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Which Workers Gain from Computer Use?*

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Abstract: In an influential 1993 paper, Alan Krueger estimated that U.S. workers who used a computer at work earned 10-15% higher wages in 1989. Since this estimate is based on a cross-sectional survey, the direction of causality cannot be determined: does computer use result in higher wages or are high-wage workers more likely to use computers? By directly and indirectly controlling for worker heterogeneity, many authors have since found that the return to the average worker for computer use is much smaller, 1-2% at most.

In fact, the introduction of a new technology can be up-skilling for some workers and de-skilling for other workers. We explore this issue using a 1999-2000 panel of workers surveyed in the Canadian Workplace and Employee Survey (WES). Cross-sectional wage regressions for the 1999 WES suggest a wage premium for computer use of 15%. When these regressions are re-estimated on the 1999-2000 panel, computer use raises wages for the average worker in the first year of adoption by a small but significant 4%. However, this result blurs important differences between types of workers. Higher-educated workers, white collar workers and those adopting the computer for scientific applications receive higher than average wage premia, while other workers do not receive higher wages in the year they adopt computers. We provide some evidence that this is partly because low-skill workers are more likely to share the learning costs associated with computer adoption in terms of sacrificed wages.

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I. Introduction

Since the 1980's, wage inequality between college graduates and high school graduates has grown substantially. One hypothesis for this increased wage gap is skill-biased technological change (Mincer 1991). It has been argued (Attewell, 1989) that reorganization of work around computers allows workers to shift their focus from routine tasks to problem solving--this "upskilling" increases the productivity and wages of workers. Using a cross-section of workers from the Current Population Survey (CPS), Krueger (1993) found that workers who used a computer earned 10-15% higher wages than those who did not. He included a variable measuring computer use at home to try to control for unobserved worker heterogeneity. However, this did not reduce the size of the returns for computer use on the job. This paper sparked debate as to whether there is truly a return for using a computer or if higher wages are a result of positive selection into computer use. If workers with high ability or unobserved skills are the workers who are given computers on the job, then cross-section results could falsely attribute a wage premium to computer use. DiNardo and Pischke (1997) reached the latter conclusion after finding that workers who used a variety of other tools associated with white-collar type work, including a pencil and a hand calculator, also received a similar return on these tools.

A few researchers have used panel data to control for unobserved individual heterogeneity. Most, with the exception of Bell (1996), found small or insignificant returns on technology use. These studies suggest that firms are allocating information technologies to their highest skilled workers, who already earn more. Using French employer-employee matched data on new technologies, Entorf and Kramarz (1997) and

Entorf, Gollac, and Kramarz (1999) confirmed Krueger's and DiNardo and Pischke's findings in their cross-section regressions. However, controlling for individual fixed-effects on a panel with retrospective data on computer use, they found that the return on computer use is positive, but insignificant, while experience with computers earns employees a maximum return of two percent. Using retrospective data on computer usage from the German Socio-Economic Panel (GSOEP), Haisken-DeNew and Schmidt (1999) found that individual fixed-effects reduced the return for computer use to one percent.

While proponents of "upskilling" argue that computerization can lead to productivity and wage increases, critics such as Braverman (1974) counter that computerization can be "deskilling"--the increased mechanization reduces workers' control over the production process and simplifies jobs, leading to lower wages. In fact, the introduction of new technology may be up-skilling for some workers (i.e. because it complements them in production) and de-skilling for other workers (i.e. because it substitutes for them in production), even within a single firm. In a case study of the introduction of Optical Character Recognition and electronic imaging of paper checks in a bank, Autor, Levy, and Murnane (2002) found that the exceptions processors spent more time on problem solving and less on repetitive tasks while check preparers in the back room had the same skill requirements, but fewer check preparers were required to perform the same tasks. In this case, computers substituted for some routine tasks and complemented problem-solving. These differences may be observable between occupational groups as computers change skill requirements. For example, word processing programs may be de-skilling for clerical workers, but up-skilling for managers because they allow them to take on a greater variety of tasks. Bresnahan, Brynjolfsson, and Hitt (1999) argue that managers and professionals with high cognitive skills are important for the implementation of new technologies. They need to be able to transform organizations to take advantage of technology and the new information it provides about the customer base. Bartel and Lichtenberg (1987) argue that since highly educated workers have a comparative advantage in adjusting to new technologies, their introduction should shift demand away from less educated workers.

Krueger (1993) recognized that there might be differential returns across groups of workers. He estimated cross-sectional computer wage differentials for seven white-collar occupations. As an example, he found that managers who use computers earn 14 percent higher wages while secretaries who use computers earn 6-9 percent higher wages. He also examined the effects on wages of particular applications performed on computers and found that workers who used electronic mail were the most highly rewarded.

