Have Internet Changed the Wage Structure Too?

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Abstract

This paper investigates whether workers who use Internet at work earn a higher wage than otherwise similar workers who do not use Internet at work. By replicating Krueger's analysis using recent Current Population Survey data sets, this study is able to compare the similarities and differences of the use of two revolutionary modern technologies, computer and Internet. Estimates suggest that while premiums to computer use have been persistent in the 1990s, premiums to Internet use decreased very rapidly over time and eventually disappeared with the rapid expansion in Internet use. Several results imply that there is little link between Internet use and its effect on wages, whereas the link between computer use and wages are clearer.

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> "Bigbrother@the.office.com? When the Society for Human Resource Management surveyed human-resource professionals about Internet use in 1997, fewer than 1 percent said their company's productivity had decreased greatly. More than 45 percent said productivity had gone up." *Newsweek*, April 27, 1998.

I. Introduction

In his influential study, Krueger (1993) finds that workers who use computers on their job earn 10 to 15 percent higher wages than nonusers. Additionally, he found that the expansion of computer use in the 1980s can account for one-third to one-half of the increase in the rate of return to education. However, several studies criticized Krueger's work, in part because he did not control for unobserved heterogeneity in any direct way. For example, DiNardo and Pischke (1997) cast doubt on the literal interpretation of the computer use wage differential as reflecting true returns to computer use. According to them, even the return to pencil use is 13 percent, suggesting that there is substantial selection in the use of *any* office tools.[1]

The Internet revolution may tell us a similar or different story to what previous studies imply. It is theoretically ambiguous whether Internet use can account for the changes in the wages of various types of workers. However, at least two characteristics of Internet use are noteworthy. On one hand, the Internet is a white-collar office tool that requires less skill to use than might be required for any other kind of computer use. The Internet is simply an electronic network of computers. People use it to communicate through e-mail, to obtain information, to purchase products, etc. It would not be surprising to observe that a ballet dancer sends e-mails to her friends or finds information at the

[1] Several other studies tried control for the unobserved heterogeneity. Using a unique matched panel data set, Entorf, Gollac, and Kramarz (1999) show that the new technologies users were already better paid before working in these jobs. Their estimates suggest that the wage increase for computer users never exceeds 2 percent, which is far below the cross-section estimates. By using a twin data set, Krashinsky (2000) also argues that the ordinary least squares estimate of the return to computer use is substantially biased upward.

website with little knowledge about it. It is hard to believe that using Internet (double clicking) proxies for knowledge or skill. The ballet dancer would not use Internet at work only because it is not needed at work.

On the other hand, the vast use of Internet since mid 1990s provided ample opportunities for business. The Internet has revolutionized the communication and computer world like nothing before. The possible benefits from an Internet-enabled transformation of business organization are enormous. For example, the Internet provides ample scope for cost reduction across all stages of the production process. The Internet can also drastically accelerate speed-to-market by reducing time it takes to transmit. The low cost of expanding a functioning network is a further advantage.[2] Pencils were obviously not as productive as the Internet in the 1990s. While we do not have any priors regarding the degree to which Internet specific technological change is linked to changes in wage structure, we may not totally ignore the possibility that a rent-sharing mechanism exists within a company, which would affect the wage structure.

An interesting question might be, whether, if any, a premium for Internet use is either quantitatively or qualitatively different from that for computer use. In this paper, we replicate Krueger's analysis using recent CPS data sets. Since these data sets include detailed information on both Internet use and computer use, we are able to compare the similarities and differences of the use of two prominent modern technologies. The ordinary least squares (OLS) estimates suggest that workers who use the Internet at work earn 5 to 13 percent higher wages than those who do not use it at work. Results also suggest

[2] For example, by moving customer service and technical support online, the Cisco Systems, a leading networking equipment vendor, increased productivity by 200-300 percent, resulting in savings of $125 million in customer costs.

that workers who use the Internet for nonproductive activities in the workplace do not have positive premiums.

However, results from several exercises suggest that the return to Internet use is quite different from that to computer use in many aspects. While premiums to computer use found in Krueger has been persistent in the 1990s, premiums to Internet use decreased rapidly in a very short period of time and eventually disappeared with the expansion in Internet technology. Our results also imply that Internet use at work is not the main determinant of earnings, rather it is the Internet use generally. Furthermore, the premium to Internet use, if any, is not larger in the nonunion sector than it is in the union sector. All these result are in stark contrast with those from computer use. Neither Krueger nor this paper controls for individual unobserved heterogeneity in any direct way. However, if selection is important for measuring the return to computer use, we should expect it to be equally important for determining that for Internet use. If the return to computer use is mostly a reflection of unobserved worker heterogeneity, then it would be difficult to explain our results. We find that there is little link between Internet use and its effect on wages, whereas the link between computer use and wages are stronger.

