Supply, demand, and the wages of recent college graduates in the 1990s

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Abstract

This paper uses data from the Current Population Survey May and Outgoing Rotation Group (ORG) files, as well as five CPS computer-use supplements, to analyze shifts in relative demand for recent college graduates in the 1990s. The paper seeks to measure two things: the size of any relative demand shifts in the 1990s and the portion of any of these shifts that can be accounted for by computer-use at work.

I. Introduction

Rising wage inequality has been an enduring feature of the labor market since the end of the 1970s. One of the most common explanations for this sustained increase in inequality is a shift in demand in favor of more-skilled workers. This paper focuses on a particular group of more-skilled workers –recent college graduates (RCGs)– and seeks to measure any shift in relative demand in their favor over the 1990s. Since technology is the most common explanation for relative demand shifts in favor of more-skilled workers (skill-biased trade and investment flows or high-wage-biased changes in labor-market institutions could also be responsible), the paper also attempts to measure how much of any of the demand shifts can be accounted for by the rise in computer-use at work.

The paper proceeds as follows. The next section describes the main data sets used in the analysis: the Current Population Survey (CPS) May and Outgoing Rotation Group (ORG) wage files and five successive computer-use supplements to the CPS. The third section reviews the basic trends in RCG wages and employment relative to three other key reference groups: recent high school graduates, older college graduates, and older high school graduates. The fourth section uses the CPS May and ORG data to estimate a simple supply-and-demand model for RCGs, relative to the three reference groups, and uses the parameters from this model to estimate shifts in relative demand over the 1990s. The fifth section uses the CPS computer-use supplements to gauge the impact of the diffusion of PCs on RCG earnings differentials over the 1984-2001 period covered by the computer-use supplements. The final section concludes, suggesting caution in the interpretation of the results presented here.

II. The Data

The paper uses data from two sources. The first is a combined, consistent, annual series of labor-market data, including hourly wage data, from the CPS May (1973-1978) and ORG (1979-2001) files, prepared by the Economic Policy Institute (EPI). The second is a combined, consistent, labor-market-focused data set created from five CPS computer-use supplements fielded in October 1984, 1989, 1993, 1997, and August 2001. All labor-market concepts, including hourly wages and education, were defined in the computer-use supplements to be consistent with the EPI CPS May and ORG files.[1]

The paper generally deals with four labor-market groups: RCGs, recent high school graduates, older college graduates, and older high school graduates. College graduates are defined as those with exactly a four-year college degree (and no more); high school graduates are those with exactly a high school degree (and no more).[2] In the CPS May and ORG, recent graduates (of both high school and college) are defined as those who are age 23 to 26; older graduates (again, of both high school and college) are those who are age 43 to 46. In the smaller samples drawn from the computer-use supplements, the age range for recent graduates is widened to ages 23 to 30; and, for older graduates, to ages 43 to 50.[3]

Wherever real wages appear in the analysis, they have been calculated using the consumer price index research series (CPI-U-RS) chained to the CPI-U-X1 series prior to 1977. The research series takes into account a number of recent changes in the methodology of the CPI and shows lower rates of inflation (and therefore higher real wage growth) through the 1980s and 1990s than is the case with the official CPI-U.

III. Review of basic trends

Figure 1 shows the average log real hourly earnings for all workers and for RCGs (ages 23-26) from the CPS May and ORG data. Real wages for RCGs generally fell during the 1970s. With the exception of a brief upward blip at the end of the 1970s, average RCG wages were flat or falling through 1981-82. By contrast, the average wage of all workers was flat or rising through the 1970s and then fell from the end of the 1970s through 1982-83. Both RCG and overall wages recovered from about 1983-84 through the end of the 1980s, with RCG wage gains far outpacing those of the average worker. In the recession of the early 1990s, however, RCG wages declined sharply, while average wages stagnated from the end of the 1980s through the middle of the 1990s. Both RCG and average wages rose very quickly after 1996, but, again, in the boom, RCG wages outstripped those of average workers. As emphasized in earlier work (Schmitt 2001), RCG wages demonstrate fairly wide cyclical swings, relative to average wages. These swings seem to reflect supply shifts –the decline in average RCG wages in the 1970s in response to a rising supply of RCGs (see Freeman, 1976)– and business cycles booms and busts –the strong rise in RCG wages in the late 1980s and 1990s booms and the stagnation and decline in the early 1980s and 1990s recessions.[4]

Figures 2 through 4 show how RCGs (ages 23-26) fared, on average, relative to recent high school graduates (23-26), older college graduates (43-46), and older high school graduates (43-46).[5] As Figure 2 demonstrates, RCGs made large gains relative to recent high school graduates in 1980s. Through most of the 1990s, however, relative RCG-recent high school graduate wages were roughly constant. The RCG premium jumped by about 5% between 1997 and 1998, but basically did not change again through

2001. Meanwhile, the data in Figure 3 show little long-term change in the RCG-older college graduate differential over the full 1973-2001 period. Finally, Figure 4 shows a complex pattern over time for the RCG-older high-school graduate premium. RCGs and older high-school graduates wages were, on average, almost identical between 1973 and 1984. During the second half of the 1980s, RCGs gained about 10% relative to older high school graduates, but most of these gains disappeared in the early 1990s recession. In the middle part of the 1990s, relative wages held nearly constant, until, after 1996, RCGs again gained about 10% against older high school graduates.

These changes in relative earnings took place against a backdrop of slowly evolving relative supply of RCGs with respect to recent high school graduates and older college and high school graduates. Figure 5 shows the share in total employment of each of these four groups over the period 1973-2001. The most striking development is the steep decline after the mid-1980s in the share of recent high school graduates in total employment. The share of older college graduates, rose slowly over the period, probably reflecting the aging of the well-educated baby-boom generation. The share of older high school graduates changed little until the middle of the 1990s, when relative shares grew slightly. The RCG share, meanwhile, remained almost constant over the full period. Figure 6 examines the corresponding shares of each group in the total population, rather than employment. The trends in population shares are similar to those for employment in Figure 5. Taken together, the information on relative supplies in Figures 5 and 6 suggests that, over the 1980s and 1990s: the supply of RCG rose relative to recent high school graduates; fell, relative to older college graduates; and fell slightly, after the mid-1990s, relative to older high school graduates.

IV. Simple supply-and-demand model

This section of the paper attempts to use a simple supply-and-demand framework to explain the movements in relative RCG wages and employment rates described in the preceding section. Equations (1) and (2) describe the basic model, implemented separately for RCGs relative to each of the three other age-education groups:

(1) $w_t = a + ße_t + ?D_t + e_t^d$ Demand

(2) $e_t = d + ?w_t + ? S_t + e_t^s$ Supply

where:

w_t is the natural logarithm of the ratio of average wages of RCGs to the average wages for each of the other three age-education groups in year t;

e_t is the natural logarithm of the ratio of total employment of RCGs to the total employment of each of the other three-age education groups;

D_t is a measure of relative demand for RCGs –a time trend (following Katz and Murphy 1992), or information technology investment as a share of total investment, or the inflation-adjusted value of the Standard & Poors 500 index);

S_t is a measure of relative supply of RCGs –the relative total populations, that is, including the unemployed and those out of the labor force;

e_t are disturbance terms;

a, ß, ?, d, ?, and ? are parameters to be estimated; and

t indexes years of the CPS May or ORG samples from 1973 though 2001.

The main parameter of interest in the model is, ß, the slope of the relative demand curve. As Figure 7 helps to illustrate, an estimate of ß will allow us to measure the shift in the relative demand for RCGs, one of the primary goals of this paper. The basic procedure is straightforward. We start with data on relative wages and employment for a point in time (say 1989), marked A on Figure 7. We also have data on relative wages and employment at a later point in time (say 2000), marked B in the figure, where both

relative wages and relative employment are higher. If we know the slope of the relative demand curve (D_A), we can then estimate the shift in the demand curve (in log-points of wages) as the vertical distance between the point on relative demand curve D_A and the new relative demand curve D_B at the new relative employment rate. Note that the more elastic (flatter) is relative demand, the smaller the estimated demand from D_A to D_B; the less elastic (steeper) is relative demand, the greater the estimated demand shift from D_A to D_B. In principle, then, the model in (1) and (2) should allow us to deduce the size of the shift over the 1980s in the relative demand for RCGs. (In the next section, we will attempt to see how much of this shift might reflect the diffusion of personal computers at work.)

Since relative wages and employment in (1) and (2) are determined simultaneously, ordinary least squares (OLS) estimation of the system will produce biased and inconsistent parameter estimates. In an attempt to correct for this problem, panels (b) and (c) of Table 1 present instrumental variable estimates of the system, in addition to the standard OLS estimates in panel (a). For the demand equation, the relative population term in the supply equation acts as an instrument; for the supply equation, the demand (D_t) term (a time trend, or IT investment, or the S&P 500 index) acts an instrument. Neither set of instruments is ideal, but both are at least plausible.[6]

Another potential problem with estimating equations (1) and (2) is the nonstationarity of the time-series variables. If the variables are not stationary, then standard estimation techniques will produce biased and inconsistent estimates, even if proper instruments are used. Appendix Table 3 shows the results from applying Dickey-Fuller tests to each of the variables used in the estimation of (1) and (2). Only one of the

variables in the analysis (relative RCG-older college graduate wages) is stationary in levels (denoted I(0) in the table). All the rest (except the inflation-adjusted S&P 500), however, are stationary in first differences (denoted I(1)). So, in order to ensure stationarity, all estimates will use the first differences of all variables.[7]

The first two columns of Table 1 show the estimates of the supply and demand responses of RCGs relative to recent high school graduates using the first-differenced versions of (1) and (2). As theory would suggest, the OLS estimates in panel (a) show a negative demand elasticity and a positive supply elasticity, but both are economically small and not statistically different from zero. (Note that the demand elasticity is the inverse of the standard demand elasticity; "small" values (in absolute terms) for the demand coefficients correspond to "elastic" demand.) The two-stage-least-squares (2SLS) estimates in panel (b), which apply instrumental variables estimation to the two equations separately, are qualitatively similar. The statistically insignificant supply elasticity using 2SLS is considerably larger than with OLS, suggesting that the instrument (here a time trend that proxies secular relative demand growth) may be helping to identify the slope of the relative supply curve. That the relative demand elasticity changes little between OLS and 2SLS, however, raises concerns that the instrument (relative population changes) may not be performing well. The three-stage-least-squares estimates in panel (c), which estimate the two equations together, potentially exploiting information contained in any correlation in the error terms across (1) and (2), are generally similar to those using 2SLS.[8] Overall, the estimates suggest moderate relative supply elasticities (about 0.5) for RCGs relative to recent high school graduates and high relative (conventional) demand elasticities.