Doms, Dunne, and Troske (1997) used firm-level data to examine the effects of the introduction of new technologies used in manufacturing (as distinct from computers used in white-collar occupations) on workers' wages and occupation mix. Using a cross-section, they found that "high-tech" firms employ more educated workers and pay them more. They also estimated separate regressions for production workers, technical, clerical and sales workers and managerial and professional workers. For the first two groups, but not for managers and professionals, they found a correlation between the number of new technologies introduced and education level. However, in time-series analyses, they do not find evidence that the introduction of new technologies leads to skill upgrading or changes in the wage structure. Therefore, they concluded that firms with higher-skilled employees are more likely to introduce new technologies.

Using a 1999-2000 panel of workers surveyed in the Canadian Workplace-Employee Survey (WES), we re-examine the issue of whether workers receive a wage differential for computer use. The panel attribute allows us to control for selection into computer use. By separately examining various subsets of workers according to occupation, education level or software use, we can further assess whether the returns for computer use are the same for all jobs. In addition, we examine whether workers pay a share of the costs of technology training and whether this affects the wage premium for computer use in the first year since adoption.

In the next section, we discuss the WES and present some descriptive statistics on computer users in Canada. In section III we estimate cross-section wage equations for comparison with Krueger's (1993) estimates. We then present results from both individual and firm fixed-effects estimations, which allow us to control for unobserved worker or establishment heterogeneity. Section IV shows the differences in returns to computer use depending on the worker's occupation, education level and type of application used. Section V considers the effects of formal training. Section VI concludes the paper.

II. Data

The data come from the Canadian Workplace and Employee Survey (WES). This survey was initially conducted in 1999. Establishments are being followed each year while employees are followed for only two years and then resampled. For our analysis, we use a panel of employees with their matched employer information from 1999 and 2000 – the data currently available. The panel aspect of the data allows us to control for unobserved individual heterogeneity.

In the 1999 WES, 23,540 employees responded to the survey. First, establishments were chosen from employers in Canada with paid employees in March of the survey year with the exception of the Yukon, Nunavut, and Northwest Territories and "employers operating in crop production and animal production; fishing, hunting, and trapping; private households, religious organizations and public administration" (Statistics Canada 2002, 23). At each establishment, a maximum of twelve paid employees were randomly sampled from a list of employees. All employees were selected in establishments with fewer than four employees. In the 2000 WES, 20,167 of the employees who responded in 1999 were still employed in the same company and responded to the follow-up survey. For the purposes of our analysis, we use a restricted sample of those employees who responded in both years. Sample means and proportions for the data are in Table A1 in the Appendix.

This survey is rich in questions concerning the use of technology by establishments and their employees. One of the central variables in our study is computer use by employees. Specifically, employees were asked "Do you use a computer in your job? Please exclude sales terminals, scanners, machine monitors, etc." Table 1 describes the proportion of workers who used a computer in 1999 and 2000.[1] More than 60 percent of Canadian workers used computers at work in 2000, which is larger than the 46.6 percent reported for U.S. workers in 1993 by Autor, Katz, and Krueger (1998). Women

[1] Survey means and proportions throughout the paper have been weighted using the sampling weights.

were more likely than men to use a computer in either year. In 2000, 68 percent of women and 61 percent of men used a computer. In both years, employees aged 25-54 (approximately 68 percent in 2000) were much more likely to use a computer than the youngest employees aged 18-24 (46 percent in 2000) and employees aged 55+ (57 percent in 2000). By occupational groupings, managers, professionals, and clerical/administrative employees were the biggest computer users, with approximately 88 percent of these workers using a computer in 2000. Non-union members were more likely to use a computer than union members and full-time workers were more likely to use a computer than part-time workers. Though the percentages are larger in magnitude, the relative computer use by demographic groups is similar to that reported by Krueger (1993) for the United States.

Employees were also asked about their experience with computers, the types of applications used, the number of hours per week spent using their computer, and the number of different technologies they have used, such as industrial robots or computer-aided design (CAD) systems. Table 2 presents means and proportions for selected technology-related questions from the WES. In both 1999 and 2000, 10 percent of employees did not use a computer but had some prior experience with computers. Among employees who used a computer, the majority were experienced computer users. In 2000, 53 percent had used a computer for three or more years while 37 percent had used a computer for seven or more years. On average, computers users spent half of their work week using computers (about 20 hours per week) and 1.7 different applications. On average, employers reported that 53 percent of their employees used computers. Besides computers, 15 percent of employees used computer-assisted technology, such as industrial robots or CAD, and 26 percent used other technology or machinery, such as cash registers or sales terminals.

The respondents were also asked which software application they used most, in terms of time of use. Table 3 presents the proportion of workers by the primary type of software application they used, by occupation. The most common primary applications used in 2000 were specialized office applications and word processors; however, there are significant differences in the most frequently used primary applications by occupation (Table 3). Managers are most likely to use word processors as a primary application, followed by communications software and specialized office applications. Professionals were most likely to use word processors, followed by specialized office applications and communications software. Technical and trade workers were most likely to use specialized office applications, followed by word processors and spreadsheets. Marketing and sales workers were most likely to use specialized office applications, followed by databases and management applications. Clerical and administrative workers were most likely to use specialized office applications, followed by word processors, and databases. Production workers were most likely to use specialized office applications, followed by communications software and databases. Computer usage is thus a fairly heterogeneous concept across workers.