The remainder of the paper is organized as follows. The next section describes the data used in this study. Section III presents our empirical results. The final section discusses the interpretation these results.

II. Data and Descriptive Analysis

The analysis in this study relies primarily on data from the Current Population Survey (CPS) conducted in October 1997, December 1998, August 2000, and September

2001. The information regarding computer use at work is based on October 1997 and September 2001 surveys, whereas the information of Internet use at work is based on surveys taken in October 1997, December 1998, and August 2000. Only the October 1997 CPS has information on both computer use at work and Internet use at work. However, unlike the 1998 and 2000 surveys, the 1997 CPS has no detailed information on Internet use at various tasks, nor does it have information on Internet use at home, which limit us to use the data set more intensively.

In order to compare the results with that of Krueger, the data set is manipulated in the same way in Krueger. The sample is restricted to individuals between ages 16 and 65. The hourly wage is the ratio of usual weekly earnings to usual weekly hours. Individuals who earned less than $1.50 per hour or more than $200 per hour are deleted from the sample. The weekly earnings variable in the 1997 CPS is top-coded at $1,923, whereas the weekly earnings in the other surveys are top-coded at $2,884.01. In order to circumvent any problems caused by changes in top-coding over time, we calculated an estimate of the mean log hourly wage for individuals who were top coded in 1998 and assigned it to each individual who was top coded in 1997. This procedure follows a method suggested by Krueger.[3]

Columns (1) through (8) in Table 1 summarize the proportion of workers who use the Internet at work. We also tabulate the proportion of workers who use computer at work for comparison. Between 1997 and 2000, the percentage of workers using the Internet at work increased by about 80 percent from 16 to 29 percent. The increase in Internet use at work during October 1997-December 1998 period is remarkable. We find that Caucasians and highly educated workers are more likely to use the Internet at work than

African Americans and less educated workers. Full-time and nonunion members are also more likely to use the Internet. However, unlike the case for computer use, there is no clear evidence that women are more likely to use the Internet at work. The most noticeable differences between Internet use and computer use occur when one segregates workers by age. While workers aged 40-54 are more likely to use computers at work than those aged 18-25, younger workers were more likely to use the Internet than older workers since 1998.

The difference between Internet use and computer use can be seen more clearly in columns (9), (10), and (11). These three columns present the percentage of workers using the Internet among workers who use computers. Column (9) is based on information from October 1997 CPS which contains information on both Internet use and computer use at work. Columns (10) and (11) are based on information of Internet use from December 1998 and August 2000 surveys and computer use in October 1997 and September 2001 surveys. Obviously, column (10) overestimates the true value in 1998 and column (11) underestimates the true value in 2000. This is because column (10) expresses Internet use in 1998 as a share of computer use in 1997 and column (11) expresses Internet use in 2000 as a share of computer use in 2001.

The percentage of workers using the Internet at work among those who use computers at work increased from 34 percent in 1997 to 51 percent in 1998, and to about 55 percent in 2000. These three columns show that there is a significant transition in the use of the Internet by groups over time. For example, although women were more likely to use computers than men, men were much more likely to use the Internet at work than women in 1997. In 1997, only 28 percent of women used the Internet at work, suggesting

[3] See Appendix A in Krueger (1993) for details.

that 72 percent of women used computers but did not use the Internet at work. However, the difference in Internet use between men and women has decreased drastically since then. In 2000, there is also almost no difference between Caucasians and African Americans in using the Internet conditional on their use of computers at work. There is also no sizable difference between blue-collar and white-collar workers in using the Internet in 2000, although white-collar workers were more likely to use the Internet at work in 1997. Even part-time workers are not less likely to use the Internet than full-time workers in 2000. All these results suggest that the between group variation in the use of Internet in columns (2) and (3) is mostly due to the between group variation in the use of computers. The data suggests that Internet use inequality was mostly disappeared by 2000, while the computer use inequality remains persistent.

III. Internet Use and Wages

A. Premium to Internet use over time

Following Krueger, we have used a variety of statistical models to estimate the premiums to Internet use. First, we estimate a log linear wage equation by the ordinary least squares method.

$$\ln w = x\beta + \gamma I + \varepsilon \qquad (1)$$

where x represents observed characteristics and I is a dummy variable that equals one if the worker uses Internet at work. To capture the premium to computer use, we also use a dummy indicator for computer use. Two covariates of our specification are different from Krueger. First, instead of years of schooling, we use four education category variables due to a change in variable definition since 1994. Second, as a result, the potential

experience variable in Krueger is replaced with an age variable. To determine whether this change in specification affects the overall result, we used the October 1989 survey and regress the wage equation first with using years of schooling and potential experience, and then with using the education category variables and age. The results are almost identical, suggesting that using education category variables instead of years of schooling minimally affect the estimated coefficient for Internet use dummy.

