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Economics Letters 82 (2004) 43–51
economics letters
www.elsevier.com/locate/econbase

Computer use and wages: evidence from Taiwan

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Received 15 April 2002; received in revised form 27 May 2003; accepted 24 July 2003

Abstract

We find a significant positive relationship between computer use and wages using Taiwan microdata. Controlling for endogeneity of computer use with simultaneous equations suggests that, although OLS estimates are biased upward, workplace computer use increases productivity.
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Keywords: Computer use; Wages; Productivity

JEL classification: J24; J31

1. Introduction

Over the past decade much research has focused on the impact of technological change on the wage structure. The technology-skill complementarity hypothesis asserts that as new technologies are installed, the relative demand for skilled workers increases and average wages tend to increase. Alternatively, the causation may be reversed: highly paid skilled workers are more likely to use advanced technologies.

Most empirical studies have investigated the wage-technology relationship in developed countries, but the issue has received little attention in the developing and newly industrializing countries. A number of recent papers use individual or plant-level data to study the wage impacts of technological change and

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0165-1765/$ - see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.econlet.2003.07.001

find a positive relationship between technology use and wages. Utilizing US data and various estimation techniques, Krueger (1993) finds that workers who use computers at work earn 10–15% more than nonusers after controlling for worker attributes. Dunne and Schmitz (1995), Doms et al. (1997), and Haskel (1999) show that technologically advanced plants pay higher wages and employ a greater fraction of skilled workers in the United States and United Kingdom. Liu et al. (2001) use a survey of manufacturing firms and confirm this result in Taiwan.

Other literature suggests that highly paid skilled workers are more likely to use advanced technologies. Oosterbeek (1997) uses a longitudinal sample of workers from the Netherlands and supports the view that the return from computer use can be attributed to unobserved heterogeneity among individuals. Chennells and Van Reenen (1997, 1998) control for endogeneity of technology adoption at plants and find that higher wages have a positive effect on the likelihood of introducing advanced technologies rather than advanced technologies increasing wages. Similarly, using matched employer–employee data, DiNardo and Pischke (1997) and Entorf and Kramarz (1997) suggest that worker quality rather than productivity enhancement drives the technology–wage correlation in Germany and France. Abowd et al. (1999) also confirm that personal effects are the major source of wage variation in France.

The purpose of this study is to provide direct evidence of the effect of computer use on wages. Utilizing micro-level data from the 1999 Taiwan Social Change Survey, we examine the simultaneous relationship between computer use and wages. Unlike prior work, we use information on worker attitudes toward technology to identify the direction of causality. Our empirical findings suggest that computer use at work is strongly and positively associated with wages. Controlling for the endogeneity of computer adoption, the correlation remains significant in the simultaneous-equation model. Our results are largely consistent with the productivity interpretation proposed by Krueger (1993).

The remainder of the paper is organized as follows. Section 2 describes the data source. In Section 3, we describe the empirical model specification. Section 4 summarizes computer ownership and computer use among demographic groups. In Section 5, we analyze the empirical results. Conclusions follow in Section 6.

2. Data

The data used in this study are drawn from the 1999 Taiwan Social Change Survey (Year 5 of Cycle 3) sponsored by the Taiwan National Science Council.[1] The data were collected through in-person interviews with questionnaires focusing on cultural values. The original sample contains 1948 individuals aged 20–70. For each respondent, the data contain demographic characteristics, including gender, age, education, income, occupation, and whether the respondent owns a home computer. The data also provide information on computer use and personal attitudes toward technology, including the ownership of various electronic goods, the purposes for which the respondent uses a computer, and variables characterizing the respondent's attitude toward modern technology. After deleting respondents with missing values on demographic variables (age and education), 1922 observations remain for

[1] The survey was conducted by the Institute of Sociology and the Office of Survey Research, Academia Sinica.

analysis. Of these, 1214 worked for a wage during the year and are retained for analysis. The major limitation of our cross-sectional data is that we cannot estimate the returns from computer use controlling for individual fixed effects, which can be examined using panel data.