The third and fourth columns show a similar set of estimates for RCGs relative to older college graduates. OLS, 2SLS, and 3SLS all produce elasticities broadly consistent with theory: demand elasticities are all negative and statistically significantly different from zero in the instrumented equations; supply elasticities are positive and statistically significant in two of the three 3SLS equations. This second set of equations suggest small to moderate relative supply elasticities and high, fairly well-defined, (conventional) demand elasticities for RCGs relative to older college graduates.

The final two columns present estimates for RCGs relative to older high school graduates. The relative demand responses are similar to those for RCGs relative to older college graduates, varying between about -0.1 and -0.2 and generally statistically significant, implying high conventional relative demand elasticities. Contrary to theory, however, the relative supply elasticities are negative, large, and statistically significant, suggesting that either the model or the estimation technique are probably not useful for understanding movements in the wages and employment of RCGs relative to older high school graduates.

As mentioned earlier, estimates of the slope of the relative demand curve from Table 1 should, following the logic sketched in Figure 7, allow us to measure the size of relative demand shifts between two points in time. Table 2 uses the estimates from Table 1 and the logic of Figure 7 to estimate the size of the relative demand shift for RCGs between 1989 and 2000. The first row of the first column gives the actual (log-point) change between 1989 and 2000 in the average wage of RCGs relative to recent high school graduates (0.023). The second row of the same column gives the predicted change in relative wages using the estimated coefficients from equation (1) (-0.021).[9] That is,

according to the estimated version of the model in equation (1), changes in relative employment and relative demand (proxied by a time trend), should have lowered the wages of RCGs relative to recent high school graduates by about 0.021 log points. The third row gives the predicted change in relative wages (-0,003) assuming that relative employment had remained constant at their 1989 level.[10] If relative employment rates, however, had remained constant at their 1989 level throughout the 1990s, then relative RCG wages would have fallen only 0.003 log points. The difference between the predicted change with supply held constant (third row) and the full predicted change (second row) is the part of the predicted change that is due to the rising relative supply shifts of RCGs over the 1990s, which appears in the fourth row of the column. Finally, the difference between the estimated supply effect and the actual change in the RCG differential is the part of the overall change that is due to a shift in the relative demand curves (in terms of Figure 7, this is the vertical distance at n_B from the original demand curve to the new demand curve through point B). This estimated demand effect appears in the fifth row of the panel, which is labeled "estimated demand plus other effects" to emphasize that (unmodeled) institutional effects, as well as demand shifts, could also be at play. As such, the demand-shift estimates calculated here are, given a particular relative demand elasticity, upper bounds on the size of relative demand shifts. To summarize these first set of results for RCGs relative to recent high school graduates in the 1990s: the relative wages of RCGs rose modestly in the 1990s (about 0.023 log points); the rising supply of RCGs relative to recent high school graduates should have lowered relative RCG wages about 0.018 log points over the period; but, demand (and,

possibly, institutional) shifts counter-acted the supply changes, raising relative RCG wages 0.041 log points.

Panel (b), which conducts an identical exercise for the period 1979-1989, allows a comparison of the RCG-recent high school graduate labor markets in the 1980s and 1990s. The actual change in the RCG premium was much larger in the 1980s (0.217) than it was in the 1990s (0.023). Supply effects were small in both decades (-0.006 in the 1980s compared with -0.018 in the 1990s). As a result, the estimated demand (and institutions) shift was much larger in the 1980s (0.223) than it was in the 1990s (0.041).

The second column of Table 2 presents results a similar analysis for RCGs relative to older college graduates. In the 1990s, RCGs wages fell slightly (0.026 log points) relative to older college graduates. Over the same period, the supply effect worked to raise the wages of RCGs relative to older college graduates about 0.078 log points, but relative demand shifts worked against RCGs, driving relative wages down about 0.104 log points. The 1980s followed a similar, though somewhat muted pattern.

The third column of the table displays the same analysis now relative to older high school graduates. The overall RCG premium rose slightly in the 1990s (0.026), which appeared to respond in about equal parts to positive supply (0.012) and demand (0.014) shifts.

The highly elastic demand elasticities used to estimate the demand shifts in Table 2, however, may lead to significant underestimation of the demand effects in Table 2. The conventional demand elasticities implicit in Table 1 generally lie outside the usual range of relative demand elasticities (a coefficient of -0.1 in Table 1 corresponds to a conventional demand elasticity of -10.0). Since these high elasticities (in absolute terms)

may simply reflect the weakness of the instruments used to estimate (1) and (2), the second, fourth, and sixth columns of Table 2 recalculate supply and demand effects on the assumption of less elastic relative demand between RCGs and the three other age-education groups (a conventional labor-demand elasticity of -2.0). Not surprisingly, these results show larger relative demand shifts in the 1990s. For RCGs relative to recent high school graduates, the relative demand shift rises from 0.041 to 0.260 (more than ten times the change in the actual RCG premium). Under this assumption on relative demand elasticities, relative demand shifts had about the same impact on relative wages in the 1990s as they did in the 1980s. Using the less elastic demand estimate also raises the magnitude of the negative demand shock against RCGs in the 1990s relative to older college graduates, from -0.104 log points assuming very elastic demand to -0.319 log points assuming less elastic demand. The effect of labor demand elasticities is smaller with respect to older high school graduates. Continuing the analysis into the range where relative demand becomes inelastic would further magnify the estimated relative demand shifts, relative to the estimates based on the model in Table 1.

Applying a very simple supply-and-demand framework to data on relative RCG wages from the CPS May and ORG data produces less than satisfactory results. The model itself suffers from a number of econometric problems including endogeneity bias and poor explanatory power (as evidenced by the generally insignificant or only marginally significant estimates of demand and supply elasticities). The crucial relative demand elasticities generated by the model here suggest a much greater degree of substitutability between RCGs and other types of labor than seems plausible at face value; on the other hand, substitution of inelastic demand estimates into the simple model

would yield estimates of relative demand that also lie far outside the economically plausible range.

Returning to the basic data plotted in Figures 2 through 6 may be as instructive as clinging to what are probably flawed econometric analyses in Tables 1 and 2. The key features of those figures are: First, the 1990s produced only a small increase in RCG wages relative to those of recent high school graduates –and almost all of this increase took place between 1997 and 1998. The mostly stagnant RCG-recent high school graduate premium in the 1990s stands in strong contrast to the 1980s, when the premium rose over 0.20 log points (see Figure 2). This slower growth in the 1990s may reflect the declining supply of recent high school graduates, but the decline in recent high school graduates started in the early 1980s and had no apparent restraining effect on the RCG premium in that decade. Second, the RCG-older college graduate differential fluctuated narrowly over the 1973-2001 period. These fluctuations generally tracked the business cycle, not the small changes in relative supplies of the recent and older college graduates. Third, the relative wages of RCG with respect to older high school graduates also appear to follow the business cycle, but with a discernible long-term upward trend. Again, small changes in relative supplies appear to have had no clear effect on the differential.

V. Personal computers and relative demand for RCGs

The analysis in the preceding section provides little solid evidence to support the view that relative demand shifts played an important role in labor-market developments for RCGs in the 1990s, especially relative to the 1980s. Nevertheless, this section attempts to assess just how important the diffusion of personal computers may have been

to any relative demand shifts that did take place in the 1990s. To do so, I turn to data from five computer-use supplements of the CPS, for 1984, 1989, 1993, 1997, and 2001.

On their face, the raw data from the computer-use supplements support the idea that computers may be responsible for at least part of the increase in inequality.[11] As Table 3 shows, computer-users consistently earn substantially more than non-users. Moreover, the share of workers who directly use a computer at work rose from about one-fourth (25%) of the work force in 1984 to over half (54%) in 2001.[12] If using a computer raises a worker's productivity relative to a worker that does not use a computer, the spread of PCs in the 1980s and 1990s could have contributed directly to the rise in overall wage inequality observed over the period.[13]

Table 4 examines computer-use over the 1984-2001 period among the four age-education categories analyzed in the preceding section. In all five years for which these data are available, RCGs were the most likely of the four groups to use computers on the job. In percentage-point terms, the gap between all RCGs and all recent and older high school graduates rose over both the 1980s and the 1990s; only older college graduates managed to close the gap with RCGs over the two periods. For men, the pattern was roughly similar; for women, older college graduates lost ground relative to younger college graduates in the 1980s, but more than made up for it in the 1990s. If computer use were the only factor determining relative wage changes in the 1980s and 1990s, relative wages of RCGs with respect to recent high school graduates should have risen in both the 1980s and the 1990s and by roughly the same size in both decades. In fact, the RCG premium rose sharply in the 1980s, but was close to flat in the 1990s. With respect to older college graduates, if changes in relative computer use were the only factor affecting

relative wages, then RCGs should have seen their wages fall somewhat relative to older college graduates in both the 1980s and the 1990s. In reality, using the CPS ORG data, the relative wages of older college graduates fell slightly (0.026 log points) between 1979 and 1989 only to rise by the same amount between 1989 and 2001. Finally, the RCG differential with respect to older high school graduates should have risen by approximately equal amounts over both the 1980s and 1990s, which is roughly what did happen.

Table 5 implements a somewhat more formal test of the impact of PC diffusion on the time series pattern of relative wage differentials. The first column of the table reports coefficients from the following OLS regression on a sample of observations from the five pooled computer-use supplements:

(3) $$w_{it} = a_t + ?_t ?_t RCG_{it} Y_t + e_{it}$$

where:

w_{it} is the natural logarithm of the real wage of individual i in each of the independent computer-use supplements for year t;

$RCG_{it} Y_t$ is an indicator variable created by interacting an indicator variable for RCGs with an indicator variable for each year's computer-use supplement;

a_t is a separate constant for each of the five supplements; and

e_{it} is a disturbance term. [14]

If the sample for estimation is limited to just RCGs and one of the three other age-education groups, the five $?_t$ coefficients on the $RCG_{it} Y_t$ term give the raw RCG differential with respect to the other included group in each of the five computer-use supplements. [15] The successive coefficients $?_t$ trace out the time series pattern of the

differential across 1984, 1989, 1993, 1997, and 2001 (see, for example, panel (a) of Table 5A).