Columns (1) through (3) of Table 2 report results of fitting equation (1). In order to distinguish this from an additional payoff associated with Internet use relative to any other type of computer use; we will call the estimates in these columns the *unconditional* wage premiums. The results suggest that workers who use the Internet while on the job receive higher wages than those who do not by 21 percent (exp(0.190)-1) in 1997, 12 percent in 1998, and 9 percent in 2000. These results are all statistically significant at the one-percent significance level. Columns (4), (5), and (6) present estimation results that include a set of eight one-digit occupation dummies. Krueger argues that including occupation dummies may be inappropriate in the wage regression because computer skills may enable workers to qualify for jobs in higher paying occupations and industries. However, our approach may be justified in the estimation of premiums to Internet use since it is unlikely that Internet skills alone enable workers to qualify for certain jobs. When these dummies are included in the estimation, the Internet use premium decreases to 13 percent in 1997, 9 percent in 1998, and 5 percent in 2000. When we include 45 two-digit occupation dummy variables, the estimated coefficients are 0.114 in 1997, 0.077 in 1998, and 0.045 in 2000 and they are highly significant.

In columns (1) through (6), the base category of the Internet use dummy includes two types of workers, those who do not use computers at work and those who use computers at work without using Internet. Since the 1997 CPS contains information on both Internet use at work and computer use at work, we can estimate the coefficients of both Internet use and any computer use. In this case, the coefficients on Internet use should be interpreted as indicating the additional payoff associated with Internet use relative to any computer use. In order to distinguish this from unconditional premium, we name the additional payoff the *conditional* premium. Column (7) presents our results. The results indicate that workers who use the Internet at work receives wages that are 21 percent higher (exp(0.074+0.113)-1) than those who do not use *computers* at work. Krueger shows that in 1989 the most highly rewarded type of computer use was electronic mail. Since Krueger's comparable estimate for the same specification was 24 percent in 1989, we conclude that the reward for using the Internet did not decrease much before 1997.

To extend the results of Krueger, we also estimate the returns to computer use by using 1997 and 2001 data sets. The results are reported in columns (8) and (9) of the table. The earnings differential in hourly pay between workers who use computers on the job and those who do not is 14 percent in 1997 and 11 percent in 2001, suggesting that there is still substantial earnings premium to computer use. Since Krueger's measure is 15 percent in 1984 and 18 percent in 1989, we conclude that there is only a slight decrease in premiums to a computer use between 1984 and 2001. This is in stark contrast with the very rapid decrease in the premium for Internet use.

Although only the 1997 CPS contains information on both Internet use at work and computer use at work, we can still calculate the approximate *conditional* premium to

Internet use in 1998 and 2000 using the information on unconditional premium and proportion of workers using Internet provided in Table 1 and 2. Again, the unconditional premium is the premium against two types of workers, the premium against those who do not use computers at work and the premium against those who use computers at work without using the Internet. Therefore, the following relationship between the unconditional and conditional wage premiums holds, assuming that there is little interaction between dummy indicators and the other variables in equation (1).

$$\gamma_u^I = (\gamma_c^{I/C} + \gamma_c^C) * \frac{1-P(C)}{1-P(I)} + \gamma_c^{I/C} * \frac{P(C)-P(I)}{1-P(I)} \quad \text{or} \qquad (2)$$

$$\gamma_c^{I/C} = \gamma_u^I - \gamma_c^C * \frac{1-P(C)}{1-P(I)} \qquad (2)'$$

where γ_u^I is the unconditional Internet premium, $\gamma_c^{I/C}$ conditional Internet premium, γ_c^C premium to any (general) computer use, *P(C)* proportion of workers using computers at work, and *P(I)* is the proportion of workers using Internet at work. If everybody uses computer (*P(C)* = 1), then γ_u^I is equal to $\gamma_c^{I/C}$. If everyone who uses computers also uses the Internet at work (*P(C) = P(I)*), then γ_u^I is equal to γ_c^C, and $\gamma_c^{I/C}$ equals zero.

Equations (2) and (2)' clearly show that the conditional Internet premium, $\gamma_c^{I/C}$, decreases if γ_u^I decreases, γ_c^C increases, or $\frac{1-P(C)}{1-P(I)}$ increases. Our results show a huge decrease in γ_u^I, rapid increase in $\frac{1-P(C)}{1-P(I)}$, and little change in the return to computer use.[4] Assuming that γ_c^C is 0.1 in both 1998 and 2000, and using the value of *P(C)* in

[4] Since the unconditional return to computer use has changed very little during the 1997-2001 period (from 0.129 to 0.102), we can also conjecture that the conditional return to computer use since 1997 (0.113) changed a little.