3. Empirical models

A major concern in interpreting the relationship between computer use and wages is the inability to control for unobserved worker heterogeneity. If more skilled workers or more highly paid workers are more likely to use computers, the estimated effect of computer use on wages may be biased upward. Recognition of this endogeneity implies that computer use and wages must be modeled simultaneously. We extend the previous literature by representing individuals' computer use as endogenous. In addition, we account for potential selectivity bias with respect to labor-force participation by including the inverse Mills ratio (λ) using a probit estimation procedure described by Heckman (1976).[2]

The empirical model can be written as follows. The wage equation is

$$\mathrm{LNW}_i = \gamma_1 C_{\mathrm{w}i} + \alpha_1' X_{1i} + \beta_1 \lambda_i + \varepsilon_{1i} \tag{1}$$

The computer-adoption equation is

$$C_{\mathrm{w}i} = \gamma_2 \mathrm{LNW}_i + \alpha_2' X_{2i} + \beta_2 \lambda_i + \varepsilon_{2i} \tag{2}$$

The dependent variable LNW_i in Eq. (1) is the log of average hourly earnings, constructed from monthly earnings and usual weekly hours. $C_{\mathrm{w}i}$ is a binary variable that equals one if a worker uses a computer at work and zero otherwise, and X_{1i} is a vector of observed characteristics. The computer-adoption variable $C_{\mathrm{w}i}$ alternatively represents individual computer use for dealing with personal and home affairs ($C_{\mathrm{h}i}$) or recreational purposes ($C_{\mathrm{r}i}$). The vector X_{1i} includes gender, marital status, three age dummies, four education dummies, nine occupation dummies, and dummy variables representing whether an individual is self-employed and received an award for outstanding performance in school.

Eq. (2) describes the determinants of computer adoption. Computer adoption is anticipated to depend on the wage rate, because highly paid workers are more likely to use computers on the job. Other control variables represented by X_{2i} include gender, martial status, three age dummies, four education dummies, three dummies for other consumer electronics (stereo, VCR, and laser disk), and two variables capturing attitudes toward technology (attitude 1 and attitude 2).

The two attitude variables were constructed by combining responses to several questions. Attitude 1 is based on the respondent's degree of agreement with the following statements: (1) the computer is a necessary instrument at work; (2) computers have much influence in our life; (3) one will be behind the times if he/she does not know how to use a computer; and (disagreement with) (4) it would be a burden if one has to learn more about computer use. Attitude 2 is based on agreement with the following

[2] We estimate a probit regression for labor-force participation. The explanatory variables include age, gender, marital status, number of children, education dummies, mother and father's education dummies.

statements: (1) I will make great efforts to obtain more relevant computer knowledge; (2) I will use a computer to handle more practical issues; and (3) I will try to use a computer for recreational purpose. Degree of agreement was coded as a five point scale ('strongly disagree' (1), 'disagree' (2), 'neither agree nor disagree' (3), 'agree' (4), and 'strongly agree' (5)). The values of the two attitude variables are the average scores of the relevant items.

For the simultaneous-equation estimates of Eqs. (1) and (2), we use exclusion restrictions to satisfy the identification condition. The variables for attitudes toward technology and ownership of other consumer electronics are proxies for unobserved technological sophistication and are anticipated to be correlated with computer adoption but not directly with wage rate. These variables enter the computer-adoption equation but are excluded from the wage equation. Variables for self-employment, occupational level, and receiving an outstanding-performance award in school (a proxy for ability) are anticipated to influence the wage rate directly but to not have a direct effect on computer adoption. We exclude these variables from the computer-adoption equation.

The two-stage estimation method suggested by Maddala (1983) is used to estimate the simultaneous-equation model (Eqs. (1) and (2)). The first stage is to estimate the reduced-form equations of wage and computer adoption, using OLS and probit models, respectively. The second stage is to estimate Eq. (1) by OLS, after the C variable is replaced by the maximum-likelihood estimate of the computer-adoption probability. We calculate the correct asymptotic covariance matrix for the two-stage estimate of Eqs. (1) and (2) using LIMDEP econometric software (Greene, 1995).

4. Computer ownership and computer use by demographic group

Table 1 reports computer ownership and computer use for different demographic groups. The first two columns report the percentage of computer owners and workplace computers users in each category, while the last two columns report the distribution of computer owners and workplace computers users across demographic categories.

