skill-biased, will affect older workers differently than prime-age workers because older workers have skills that are complementary with older technology and, moreover, have a shorter time horizon when facing the decision to acquire new skills. New data on computer use at work offers insight into the impact of technological change on older workers.

The notion that older workers adapt less readily to new technologies is supported by the age patterns of computer use in the CPS. Nevertheless, the age profile of computer use is remarkably flat for workers up into the 50s, suggesting that other workers acquire computer skills as necessary – even if they have been out of school for many years or have dated skills. In that light, the lag in computer use of the oldest workers along many observable dimensions suggests that age alone is not the key factor. Impending retirement appears to play an important role in determining the response of older workers to computerization and other technological changes.

Longitudinal data from the HRS offers insight into the relationship between computer use and retirement. Non-computer users in the HRS were 25% more likely to leave work between 1992 and 1996 than computer users. That might be observed because computer users have skills that are in demand, and also because computer users acquired skills because they intended to retire later. Average computer use rates for prime-age workers in the same occupation and industry measure the importance of computer skills and serve as instruments to sort out these effects. The rich set of job and worker characteristics reported in the HRS are crucial to control for other attributes that influence retirement along with computer use.

Instrumental variables estimates indicate a strong effect of computer use on retirement, irrespective of how earlier retirement plans affected the decision to use a computer. The estimates imply that computer use raises the likelihood of continuing to work by up to 25-30%. After trying several tactics to address concerns about omitted variable bias, the resulting estimates are not very precise, but they do hold up well for 55-59 year olds in particular.

It will be important to continue investigating how older workers are affected by computers and other new technologies. Proposed changes in Social Security and other public programs designed to encourage more saving and later retirement might have a limited effect if older workers face pressure from technological change. On the other hand, the conclusions here highlight the possibility that any delays in retirement may lead older workers to adapt more readily to new technologies.

REFERENCES

Autor, David, Lawrence Katz, and Alan Krueger. 1998. "Computing Inequality: Have Computers Changed the Labor Market?" *The Quarterly Journal of Economics* 113 (4): 1169-214.

Bartel, Ann, and Frank Lichtenberg. 1987. "The Comparative Advantage of Educated Workers in Implementing New Technology." *The Review of Economics and Statistics* 59 (1): 1-11.

Bartel, Ann, and Nachum Sicherman. 1993. "Technological Change and Retirement Decisions of Older Workers." *Journal of Labor Economics* 11 (1, part 1): 162-83.

Berman, Eli, John Bound, and Zvi Griliches. 1994. "Changes in the Demand for Skilled Labor Within U.S. Manufacturing Industries." *The Quarterly Journal of Economics* 109 (2): 367-98.

Bresnahan, Timothy, Eric Brynjolfsson, and Loren Hitt. 1999. National Bureau of Economic Research Working Paper.

Brynjolfsson, Eric, and Loren Hitt. 1997. "Computing Productivity: Are Computers Pulling Their Weight?" Draft, Sloan School of Management, Massachusetts Institute of Technology.

DiNardo, John, and Jörn-Steffen Pischke. 1997. "The Returns to Computer Use Revisited: Have Pencils Changed the Wage Structure Too?" *The Quarterly Journal of Economics* 112 (1): 291-304.

Doms, Mark, Timothy Dunne, and Kenneth R. Troske. 1997. "Workers, Wages, and Technology." *The Quarterly Journal of Economics* 112 (1): 253-90.

Farber, Henry S. 1996. "The Changing Face of Job Loss in the United States, 1981-1993." National Bureau of Economic Research Working Paper No. 5596.

Goldin, Claudia, and Larry Katz. 1998. "The Origins of Technology-Skill Complementarity." *The Quarterly Journal of Economics* 113 (3) : 693-732.

Goldin, Claudia, and Robert Margo. 1992. "The Great Compression: The Wage Structure in the United States at Mid-Century." *The Quarterly Journal of Economics* 107 (1): 1-34.

Goolsbee, Austan, and Peter J. Klenow. 1998. "Evidence On Network and Learning Externalities in the Diffusion of Home Computers." Manuscript, University of Chicago Graduate School of Business.