III. Wage Differential for Computer Use

A. Cross-section estimation

In this section, we estimate cross-section wage equations including either the computer use variable or the hours spent per week using a computer as the variable of interest. Specifically, we estimate:

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

where W_i is individual i's hourly wage rate; X_i is a vector of observed characteristics of i; C_i is an indicator variable equaling one if i uses a computer, and zero otherwise or, alternatively, the hours spent per week using a computer; β and α are parameters to be estimated; and ε_i is a stochastic disturbance term assumed to follow a normal distribution.

Table 4 reports results for cross-section regressions using the 2000 data, estimated by ordinary least squares.[2] In column I, we include the computer use indicator variable and employee demographic variables similar to those used in Krueger (1993): years of education, potential experience, potential experience squared, part-time status, marital status, gender, gender interacted with marital status, is a union member, regional dummies, and five occupational dummies.[3] Although Krueger also includes a race indicator and a Hispanic ethnicity indicator, these are not present in the Canadian data. Instead, we use an indicator for having parents or grandparents who descended from non-European countries and one for whether the employee spoke a different language at work than at home. Results from this regression indicate a wage differential for computer use of 22 percent (exp(.195)-1). This result is slightly higher than the 17.6 percent found by Krueger (1993) in 1989.

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[2] Results are similar for the 1999 data and are available upon request from the authors. The sample is also restricted to those who were present in both years of data and who worked with the same employer in both years.

[3] It may be inappropriate to include occupational dummies in these regressions because employees with computer skills may be more likely to obtain jobs in higher paying occupations (Krueger 1993). Results were similar excluding occupational dummies.

In column II, we attempt to control for establishment heterogeneity by adding employer characteristics, such as the log(size of establishment) and the percentage of computer users in the firm. We also include the worker's tenure with the establishment. These characteristics may be important determinants of the wage but were unavailable in the CPS and were thus omitted in regressions by Krueger (1993). These additional controls reduce the wage differential for computer use to 17.9 percent.

In column III, we examine the effects of intensity of computer use on wages conditional on using a computer, by substituting the number of hours spent using a computer for whether or not the employee used a computer on the job. If computer use increases productivity, then the intensity of use should have a positive effect upon wages, at least initially or to some threshold level. Results show that for each hour of computer use, wages increase by 0.08 percent.

B. Controlling for Heterogeneity

Other researchers[4] have found that the wage differential for computer use is greatly diminished or no longer exists when they have controlled for unobserved individual heterogeneity. Using our 1999-2000 panel of Canadian employees matched with their employers, we, alternately, control for individual and establishment heterogeneity.[5] First we estimate the following equation by fixed effects:

$$\ln W_{ijt} = \delta_j + X_{it}\beta + C_{it}\alpha + \varepsilon_{ijt} \quad (2)$$

where δ_j is an establishment-specific effect assumed to be constant over time; X_{it} are time-varying observables for employee *i*; C_{it} is time-varying computer use for employee *i*;

[4] See, for example, Entorf and Kramarz (1997), Entorf, Gollac and Kramarz (1999) and Bell (1996).
[5] It is not possible to control for both at the same time since no employees were observed to have different employers in the two years.

β and α are parameters; and ε_{ijt} is a stochastic disturbance term assumed to follow a normal distribution. If some characteristic of firms results in both extensive computerization and also higher wages (regardless of computer use), then including establishment effects will diminish the size of the computer wage premium measured for individual workers.

There may also be unobserved worker characteristics, such as ability, that make computer-users different from other workers. If these unobservables are correlated with wages, wage differentials would be incorrectly attributed to computer use. To check this, we estimate the following first-differenced model:

$$(\ln W_{i,t-1} - \ln W_{i,t}) = (X_{i,t-1} - X_{i,t})\beta + (C_{i,t-1} - C_{i,t})\alpha + (\varepsilon_{i,t-1} - \varepsilon_{i,t}) \qquad (3)$$

Many of the demographic variables from Table 4 are time invariant and so do not appear in the first-differenced model. However, education does change for quite a few workers, possibly due to measurement error in one or both of the years. Additionally, marital status, work-home language differences, part-time status, and union membership can change from one year to the next for some workers. We capture transitions into and out of computer use by expanding the computer use variable into three indicators: those who adopted a computer between 1999 and 2000, those who ceased using a computer over that time period and those who used a computer consistently throughout the period. Thus the omitted reference category is the group of workers who did not use a computer in either period.