The second column of the table reports the results of a similar structured equation:

(3') $$w_{it} = a_t + ?_t RCG_{it} Y_t + pC_{it} + e_{it}$$

which is identical to (3) except that a term has been added to indicate whether the individual uses a computer at work. A comparison of the $?_t$ coefficients in (3) and (3') provides a simple test of the ability of computer-use on the job to explain the time-series pattern of wage differentials.

Turning to panel (a) of Table 5A, without controlling for computer use, the overall RCG-recent high school graduate differential in the computer-use supplements increased about 0.101 log points between 1989 and 2001. Including the computer term in the second column reduces the increase in the RCG premium over the period to 0.060 log points, suggesting that computer use can account for about 40% of the rise in this differential over the period.

Before examining the full set of results in Tables 5A, 5B, and 5C, two issues bear examination. The first issue is that the pattern of relative wage differentials over time differs in important ways between the CPS ORG files and the CPS computer-use supplements. For example, over the "1990s" (1989-2000 in Table 2 using the ORG and 1989-2001 in Table 5 using the computer-use supplements), the RCG-recent high school graduate differential for all workers increased 0.023 log points in the CPS ORG data but 0.101 log points in the computer-use supplements. Several factors probably contributed to this large discrepancy. First, the time periods are obviously different 1989-2000 in the CPS ORG, versus 1989-2001 with the computer-use supplements. Second, the samples of

individuals examined also differ: the CPS May and ORG data refer to 23-26 and 43-46 year olds, while the smaller sample size available in the computer-use supplements led to the decision to use 23-30 and 43-50 year-old age groupings. Third, while both differentials purport to cover men and women together, the differentials for "all" reported in Table 5 using the computer-use supplements are derived from an equation that includes a control for males, which is not the case with the CPS ORG data. Fourth, while the underlying treatment of the wage series with respect to top-coding, varying hours (after 1993), education coding changes (after 1991), and other issues are close to one another, the procedures are not identical across the two data sets. Finally, and probably most importantly, each annual ORG sample covers a full year of data, while the computer-use supplements are based on wage data from only a single month. As a result, for any given year, the computer-use sample is only one-twelfth the size of the ORG sample and therefore is much more subject to sampling error than is the ORG.

This small sample size may, in addition, interact with month-specific wage patterns in the computer-use supplement. The small sample size and monthly timing may be particularly important for RCGs in the August 2001 computer-use supplement. Between 1989 and 2001, the average RCG-recent high school graduate differential in the full year of the CPS ORG rose 0.026 log points, substantially less than the 0.114 log-point change in the differential when the ORG sample is limited to a comparison between October 1989 and August 2001, the months of the corresponding computer-use supplements.[16] Taken together, these factors suggest caution when comparing results across the separate CPS May and ORG sample and the computer-use sample. When big differences arise between patterns in the two samples, the much larger sample size and

lack of seasonal distortions in the ORG argue strongly for siding with the findings in the ORG. A particularly frustrating limitation on this analysis, in this respect, is the sizeable difference in the estimated change over the 1990s for the RCG-recent high school graduate differential between the full-year ORG samples and the computer-use supplements. In the 1990s, the computer-use supplements appear to show a much larger increase in the RCG premium (and therefore a potentially larger role for computers to play) than is the case in the CPS ORG.[17]

The second issue that merits discussion before examining the full set of results in Tables 5A-5C concerns additional limitations to the test in that table. Since other factors besides computers certainly affect the time-series pattern of the differentials in Tables 5A-5C (such as changes over time in the shares of workers who are married, or veterans, or who live in high-wage states, and, so on), the computer indicator variable may reflect both the computer effect and any correlation between the computer diffusion and these other compositional changes, especially given the bare-bones specifications in equations (3) and (3').[18] If the excluded variables also raise the RCG premium relative to the other groups and are positively correlated with diffusion of computers over time, the simple test in Tables 5A-5C would systematically overstate the role of computers in accounting for changes in the RCG differentials. The best solution would be to include in both the base ("no computer") and the computer specifications in Tables 5A-5C all factors that could conceivably affect the RCG differentials. This would eliminate the scope for the computer-use variable to act as a proxy for other trended variables affecting the measured differentials. Since the limited number of variables available here does not permit such an approach, I have taken the simpler step of implementing the test in Tables 5A-5C using

an indicator variable for each of the years of the computer-use survey (see Appendix Tables 5A-5C). The inclusion of the year indicators removes any of the systematic variation over time (including the part correlated with computer use). Under the assumption that the relevant excluded variables raise the RCG premium and are positively correlated with computer diffusion (or lower the RCG premium and are negatively correlated with computer diffusion), a reasonable interpretation of the test without the year indicators is that the results represent an upper bound on the computer effect, while the test with the inclusion of the year indicators represents a lower bound on the computer effect.

With this in mind, Table 6 shows the lower and upper bounds (in percent terms) from Tables 5A-5C and Appendix Tables 5A-5C of the effect of computer diffusion on various RCG differentials over the 1989-2001 and 1984-1989 periods. According to this test, computers accounted for 30-40% of the 0.101 rise in the overall RCG-recent high school graduate differential; 14-35% of the 0.099 log-point rise in the corresponding differential for men; and, 54-63% of the 0.098 log-point rise for women. An important caveat here is that the more reliable estimates of the change in the overall RCG-recent high school graduate differential from the full-year CPS ORG put the increase in the differential at only 0.026 log points, which is well below the increases captured between October 1989 and August 2001 in the computer-use supplements.

The results for the impact of computers on the RCG differential with respect to older college and older high school graduates are also difficult to interpret. Computer-use can account for 25-52% of the small (0.047 log point) rise in the RCG-older college graduate premium for women, but the range for the share of the corresponding

differentials is -11% to 53% for men and -88% to 53% for men and women together. Depending on which of the versions of the test is most accurate, computers use either worked to reduce or to raise the RCG-older college graduate differential in the 1990s. With respect to the RCG-older high school graduate differential, computers can account for 9-46% of the 0.103 log-point increase for men and women together, and 17-47% of the 0.099 log-point rise for men alone. The addition of year controls to the test (as in Appendix Table 5C), however, all but eliminates the rise in the RCG-older high school graduate differential among women. As a result, the small change in the differential explained by computers (-0.018) "explains" over 500% of the even smaller change in the actual premium (-0.003).

The simple test presented here of the impact of the diffusion of computers on the time trend of relative RCG earnings produces mixed results. Computers may account for 14-63% of the increase during the 1990s in the RCG premium with respect to recent high school graduates. However, the measured increase in the differential in the computer-use supplements used to calculate these estimates is about five times larger than differential calculated using the more reliable full-year CPS ORG data for the same years, raising questions about the usefulness of these kinds of estimates across the October 1989-August 2001 computer-use supplements. The same test produces wide ranges for the impact of computer use on the RCG-older high school graduate and RCG-older college graduate differentials. With respect to older high school graduates, computers may account for 9-47% of the increase in the overall and male RCG premiums in the 1990s, but for women, the effect of computers is small in absolute terms (even though it is large

relative to the tiny change in the corresponding differential). In the case of older college graduates, the tests suggest that computers may have reduced or increased inequality.

VI. Conclusions

This paper set out to measure two things: the shift in relative demand for RCGs during the 1990s and the portion of this shift in demand that might be related to the diffusion of computer technology at work. The simple supply-and-demand model found only small relative demand shifts in favor of RCG with respect to recent high school graduates (0.041 log points over 11 years) and older high school graduates (0.014 log points over 11 years) and found a larger shift *against* RCG with respect to older college graduates (-0.104 log points over the same period). This simple model, however, had a number of economically and econometrically undesirable characteristics, all of which caution against drawing strong conclusions from the results. One key limitation of the model is its inability to explain the large deceleration in the RCG-recent high school graduate premium in the 1990s (up 0.023 log points) relative to the 1980s (up 0.217 log points) in the face of almost identical trends in relative RCG-recent high school graduate supplies.

The tests of the role of computers in explaining changing RCG differentials also failed to provide clear-cut results. The range of estimated computer effects is large. In most cases, computers appear to have raised inequality, generally accounting for 10-50% of the increase in RCG differentials over the 1990s. In some cases, however, computers lowered differentials. In any event, all of the tests using the computer-use supplements between October 1989 and August 2001 are potentially marred by the idiosyncratic wage changes across these two particular months of the CPS. The rise in the RCG-recent high

school graduate differential between these two months in both the CPS ORG and the computer-use supplements is much larger (about 10%) than is the corresponding change in the full-year CPS ORG between 1989 and 2001 (about 2%).

Notes

I would like to thank the Russell Sage Foundation for generous financial support and Danielle Gao for assistance with the CPS May and ORG data.

[1] For a description of the EPI May and ORG data files, see Mishel, Bernstein, and Schmitt (2001), Appendix B and Webster (2000).

[2] Prior to the 1992 education coding change in the CPS, high school graduates are those with exactly 12 years of completed schooling; college graduates are those with 16 years of completed schooling. For a discussion of the impact of the 1992 coding change on consistency of the CPS and recommendations on ways to handle the change, see Jaeger (1997).

[3] The CPS May, used for 1973-1978, and the computer-use supplements have approximately the same sample size. The decision to use the narrower age band for the CPS May is less problematic because the CPS May and ORG analysis always treats the pooled sample of men and women. The analysis of the computer-use samples frequently treats men and women separately, which magnifies sample-size problems.

[4] The different responses of average RCG wages to the 1980s and 1990s recessions are interesting. The 1980s recession was deep, but average RCG only stagnated in real terms; the 1990s recession was shallower, but average RCG wages fell steeply.

[5] The data for Figures 2-4 appear in the first three columns of Appendix Table 1.

[6] In the face of problems finding valid instruments, much earlier research along similar lines has simply relied on OLS estimates (see, for example, Katz and Murphy, 1992).