Gottschalk, Peter. 1997. "Inequality, Income Growth, and Mobility: The Basic Facts." *Journal of Economic Perspectives* 11 (2): 21-40.

Hurd, Michael, and Kathleen McGarry. 1993. "The Relationship Between Job Characteristics and Retirement." National Bureau of Economic Research Working Paper 4558.

Johnson, George. 1997. "Changes in Earnings Inequality: The Role of Demand Shifts." *Journal of Economic Perspectives* 11 (2): 41-54.

Juhn, Chinhui. 1992. "Decline of Male Labor Market Participation: The Role of Declining Market Opportunities." *The Quarterly Journal of Economics* 107 (1): 79-122.

Katz, Lawrence, and Kevin Murphy. 1992. "Changes in Relative Wages, 1963-1987: Supply and Demand Factors." *The Quarterly Journal of Economics* 107 (1): 1-34.

Krueger, Alan. 1993. "How Computers Have Changed the Wage Structure: Evidence from Micro Data." *The Quarterly Journal of Economics* 107 (1): 35-78.

Krusell, Per, Lee Ohanian, José Víctor Ríos-Rull, and Giovanni Violante. 1998. "Capital-Skill Complementarity and Inequality: A Macroeconomic Analysis." Draft, University of Rochester.

Lehr, Bill, and Frank Lichtenberg. 1997a. "Computer Use and Productivity Growth in Federal Government Agencies, 1987-92." Draft, Graduate School of Business, Columbia University. Forthcoming, *Journal of Industrial Economics*.

Lehr, Bill, and Frank Lichtenberg. 1997b. "Information Technology and Its Impact on Productivity: Firm-level Evidence from Government and Private Data Sources, 1977-1993." Draft, Graduate School of Business, Columbia University.

Levy, Frank, and Richard Murnane. 1996. "With What Skills are Computers a Complement?" *American Economic Association Papers and Proceedings* 86 (2): 258-62.

McConnell, Sheila. 1996. "The Role of Computers in Reshaping the Work Force." *Monthly Labor Review* 119 (8): 3-5.

Peracchi, Franco, and Finis Welch. 1995. "How Representative are Matched Cross-Sections? Evidence from the Current Population Survey." *Journal of Econometrics* 68: 153-79.

Topel, Robert. 1997. "Factor Proportions and Relative Wages: The Supply-Side Determinants of Wage Inequality." *Journal of Economic Perspectives* 11 (2): 55-74.

APPENDIX

Decomposing changes in computer use across and within occupations

The role of occupation can be decomposed into cross-occupation versus within-occupation differences in computer use. This involves regressing computer use on occupation dummies for a reference cohort in a reference year. The resulting occupational coefficients, along with the occupation distribution of another cohort or of the same cohort in another year, are aggregated to arrive at predicted computer use for the comparison cohort, if they had the same within-occupation computer use of the reference cohort. The difference between computer use of the reference cohort and the prediction for the comparison cohort arises from differences in computer use across occupations; the difference between predicted and actual computer use of the comparison cohort arises from differences in computer use within occupations.

Appendix Table 1:
Decomposing Differences in Computer Use by Age and Occupation

Decomposing differences among cohorts, within years

	1984			1993		
Age in 1993	32-49	50-59	60-64	32-49	50-59	60-64
% computer use	28.3	23.5	19.8	51.0	43.9	32.7
Difference in computer use relative to the youngest cohort, attributable to:						
(1) age difference in occupations		-0.3	-0.7		-0.7	-3.7
(2) within-occ differences in computer use		-4.5	-7.8		-6.4	-14.6

Decomposing differences over time, within cohorts

Age in 1993	32-49		50-59		60-64	
	1984	1993	1984	1993	1984	1993
% computer use	28.3	51.0	23.5	43.9	19.8	32.7
Difference in computer use over time, attributable to:						
(3) shifts in occupations over time	+2.5		+1.6		-0.6	
(4) within-occ differences	+20.2		+18.8		+13.5	

CPS, see the Table 1 notes.