As shown in Table 1, 61% of respondents own a computer. Computer ownership was highest among those aged 20–29 and aged 40–49, with about 63% and 71% of people in these two age categories owning a computer. Men own computers more often than women do—64% of men and 60% of women. There is a positive relationship between education and computer ownership. Compared with 43% of people with junior high school education, 89% of people with university (or above) education own a computer. Occupational differences in computer ownership are enormous. Computer ownership is most prevalent among professionals, managers, and clerks (78–89%), intermediate among technicians (70%), and much lower among agricultural workers (29%) and laborers (35%). The third column of Table 1 shows that technicians and clerks account for 18% and 16% of computer ownership, respectively.

With respect to computer adoption, 52% of respondents use a computer at work. As column 2 shows, young people use computers more than older people. Computer use peaks at 72% among 20–29 year olds and drops to 29% among 50–70-year-olds. The link between computer use and education is also strong. Computer use among university (or above) graduates was 93%, which is far higher than among junior-high-school graduates (20%). Similar to the pattern of computer ownership, computer use is most prevalent among managers, professionals, technicians, and clerks (at 77–92%), which account for more than three-fourths of computer usage.

Table 1
Computer ownership and computer adoption by demographic group

	% who		% of	
	Own computers	Use computers at work	Computer owners	Computer users at work
All individuals	61.1	52.2		
Age				
20–29	63.1	71.5	22.9	30.0
30–39	56.8	57.6	29.5	34.7
40–49	70.6	47.3	34.6	27.0
50–70	53.9	29.2	13.1	8.3
Education				
< Junior High	38.8	6.4	13.2	2.6
Junior High	43.1	20.1	10.1	5.4
Senior High	59.4	55.1	29.6	32.2
Junior College	79.0	90.2	22.2	29.3
University +	88.9	92.8	24.9	30.5
Gender				
Male	63.5	53.8	39.0	38.3
Female	59.7	51.3	61.0	61.7
Occupation				
Managers	81.7	79.4	14.1	16.0
Professionals	89.4	92.0	13.8	16.6
Technicians	69.7	77.1	17.6	22.7
Clerks	77.6	88.8	15.7	20.8
Service	58.0	22.7	13.6	6.4
Agricultural	29.2	7.7	2.6	0.8
Craftsmen	40.5	27.0	10.1	8.0
Operators	49.2	30.8	8.0	5.8
Laborers	35.0	16.3	3.7	2.1
Soldiers	66.7	55.6	0.8	0.8

Table 2 reports the descriptive statistics for monthly earnings, weekly hours and the log of average hourly earnings. On average, people who use computers at work earn 11% higher (log) wages than those who do not use computers at work.

Table 2
Descriptive statistics

Variables	Use computers at work	Not use computers at work	All workers
Monthly earnings (NT$)	50,860 (32,528)	32,629 (21,384)	42,203 (29,176)
Weekly hours	47.40 (15.43)	52.22 (20.35)	49.79 (18.02)
Hourly wage rate (NT$/h)	307.50 (312.14)	188.45 (192.70)	250.92 (268.47)
log (hourly wage rate) (NT$/h)	5.50 (0.61)	4.95 (0.74)	5.24 (0.71)

Figures in parentheses are standard deviations. The exchange rate in 1999 was US$1=NT$32.27.

5. Empirical results

5.1. OLS with sample-selection correction

We begin our analysis by performing wage regressions similar to those in Krueger (1993). Table 3 presents the estimates for OLS wage regressions with sample selection correction. The first column reports that the log wage differential for computer use on the job is 0.14 in Taiwan after controlling for the covariates. The estimated coefficient is statistically significant at the 1% level. This result is comparable to estimates for developed countries, where Krueger (1993) and Oosterbeek (1997) estimate proportional wage differentials of 0.16 and 0.11 in the US and DiNardo and Pischke (1997) and Entorf and Kramarz (1997) estimate differentials of 0.17 and 0.16 in Germany and France, respectively.