[7] This includes the inflation-adjusted S&P 500 variable, which is not difference-stationary, but is included anyway.

[8] The one exception is the supply elasticity estimate that uses the S&P 500 as an instrument. Here, the supply elasticity is close to zero with a large standard error.

[9] Calculated as the difference between $w_t = a + be_t + cD_t$, for t equals 2000 and t equals 1989, where a, b, and c are estimates of the corresponding parameters in (1).

[10] Calculated as the difference between $w_t' = a + be_t + cD_{1989}$, for t equals 2000 and t equals 1989.

[11] Krueger (1993) is the most important presentation of this view.

[12] Women have always been more likely to use computers than have men. By 2001, over 60% of women and only 49% of men used a computer at work. On average, women computer users have consistently earned less than men who use computers; in 1984, when computer use was still relatively uncommon, women computer users earned less than men who did not use a computer.

[13] Serious questions remain as to whether computers raise worker's productivity or whether firms simply give computers to high-wage workers. DiNardo and Pischke (1997), for example, have used German data to demonstrate that workers who use a pencil on the job earn more than those who do not do so and that the size of this "pencil premium" is comparable to that of computers. More recently, Handel (1998) has produced similar results for the United States.

[14] When data for men and women are pooled, (3) also includes an indicator variable for gender is male.

[15] The coefficient for the pooled male and female regression differs somewhat from the actual raw differential because the equation includes an indicator variable for males.

[16] In the raw computer-use data over the period (that is, the differential without including an indicator for gender, as is done in Table 5A), the October 1989 to August 2001 change in the RCG-recent high school differential is 0.118 log points; and 0.109 log points when the sample is limited to only those individuals with a valid computer-use observation. Both are close to the change in the differential in the CPS ORG between the same two months (0.114 log points). The similarity of the month-to-month differentials in the ORG and the computer-use supplements suggests that differences in trends caused by the single-month character of the computer-use supplements may be large relative to differences caused by the other factors discussed here.

[17] One final note of caution, even small differences in the measurement of the differential can lead to fairly large differences in economic conclusions. Since the analysis here largely concerns changes over time, measurement errors that are small relative to the levels of the things being measured in any given year, can be large relative to changes in the things measured over time.

[18] The inclusion of an indicator variable for males eliminates the possibility that changes over time in the relative employment rates of men and women appear as "computer effects."

References

DiNardo, John E. and Jörn-Steffen Pischke. 1997. "The Returns to Computer Use Revisited: Have Pencils Changed the Wage Structure Too?" *Quarterly Journal of Economics*, vol. 112, pp. 290-303.

Freeman, Richard. 1976. *The Overeducated American*. New York, NY: Academic Press.

Handel, Michael J. 1998. "Computers and the Wage Structure," unpublished paper, Department of Sociology, Harvard University.

Jaeger, David A. 1997. "Reconciling the Old and New Census Bureau Education Questions: Recommendations for Researchers," Journal of Business and Economic Statistics, vol. 15, no. 3, pp. 300-10.

Katz, Lawrence and Kevin Murphy. 1993. "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *Quarterly Journal of Economics*, vol. 107 (February), pp. 35-78.

Krueger, Alan. 1993. "How Computers Have Changed the Wage Structure: Evidence from Microdata, 1984-1989," *Quarterly Journal of Economics*, vol. 108 (February), pp. 33-60.

Mishel, Lawrence, Jared Bernstein, and John Schmitt. 2001. *The State of Working America 2000-2001*. Ithaca, NY: Cornell University Press.

Schmitt, John. 2001. "Earnings of recent college graduates in the 1980s and 1990s: evidence from the Current Population Survey, the National Association of Colleges and Employers 'Salary Survey,' and the Recent College Graduate/Baccalaureate and Beyond Surveys," unpublished paper, Washington, DC: Economic Policy Institute.

Webster, David. 2000. "Economic Policy Institute CPS ORG Labor Extracts, 1973-1999, Version 1.31," unpublished paper, Washington, DC: Economic Policy Institute.

APPENDIX TABLE 1
Main time-series data

	Ln real hourly wage differential			Ln relative employment			Ln relative population		
Year	RCG-RHG	RCG-OCG	RCG-OHG	RCG-RHG	RCG-OCG	RCG-OHG	RCG-RHG	RCG-OCG	RCG-OHG
1973	0.152	-0.445	-0.004	-0.840	1.035	-0.492	-1.048	0.998	-0.641
1974	0.173	-0.408	-0.005	-0.724	0.923	-0.412	-0.940	0.906	-0.595
1975	0.155	-0.457	-0.003	-0.579	1.117	-0.329	-0.851	1.057	-0.512
1976	0.169	-0.418	0.020	-0.735	1.059	-0.373	-0.938	1.017	-0.545
1977	0.135	-0.470	-0.019	-0.690	1.136	-0.286	-0.854	1.123	-0.439
1978	0.128	-0.481	-0.022	-0.757	0.999	-0.267	-0.901	1.010	-0.413
1979	0.121	-0.413	-0.033	-0.839	1.033	-0.272	-0.994	0.993	-0.428
1980	0.145	-0.399	-0.023	-0.803	1.044	-0.263	-0.983	1.003	-0.398
1981	0.152	-0.383	-0.003	-0.876	0.976	-0.324	-1.058	0.943	-0.444
1982	0.197	-0.410	-0.002	-0.838	0.999	-0.333	-1.040	0.963	-0.454
1983	0.221	-0.441	-0.007	-0.796	1.031	-0.286	-0.983	0.991	-0.412
1984	0.237	-0.415	-0.015	-0.817	0.964	-0.282	-0.977	0.946	-0.413
1985	0.270	-0.431	0.019	-0.769	0.887	-0.295	-0.933	0.861	-0.431
1986	0.282	-0.434	0.022	-0.780	0.819	-0.332	-0.928	0.803	-0.460
1987	0.297	-0.439	0.032	-0.715	0.721	-0.331	-0.864	0.709	-0.455
1988	0.304	-0.425	0.034	-0.679	0.649	-0.337	-0.834	0.624	-0.454
1989	0.338	-0.387	0.068	-0.689	0.528	-0.401	-0.823	0.520	-0.488
1990	0.337	-0.368	0.093	-0.639	0.392	-0.446	-0.782	0.396	-0.545
1991	0.307	-0.390	0.056	-0.580	0.227	-0.472	-0.719	0.246	-0.562
1992	0.295	-0.451	0.012	-0.447	0.126	-0.408	-0.583	0.156	-0.499
1993	0.314	-0.440	0.016	-0.409	0.061	-0.432	-0.559	0.090	-0.517
1994	0.303	-0.467	0.018	-0.304	0.126	-0.290	-0.441	0.160	-0.370
1995	0.298	-0.452	0.029	-0.281	0.110	-0.293	-0.405	0.152	-0.364
1996	0.313	-0.438	0.013	-0.229	0.122	-0.320	-0.346	0.148	-0.394
1997	0.317	-0.436	0.023	-0.261	0.053	-0.418	-0.377	0.079	-0.496
1998	0.360	-0.434	0.055	-0.267	-0.039	-0.501	-0.380	-0.009	-0.570
1999	0.366	-0.422	0.083	-0.290	-0.085	-0.577	-0.381	-0.053	-0.629
2000	0.360	-0.413	0.094	-0.213	-0.057	-0.521	-0.322	-0.037	-0.579
2001	0.358	-0.404	0.114	-0.151	-0.027	-0.506	-0.247	-0.002	-0.558
Mean	0.255	-0.427	0.023	-0.586	0.584	-0.372	-0.741	0.579	-0.485
s.d.	0.083	0.027	0.038	0.238	0.454	0.090	0.266	0.426	0.077

Source: Author's analysis of Economic Policy Institute CPS May (1973-78) and ORG (1979-2001) extracts.

APPENDIX TABLE 2
Additional time-series data

Year	Infl-adjusted S&P 500	IT investment/ total investment
1973	351.1	0.101
1974	246.3	0.114
1975	236.6	0.119
1976	264.9	0.118
1977	239.7	0.114
1978	224.7	0.118
1979	220.4	0.124
1980	228.7	0.144
1981	225.4	0.152
1982	198.9	0.167
1983	256.1	0.177
1984	246.3	0.182
1985	277.4	0.183
1986	344.8	0.186
1987	404.7	0.188
1988	361.8	0.194
1989	421.2	0.205
1990	415.6	0.208
1991	450.8	0.227
1992	485.3	0.232
1993	513.7	0.230
1994	512.7	0.226
1995	588.5	0.236
1996	709.1	0.237
1997	904.2	0.245
1998	1108.2	0.248
1999	1327.3	0.253
2000	1380.8	0.272
2001	1123.7	0.254
Mean	492.0	0.188
s.d.	345.7	0.074

Notes: S&P 500 composite index (1941-43 =10) from Economic Report of the President, (ERP) February 2002, Table B-95, deflated using CPI-U-RS, from ERP, Table B-62 (CPI-U-X1 chained to CPI-U-RS prior to 1977). IT investment as a share of private nonresidential fixed investment, from ERP, Table B-18.

APPENDIX TABLE 3
Testing for stationarity of time-series variables

	MacKinnon z statistic		
Variable	Levels	First Differences	I(0), I(1)
(a) Ln relative wages			
RCG-RHG	-0.621	-4.394**	1
RCG-OCG	-3.256*	-6.218**	0
RCG-OHG	-0.473	-4.208**	1
(b) Ln relative employment			
RCG-RHG	0.031	-5.470**	1
RCG-OCG	0.013	-4.877**	1
RCG-OHG	-1.682	-4.535**	1
(c) Ln relative labor force			
RCG-RHG	0.384	-4.775**	1
RCG-OCG	-0.021	-4.728**	1
RCG-OHG	-1.502	-4.386**	1
(d) Ln relative population			
RCG-RHG	0.408	-4.880**	1
RCG-OCG	0.097	-4.419**	1
RCG-OHG	-2.515	-4.464**	1
(e) Other			
Inflation-adj. S&P 500	0.507	-2.050	Not I(0), I(1)
IT investment/tot. investment	-1.223	-4.644**	1

Source: Author's analysis of CPS and other data. Z-statistic distribution calculated using Stata version 6.0 under null hypothesis that the variable is not stationary; # indicates that the test rejects non-stationarity at the 10% level, *, at the 5% level, and, **, at the 1% level.