Job training in the January 1991 CPS

Appendix Table 2 shows data on training ever received in their current job. On average, 42.6% of workers have received some type of training in their present job to improve their skills. Training rates are lower for the youngest and oldest workers. Training for people of all ages is most likely to be in occupation-specific technical skills, at 63.7%, while 32.7% have been trained in computer-related skills, 26.8% in managerial or supervisory skills, 14.2% in reading, writing, or math skills, and 16.5% in other skills. Among 60-64 year old workers, training in occupation-specific is slightly more common and training in other categories is less common.

Appendix Table 2: General Job Training, January 1991 CPS

	All	18-22	23-39	40-49	50-59	60-64
% taking training to improve their skills in their present job	42.6	25.1	43.1	48.8	42.8	34.7
% trained in:						
reading, writing, math	14.2	11.7	13.6	15.8	14.7	12.7
computer-related	32.7	21.9	32.1	35.4	34.3	29.4
occupation-specific	63.7	60.8	64.3	63.0	63.7	65.2
managerial, supervisory	26.8	12.8	26.0	30.0	29.2	23.4
other	16.5	22.1	15.9	16.3	16.9	16.1
% taking training in: school	32.5	22.4	31.0	36.2	33.9	32.9
formal company training prog.	38.5	21.6	40.1	39.7	37.2	34.3
informal on-the-job	37.0	57.6	37.5	33.5	35.4	35.6
other	17.0	7.5	16.2	19.2	18.0	20.6
of those receiving training in school:						
employer paid:						
all	38.2	18.7	40.2	38.7	36.0	32.4
some	17.3	6.0	18.5	17.5	16.7	13.4
none	44.5	75.2	41.3	43.8	47.3	54.2
employer allowed time off	38.4	33.4	39.2	39.7	35.8	30.3
how long was the training in school?						
1 week or less	12.8	8.0	12.8	13.2	13.1	12.3
2-12 weeks	26.8	17.2	26.7	26.0	30.9	26.7
13-25 weeks	14.8	15.4	15.3	14.3	13.3	18.1
26+ weeks	45.6	59.4	45.2	46.5	42.7	43.0
how long was the training in the formal company training program?						
1 week or less	39.6	49.2	40.2	37.4	38.8	45.3
2-12 weeks	38.2	33.5	39.4	38.2	36.2	31.1
13-25 weeks	7.6	6.3	7.2	8.9	7.2	6.2
26+ weeks	14.5	11.0	13.2	15.6	17.9	17.4

Data: January 1991 CPS Supplement. Sample: workers age 18-64. Computed with CPS final weights.

Of those who have been trained in their current job, 32.5% got some training in school, 38.5% in formal company programs, and 37.0% in informal on-the-job training. Young people are much more likely to be trained on the job, while prime-age workers are the most likely to be in formal company programs. 60-64 year olds workers are somewhat less likely to be in formal company programs than prime-age workers.

Of those trained in school, 38.2% of the financial costs were entirely paid for by the employers, 44.5% by the employees, and 17.3% were split. 38.4% were given time off by their employers for in-school training. 60-64 year old workers were somewhat more likely to pay all the financial costs of training and were less likely to get time off.

Training in school was less than 1 week for 12.8%, 2-12 weeks for 26.8%, 13-25 weeks for 14.8%, and 26 weeks or more for 45.6%. Training in formal company programs was generally much shorter. 60-64 year old workers were more likely to be either in very short or very long programs.

What did people use computers for?

The CPS computer use supplements since 1989 have asked workers what they used computers for. They were allowed to choose any number of about two dozen possible tasks. Appendix Table 3 reports a classification of specific uses into the broad tasks that appear in the text in Table 9.

Appendix Table 3: What People Used Computers For

Broad tasks	Specific uses
common applications	word processing, databases, spreadsheets, calendar/scheduling
communication tasks	communication, electronic mail, bulletin boards [b]
tracking tasks	bookkeeping, inventory control, invoicing, customer records and accounts [c]
sales tasks	sales, marketing, telemarketing [b]
graphics tasks	graphics, design, desktop publishing, newsletters, computer assisted design
programming	programming
analysis	analysis
learning	learning to use the computer [b], educational programs [b], instruction [a]
games	games
other	other
don't know	don't know

October 1989, 1993, 1997 Current Population Surveys. [a] 1989 only. [b] 1993 only. [c] 1997 only.