Table 5 shows the effects of controlling for, alternately, firm heterogeneity or individual heterogeneity. Column I reports results from equation (2). The estimate of the effect of computer use on wages is reduced to 8.8 percent, showing that some unobserved establishment characteristics correlate with both computer use and wages[6]. Thus those who use computers work for higher-paying companies. Column II reports results from estimating equation (3). By utilizing the panel data set, we capture movements both into and out of computer use over a one year period. In this case, the effect of computer use on wage growth for the average worker in the first year of adoption is a smaller but still statistically (and economically) significant four percent. This result is somewhat larger than that found by Haisken-DeNew and Schmidt (1999), although their measure is a combined effect of all movements into or out of computer use, while ours is specifically a measure of the return to adopting a computer. In fact, the coefficient on ceasing to use a computer is not statistically significantly different from zero. The small wage premium in our panel does not necessarily indicate returns for computer use are this small but merely that returns to the worker in the first year of computer use are small. Returns might be small in the first year if employers pass along some or all of the costs of training onto the workers. We will examine this further in section V.

IV. Wage Differential for Computer Use by Occupation and Detailed Technology Uses

The evidence thus far implies that the average worker does not earn the high wage premiums initially associated with computers--at least in the short run. Nevertheless, particular workers may earn higher returns than this average. Specifically, we would expect to find that workers whose skills are complements to computer technologies may

[6] In additional specifications not shown here, we have attempted to identify which establishment characteristics might be important, using the linked employer files. The combined effect of all relevant *observable* establishment variables reduces the computer wage premium only a few percentage points.

earn a positive wage premium, while workers whose skills are substitutes may earn a negative wage premium.

We look for evidence of such differential effects by re-estimating regressions for workers separately by occupational groups. While the Workplace and Employee Survey does not provide detailed occupational information on workers, it does contain a variable for broad occupation groups: managers, professionals, technical and skilled production workers, marketing and sales, clerical and administrative workers, and unskilled production workers with no trade or certification. Results for these groups are reported in Table 6. In the cross-section (column I), all workers earn a positive wage premium for computer use, but there is no particular pattern across types of workers. The inclusion of establishment fixed-effects (column II) reduces the size of the wage premium for all workers except managers. Especially noticeable are the marketing and sales workers, who had the highest premium in the cross-sectional estimation and zero premium once fixed effects are included. Retail establishments may be heavily computerized and also pay higher wages, but that wage premium is not in fact a return to computer use by the worker. Column III reports the results of first-difference models. Here the dependent variable is the two-year wage growth, and the sample is restricted to those who were in the same occupation both years. Even controlling for individual heterogeneity, managers earned 7.3 percent higher wages in the first year of computer use, while professionals and technical/trade workers earned 4.7 percent and 4 percent, respectively. The remaining occupation groups, however, earned no wage premium at all for adopting computers.[7] This result accords with our expectations, since the white collar workers are likely to

[7] In Appendix Table A2, we document demographic characteristics of workers who transition into or out of computer use.

possess more problem-solving skills than other workers. If, as suggested by Autor, Levy, and Murnane (2002), computers are a complement to high-skilled workers and a substitute for low-skilled workers, it makes sense that the adoption of computers would affect the wages of these groups of workers differently. Clearly, estimations of the wage effect for the average worker will blur these important differences between types of workers.

A second way to test whether there are differential effects of computerization for particular types of workers is to re-estimate the model separately by educational group. We divide the sample into those workers with less than a high school diploma, with only a high school diploma, with some college or a vocational degree, with a Bachelor's degree and those with advanced degrees. Table 7 shows the results for these education groups. As with the occupational groups, no clear pattern emerges from the cross-section model, but the inclusion of establishment fixed effects greatly reduces the size of the wage premium for computer use. In the first-differenced model, wage premiums are quite high for workers with college degrees, still positive for those with some college or a vocational degree, and zero for those with only high school or less.

Another source of heterogeneity that may affect the returns on technology use stems from the different tasks that a worker performs with that technology. As Autor, Levy and Murnane (2002) showed, technology may complement a worker who performs problem solving tasks, but may be a substitute for a worker who performs repetitive tasks. If this is the case, then it may be important to look at more detailed questions of technology use. To do this, we estimate equations similar to (1), (2) and (3), but add to the set of independent variables a set of indicators for which software application the worker used primarily. While the respondents were free to answer any specific application, the answers were then grouped into one of fourteen types of software applications listed in Table 3. We include thirteen of these categories in the independent variable list, leaving specialized office programs--an especially low-skill software type--as the reference group. In addition, we re-estimate the equations for two other types of technology--computer-aided tools (e.g. industrial robots) and other technologies (e.g. cash registers and scanners). Finally, as an additional measure of heterogeneity in technology use, we estimate how the number of software types used by the worker, conditional on computer use, affects the wage rate.