1997 and 2001, the calculated conditional premium to Internet use never exceeds 2 percent in 1998. Considering that the calculated γ_c^C is overestimated for 1998 and underestimated for 2000, we also used much more conservative numbers for $\frac{1-P(C)}{1-P(I)}$ and γ_u^I. The calculated conditional premium to Internet use never exceeded 3 percent in 1998. In both cases, the calculated conditional premium to Internet use is zero in 2000.

The results imply that the estimated reward for using the Internet, whether unconditional or conditional, decreased very rapidly between 1997 and 2000. This is in contrast to the very slow decrease in the returns to computer use during the much longer period of time. In particular, the conditional premium to Internet use, the additional payoff associated with Internet use relative to any computer use, has completely disappeared since 1997, while the premiums to computer use changed little. This result suggests that the premium to Internet use since 1998, if any, is entirely due to the premium to general computer use.

These results may be closely related with the rapid expansion of Internet technology. Krueger argues that the higher premium to e-mail use in 1989 probably reflects the fact that e-mail was first introduced to higher paying or high-ranking jobs. In fact, less than 6 percent of workers used e-mail at work in 1989.[5] We have also observed a high degree of inequality between workers in using Internet at work until 1997, but the inequality by groups has disappeared by 2000. This strongly implies that a substantial portion of the 1997 Internet premium might be due in part to the fact that Internet use was

[5] Although the Internet and e-mail protocols were born in 1960s, it was not until 1989 that the first relay was made between a commercial e-mail carrier and the Internet. The Gopher and World-Wide Web was first released in 1991 (source: Hobbe's Internet timeline v5.6 http://www.zakon.org/robert/internet /timeline).

not universal in 1997 and was instead often limited to selected workers, high-ranking or high paying workers. Krueger also argues that, given the substantial expansion in the supply of workers who have computer skills between 1984 and 1989, the absence of a decline in the wage differential for computer use suggests that the demand for workers with computer skills may have shifted out as fast as the outward shift in the supply of computer-literate workers. Since possession of Internet skills is not as scarce as those for specific computer skills, the rapid expansion of Internet technology removed the premiums attached to it.

As an alternative approach to measuring the payoff to Internet use, this study also estimates the relationship between the growth in wages and the growth in Internet use at the occupational level, following Krueger. The idea is that, while the characteristics of workers and employers in an occupation are likely to change slowly over time, some occupations might have adapted to Internet very quickly during the period. Specifically, we used the 1997 and 2000 CPSs to calculate the proportion of workers who use the Internet at work for three-digit occupations, and also calculated the mean log wage for the same set of occupations. We then regressed the change in the mean log wage on the change in Internet use. The coefficient estimates, with standard errors in parentheses, are as follows:

Between 1997 and 1998: $\Delta\overline{\ln w}_j = 0.028 + 0.092\Delta\bar{I}_j$
$(0.009)\ \ (0.060) \qquad R^2 = 0.006$

Between 1998 and 2000: $\Delta\overline{\ln w}_j = 0.002 + 0.038\Delta\bar{I}_j$
$(0.007)\ \ (0.056) \qquad R^2 = 0.001$

where $\Delta\overline{\ln w}$ is the growth in mean log hourly earnings in occupation j and $\Delta\bar{I}_j$ is the growth in the proportion of workers who use Internet at work in occupation j. The equa-

tions are estimated by weighted least squares, using the number of workers in occupation j in base years as weights.

The results provide no evidences supporting the notion that Internet growth is positively related with wage growth in occupation during the period of 1997-2000, particularly between 1998 and 2000, which is consistent with our previous findings. In order to compare the results with that of computer use, we also regressed the change in mean log wage on the change in computer use during the 1997-2001 period. The coefficient estimates, with standard errors in parentheses, are

Between 1997 and 2001: $\Delta\overline{\ln w}_j = 0.051 + 0.098\Delta\overline{C}_j$
(0.007) (0.049) $R^2 = 0.011$

In contrast to the results of Internet use, this result indicates that computer growth is significantly and positively associated with wage growth in occupation. If an occupation moved from no computer use in 1997 to 100 percent computer use in 2001, wages are estimated to rise by 9.8 percent. This figure is also very close to the return to computer use in Table 2. All these evidences are consistent with what Table 2 suggests.

B. Specific Internet tasks

The 1998 and 2000 surveys asked workers what tasks they use Internet for. Respondents were allowed to indicate multiple tasks. Table 3 presents estimates of the coefficients on the specific Internet tasks for wage regression. We use the specification in Table 2 including eight one-digit occupation dummies. The regression includes a dummy variable that equals one if the individual used the Internet for any task in addition to dummy variables for specific tasks. Thus, the coefficients on the specific tasks should be

interpreted as indicating the additional payoff associated with a specific task relative to any Internet use at all.

The result shows that the most highly rewarded task Internet are used for job related use. On the other hand, the results show a negative premium for individuals who use Internet for taking school courses and job search. The negative coefficients on Internet use exceed the positive coefficient for using Internet. However, the negative premium to Internet use for taking school courses and job search at work may, as the tasks themselves imply, simply represent workers' unobserved characteristics.