APPENDIX TABLE 4
Sample sizes for recent and older college and high school graduates

	1984	1989	1993	1997	2001
(a) Complete computer supplement					
Total population	96,694	92,746	89,856	77,525	91,910
23-30	21,115	18,607	16,610	12,736	14,104
43-50	12,280	13,092	15,095	14,203	17,675
College					
23-30	3,062	2,992	3,272	2,846	3,096
43-50	1,216	1,612	2,556	2,628	3,339
High school					
23-30	9,129	7,653	5,782	4,003	4,255
43-50	5,226	5,293	5,081	4,529	5,576
(b) Computer supplement with valid hourly wage data					
Total population	13,420	13,412	13,370	12,475	14,609
College					
23-30	651	613	673	643	611
43-50	213	281	492	545	639
High school					
23-30	1,590	1,287	1,049	697	735
43-50	805	838	885	810	982

Notes: Author's analysis of CPS Computer-use supplements.

APPENDIX TABLE 5A
Recent college graduate premium, all, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.290	0.230	-0.060	-20.7
	(0.022)	(0.021)	(0.030)	
1989	0.409	0.330	-0.079	-19.3
	(0.023)	(0.023)	(0.032)	
1993	0.364	0.263	-0.100	-27.6
	(0.023)	(0.023)	(0.033)	
1997	0.379	0.286	-0.094	-24.6
	(0.025)	(0.025)	(0.035)	
2001	0.493	0.390	-0.104	-21.1
	(0.025)	(0.025)	(0.035)	
Computer	--	0.231	--	--
		(0.011)		
Change				
1984-1989	0.119	0.100	-0.019	-15.9
	(0.032)	(0.031)	(0.045)	
1989-2001	0.085	0.060	-0.025	-29.7
	(0.034)	(0.034)	(0.048)	
(b) RCG-OCG				
1984	-0.365	-0.395	-0.030	8.1
	(0.041)	(0.040)	(0.057)	
1989	-0.202	-0.224	-0.022	11.1
	(0.037)	(0.036)	(0.052)	
1993	-0.327	-0.345	-0.018	5.5
	(0.031)	(0.030)	(0.043)	
1997	-0.344	-0.347	-0.004	1.0
	(0.030)	(0.029)	(0.041)	
2001	-0.182	-0.187	-0.005	2.7
	(0.029)	(0.023)	(0.037)	
Computer	--	0.297	--	--
		(0.015)		
Change				
1984-1989	0.164	0.171	0.007	4.5
	(0.055)	(0.054)	(0.078)	
1989-2001	0.020	0.037	0.017	87.8
	(0.047)	(0.043)	(0.064)	

(continued)

APPENDIX TABLE 5A (continued)
Recent college graduate premium, all, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	0.072	0.000	-0.073	-100.4
	(0.026)	(0.025)	(0.036)	
1989	0.168	0.087	-0.081	-48.4
	(0.026)	(0.025)	(0.036)	
1993	0.121	0.030	-0.090	-74.8
	(0.025)	(0.025)	(0.035)	
1997	0.105	0.016	-0.089	-84.4
	(0.025)	(0.025)	(0.035)	
2001	0.252	0.150	-0.102	-40.7
	(0.024)	(0.024)	(0.034)	
Computer	--	0.268	--	--
		(0.012)		
Change				
1984-1989	0.096	0.087	-0.009	-9.0
	(0.036)	(0.036)	(0.052)	
1989-2001	0.084	0.063	-0.021	-25.1
	(0.036)	(0.035)	(0.050)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of real hourly wage. All regressions include indicator variable for gender and for year 1989, 1993, 1997, and 2001. Standard errors are in parentheses.

APPENDIX TABLE 5B

Recent college graduate premium, men, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.223	0.147	-0.076	-34.0
	(0.031)	(0.031)	(0.043)	
1989	0.355	0.246	-0.108	-30.6
	(0.033)	(0.033)	(0.047)	
1993	0.297	0.168	-0.129	-43.5
	(0.033)	(0.034)	(0.048)	
1997	0.322	0.203	-0.119	-37.0
	(0.035)	(0.035)	(0.050)	
2001	0.452	0.330	-0.122	-26.9
	(0.036)	(0.036)	(0.051)	
Computer	--	0.225	--	--
		(0.017)		
Change				
1984-1989	0.132	0.099	-0.033	-24.8
	(0.045)	(0.045)	(0.064)	
1989-2001	0.097	0.084	-0.013	-13.8
	(0.048)	(0.049)	(0.069)	
(b) RCG-OCG				
1984	-0.543	-0.569	-0.026	4.7
	(0.057)	(0.054)	(0.079)	
1989	-0.367	-0.373	-0.006	1.6
	(0.055)	(0.052)	(0.076)	
1993	-0.462	-0.482	-0.020	4.4
	(0.046)	(0.044)	(0.064)	
1997	-0.433	-0.428	0.006	-1.3
	(0.045)	(0.043)	(0.062)	
2001	-0.228	-0.236	-0.008	3.4
	(0.044)	(0.042)	(0.061)	
Computer	--	0.353	--	--
		(0.023)		
Change				
1984-1989	0.176	0.196	0.020	11.3
	(0.079)	(0.076)	(0.112)	
1989-2001	0.139	0.137	-0.002	-1.5
	(0.071)	(0.068)	(0.098)	

(continued)

APPENDIX TABLE 5B (continued)
Recent college graduate premium, men, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	-0.107	-0.199	-0.093	86.8
	(0.038)	(0.037)	(0.053)	
1989	0.001	-0.114	-0.115	-12346.5
	(0.039)	(0.038)	(0.055)	
1993	-0.026	-0.178	-0.152	587.8
	(0.038)	(0.038)	(0.054)	
1997	0.008	-0.132	-0.140	-1699.3
	(0.038)	(0.037)	(0.053)	
2001	0.172	0.028	-0.144	-83.6
	(0.037)	(0.037)	(0.053)	
Computer	--	0.303	--	--
		(0.018)		
Change				
1984-1989	0.108	0.085	-0.022	-20.8
	(0.054)	(0.053)	(0.077)	
1989-2001	0.171	0.142	-0.029	-17.0
	(0.054)	(0.053)	(0.076)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of hourly wage. All regressions include indicator variables for year 1989, 1993, 1997, and 2001. Standard errors are in parentheses.

APPENDIX TABLE 5C

Recent college graduate premium, women, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.364	0.318	-0.046	-12.7
	(0.031)	(0.029)	(0.042)	
1989	0.464	0.414	-0.050	-10.8
	(0.032)	(0.031)	(0.045)	
1993	0.425	0.348	-0.077	-18.1
	(0.032)	(0.031)	(0.045)	
1997	0.437	0.367	-0.069	-15.9
	(0.036)	(0.035)	(0.050)	
2001	0.532	0.440	-0.092	-17.4
	(0.036)	(0.035)	(0.050)	
Computer	--	0.260	--	--
		(0.015)		
Change				
1984-1989	0.100	0.096	-0.004	-4.1
	(0.044)	(0.043)	(0.063)	
1989-2001	0.068	0.025	-0.042	-62.5
	(0.048)	(0.047)	(0.067)	
(b) RCG-OCG				
1984	-0.096	-0.126	-0.030	31.5
	(0.059)	(0.058)	(0.083)	
1989	-0.013	-0.047	-0.034	267.0
	(0.050)	(0.049)	(0.070)	
1993	-0.185	-0.201	-0.016	8.7
	(0.041)	(0.040)	(0.058)	
1997	-0.257	-0.266	-0.010	3.8
	(0.039)	(0.038)	(0.054)	
2001	-0.143	-0.144	-0.002	1.1
	(0.037)	(0.036)	(0.051)	
Computer	--	0.236	--	--
		(0.020)		
Change				
1984-1989	0.083	0.079	-0.004	-5.1
	(0.078)	(0.076)	(0.110)	
1989-2001	-0.130	-0.097	0.033	-25.4
	(0.062)	(0.061)	(0.087)	

(continued)

APPENDIX TABLE 5C (continued)
Recent college graduate premium, women, including year effects

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	0.247	0.183	-0.064	-25.8
	(0.034)	(0.033)	(0.047)	
1989	0.315	0.252	-0.062	-19.8
	(0.034)	(0.033)	(0.047)	
1993	0.248	0.196	-0.052	-21.0
	(0.032)	(0.031)	(0.045)	
1997	0.192	0.135	-0.057	-29.7
	(0.033)	(0.032)	(0.045)	
2001	0.318	0.238	-0.080	-25.3
	(0.032)	(0.031)	(0.044)	
Computer	--	0.266	--	--
		(0.015)		
Change				
1984-1989	0.068	0.069	0.001	2.1
	(0.048)	(0.046)	(0.068)	
1989-2001	0.003	-0.015	-0.018	-544.0
	(0.046)	(0.045)	(0.065)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of hourly wage. All regressions include indicator variables for year 1989, 1993, 1997, and 2001. Standard errors are in parentheses.