Among those using the computer for "analysis", spreadsheets was the most correlated specific use. Among those using the computer for "other", 72% reported additional uses. The most common were word processing and communications tasks Among those using the computer for "don't know", only 12% reported additional uses.

Data on retirement plans

The paper discusses estimation results where the left-hand side variable is planned years to retirement. This data is obtained from question K13 of wave 1 of the HRS, which asks when workers plan to retire completely. Planned years to retirement drop from 11.8 at age 50 to 3.5 at age 62. 27% of the IV-4 sample did not answer, and 37% of those who answered had given little or hardly any thought to retirement, rather than a lot or some thought, according to question K16. The regressions are specified as in OLS-4 and IV-4 and also include dummies for how much thought has been given to retirement.

Retirement patterns by occupation and industry in the 1970s

The last section of the paper discusses estimates that include controls for retirement patterns by occupation and industry from a time period before computers were important. Because we do not have longitudinal data on retirement covering the late 1970s, I calculated a measure of retirement patterns using data from the outgoing rotation groups of the March CPSs of 1977-80, and for comparison, 1992-93 as well.

The data are not conducive to computing the average retirement age for each occupation and industry. Instead, I construct a summary statistic for 60-62 year olds, an age that may be thought of as being "on the margin" between working and retiring. The statistic is the "work rate": the ratio of the number who are currently working to the total number who are currently working or used to work in the same occupation and industry. Until 1993 the CPS reported the last occupation and industry of people who do not work today but who have worked within the last five years. I stopped at age 62 in order to limit selection bias, since many older people may have retired more than five years earlier.

The resulting work rates range from 0.802 for managerial specialties to 0.606 for transport operators. Thus, 80.2% of 60-62 year olds who have worked in managerial specialties are still working, but many more of those who have worked as transport operators are retired. Occupation codes changed substantially after 1982, so these are computed for the 12 occupation codes consistent with the HRS classification. I also computed work rates for 1983-84 when the occupation codes are the same as today, with the same estimation results. Consistent occupation and industry codes across decades used in Autor, Katz, and Krueger (1997) were helpfully provided by David Autor.

Additional variables from HRS regressions

Appendix Table 4 reports additional coefficients from regressions OLS-4 and IV-4. Below are descriptions of these variables:
(1) Usual retirement age in your job relative to your own age. From question F90, "On your main job, what is the usual retirement age for people who work with you or have the same kind of job in your job." The omitted category is 3 or more years younger than usual retirement age.
(2) Average usual retirement age in your occupation and industry relative to your own age. The variable in (1) is averaged over people in the same occupation and industry, for age-eligibles who answer the computer use question, using the person level analysis weights.
(3) Pension plan in your job. From questions F39 (what type of pension plan are you included in through your work), F45 (normal retirement age of defined benefit plan), F48 (early retirement age of defined benefit plan). The omitted category is no pension plan at work. era/nra refers to the minimum of the pension's early and normal retirement ages.
(4) Health insurance coverage. From questions R2-R15a. No health insurance: none from the government (R2), an employer (R3), or purchased directly from an insurer (R14). People may have more than one of these sources of insurance. It is important to note that the question about employer coverage (R3) is, "Do you have any type of health insurance coverage obtained through your or your [spouse's] employer, former employer or union?", and after