Our survey inquires about individuals' other purposes for using a computer. Columns (2) and (3) report differentials of 8% and 6% associated with using a computer for personal and home affairs and for recreational activities. While the coefficient of C_{hi} is marginally significant at the 10% level, the coefficient of C_{ri} is not statistically different from zero. Column (4) includes all three computer-use variables. The results suggest that computer use on the job rather than computer use in general is the main source of higher earnings. Individuals who use a computer at work earn about 14% more per hour than those who do not use a computer at all, whereas individuals who use a computer for dealing with personal and home affairs earn only 3% more than those who do not use a computer at all. The estimated premium for individuals who use a computer only for recreational activities is negative, which suggests that using a computer for nonproductive activities does not enhance earnings. These findings are consistent with evidence for the US (Krueger, 1993).

Table 3
The impact of computer adoption on wages (OLS with sample selection correction)

	(1)	(2)	(3)	(4)
Constant	4.310 (21.92)***	4.325 (21.95)***	4.313 (21.84)***	4.315 (21.89)***
C_w	0.143 (3.14)***			0.139 (2.54)***
C_h		0.077 (1.89)*		0.028 (0.50)
C_r			0.057 (1.40)	− 0.022 (− 0.40)
Age 30–39	0.270 (5.23)***	0.272 (5.25)***	0.271 (5.22)***	0.270 (5.21)***
Age 40–49	0.311 (5.10)***	0.314 (5.13)***	0.315 (5.14)***	0.310 (5.06)***
Age 50–70	0.284 (3.68)***	0.283 (3.65)***	0.284 (3.65)***	0.283 (3.65)***
Junior High	0.240 (3.86)***	0.244 (3.93)***	0.245 (3.94)***	0.240 (3.86)***
Senior High	0.362 (5.12)***	0.386 (5.50)***	0.390 (5.54)***	0.362 (5.11)***
Junior College	0.448 (5.32)***	0.485 (5.82)***	0.496 (5.96)***	0.447 (5.27)***
University	0.623 (7.50)***	0.657 (7.94)***	0.667 (8.07)***	0.622 (7.40)***
Male	0.179 (2.21)**	0.176 (2.17)**	0.179 (2.21)**	0.176 (2.19)**
Married	0.070 (1.16)	0.064 (1.05)	0.067 (1.09)	0.069 (1.14)
Self-Employed	0.116 (2.72)***	0.113 (2.65)***	0.115 (2.68)***	0.116 (2.70)***
Award	0.062 (1.42)	0.0640 (1.45)	0.067 (1.52)	0.061 (1.39)
λ	− 0.022 (− 0.11)	− 0.0260 (− 0.13)	− 0.021 (− 0.11)	− 0.023 (− 0.12)
$\overline{R}^2$	0.38	0.38	0.38	0.38

All regressions include dummy variables for nine occupations. Figures in parentheses are *t*-statistics. ***, **, and * represent statistically significant at 1%, 5% and 10% levels, respectively.

Table 4
Determinants of computer adoption and the impact of computer adoption on wages (simultaneous-equation model)