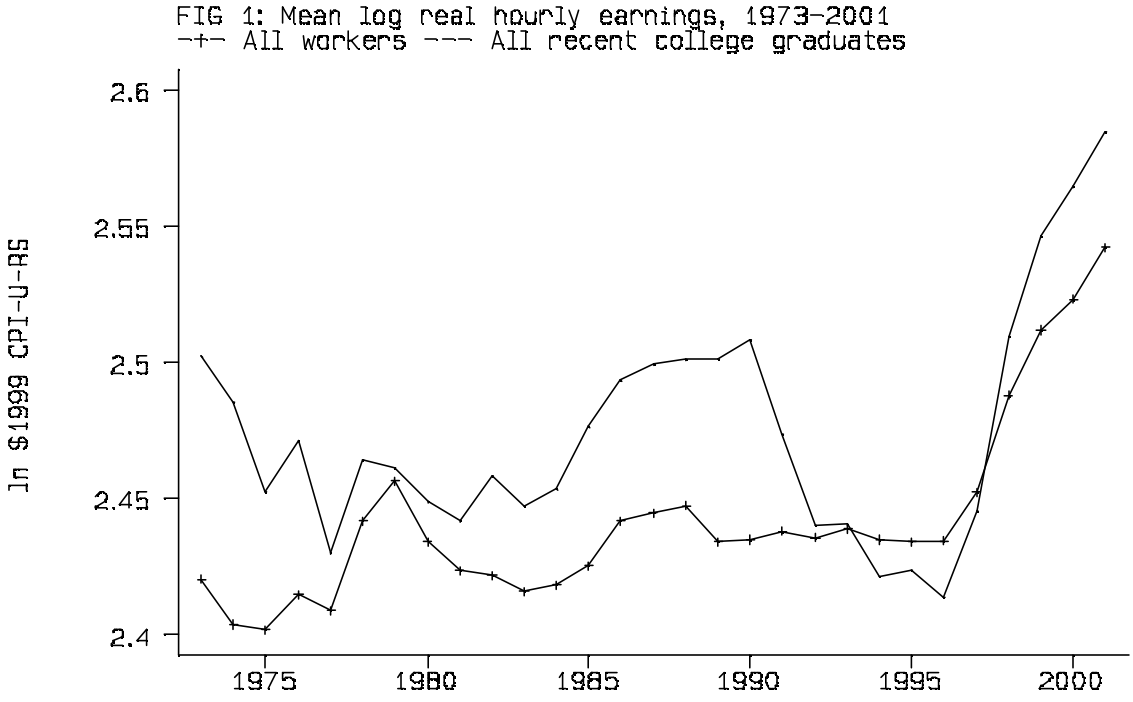
FIG 1: Mean log real hourly earnings, 1973-2001
-+- All workers --- All recent college graduates
ln $1999 CPI-U-RS
2.6
2.55
2.5
2.45
2.4
1975
1980
1985
1990
1995
2000

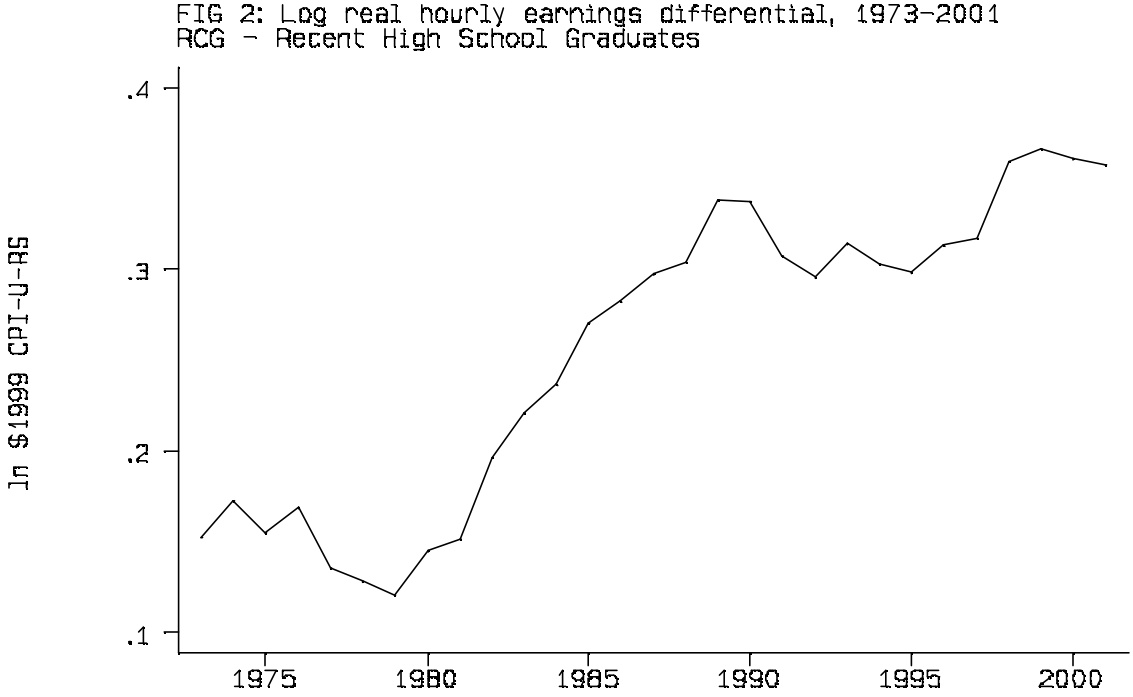
FIG 2: Log real hourly earnings differential, 1973-2001
RCG - Recent High School Graduates
ln $1999 CPI-U-RS
.4
.3
.2
.1
1975
1980
1985
1990
1995
2000

FIG 3: Log real hourly earnings differential, 1973-2001
RCG - Older College Graduates

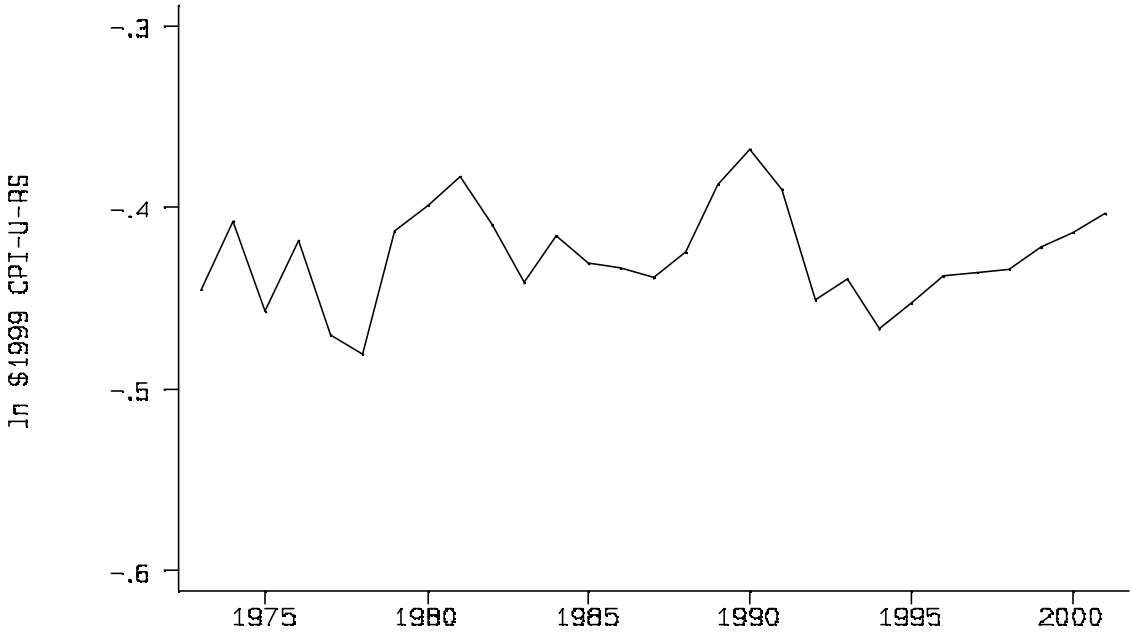

FIG 4: Log real hourly earnings differential, 1973-2001
RCG - Older High School Graduates

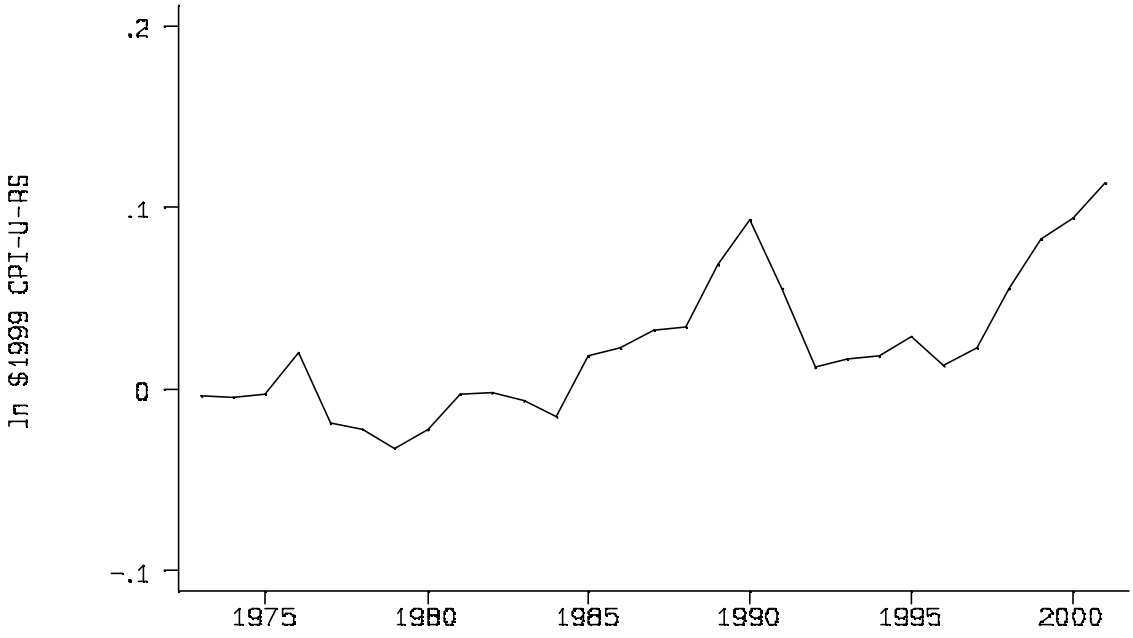

FIG 5: Share in total employment age 18-64, 1973-2001
-+- RCG --- AHG -o- OCG -<>- OHG