(R4), people answer whether the health insurance (up to two plans) is provided by the own employer/former employer, own union, spouses' employer/former employer, or spouse's union. Thus, we cannot learn whether the current or former employer provides the insurance. Retiree health insurance is coded from R8, which asks whether the employer has "any health insurance plan available to retirees."
(5) Log hourly earnings. If the person is paid by the hour, this is hourly pay on the main job (F16d). If not, it is computed as earnings on the main job divided by annual hours. Earnings are computed from questions about salary on the main job for those not paid by the hour (F16a, F30a), which is computed as usual hours per week (F8) times weeks per year (F10) at the main job.
(6) Log liquid wealth. The natural log of variable 5354, "Net Worth: Liquid assets".
(7) Expects to receive Social Security. Computed from question N46, "Do you expect to receive Social Security" (yes=1), or if there is no answer, from N41 "Did you receive any income in 1991 from Social Security" (yes=1,2,3) .
(8) Hospitalization. Questions B45 in wave 1, B29 in wave 2, and E1 in the 1998 release of wave 3 ask whether the person has been hospitalized. Questions B45a, B29a, and E2 ask how many times the person was a patient in a hospital overnight. The omitted category for each wave is not hospitalized.
(9) Education. Less than high school: no high school diploma or equivalency test (A3a=5), or if A3a not answered then highest grade completed (A3) is less than 12. High school: high school diploma or equivalency test, or if A3a not answered then highest grade completed is 12. Some college: highest degree earned is Associates (A3d=1) or if no degree reported then highest grade completed is greater than 12. Four year college degree or more: answers 2-7 reported for highest degree in A3d. The omitted category is less than high school.
(10) Demographics. Married in wave 1: question A10=1 (married), 7 or 8 (married with two family residences). Female: question 47=2. Race is black: question 48=2. Race is other: question 48=3 through 7. Omitted categories are not married, male, race is white.
(11) Was married in wave 1, not in later waves. Same coding as for marital status, using questions A1 (1,7,8) in wave 2 and E256A (1,2,7) in the 4/99 release of wave 3.
(12) Age. Question 46, calculated age of respondent.
Computer use: The first three answers from question F82g, "My job requires me to work with computers: all or almost all, most, some, or none or almost none of the time."
Work: The person is working if they answer that they are working for pay in questions F2 in wave 1, FA2 in wave 2, and G3 in wave 3.
Industry: Question F4. Occupation: Questions F5, F6.