C. Employer characteristics

As Krueger argues, it is highly possible that characteristics of employers are correlated with the provision of computers and Internet and the generosity of compensation. Such a relationship exists in rent-sharing model, in which employees are able to capture some of the return to the employer's capital stock. In order to explore this issue, we first include 48 two-digit industry dummies as well as 45 two-digit occupation dummies in a model, followed by Krueger. The estimated Internet use wage differential is 0.101 in 1997, 0.075 in 1998, and 0.039 in 2000, suggesting that inclusion of the industry dummies barely affects the results.

We have also estimated the model separately for union and nonunion workers. The results are presented in Table 4. In this table, we do not include eight one-digit occupation dummies to make it comparable to Krueger's estimates. The premium for Internet use is about 8 percent in the union sector and 23 percent in the nonunion sector in 1997. Thus, this result is similar to Krueger's estimates for computer use in 1989, in the sense

that the premium to Internet use is also much higher in the nonunion sector. Including both Internet and computer use dummies does not change the result qualitatively. Krueger argues that this finding for computer use is consistent with the notion that unions compress skill differentials (Card, 1991). Since unions tend to reduce all types of dispersion of earnings among workers, such as wage differentials between white-collar and blue-collar workers and between white and black workers (DiNardo et. al. 1997; Peoples Jr. 1994), our results are not surprising given the fact that the Internet might have been used by selected workers in 1997.

However, the results are quite different when we estimate the model by using the 1998 and 2000 surveys. The premium to Internet use is, if any, slightly higher in the union sector than in the nonunion sector in both 1998 and 2000. This is contrary to the estimated premiums to computer use of 2000 survey as well as Krueger's estimate of 1989 survey. If Internet use is a skill and unions are believed to compress skill differentials, it is difficult to explain why the premium to Internet use is not larger in the union sector than it is in the nonunion sector when the return to computer use is much larger in the nonunion sector than it is in the union sector. This result is also consistent with our findings of the rapid expansion of Internet use and the disappearance of inequality in Internet use associated with it. In fact, the slightly higher Internet use premium in the union sector during the 1998-2000 period suggests that the Internet use premium found in the year 1998 and 2000, although small, could be a result of employees capturing their respective firm's capital rents rather than a return to a skill.

D. Internet use at home and at work

The December 1998 and August 2000 CPS surveys collected information on Internet use at home as well as work. The October 1997 and September 2001 CPSs collected information on computer use at home as well as work, allowing us to compare Internet use premium to computer use premium. Following Krueger, we estimate the following wage equation:

$$\ln w = x\beta + \gamma_w I_w + \gamma_h I_h + I_w I_h \delta + \varepsilon \qquad (3)$$

where I_w is a dummy that equals one if a worker uses Internet at work and zero otherwise, I_h is a dummy variable that equals one if a worker uses Internet at home and zero otherwise, and $I_w I_h$ is an interaction term between Internet use at home and at work.

Krueger argues that workers' unobserved characteristics that are associated with computer use at home might be also related with computer use at work. By the same token, although the relationship is not as clear as in the case of computers, controlling for whether workers use Internet at home would capture some of the unobserved heterogeneity that is correlated with Internet use at work. For example, workers with high earnings capacity may use the Internet at both home and work. On the other hand, there simply might be a positive correlation between the tendency to use the Internet and unobserved earnings capacity.

Table 5 presents OLS estimates of equation (3). These results are striking because they imply that the main determinant of the earnings differential is Internet use in general rather than on the job Internet use. For example, in 1998, individuals who used the Internet at work earned 12.5 percent more than those who did not use the Internet at all, whereas individuals who used Internet at home earned 10.1 percent more than those who did not use Internet at all. Thus, the earnings differential between Internet use at home

and Internet use at work is only 2.4 percent and it is statistically insignificant. In 2000, there is no sizable difference between Internet use at work and Internet use at home. However, even as late as 2001, individuals who used a *computer* at work earned 12.9 percent more than those who did not use computer at all, whereas individuals who used a computer at home earned only 6.1 percent more than those who did not use computer at all. That is, Internet use at work is in fact workers' characteristics that are main determinant of earnings and associated with Internet use generally. Again, this result is contrary to that of computer use at work.

E. Internet use and returns to schooling

This section examines the effect of computer use on returns to education. For this purpose, we re-estimate the wage equation first including both the Internet and education variables and then without them. Since our education variable is made up of 4 categorical variables, interpreting the result is not straightforward. In order to make it easy to interpret the results, we now categorize the education group into two groups: individuals with at least some college and those without. We did a similar estimation for the effects of computer use.