	(1)		(2)		(3)	
	C_w	LNW	C_h	LNW	C_r	LNW
Constant	− 8.782 (− 21.37)***	4.415 (21.34)***	− 4.985 (− 11.05)***	4.424 (21.31)***	− 4.451 (− 10.12)***	4.354 (21.82)***
C_w		0.072 (2.00)**				
C_h				0.061 (1.71)*		
C_r						0.046 (1.48)
LNW	1.237 (13.99)***		0.331 (3.48)***		0.355 (3.83)***	
Age 30–39	− 0.405 (− 6.29)***	0.277 (5.20)***	− 0.293 (− 4.17)***	0.285 (5.31)***	− 0.365 (− 5.34)***	0.283 (5.28)***
Age 40–49	− 0.379 (− 5.11)***	0.312 (4.99)***	− 0.225 (− 2.75)***	0.322 (5.16)***	− 0.401 (− 5.03)***	0.326 (5.19)***
Age 50–70	− 0.570 (− 6.39)***	0.306 (3.78)***	− 0.451 (− 4.60)***	0.309 (3.80)***	− 0.720 (− 7.53)***	0.313 (3.77)***
Junior High	0.088 (1.28)	0.219 (3.35)***	0.126 (1.72)*	0.231 (3.60)***	0.114 (1.54)	0.234 (3.68)***
Senior High	0.673 (7.91)***	0.320 (3.88)***	0.654 (7.16)***	0.351 (4.54)***	0.621 (6.77)***	0.361 (4.76)***
Junior College	1.345 (13.16)***	0.378 (3.46)***	1.256 (11.27)***	0.426 (4.28)***	1.076 (9.66)***	0.452 (4.79)***
University	1.240 (11.01)***	0.548 (4.98)***	1.489 (12.28)***	0.584 (4.13)***	1.439 (11.86)***	0.609 (6.07)***
Male	− 0.371 (− 4.36)***	0.183 (2.20)**	0.030 (0.32)	0.174 (2.12)**	− 0.213 (− 2.31)**	0.186 (2.27)**
Married	− 0.224 (− 3.39)***	0.079 (1.26)	0.078 (1.10)	0.063 (1.02)	− 0.108 (− 1.56)	0.072 (1.17)
Self-employed		0.120 (2.75)***		0.112 (2.57)***		0.116 (2.68)***
Award		0.054 (1.18)		0.055 (1.22)		0.064 (1.44)
Video	0.059 (1.24)		0.206 (4.09)***		0.185 (3.74)***	
Camera	0.161 (3.75)***		0.136 (2.83)***		0.063 (1.35)	
Laser disk	0.129 (2.90)***		0.174 (3.64)***		0.192 (4.04)***	
Attitude 1	0.099 (14.59)***		0.091 (12.22)***		0.066 (9.01)***	
Attitude 2	0.089 (12.28)***		0.102 (13.33)***		0.149 (19.54)***	
λ	0.132 (0.66)	− 0.004 (− 0.02)	0.102 (0.46)	− 0.009 (− 0.05)	− 0.322 (− 1.48)	0.005 (0.03)

See Table 3.

Examining the other variables, we find that male, older, more highly educated, and self-employed workers have higher wages. Receipt of an outstanding-performance award in school is insignificantly positively correlated with wages. The coefficients of λ are all insignificantly negative, providing no evidence of sample-selection bias.

5.2. The simultaneous-equation model

Estimating the mixed model allows us to investigate the effect of treating computer adoption as endogenous. The results are reported in Table 4 . Turning to the computer-adoption regressions first, we find that wages have a significantly positive effect on computer use for different purposes. While female and unmarried workers are more likely to use computers on the job, there are no substantial marital-status differences for home and recreational purposes. Highly-educated and younger workers also tend to have higher likelihoods of using computers for every purpose. Attitudes toward technology and ownership of other consumer electronics are strongly associated with computer use.

Treating the computer-adoption variable as endogenous yields a smaller estimated effect of computer use on wages. The estimated coefficient of C_{wi} in column (1) of Table 4 (0.07) is smaller than the OLS estimate in column (1) of Table 3 (0.14) but remains statistically significant at the 5% level. The Hausman test shows that the difference between the estimates of these two specifications is statistically significant. Thus, we reject the hypothesis that computer adoption at work is exogenous. In contrast, the estimated premiums for computer use for dealing with home affairs and recreation are only slightly smaller than the OLS estimates. Based on the Hausman test, the differences between these two specifications are not statistically significant.[3] Therefore, we cannot reject the hypothesis that home computer use, for practical or recreational purposes, is exogenous to the wage equation. The insignificant coefficients on λ again provide no evidence of selection bias.

Because LNW is constructed by dividing monthly earnings by usual weekly hours, there is a possibility that measurement error in hours can lead to outliers in the estimated wage. We re-estimated the models in Table 4 using the logarithm of monthly earnings in place of LNW and including usual weekly hours as a regressor. These models yield similar conclusions about the effects of computer use on earnings.

6. Conclusions

This paper investigates the effect of computer use on wages in Taiwan. Using micro-level data from the 1999 Taiwan Social Change Survey, we find a significant and positive correlation between computer use and wages. After controlling for potential selection bias, we examine the relationship between computer use and wages using a simultaneous-equation model. The results suggest that highly-paid workers are more likely to use computers on the job and that computer use at work has a direct positive effect on wages. Our results are consistent with the interpretation, proposed by Krueger (1993), that computer use at work increases productivity.

[3] The Hausman test statistics for the three wage regressions (columns (1), (2), and (3) in Table 4) are 6.39, 0.68, and 0.18, respectively.

Acknowledgements

Partial support for this research was provided by the National Science Council, Taiwan.

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