Results of these estimations are in Table 8. The cross-section results suggest that there are indeed differences in the return to technology use across types of technologies. Computer-aided tools, other machines and database, desktop publishing and other software are negatively correlated with workers' wages. Word processing, spreadsheets, communications, programming and data analysis software are positively correlated with the wages of users. In addition, workers who use multiple types of software earn higher wages. With the inclusion of establishment fixed effects, many of these effects become smaller and many are no longer statistically significant. In the first-differenced model, only the other software category is statistically significant. However, the variance for these coefficients comes from individual workers who adopt a new computer and this particular software between the first and second year. The number of workers in each group is quite small, causing quite high standard errors. Thus while the estimates in the first-differenced model are quite noisy, there do appear to remain some differences in the wage premium depending upon the type of application adopted. The scientific applications, such as programming, data analysis and expert systems have fairly large, positive wage premia, while communications has dropped to nearly zero from a very large result in the cross-section. This implies that a particular kind of worker whose high skill is unmeasured by our other variables is likely to use mainly communications software. The three different groupings of workers--by occupation, by education and by software application used--seem to largely confirm the findings of Autor, Levy and Murnane (2001) that technology can affect workers differently.

V. Training

One reason the first-differenced model might yield small estimates of the return to computer use is that it measures the wage changes within the first year of adopting a computer--it is only for those workers who experience a change in computer use that we can control for individual heterogeneity. In the first year, however, there may be high learning costs. While some of these will be paid by the employer, workers may share in these costs, since these are mostly general skills rather than firm-specific, and can thus be transported by the worker should he change jobs. Additionally, the size of these learning costs and the extent to which workers share the costs may vary across types of workers. If, for example, low-skill workers require more learning to master the computer, then it might take longer for any premium to be reflected in their wages, relative to higher-skilled or more highly educated workers.

While we do not have a long panel with which to test this idea, we do have information on whether the worker who adopted a computer received formal training provided by the employer[8]. In Table 9, the first-differenced model is re-estimated with an interaction term between the computer adoption indicator and an indicator for whether the worker received formal training. If the worker pays a share of the training costs in terms of slower wage growth during the learning period, this would be reflected in a negative sign on the coefficient of the interaction term. As Table 9 shows, this is the case for the average workers as well as for many of the skill subsets of workers. Notably, managers do not earn lower wages when they receive training in computers. There is some evidence that the sharing of these costs is especially high for particular groups of workers, although the pattern is not clearly related to skill level. It is important to keep in mind that although the first-differencing method controls for worker heterogeneity that affects, for example, wages in both periods, it does not control for unobservables that might cause one worker to receive training in the second period and another worker not to receive the training. Thus, although the large negative effect for workers who hold advanced degrees is somewhat surprising, it is likely that many holders of advanced degrees do not require formal training and those who do require it are different in some important unobservable way.

What is important to learn from this table is that the size of the wage premium for those who do not receive formal training is larger for several of the low-skilled groups than in the models that do not control for training. It is plausible that if we observed workers a few years after adopting computers, their wages would be higher than similar workers who did not adopt a computer between 1999 and 2000. In fact, the effect should

[8] The survey question on training refers specifically to what type of training (if any) the respondent received to learn the software application he/she uses most.

be larger than was measured here, since much of the learning costs are not reflected in formal training but in the on-the-job experience at using the computer.

VI. Conclusion

In this paper, we examine the issue as to whether or not there is a return for using a computer using the 1999-2000 panel of the Canadian Workplace and Employer Survey. In a cross-section wage regression, we find a wage differential of 16.5 percent. When these regressions are re-estimated on the 1999-2000 panel, the wage differential for the first year of adoption is a small but statistically significant 4 percent. This may not mean there is very little return on computer use, but rather that the return is small in the first year. This panel estimate of a small return for computer use also blurs important differences between types of workers and returns for using different types of technologies. We find that technical workers, professionals and managers earn 4-7 percent higher wages in the first year of computer use while other occupation groups earn no wage premium for adopting computers. Similarly, workers with a Bachelor's or advanced degree earn 10-18 percent higher wages, while those with some college or a high school diploma earn around 3 percent and those with less than high school do not earn a premium at all. Finally, we find that workers who adopt a computer for scientific applications earn significant wage premiums relative to those who adopt a computer for less skill-intensive applications. Workers who use other machinery or computer-controlled technology do not earn a return when we control for individual heterogeneity. These results suggest that computers are a complement to high-skilled workers performing problem solving tasks and a substitute for low-skilled workers performing repetitive tasks.

We also examine to what extent these results may reflect differences across employees in the costs of learning the new technology and the sharing of these costs between employers and employees. We find a negative effect associated with receiving training in the new computer, which suggests either that the workers pay for this in terms of slower wage growth or that workers who receive training are different in some important unobservable way. Controlling for training does increase the size of the wage premium for computer use for many of the low-skilled groups whose premia were small or zero in previous models. Thus we speculate that we would observe wage gains from computer use for most workers given appropriate data to test for long-run effects.