Table 6 presents the results. It shows that the return to college education decreased by one-half of a point between 1997 and 2000 if the Internet use dummy is not included in the equation. If the Internet dummy is included in the equation, the return to college education decreases by 0.6 point, so a 20 percent of decrease in the return to college education can be attributed to the expansion in Internet use. That is, the Internet led to *decrease* in the return to college education, rather than increase in it.

The return to college education decreased by one point between 1997 and 2001, suggesting that the return to college education decreased by another half point between 2000 and 2001. If the computer dummy is included in the equation, the return to college education increases by 0.4 point, suggesting that the decrease in returns to education is attenuated by 40 percent due to the expansion in computer use. Using several other specifications including interaction dummies and other samples do not change the result qualitatively. Thus, we do not find any strong evidence that Internet use have led to an increase in the return to education, whereas computer use have might have done it.

IV. Discussion

One of the interesting questions raised by Krueger is whether changes in the wage structure observed in 1980s would persist in 1990s. He speculated that the premium to computer use might decrease since the supply of computer-literate workers is likely to continue to increase in the future, whereas the demand for computer-literate workers is less likely to expand as rapidly as it did in the 1980s. On the other hand, he argued that there was little evidence that the value of computer skills had declined in early 1990s. Krueger concluded that computer training might, at least in the short run, be a profitable investment. Our results support his speculation, more or less; the return to computer use decreased a small amount during 1990s and there is still substantial amount of return to computer use even as recently as 2001. However, our results from Internet use are quite different; within less than three years, there was nearly 80% increase in Internet use at work, so it did remove the premiums attached to it.

Most of our results are consistent with this finding. Results suggests that the premium to Internet use since 1998, if any, is entirely due to the premium to general computer use, not due to the additional premium to Internet use. Our results also imply that the premiums to Internet use at work are not greater than the premiums to Internet use at home, suggesting that general Internet use is the main determinant of earnings, rather than Internet use at work. Furthermore, the premium to Internet use, if any, is not larger in the nonunion sector than it is in the union sector. If we regard Internet use as skill and unions are believed to compress skill differentials, it is difficult to explain this phenomenon. We note that all these results are in stark contrast to those regarding computer use.

Our study does not control for unobserved heterogeneity in any direct way. It is far from clear whether all these indirect exercises can remove potential bias from the estimates. On the other hand, it is not clear whether using a fixed-effects approach would yield a true return to the adoption of new technology. If returns to unobserved skills quickly changes in response to the introduction of a revolutionary technology, then using fixed-effects would be of less use. We cannot even imagine what the return to a professional computer-game player's unobserved skill would be ten years ago.

DiNardo and Pischke's findings do cast some doubt on the literal interpretation of the computer use wage differential as reflecting true returns to computer use, but it does not prove there is no link between change in wage structure and computer use. Although we still do not prove whether Krueger's estimates represent a return to skills or a selection effect, our results do suggest that computer use is quite different from Internet use in terms of its effect on wage structure. If selection is important for computer, we should expect it to be equally important for Internet. If returns to computer use are mostly a re-

flection of unobserved worker heterogeneity, it is difficult to explain the result for Internet.

Is the evolution of the wage structure tied to future development in technology? One of the leading hypotheses to explain the rapid changes of the wage structure in the US is the skill-biased technological change hypothesis. That is, the rapid changes in technology in the 1980s are responsible for much of the dramatic changes in the wage structure. As implied by Levy and Murnane (1996), it is possible that technologies may cause changes in productivity leaving the wage structure unchanged. However, the answer to the question might be closely related with whether the adoption of new technology is related with skill upgrading. For example, in their plant-level study, Doms, Dunne, and Troske (1997) show that the adoption of factory automation technologies is less correlated with skill upgrading than investment in new computer equipment. Likewise, we found little link between Internet use and its effect on wages, whereas the link between computer use and wages are stronger.

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Table 1. Percent of Workers in Various Categories Who Use Internet at Work / Computer at Work

