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The Wage Effect of Computer-use in Norway

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Abstract: Use of computers at work has undeniably transformed the way jobs are organized but is there productivity premium attached to their use? This paper employs earnings functions to estimate various specifications in an attempt to investigate the relationship between computer use and wages. We utilize a Norwegian cross-section data and a comprehensive set of control variables. In addition we specify literacy skills scores in an effort to control for skills termed as unobservable in many previous researches on this subject. Our estimates provide a proof that no substantial premium is attached to computer use at work.

Keywords: Computer-use; Literacy skills; Wages

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Introduction

Stimulated by the need to explain the impact of technical change on the wage structure, Krueger (1993) studies the relationship between computer-use at work and income and found that computer-users earned a 15%-20% premium over those who didn't. Kruger interpreted this as a computer's contribution to individual productivity. A handful of papers have been written since but the empirical results on this subject have been an issue for controversy as there is little consensus regarding the causal nature of computer-use at work on wages. Succeeding Kruger (1993), other researchers like DiNardo and Pischke (1997), Borghans and ter Weel (2003), and Ng Y. C. (2006), have followed suit and estimated significant premiums ranging between 15% and 57%.

The conspicuously high cross-section estimates have given way to skepticism on the causal interpretation between computer-use and wages. The inability of cross-section models to accommodate individual fixed effects has led to the belief that wage differentials observed between PC-users and non users could be a reflection of unobserved worker heterogeneity such as skills differences. The methodologies applied were mainly indirect though. DiNardo and Pischke (1997), for example, questioned the credibility of the strong statistical relationship and the economic significance of the interpretations established between earnings and computer-use. In an indicative research they examined a host of worker tools in addition to computer use and found that use of office equipments such as pencils and sitting while working exhibited a similar tendency. The fact that such equipments are unlikely to yield big wage differential has been exported to a conclusion that computer-use as well might be reflecting other unobserved skills and hence the effect might disappear upon inclusion of more variables. A similar conclusion was drawn from a pooled data by Anger and Schwarz (2002), and Silles (2005) after finding that future computer use affected current earnings.

DiNardo and Pischke's criticisms are well founded on the basis that individual unobserved characteristics would be difficult to control for by using a cross-sectional data. But their work does not discredit Kruger's findings completely for a couple of reasons. One, because their conclusions are based on an indicative finding such that other office equipments which are least likely to affect productivity such as pen and pencils exhibited a similar tendency. Two, it is nearly impossible to find an appropriate instrumental variable to remedy what they call "treatment effect" and not least they included limited explanatory variables which in turn boasts the effect of unobserved heterogeneity.

The effort to ascertain the causal nature of wage-computer-use relationship has pretty much been conditioned to whether one uses a panel or cross-sectional data until recently. Cross-section estimates appeared to be of larger magnitude in contrast to their panel counterparts which are close to zero or insignificant. Entorf and Kramartz (1997), and Anger and Schwartz (2002) used fixed effect models to reduce individual unobserved characteristics, assuming constant returns to computer-use across time, and estimated insignificant premiums. Recently how ever Dostie and others (2006) revisited Kruger's work using 1999-2002 *Canadian workplace and employee survey* data. By analyzing a panel data they were able to control for worker selection problem and confirmed the existence of a positive (4%) wage premium.

A cross-sectional data from Norway will be subjected to OLS analysis in our paper. The relative magnitude of the cross-section and fixed effects estimates appear to suggest that cross-section estimates are upwardly biased. However the observed divergence in the literature on this subject could partly be argued to be the result of specification bias. What happens to cross-section estimates if one reduces the extent of omitted variables by including more of them in to the model? Dolton and Makepeace (2004), after estimating a variety of models, found cross-section estimates to be fairly close to their panel counter parts. This is attributable to specifying wide ranging control variables in their model. It is note worthy to mention that Silles M. (2005) applying similar models on the same data set but fewer control variables obtained more than a double of Dolton and Makepeace (2004) estimates. Consequently, following Dolton and Makepeace (2004), building a comprehensive cross-section model with more explanatory variables can also generate reliable estimates. Computer-wage premium can be upward- or downward biased depending on which independent variables are considered in the model given that the explanatory variable happens to affect wages and are correlated with computer-use at work. Consistently our model encompasses one of the most comprehensive lists of control variables in the literature.