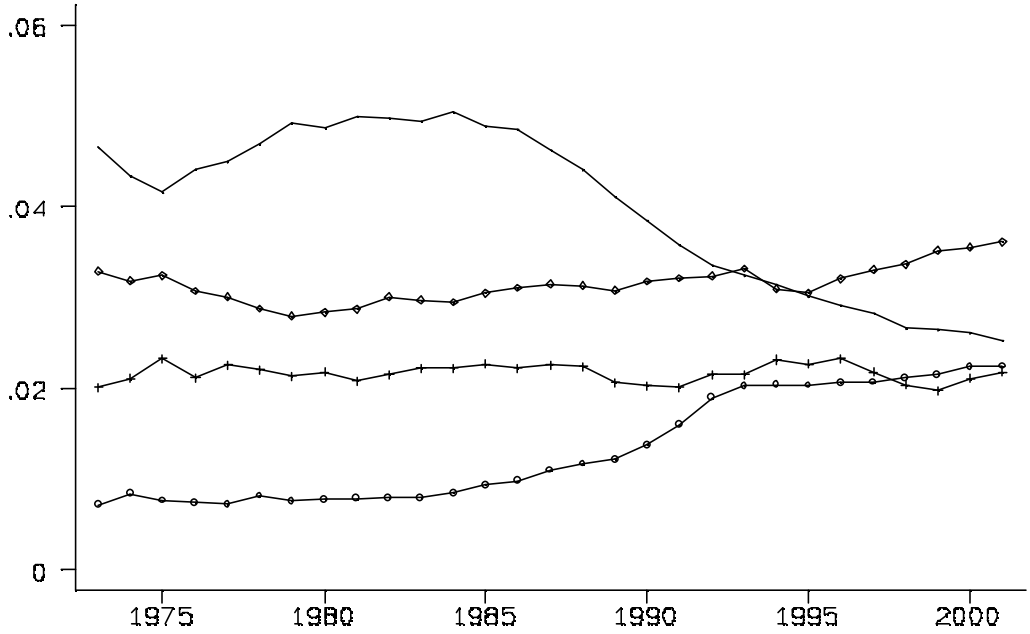

FIG 6: Share in total population age 18-64, 1973-2001
-+- RCG --- AHG -o- OCG -<>- OHG

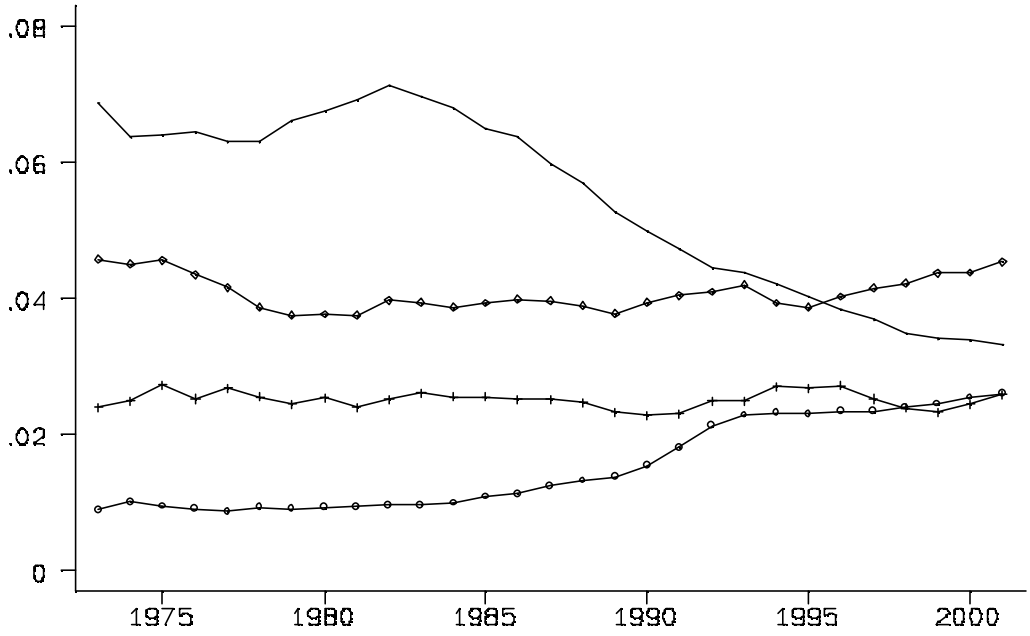

FIG 7: Simple relative supply-and-demand model

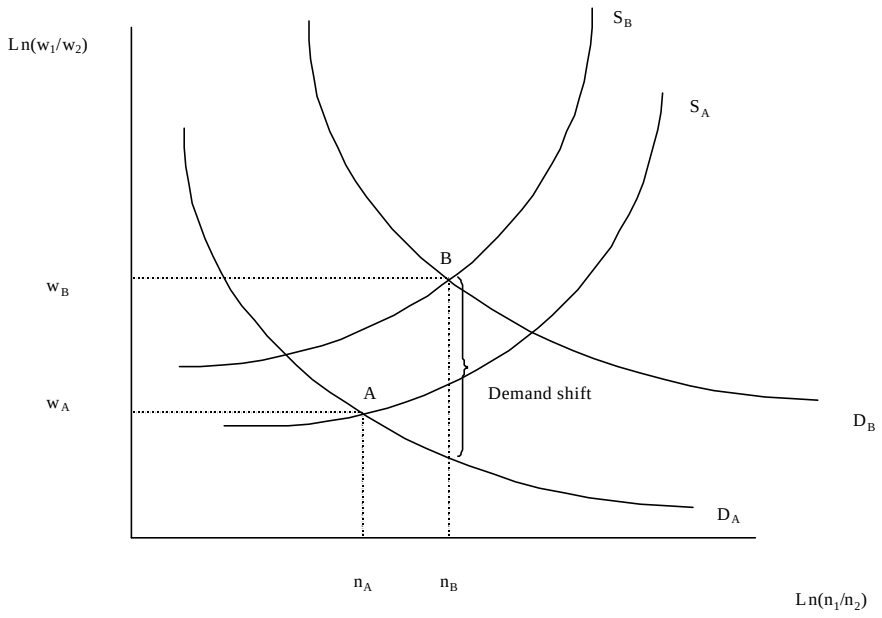

TABLE 1
Estimates of relative supply and demand responses for recent college graduates

	Recent college graduates relative to:					
	Recent high school		Older college		Older high school	
	Demand	Supply	Demand	Supply	Demand	Supply
(a) OLS						
Elasticity	-0.059	0.125	-0.109	0.155	-0.168*	-0.092
	(0.058)	(0.229)	(0.072)	(0.115)	(0.065)	(0.134)
D.W.	1.687	2.085	1.992	2.380	1.613	1.812
(b) 2SLS						
Elasticity	-0.069	0.446	-0.123#	0.251	-0.172**	-0.873
	(0.061)	(0.543)	(0.073)	(0.208)	(0.066)	(0.818)
D.W.	1.686	2.222	1.945	2.424	1.611	1.670
(b) 3SLS						
Time trend						
Elasticity	-0.039	0.531	-0.133*	0.188#	-0.100#	-1.681**
	(0.054)	(0.373)	(0.066)	(0.186)	(0.056)	(0.433)
D.W.	1.666	2.271	1.911	2.546	1.647	1.651
S&P 500						
Elasticity	-0.030	0.075	-0.126#	0.089	-0.097	-0.807
	(0.053)	(0.423)	(0.067)	(0.158)	(0.063)	(0.515)
D.W.	1.755	1.998	1.940	2.365	1.604	1.720
IT inv.						
Elasticity	-0.040	0.697#	-0.120#	0.319#	-0.110*	-1.121*
	(0.051)	(0.397)	(0.066)	(0.190)	(0.053)	(0.497)
D.W.	1.852	2.287	1.967	2.566	1.627	1.682

Notes: Author's analysis of CPS and other data. Standard errors in parentheses; # indicates statistical significance at the 10% level, *, at the 5% level, **, at the 1% level. Critical bounds at the 5% level of Durbin-Watson statistic with two regressors and 28 observations are: 1.325 (upper) and 1.037 (lower). See text for full description of regressions.

TABLE 2
Estimating effect of supply changes on relative wages

	RHG		OCG		OHG	
Ln relative wages	Model	e = -2.0	Model	e = -2.0	Model	e = -2.0
(a) 1989-2000						
Actual change	0.023	0.023	-0.026	-0.026	0.026	0.026
Predicted change	-0.021	-0.240	0.076	0.290	0.013	0.062
Predicted, supply constant	-0.003	-0.003	-0.002	-0.002	0.001	0.001
Est'd supply effect	-0.018	-0.238	0.078	0.293	0.012	0.060
Est'd demand + other effect	0.041	0.260	-0.104	-0.319	0.014	-0.034
(b) 1979-1989						
Actual change	0.217	0.217	0.026	0.026	0.101	0.101
Predicted change	-0.008	-0.078	0.065	0.251	0.014	0.065
Predicted, supply constant	-0.002	-0.002	-0.002	-0.002	0.001	0.001
Est'd supply effect	-0.006	-0.075	0.067	0.253	0.013	0.064
Est'd demand + other effect	0.223	0.292	-0.041	-0.227	0.088	0.037
(c) 1979-2000						
Actual change	0.240	0.240	0.000	0.000	0.127	0.127
Predicted change	-0.029	-0.318	0.141	0.541	0.027	0.127
Predicted, supply constant	-0.005	-0.005	-0.004	-0.004	0.002	0.002
Est'd supply effect	-0.024	-0.313	0.145	0.545	0.025	0.125
Est'd demand + other effect	0.264	0.553	-0.145	-0.545	0.102	0.002

Source: Author's calculations based on CPS and other data. "Model" refers to the supply-demand model discussed in text and summarized in the first part of Table 1, panel (c); "e = -2.0" uses a demand elasticity of -2.0 instead of the higher elasticity estimated in the model.

TABLE 3
Computer use at work and real wages, population 18-64

	Share of workers who use computer at work	Average real wage	
		No computer	Computer
(a) All			
1984	0.246	12.22	16.37
1989	0.368	11.79	16.65
1993	0.460	11.14	16.49
1997	0.499	10.95	16.79
2001	0.542	11.54	18.55
Change			
1984-1989	0.122	-3.5%	1.7%
1989-2001	0.174	-2.1%	11.4%
(b) Men			
1984	0.211	14.13	20.61
1989	0.317	13.39	20.25
1993	0.405	12.20	19.53
1997	0.441	12.05	20.14
2001	0.486	12.70	21.97
Change			
1984-1989	0.106	-5.2%	-1.7%
1989-2001	0.169	-5.2%	8.5%
(c) Women			
1984	0.290	9.64	12.74
1989	0.429	9.65	13.65
1993	0.524	9.58	13.97
1997	0.565	9.45	13.98
2001	0.607	9.88	15.58
Change			
1984-1989	0.140	0.1%	7.1%
1989-2001	0.178	2.4%	14.1%

Notes: Author's analysis of CPS computer-use supplements. Wages are in 1999 dollars, deflated using the CPI-U-RS.