Appendix Table 4: Additional Regression Coefficients

1992 → 96	Mean (s.d.)	OLS-4 (s.e.)	IV-4 (s.e.)
Job characteristics			
(1) 1-2 years younger than usual retirement age in your job (dummy)	0.051 (0.220)	-0.117**(0.036)	-0.116**(0.036)
Age = usual retirement age (dummy)	0.008 (0.089)	-0.354**(0.080)	-0.356**(0.080)
Age > usual retirement age (dummy)	0.020 (0.140)	-0.051 (0.053)	-0.046 (0.054)
Usual age not reported (dummy)	0.302 (0.459)	-0.013 (0.014)	-0.011 (0.014)
(2) Age-average age of usual retirement, occup	7.500 (3.177)	0.005 (0.013)	0.001 (0.013)
Age-average age of usual retirement, industry	7.521 (3.207)	-0.001 (0.009)	-0.000 (0.009)
(3) DB pension, your age > era/nra (dummy)	0.091 (0.287)	-0.121**(0.028)	-0.134**(0.029)
DB, your age = era/nra (dummy)	0.039 (0.194)	-0.083**(0.037)	-0.094**(0.038)
DB, your age < era/nra (dummy)	0.251 (0.434)	-0.017 (0.017)	-0.026 (0.018)
DB, no era or nra reported (dummy)	0.018 (0.134)	-0.014 (0.042)	-0.024 (0.043)
Has DC pension only (dummy)	0.183 (0.386)	0.006 (0.018)	-0.004 (0.019)
(4) Has health insurance from an employer (d)	0.826 (0.380)	0.060**(0.028)	0.057**(0.029)
Has retiree hlth insurance from an employer (d)	0.578 (0.494)	-0.076**(0.014)	-0.074**(0.014)
Has health insurance from the government (d)	0.075 (0.264)	-0.035 (0.025)	-0.036 (0.025)
Has health insurance purchased privately (d)	0.168 (0.374)	0.016 (0.020)	0.017 (0.020)
Has no health insurance (dummy)	0.084 (0.278)	-0.025 (0.035)	-0.025 (0.035)
(5) Log hourly earnings	2.440 (0.663)	-0.009 (0.011)	-0.014 (0.012)
Personal characteristics			
(6) Log liquid wealth (if wealth > 0)	7.898 (3.136)	-0.002 (0.004)	-0.003 (0.004)
Liquid wealth=0 (dummy)	0.101 (0.301)	-0.077**(0.038)	-0.078**(0.038)
(7) Expects to receive Social Security (dummy)	0.939 (0.239)	-0.007 (0.025)	-0.009 (0.025)
(8) Hospitalized once, yr before wave 1(dummy)	0.055 (0.229)	-0.058**(0.029)	-0.057* (0.029)
Hospitalized 2+ times in year before wave 1	0.013 (0.114)	-0.117* (0.060)	-0.114* (0.060)
Hospitalized once between waves 1,2 (dummy)	0.101 (0.301)	-0.037* (0.022)	-0.038* (0.022)
Hospitalized 2+ times betw wvs 1,2 (dummy)	0.032 (0.177)	-0.140**(0.039)	-0.139**(0.039)
Hospitalized once between waves 2,3 (dummy)	0.116 (0.320)	-0.051**(0.020)	-0.051**(0.020)
Hospitalized 2+ times betw wvs 2,3 (dummy)	0.044 (0.205)	-0.142**(0.037)	-0.142**(0.037)
(9) High school diploma (dummy)	0.381 (0.486)	0.070**(0.019)	0.061**(0.020)
Some college (dummy)	0.223 (0.416)	0.087**(0.022)	0.072**(0.024)
Four-year college degree or more (dummy)	0.228 (0.419)	0.126**(0.023)	0.107**(0.026)
(10) Married in wv 1, spouse younger (dummy)	0.464 (0.499)	0.075**(0.025)	0.075**(0.025)
Married in wv 1, spouse is older (dummy)	0.269 (0.443)	0.066**(0.030)	0.064**(0.030)
Married in wv 1, don't know sps age (dummy)	0.013 (0.112)	0.148**(0.046)	0.149**(0.045)
Female (dummy)	0.463 (0.499)	0.024 (0.029)	0.015 (0.030)
Female, married in wave 1 (dummy)	0.293 (0.455)	-0.144**(0.034)	-0.143**(0.034)
Race=black (dummy)	0.085 (0.279)	0.046* (0.024)	0.048* (0.024)
Race=other nonwhite (dummy)	0.066 (0.249)	-0.005 (0.029)	-0.004 (0.029)
Female, race=black (dummy)	0.048 (0.214)	-0.031 (0.034)	-0.025 (0.034)
Female, race=other nonwhite (dummy)	0.029 (0.168)	0.045 (0.043)	0.045 (0.043)
(11) Was married in wave 1, not in 2 (dummy)	0.019 (0.135)	-0.015 (0.049)	-0.019 (0.049)
Female, was married in wave 1, not 2 (dummy)	0.010 (0.102)	0.153**(0.067)	0.156**(0.068)
Was married in wave 2, not in 3 (dummy)	0.020 (0.140)	-0.049 (0.055)	-0.051 (0.056)
Female, was married in wave 2, not 3 (dummy)	0.001 (0.099)	0.086 (0.080)	0.093 (0.080)

Appendix Table 4: Additional Regression Coefficients

1992 → 96	Mean (s.d.)	OLS-4 (s.e.)	OLS-4 (s.e.)
(12) Age 50 (dummy)	0.004 (0.063)	0.389** (0.184)	0.411** (0.185)
Age 51	0.096 (0.295)	0.281 (0.172)	0.295* (0.172)
Age 52	0.106 (0.308)	0.280* (0.160)	0.293* (0.160)
Age 53	0.099 (0.299)	0.267* (0.148)	0.278* (0.148)
Age 54	0.101 (0.301)	0.260* (0.138)	0.271** (0.138)
Age 55	0.095 (0.294)	0.262** (0.126)	0.270** (0.126)
Age 56	0.090 (0.286)	0.259** (0.116)	0.267** (0.116)
Age 57	0.088 (0.283)	0.201* (0.107)	0.209* (0.107)
Age 58	0.090 (0.286)	0.141 (0.099)	0.146 (0.099)
Age 59	0.075 (0.263)	0.116 (0.093)	0.118 (0.092)
Age 60	0.081 (0.272)	0.064 (0.088)	0.066 (0.087)
Age 61	0.067 (0.250)	-0.026 (0.086)	-0.025 (0.086)
Constant	-	0.527** (0.102)	0.547** (0.102)

Other coefficients from these regressions appear in Tables 13 and 14.