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Table 1. Computer Usage Among Employees in the 1999 and 2000 Canadian Workplace and Employee Survey*		
	1999 workers	*2000 workers*
Total	.62	.65
Men	.59	.61
Women	.65	.68
European	.60	.63
Non-European	.63	.65
Ages 18-24	.45	.46
Ages 25-39	.67	.68
Ages 40-54	.65	.67
Ages 55+	.50	.56
Managers	.84	.88
Professionals	.85	.87
Technical/trades	.48	.50
Marketing/sales	.42	.47
Clerical/admin	.86	.88
Production/no trade	.19	.21
Union member	.52	.55
Non-union member	.66	.69
Full-time	.67	.68
Part-time	.46	.50
Number of Obs.	20,167	20,167

* The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Proportions are weighted.

Table 2. Selected Technology-Related Characteristics of Workers*		
	1999 workers	*2000 workers*
Computer experienced non-user	.1091	.1036
<1 year computer experience	.0186	.0013
1 year computer experience	.0369	.0304
2 years computer experience	.0433	.0381
3 years computer experience	.0423	.0307
4 years computer experience	.0382	.0358
5 years computer experience	.0504	.0520
6 years computer experience	.0376	.0400
7+ years computer experience	.3547	.3721
Hours per week spent at computer	11.86 (.2807)	12.68 (.3027)
Hours per week spent at computer (conditional on using a computer)	19.06 (.2992)	19.62 (.3138)
Number of applications	1.647 (.0409)	1.700 (.0414)
Computer users in employee's workplace	.4674	.5266
Computer-assisted technology	.1201	.148
Other technology	.2687	.2624

* *Source*: 1999 and 2000 Canadian Workplace and Employee Survey.The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Means are calculated using employee weights.

Table 3. Primary Use of Computer Applications by Workers, by Occupation*

	All	*Manager*	*Professional*	*Technical*	*Sales*	*Clerical*	*Production*
Word processing	.1274	.1846	.3011	.0806	.0150	.1820	.0105
Spreadsheets	.0646	.1403	.0921	.0562	.0144	.0678	.0089
Databases	.0665	.0918	.0746	.0474	.0973	.1244	.0299
Desktop publishing	.0071	.0143	.0124	.0053	0	.0095	0
Mgmt. applications	.0181	.0297	.0137	.0187	.0218	.0258	.0025
Communications	.0626	.1799	.0999	.0373	.0163	.0408	.0328
Programming	.0079	.0046	.0233	.0055	.0112	.0055	0
Specialized office	.1362	.1421	.1307	.1248	.1491	.2597	.0992
Data analysis	.0040	.0034	.0125	.0026	.0058	.0013	.0001
Graphics	.0066	.0099	.0094	.0082	.0012	.0051	.0002
Computer-aided design	.0047	.0064	.0100	.0054	.0015	.0012	0
Computer-aided engr.	.0034	.0041	.0050	.0042	.0064	0	.0001
Expert systems	.0094	.0118	.0066	.0128	.0050	.0133	.0006
Other	.0815	.0603	.0821	.0850	.1310	.1412	.0235

* *Source*: 2000 Canadian Workplace and Employee Survey.The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Means are calculated using employee weights. Communications includes e-mail and web browsers.

Table 4. Determinants of Wages, Ordinary Least Squares Estimations*			
	I	II	III
Computer use (1=yes)	.1953* (.0070)	.1651* (.0069)	
Hours using computer/week conditional upon using a computer			.0008* (.0003)
Years of education	.0567* (.0016)	.0542* (.0016)	.0632* (.0020)
Potential experience	.0272* (.0010)	.0229* (.0010)	.0260* (.0013)
Potential experience^2	-.0435* (.0020)	-.0410* (.0020)	-.0462* (.0027)
Non-European background	-.1067* (.0095)	-.1027* (.0093)	-.0834* (.0114)
Spoke different language at work than home	-.0500* (.0108)	-.0498* (.0105)	-.0438* (.0131)
Part-time	-.0694* (.0089)	-.0447* (.0087)	-.0118 (.0115)
Married	.1112* (.0081)	.1016* (.0079)	.1145* (.0102)
Female	-.1612* (.0093)	-.1580* (.0091)	-.1248* (.0113)
Female*married	-.0790* (.0115)	-.0721* (.0113)	-.0962* (.0137)
Union member	.1055* (.0063)	.0320* (.0067)	-.0378* (.0085)
Tenure		.0080* (.0004)	.0079* (.0005)
Ln (establishment size)		.0305* (.0016)	.0384* (.0019)
Establishment computer users		.0097* (.0026)	.0110* (.0032)
Adjusted R^2	.4170	.4437	.4215
Number of observations	19,364	19,364	12,989

* *Source*: 2000 Canadian Workplace and Employee Survey. The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Standard errors are in parentheses. The regressions also include full sets of occupation and region indicators. Asterisk indicates $p<.05$.