	Use Internet at work			Use a computer at work					Internet at work/ computer at work		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Oct.1997	Dec.1998	Aug.2000	Oct.1984	Oct.1989	Oct.1993	Oct.1997	Sep.2001	1997/ 1997	1998/ 1997	2000/ 2001
All workers	16.2	24.5	29.1	25.1	37.4	46.6	48.2	52.5	33.6	50.8	55.4
Gender											
Men	17.1	24.4	27.7	21.6	32.2	41.1	42.8	47.2	40.0	57.0	58.7
Women	15.2	24.7	30.6	29.6	43.8	53.2	54.2	58.4	28.0	45.6	52.4
Education											
Less than high	0.7	4.9	4.2	5.1	7.7	10.4	6.4	8.2	10.9	76.6	51.2
High school	5.8	13.1	16.7	19.2	28.4	34.6	31.8	34.5	18.2	41.2	48.4
Some college	15.7	25.8	29.9	30.6	45.0	53.1	54.2	56.7	29.0	47.6	52.7
College	35.4	43.6	50.7	42.1	58.5	70.2	74.3	78.3	47.6	58.7	64.8
Race											
White	16.9	25.2	29.8	25.8	38.5	48.0	49.6	54.0	34.1	50.8	55.2
Black	10.1	18.6	22.7	18.6	28.1	36.7	36.6	40.6	27.6	50.8	55.9
Age											
Age 18-24	9.1	29.0	31.5	20.5	29.6	34.3	34.0	34.8	26.8	85.3	90.5
Age 25-39	17.9	26.6	31.3	29.6	41.4	49.8	51.6	55.9	34.7	51.6	56.0
Age 40-54	18.7	22.5	28.4	23.9	38.9	50.0	53.3	57.7	35.1	42.2	49.2
Age 55-64	13.2	17.0	20.5	17.7	27.0	37.3	43.1	51.6	30.6	39.4	39.7
Occupation											
Blue-collar	3.6	9.9	12.7	7.1	11.2	17.1	20.1	24.0	17.9	49.3	52.9
White-collar	25.4	33.9	40.0	39.7	56.6	67.6	69.7	72.8	36.4	48.6	54.9
Union member											
Yes	12.9	21.7	25.0	19.9	31.8	39.1	45.6	51.0	28.3	47.6	49.0
No	16.3	24.6	29.2	25.3	37.7	46.9	48.3	52.5	33.7	50.9	55.6
Hours											
Part-time	7.5	22.8	22.4	14.8	24.4	29.3	31.7	38.2	23.7	71.9	58.6
Full-time	18.1	24.9	30.2	29.3	42.3	51.0	51.7	55.4	35.0	48.2	54.5
Region											
Northeast	15.8	23.3	28.4	25.5	37.6	46.9	48.4	53.3	32.6	48.1	53.3
Midwest	15.4	25.3	30.1	24.3	36.6	46.7	48.8	53.3	31.6	51.8	56.5
South	15.5	23.1	27.4	23.2	36.6	45.0	46.9	51.1	33.0	49.3	53.6
West	18.1	26.5	30.5	28.9	39.7	48.8	48.9	52.6	37.0	54.2	58.0
Number of obs.	60,091	60,196	60,698	61,704	62,748	59,852	60,091	71,090	..	..	..

Columns (4), (5), and (6) are from Table 4 in Autor, Katz, and Krueger (1997). The other columns are the authors' tabulations. Data for all columns are from the Current Population Survey.

Table 2. OLS Regression Estimates of the Effect of Internet and Computer Use on Pay

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Oct. 1997	Dec. 1998	Aug. 2000	Oct. 1997	Dec. 1998	Aug. 2000	Oct. 1997	Oct. 1997	Sep. 2001
Use internet at work	0.190	0.114	0.088	0.126	0.083	0.052	0.074	..	..
	(0.016)	(0.012)	(0.011)	(0.015)	(0.011)	(0.010)	(0.016)		
Use computer at work	..	..	..	..	..	..	0.113	0.129	0.102
							(0.010)	(0.010)	(0.009)
High school	0.212	0.213	0.175	0.186	0.196	0.158	0.168	0.171	0.183
	(0.019)	(0.018)	(0.018)	(0.018)	(0.017)	(0.017)	(0.018)	(0.018)	(0.018)
Some college	0.311	0.316	0.283	0.249	0.257	0.217	0.218	0.222	0.222
	(0.020)	(0.019)	(0.019)	(0.019)	(0.018)	(0.018)	(0.019)	(0.019)	(0.019)
College	0.507	0.535	0.472	0.367	0.396	0.333	0.333	0.338	0.372
	(0.023)	(0.022)	(0.023)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
Graduate	0.687	0.706	0.671	0.465	0.504	0.439	0.431	0.440	0.510
	(0.036)	(0.034)	(0.033)	(0.035)	(0.033)	(0.032)	(0.034)	(0.034)	(0.032)
Age	0.045	0.042	0.047	0.039	0.034	0.039	0.038	0.038	0.033
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Age-squared ÷ 100	-0.049	-0.043	-0.051	-0.042	-0.035	-0.042	-0.041	-0.041	-0.034
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Black (1=yes)	-0.117	-0.084	-0.053	-0.078	-0.046	-0.026	-0.067	-0.068	-0.045
	(0.014)	(0.014)	(0.015)	(0.013)	(0.013)	(0.014)	(0.013)	(0.013)	(0.013)
Other race (1=yes)	0.006	-0.049	-0.059	0.012	-0.031	-0.048	0.020	0.019	-0.014
	(0.020)	(0.020)	(0.019)	(0.019)	(0.018)	(0.018)	(0.019)	(0.019)	(0.017)
Par-time (1=yes)	-0.155	-0.209	-0.172	-0.125	-0.171	-0.134	-0.111	-0.113	-0.142
	(0.011)	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.010)
Lives in SMSA (1=yes)	0.058	0.061	0.077	0.056	0.060	0.075	0.056	0.057	0.059
	(0.009)	(0.009)	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Veteran (1=yes)	0.033	0.018	0.065	0.027	0.020	0.057	0.026	0.027	0.046
	(0.016)	(0.016)	(0.017)	(0.015)	(0.015)	(0.016)	(0.015)	(0.015)	(0.014)
Female (1=yes)	-0.103	-0.154	-0.116	-0.080	-0.113	-0.077	-0.087	-0.090	-0.087
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Married (1=yes)	0.137	0.114	0.122	0.114	0.095	0.099	0.113	0.111	0.084
	(0.013)	(0.013)	(0.013)	(0.012)	(0.013)	(0.012)	(0.012)	(0.012)	(0.012)
Married*female	-0.102	-0.035	-0.068	-0.097	-0.046	-0.076	-0.099	-0.099	-0.082
	(0.017)	(0.018)	(0.018)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.015)
Union member (1=yes)	0.245	0.212	0.188	0.247	0.212	0.188	0.234	0.248	0.198
	(0.013)	(0.013)	(0.013)	(0.012)	(0.012)	(0.012)	(0.011)	(0.012)	(0.011)
8 occupation dummies	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.375	0.392	0.359	0.458	0.477	0.459	0.466	0.465	0.437
Number of obs.	7766	7739	7966	7766	7739	7966	7766	7766	9171