In this research, in addition to the extensive employee and employer characteristics, literacy skills acquired from test scores on *prose literacy*, *numeracy*, *document literacy, and problem solving* are included in to our model to control for individual unobserved heterogeneity in skills. Most previous literatures (for example DiNardo and Pischke, 1997; Dolton and Makepeace, 2004; Dostie and others, 2006, etc) used early age test scores on reading and mathematics, experience, and other office tools to control for the unobserved worker heterogeneity such as skills. The use of early test scores as a proxy to ability is debatable, while computing experience as a proxy to skill (computer skill) is found little to offer in reducing the bias. Dolton and Makepeace (2004) have shown that computer premium remains constant across time. Borghans and ter Weel (2003) also found little evidence that computer skills are linked to computer premium. In addition to being extensive, use of literacy scores (as defined by ALL[1]) as a proxy to skills has an added value as there exist a strong correlation between literacy skills and information and communications technology (ICT)-use.[2] More over Bussiere and Gluszynski (2004) have documented a positive relationship between computer-use at home and reading skills among 15-year-old students.

[1] Learning a leaving, First Results of the Adult Literacy and Life Skills Survey, Statistics Canada and OECD, 2005
[2] Ibid

Similarly a comparison of computer users and non-users from an "ALL" survey reveals a literacy gap in all OECD countries[3].

Objective

Computers arguably constitute the single most pervasive manifestation of skill biased technological change[4]. Hence establishing a definite relationship between income and computer-use can have a far reaching implication, among others, in explaining changes in wage structure with the prevalence of technical change, and in designing efficient employee/workforce training schemes. This being said however little consensus exists on the causal relationship between computer-use at work and earnings. The main theme of this research is thus to investigate the existence of premium attached to computer-use at work. And more importantly ascertain if observed relationships would imply causality.

Some previous researches (example: Ng, 2006; Hipple and Kosanovich, 2003; Dolton and Makepeace, 2004) have concluded that computer premium differs by gender. This paper, conditional on the existence of causality between PC-use and earning, opts to investigate whether these conclusions hold for the Norwegian data.

The rest of the paper is organized as follows: Next is description of the data to be utilized followed by descriptive statistics shortly after. Part three of the paper will focus on the empirical analysis. And the last part will cover the concluding remarks.

Data Description

This research is built on a cross-sectional data obtained from a survey conducted in 2003 and carried out by Statistics Norway (SSB) in an effort to document various types of skills[5]. The survey contains comprehensive information on age groups falling between 16 and 65 years. In this survey respondents are also asked, among others, whether they use a computer in their job. The data is rich in labor market variables and job attributes which includes a list of respondent characteristics including four skill-assessment variables known as literacy skills as defined by *the Adult Literacy and Life Skills Survey: New Frameworks for assessment* (Statistics Canada and OECD, 2005)[6].

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[3] Ibid

[4] Dostie, B., Jayaraman, R., Trepanier, M., (2006) The Returns to computer use revisited, Again

[5] A comprehensive report on the Norwegian "Adult Literacy and Life Skills (ALL)" is available by Gabrielsen, E. Haslund J. and Lagerstrøm B. (2005) Lese- og mestringskompetanse i den norske voksenbefolkningen. Resultat fra "Adult Literacy and Life Skills" (ALL). Nasjonalt senter for leseopplæring og leseforskning, Universitet i Stavanger.

[6] See appendix for a detailed variable description

A total of 3183 observations are put to econometric scrutiny in our analysis. About 16 major independent variable categories are included for analysis, many of which are allotted in to multiple dummies. Allscore; an average across skill types: *prose literacy*, *numeracy*, *document literacy* & *problem solving* is included to account for individual skills attributes.[7] Our dependent variable is the logarithm of gross annual wage where gross annual wage is a product of hourly wage, hours worked per day and days of employment in a year.