TABLE 4
Computer use at work, recent and older high school and college graduates

	Recent graduates (23-30)		Older graduates (43-50)	
	College	High school	College	High school
(a) All				
1984	0.477	0.209	0.382	0.216
1989	0.647	0.284	0.568	0.315
1993	0.716	0.317	0.683	0.401
1997	0.772	0.347	0.727	0.417
2001	0.818	0.371	0.789	0.432
Change				
1984-1989	0.170	0.075	0.186	0.099
1989-2001	0.171	0.087	0.221	0.117
(b) Men				
1984	0.469	0.120	0.389	0.170
1989	0.632	0.181	0.617	0.242
1993	0.717	0.209	0.708	0.283
1997	0.772	0.241	0.734	0.312
2001	0.812	0.281	0.777	0.330
Change				
1984-1989	0.163	0.062	0.228	0.071
1989-2001	0.180	0.099	0.160	0.088
(c) Women				
1984	0.485	0.329	0.371	0.264
1989	0.661	0.416	0.498	0.383
1993	0.716	0.459	0.648	0.506
1997	0.773	0.492	0.719	0.521
2001	0.823	0.502	0.802	0.544
Change				
1984-1989	0.176	0.087	0.128	0.119
1989-2001	0.162	0.086	0.303	0.161

Notes: Author's analysis of CPS computer-use supplements. Wages are in 1999 dollars, deflated using the CPI-U-RS.

TABLE 5A
Recent college graduate premium, all

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.327	0.286	-0.041	-12.7
	(0.019)	(0.019)	(0.027)	
1989	0.410	0.333	-0.077	-18.8
	(0.020)	(0.020)	(0.028)	
1993	0.327	0.227	-0.100	-30.7
	(0.019)	(0.019)	(0.027)	
1997	0.330	0.224	-0.107	-32.3
	(0.019)	(0.019)	(0.027)	
2001	0.511	0.393	-0.117	-23.0
	(0.020)	(0.020)	(0.028)	
Computer	--	0.225	--	--
		(0.011)		
Change				
1984-1989	0.083	0.047	-0.036	-43.0
	(0.028)	(0.027)	(0.039)	
1989-2001	0.101	0.060	-0.040	-40.1
	(0.028)	(0.028)	(0.040)	
(b) RCG-OCG				
1984	-0.342	-0.280	0.063	-18.3
	(0.023)	(0.023)	(0.032)	
1989	-0.259	-0.243	0.017	-6.4
	(0.024)	(0.023)	(0.033)	
1993	-0.342	-0.356	-0.014	4.2
	(0.023)	(0.022)	(0.032)	
1997	-0.339	-0.361	-0.022	6.4
	(0.023)	(0.022)	(0.032)	
2001	-0.158	-0.195	-0.037	23.3
	(0.023)	(0.023)	(0.033)	
Computer	--	0.290	--	--
		(0.015)		
Change				
1984-1989	0.083	0.037	-0.046	-55.6
	(0.033)	(0.032)	(0.047)	
1989-2001	0.101	0.048	-0.054	-52.8
	(0.033)	(0.032)	(0.047)	

(continued)

TABLE 5A (continued)
Recent college graduate premium, all

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	0.088	0.059	-0.029	-32.9
	(0.020)	(0.020)	(0.028)	
1989	0.171	0.101	-0.070	-41.0
	(0.021)	(0.021)	(0.029)	
1993	0.090	-0.008	-0.097	-108.7
	(0.020)	(0.020)	(0.029)	
1997	0.092	-0.012	-0.104	-113.2
	(0.020)	(0.020)	(0.028)	
2001	0.274	0.157	-0.117	-42.7
	(0.021)	(0.021)	(0.029)	
Computer	--	0.261	--	--
		(0.012)		
Change				
1984-1989	0.083	0.042	-0.041	-49.5
	(0.029)	(0.028)	(0.041)	
1989-2001	0.103	0.056	-0.047	-45.6
	(0.029)	(0.029)	(0.041)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of real hourly wage. All regressions include indicator variablefor gender. Standard errors are in parentheses.

TABLE 5B
Recent college graduate premium, men

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.279	0.219	-0.060	-21.4
	(0.028)	(0.028)	(0.039)	
1989	0.358	0.257	-0.100	-28.1
	(0.029)	(0.029)	(0.041)	
1993	0.248	0.122	-0.125	-50.7
	(0.028)	(0.029)	(0.041)	
1997	0.264	0.136	-0.128	-48.4
	(0.028)	(0.029)	(0.040)	
2001	0.457	0.322	-0.135	-29.5
	(0.029)	(0.031)	(0.042)	
Computer	--	0.217	--	--
		(0.017)		
Change				
1984-1989	0.079	0.038	-0.041	-51.8
	(0.040)	(0.040)	(0.057)	
1989-2001	0.099	0.065	-0.035	-34.8
	(0.041)	(0.042)	(0.059)	
(b) RCG-OCG				
1984	-0.436	-0.355	0.081	-18.5
	(0.035)	(0.034)	(0.048)	
1989	-0.357	-0.338	0.018	-5.2
	(0.036)	(0.035)	(0.050)	
1993	-0.467	-0.487	-0.020	4.2
	(0.035)	(0.034)	(0.049)	
1997	-0.450	-0.474	-0.023	5.2
	(0.035)	(0.034)	(0.048)	
2001	-0.257	-0.292	-0.034	13.3
	(0.036)	(0.035)	(0.050)	
Computer	--	0.330	--	--
		(0.023)		
Change				
1984-1989	0.079	0.017	-0.062	-79.0
	(0.050)	(0.048)	(0.070)	
1989-2001	0.099	0.047	-0.053	-53.0
	(0.051)	(0.049)	(0.071)	

(continued)

TABLE 5B (continued)
Recent college graduate premium, men

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	-0.030	-0.086	-0.056	183.7
	(0.030)	(0.029)	(0.042)	
1989	0.048	-0.063	-0.111	-229.3
	(0.031)	(0.031)	(0.044)	
1993	-0.062	-0.207	-0.145	233.9
	(0.031)	(0.031)	(0.044)	
1997	-0.045	-0.193	-0.148	327.8
	(0.030)	(0.031)	(0.043)	
2001	0.148	-0.010	-0.158	-106.7
	(0.032)	(0.032)	(0.045)	
Computer	--	0.292	--	--
		(0.018)		
Change				
1984-1989	0.079	0.024	-0.055	-69.9
	(0.043)	(0.043)	(0.061)	
1989-2001	0.099	0.053	-0.047	-47.0
	(0.045)	(0.045)	(0.063)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of hourly wage. Standard errors are in parentheses.

TABLE 5C
Recent college graduate premium, women

	Computer control		Difference	
	No	Yes	Log points	Percent
(a) RCG-RHG				
1984	0.380	0.358	-0.021	-5.6
	(0.027)	(0.026)	(0.037)	
1989	0.465	0.411	-0.055	-11.7
	(0.028)	(0.027)	(0.038)	
1993	0.405	0.325	-0.080	-19.8
	(0.026)	(0.026)	(0.037)	
1997	0.397	0.307	-0.090	-22.6
	(0.026)	(0.026)	(0.037)	
2001	0.563	0.456	-0.107	-19.0
	(0.026)	(0.026)	(0.037)	
Computer	--	0.255	--	--
		(0.015)		
Change				
1984-1989	0.085	0.052	-0.033	-38.8
	(0.039)	(0.037)	(0.055)	
1989-2001	0.098	0.046	-0.053	-53.6
	(0.038)	(0.037)	(0.053)	
(b) RCG-OCG				
1984	-0.241	-0.194	0.047	-19.4
	(0.030)	(0.030)	(0.043)	
1989	-0.156	-0.141	0.014	-9.2
	(0.031)	(0.030)	(0.043)	
1993	-0.216	-0.227	-0.010	4.8
	(0.030)	(0.029)	(0.041)	
1997	-0.224	-0.244	-0.020	9.0
	(0.030)	(0.029)	(0.041)	
2001	-0.058	-0.094	-0.037	64.1
	(0.030)	(0.029)	(0.042)	
Computer	--	0.249	--	--
		(0.020)		
Change				
1984-1989	0.085	0.053	-0.032	-37.8
	(0.043)	(0.042)	(0.061)	
1989-2001	0.098	0.047	-0.051	-52.3
	(0.043)	(0.042)	(0.060)	

(continued)

TABLE 5C (continued)
Recent college graduate premium, women

	Computer control		Difference	
	No	Yes	Log points	Percent
(c) RCG-OHG				
1984	0.198	0.189	-0.010	-4.9
	(0.027)	(0.026)	(0.037)	
1989	0.284	0.239	-0.044	-15.6
	(0.028)	(0.027)	(0.039)	
1993	0.223	0.152	-0.071	-31.8
	(0.026)	(0.026)	(0.037)	
1997	0.216	0.135	-0.081	-37.7
	(0.026)	(0.026)	(0.037)	
2001	0.382	0.283	-0.099	-26.0
	(0.026)	(0.026)	(0.037)	
Computer	--	0.267	--	--
		(0.015)		
Change				
1984-1989	0.085	0.051	-0.035	-40.6
	(0.039)	(0.037)	(0.055)	
1989-2001	0.098	0.043	-0.055	-56.0
	(0.038)	(0.037)	(0.053)	

Source: Author's analysis of CPS computer-use supplements. The dependent variable is the natural log of hourly wage. Standard errors are in parentheses.

TABLE 6

Estimated impact of computers on change in RCG differential

(Percent of change in differential over period)

	Year effects	
	Included	Excluded
(a) 1989-01		
RCG-RHG		
All	30	40
Men	14	35
Women	63	54
RCG-OCG		
All	-88	53
Men	-11	53
Women	25	52
RCG-OHG		
All	9	46
Men	17	47
Women	544	56
(b) 1984-89		
RCG-RHG		
All	16	43
Men	25	52
Women	4	38
RCG-OCG		
All	-5	56
Men	2	79
Women	5	38
RCG-OHG		
All	25	50
Men	20	70
Women	-2	41

Notes: Author's analysis of CPS computer-use supplements. Negative numbers indicate that controlling for computer-use at work widened rather than narrowed the change in differential over the period. The total change in the log-point differential between women recent college and older high school graduates was close to zero for 1989-2001.