The dependent variable is log hourly wage. Standard errors are shown in parentheses.

Table 3. The Return to Various Uses of Internet

	1998	2000
Internet use	0.057	0.031
	(0.021)	(0.020)
E-mail	0.024	-0.016
	(0.020)	(0.018)
Checking news/weather	-0.018	-0.004
	(0.023)	(0.022)
Job related tasks	0.073	0.087
	(0.021)	(0.018)
Making phone calls	-0.004	0.056
	(0.049)	(0.053)
Other use	-0.039	0.027
	(0.042)	(0.037)
Information search	0.038	0.022
	(0.020)	(0.018)
Shopping, paying bills	0.026	0.053
	(0.035)	(0.028)
Search for jobs	-0.038	-0.101
	(0.030)	(0.030)
Educational course	-0.094	-0.066
	(0.022)	(0.021)

The dependent variable is log hourly wage. Standard errors are shown in parentheses.

Table 4. The Return to Internet and Computer Use at Work by Union Status

	Oct. 1997	Dec. 1998	Aug. 2000	Oct. 1989	Oct. 1997	Sep. 2001	Oct. 1997
Internet							
Union	0.073	0.126	0.098	..	..	..	0.016
	(0.044)	(0.031)	(0.030)				(0.047)
Nonunion	0.206	0.112	0.084	..	..	..	0.123
	(0.017)	(0.013)	(0.012)				(0.018)
Computer							
Union	..	..	..	0.078	0.106	0.077	0.103
				(0.018)	(0.025)	(0.025)	(0.026)
Nonunion	..	..	..	0.204	0.176	0.161	0.150
				(0.009)	(0.010)	(0.010)	(0.011)

The result for October 1989 is from Krueger (1993). The dependent variable is log hourly wage. Standard errors are shown in parentheses.

Table 5. The Return to Internet Use at Work, Home, and Work and Home

	Internet		Computer		
	Dec. 1998	Aug. 2000	Oct. 1989	Oct. 1997	Sep. 2001
Home or work					
Work	0.118	0.082	0.177	0.151	0.121
	(0.014)	(0.014)	(0.009)	(0.011)	(0.014)
Home	0.096	0.086	0.070	0.051	0.059
	(0.012)	(0.011)	(0.019)	(0.014)	(0.011)
Home and work	-0.030	0.010	0.017	0.024	0.022
	(0.025)	(0.021)	(0.023)	(0.020)	(0.017)

The dependent variable is log hourly wage. Standard errors are shown in parentheses.

Table 6. The Effect of Internet (Computer) Use on the Return to College Education

	Excluding Internet (computer) dummy			Including Internet (computer) dummy			Percent f change accounted for by Internet (computer) use
	1997	2000	Change	1997	2000	Change	
Internet	..	..		0.140	0.065		
				(0.015)	(0.010)		
College	0.115	0.110	-0.005	0.108	0.102	-0.006	-20%
	(0.009)	(0.009)		(0.009)	(0.009)		
	1997	2001	Change	1997	2001	Change	
Computer	..	..	..	0.141	0.120		
				(0.010)	(0.009)		
College	0.115	0.105	-0.010	0.093	0.087	-0.006	40%
	(0.009)	(0.008)		(0.009)	(0.009)		

The dependent variable is log hourly wage. Standard errors are shown in parentheses.