Our sample is selected from the data pool in light of pc-use at work and effort is made to include all observations where responses for pc-use at work are available and no interpolation applied to generate missing data.

To suit our analysis and reflect observed characteristics of our data set, different sub samples are drawn based on gender as well as setting different restrictions such as differences in time worked to maintain homogeneity and consistency in the sub samples.

Descriptive statistics

Since our income data is in annual gross wages it deems appropriate to control for variation in time worked and focus on the equivalent of hourly gross wages. Hence we restrict our sample to include only those working full time and throughout the year, and non-students. Gross annual wage limits are set to minimum of 100,000NOK. The wage limit might be elevated to 180,000NOK (*15,000NOK per month*) for comparison. The rational for setting a wage limit is that in Norway a worker working full time in a given year earns more than 100,000NOK in annual gross wages.

Table 1 below shows average incremental wages for computer users over non users by gender for each wage limit under the specified restrictions. The difference in earning between computer users and non-users is significant as displayed in table 1. With no restriction imposed, computer users appear to earn almost a double to those who do not use computers at work. But these tremendous differences in earnings could be ascribed to the significant number of workers at very low wage levels. When a better approximate to gross annual wage is considered male computer users still earn nearly as half (45%-49%) more in wages relative to non-users. For the female category computer-using workers' earning, above and over non users', ranges from 39% to 19%.

[7] Variable names and description in appendix 1

Table 1. Average incremental wages for computer users (relative to nonusers)

Comp. use	No wage restriction			Wage>=100000NOK			Wage>=180000NOK		
	All	Male	Female	All	Male	Female	All	Male	Female
Percentages[8]	98.3%	88.8%	99.5%	37 %	45 %	25 %	31 %	48 %	19 %
N	3183	1651	1532	1668	1077	591	1571	1036	535

**All refers to male and female pooled together*

Generally speaking females seem to earn less than their male counterparts and this seems to suggest the prevalence of gender difference in computer premium. Although females appear to earn less on average it is important to note however that the non-PC-using male cluster documented lower average earning compared to PC-using women.

Using a computer at work has become a regular phenomenon recently and our data seems to reflect just that. Table 2 below presents a summary of percentage computer users at work by samples of interest. Generally speaking computer use at work is high as shown in the table. The proportion of female computer users is higher than that of male for gross annual wage levels above 100,000NOK and 180,000NOK.

Table 2. Percentage computer users at work by samples of interest

Restrictions	**All workers**	**Male**	**Female**
No restriction	81.5%	84 %	79 %
Working fulltime and throughout the year, non students, and wage>=100000NOK	88 %	87 %	90 %
Working fulltime and throughout the year, non students, and wage>=180000NOK	89 %	88 %	91 %

Table 3 presents percentage pc-users by worker or firm characteristics. Figures in the second column show values without restriction while the last column reports percentage computer users among only those working through out the year, working full time, and earning above 100,000NOK in annual wages. Although the gender gap in computer use is not too big, our data indicates that women have a higher computer use rate compared to men for those earning above 100,000NOK in annual wages. Age groups falling between 25 and 54 years show a similar likelihood to using a computer at work. And people aging between 55 and 65 tend to use computers at work the most. The percentage of workers using a computer at work also rises with level of education and job status.

[8] the percentages are calculated as:

$$\frac{\text{Mean gross annual wage for computer users} - \text{mean gross annual wage for non computer users}}{\text{mean gross annual wage for non computer users}}$$

Generally speaking, although computer-use is high for all categories but elementary occupation, it is apparent from table 4 that highly educated workers with managerial responsibilities working for bigger firms are more likely to use computers at work.

To tip-off on the probability of using a computer at work for various variable categories, probit results are reported (results are reported in appendix 2 by the end of the text) by gender group for those working full time through out the year and earning more than 100,000NOK. Apparently there exists a greater likelihood of using a computer at work for male where a worker uses fax at work, works in medium to larger firms, is a manager and has a higher score in literacy skills. Where as for the female group, the likelihood is higher for those using fax at work and/or have intermediate (below first degree) education.