Table 5. Determinants of Wages, Additional Controls for Establishment and Worker Heterogeneity*		
	Establishment Fixed-Effect Model	*First-Differenced Model*
Computer use (1=yes)	.0877* (.0076)	--
Adopted computer in 2000	--	.0400* (.0098)
Used computer in both periods	--	.0411* (.0054)
Ceased computer use in 2000	--	.0038 (.0123)
Years of education	.0416* (.0017)	-.0002 (.0017)
Potential experience	.0181* (.0010)	--
Potential experience^2	-.0314* (.0020)	--
Non-European background	-.0609* (.0097)	--
Spoke different language at work than home	-.0300* (.0108)	-.0134 (.0103)
Part-time	.0333* (.0097)	.1021* (.0080)
Married	.0750* (.0078)	.0659* (.0119)
Female	-.1054* (.0093)	--
Female*married	-.0548* (.0111)	-.0389* (.0181)
Union member	-.0171 (.0090)	.0595* (.0093)
Tenure	.0060* (.0004)	--
R^2	.3757	.0198
Number of observations	19,364	

* *Source*: 1999 and 2000 Canadian Workplace and Employee Survey.The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Standard errors are in parentheses. The first model includes region and occupation indicators; the second includes only occupation indicators. Asterisk indicates p<.05.

Table 6. Effect of Computer Use on Wages, by Occupation Group*			
	Cross-Section Model	*Establishment Fixed-Effect Model*	*First-Differenced Model*
Managers	.1672* (.0300) (N = 2,713)	.1740* (.0631) (N = 2,713)	.0730 (.0392) (N = 2,477)
Professionals	.0963* (.0244) (N = 2,947)	.0487 (.0363) (N = 2,947)	.0465 (.0354) (N = 2,660)
Technical/trade	.1715* (.0088) (N = 8,678)	.0959* (.0107) (N = 8.678	.0404* (.0128) (N = 8,143)
Marketing/sales	.2645* (.0365) (N = 697)	-.0353 (.0702) (N = 697)	-.0009 (.0586) (N = 603)
Clerical/admin.	.1407* (.0192) (N = 3,111)	.0569 (.0317) (N = 3,111)	.0131 (.0310) (N = 2,899)
Production/no trade	.1216* (.0236) (N = 1,218)	.0826* (.0423) (N = 1,218)	.0268 (.0365) (N = 1108)

* *Source*: 1999 and 2000 Canadian Workplace and Employee Survey.The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years, and in the case of the first-differenced model, remained in the same occupation both years. Standard errors are in parentheses. The first model includes region and occupation indicators. Asterisk indicates $p<.05$.

Table 7. Effect of Computer Use on Wages, by Education Group*			
	Cross-Section Model	*Establishment Fixed-Effect Model*	*First-Differenced Model*
Advanced degree (N = 1,056)	.1638* (.0522)	.0500 (.1063)	.1757 (.0744)
Bachelor's degree (N = 2,543)	.1981* (.0292)	.0624 (.0539)	.1063* (.0390)
Some college/vocational degree (N = 10,367)	.1710* (.0089)	.0914* (.0108)	.0314* (.0130)
High school graduate (N = 3,280)	.1978* (.0150)	.1111* (.0258)	.0339 (.0205)
Less than high school graduate (N = 2,118)	.1040* (.0190)	.0688* (.0350)	.0198 (.0267)

* *Source*: 1999 and 2000 Canadian Workplace and Employee Survey.The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years, and in the case of the first-differenced model, remained in the same occupation both years. Standard errors are in parentheses. The first model includes region and occupation indicators. Asterisk indicates p<.05.

Table 8. Effects of Specific Technology Use on Wages*			
	Cross-Section Model	*Establishment Fixed-Effect Model*	*First-Difference Model*
Computer-aided technologies	-.0154 (.0081)	.0099 (.0080)	-.0053 (.0076)
Other technologies	-.0388* (.0064)	-.0067 (.0063)	-.0036 (.0062)
Main application used (conditional on computer use)			
Word processing	.0452* (.0100)	.0266* (.0100)	.0352 (.0231)
Spreadsheets	.0465* (.0117)	.0174 (.0116)	-.0163 (.0284)
Databases	-.0086 (.0121)	-.0168 (.0118)	.0158 (.0264)
Desktop publishing	-.0636* (.0326)	-.0239 (.0322)	.1690 (.1111)
Mgmt. applications	.0299 (.0202)	.0116 (.0197)	-.0110 (0508)
Communications	.1434* (.0124)	.0889* (.0123)	.0307 (.0287)
Programming	.1120* (.0305)	.0359 (.0302)	.0578 (.0849)
Specialized office	omitted	omitted	omitted
Data analysis	.0882* (.0368)	.0572 (.0346)	.0719 (.1039)
Graphics	.0452 (.0285)	.0254 (.0283)	-.0549 (.0695)
Computer-assisted design	.0385 (.0316)	.0064 (.0312)	-.0078 (.0816)
Computer-assisted engineering	.0327 (.0471)	.0374 (.0449)	-.0175 (.1199)
Expert systems	-.0195 (.0264)	-.0240 (.0251)	.0542 (.0579)
Other	-.0270* (.0117)	-.0260* (.0113)	-.0558* (.0225)
Number of Software Apps (conditional on computer use)	.0220* (.0017)	.0081* (.0018)	.0006 (.0012)
Number of Observations	19,364		

* *Source*: 1999 and 2000 Canadian Workplace and Employee Survey. The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Standard errors are in parentheses. Asterisk indicates p<.05.

Table 9. Effect of Formal Training on the Computer Adoption Wage Premium in 1999 and 2000 Canadian Workplace and Employee Survey*		
	Computer adopter	*Training interacted with computer adopter*
All workers	.0492* (.0109)	-.0394 (.0209)
By occupation group:		
Managers	.0618 (.0419)	.0638 (.0844)
Professionals	.0591 (.0399)	-.0456 (.0665)
Technical/trade	.0458* (.0144)	-.0232 (.0282)
Marketing/sales	.0295 (.0643)	-.1490 (.1295)
Clerical/admin.	.0185 (.0340)	-.0254 (.0653)
Production/no trade	.0314 (.0407)	-.0217 (.0858)
By education group:		
Advanced degree	.1933* (.0786)	-.1232 (.1766)
Bachelor's degree	.1246* (.0427)	-.0800 (.0761)
Some college/vocational degree	.0389* (.0149)	-.0271 (.0261)
High school graduate	.0326 (.0222)	.0078 (.0502)
Less than high school graduate	.0455 (.0294)	-.1306* (.0634)

* Each row represents a separate first-differenced estimation for the group. The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Standard errors are in parentheses. Asterisk indicates $p<.05$.

Table A1. Selected Characteristics of Employees in the 1999 and 2000 Canadian Workplace and Employee Survey*		
	1999 workers	*2000 workers*
Log wage	2.795 (.0106)	2.830 (.0113)
Years education	13.77 (.0444)	13.72 (.0397)
Potential experience	19.85 (.2151)	20.65 (.2226)
Tenure	8.657 (.1573)	9.135 (.1635)
Non-European	.1317 (.0070)	.1319 (.0074)
Spoke different language at work than home	.0786 (.0042)	.0779 (.0044)
Part-timer	.2111 (.0080)	.1846 (.0078)
Married	.5797 (.0088)	.5762 (.0094)
Female	.5286 (.0088)	.5307 (.0090)
Union member	.2847 (.0108)	.2691 (.0099)
Managers	.1465 (.0066)	.1454 (.0069)
Professionals	.1696 (.0072)	.1731 (.0069)
Technical/trade	.3880 (.0085)	.3967 (.0085)
Marketing/sales	.0781 (.0062)	.0781 (.0062)
Clerical/admin	.1422 (.0053)	.1342 (.0050)
Production/no trade	.0756 (.0060)	.0725 (.0059)

* The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Means are calculated using employee weights.

Table A2. Selected Characteristics of Employees in the 2000 Canadian Workplace and Employee Survey*, by Computer Use Transition since 1999.				
	Continued Use	*Adopted Computer*	*Ceased Computer Use*	*Continued Non-Use*
Years education	14.30 (.0496)	13.30 (.1262)	13.22 (.2090)	12.84 (.0582)
Female	.5555 (.0107)	.5153 (.0358)	.4454 (.0509)	.4810 (.0175)
Part-time status	.1284 (.0074)	.2545 (.0333)	.1889 (.0321)	.2717 (.0171)
Tenure	9.618 (.2114)	7.726 (.5134)	7.326 (.8430)	8.691 (.2492)
Managers	.2090 (.0093)	.1214 (.0272)	.0833 (.0262)	.0434 (.0099)
Professionals	.2413 (.0095)	.1501 (.0252)	.1221 (.0273)	.0530 (.0060)
Technical/trade	.2928 (.0093)	.3987 (.0330)	.5235 (.0521)	.5719 (.0167)
Marketing/sales	.0494 (.0058)	.1371 (.0299)	.0935 (.0264)	.1201 (.0138)
Clerical/admin.	.1922 (.0074)	.0988 (.0175)	.0697 (.0197)	.0432 (.0053)
Production/no trade	.0152 (.0050)	.0939 (.0245)	.1079 (.0329)	.1684 (.0130)
Promoted in past year	.1338 (.0075)	.1619 (.0254)	.0718 (.0163)	.1152 (.0095)
Union member	.2326 (.0116)	.3478 (.0352)	.3420 (.0547)	.3729 (.0214)
1999 ln(wage)	2.939 (.0128)	2.603 (.0408)	2.650 (.0398)	2.588 (.0170)
Number Observations	11893	1,094	635	5,735

* The sample is restricted to those employees who responded to the survey in both years and also remained with the same employer for both years. Means are calculated using employee weights.