Table 3. Percentage workers using computer at work in various categories

Group	NO Restrictions	With Restrictions
All workers (3809) (1669)*	81.5	88.0
Gender		
Male (1984) (1087)*	83.6	86.8
Female (1825) (591)*	79.2	90.2
Age		
Age 16-24 (589) (58)*	56.5	69.0
Age 25-39 (1392) (612)*	85.6	88.6
Age 40-54 (1339) (696)*	85.4	88.1
Age 55-65 (529) (303)*	86.8	90.1
Education		
Less than upper secondary school (575) (194)*	54.1	67.5
Upper & post secondary, non-tertiary (1197) (503)*	72.5	77.9
Tertiary and intermediate (1362) (624)*	93.4	96.7
First degree, Advanced research (664) (343)*	97.3	98.8
Job status		
Without supervisory responsibility (2608) (990)*	75.7	82.7
Supervise <= 5 persons (617) (324)*	91.3	92.9
Supervise > 5 persons (584) (355)*	97.1	98.0
Firm Size		
Less than 20 employees (1003) (451)*	80.9	85.8
20-99 employees (1150) (553)*	84.4	89.0
100 - 499 Employees (673) (348)*	85.0	89.1
500-999 Employees (172) (101)*	90.1	91.1
Greater than 1000 employees (250) (125)*	92.4	89.6
Industry		
Mining and quarrying (65) (39)*	89.2	92.3
Manufacturing (356) (207)*	77.8	78.7
Electric, gas and water supply (30) (18)*	86.7	94.4
Construction (183) (96)*	55.2	60.4
Whole sale & retail trade, hotels & restaurants (510) (186)*	81.6	93.0
Transport storage and communications (229) (124)*	76.9	78.2
Financial intermediation (99) (49)*	97.0	100.0
Real estate, renting & business activities (424)(216)*	89.2	94.9
Public administration and defense (304) (165)*	92.1	95.15
Education (498) (220)*	95.2	98.2
Health and social work (728) (220)*	77.9	85.9
Other community, social and personal service (160) (74)*	79.4	90.5
Occupation		
Legislators, senior officials & managers (292) (194)*	99.3	99.5
Professionals (525) (272)*	97.3	98.2
Technicians & associate professionals (1043) (479)*	96.5	98.1
Clerks (277) (132)*	91.7	93.9
Service and marketsales workers (739) (179)*	62.8	73.7
Crafts and related trades workers (221) (121)*	61.5	59.5
Plant and machine operators & assemblers (211) (110)*	56.4	54.6
Elementary occupations (178) (34)*	29.2	44.1

N.B: Figures in parentheses are sample sizes, * refers samples with restrictions, sample restrictions are: working fulltime, working whole year, non student, and wage>=100,000NOK

Empirical Model

To assess the computer-use-wage relationship we adopt a log linear regression specification following Krueger (1993). The logarithm of gross annual wage is regressed on a dichotomous variable representing computer-use at work and other observed worker characteristics.

$$\ln Y_i = \alpha + \mu C_i + \beta X_i + \varepsilon_i$$

Where Y_i is gross annual wage, C_i is a computer-use dummy which assumes a value 1 if an individual uses a computer and 0 otherwise. X_i is a vector of control variables including gender, age and its square, months worked, literacy test scores, 12 industry dummies, 8 occupation dummies, 4 education dummies, 5 firm size dummies, 3 supervision dummies, a student dummy, and 4 dummies for office technologies other than a computer. ε_i is an error term referring to unobserved individual as well as firm characteristics with the usual properties. For the model above to offer consistent estimates the zero covariance assumption between error term and the explanatory variables and particularly C_i should hold. This means in an event where cov (ε_i, $C_i|x_i$) $\neq 0$, it becomes difficult to isolate the effect of C_i and ε_i on lnY leading to an upward bias in C_i. In our mode this might arise if, for example, some predictors with significant impact on wage and correlated with C_i are missing from the model. In a panel data, problem such as this could be solved more easily by specifying a fixed effect model. By capturing a separate dummy it hinders unobserved heterogeneity from being dumped in to ε_i and there by reduces the extent of upward bias on our coefficient of interest. Since our data is a cross-sectional one, our success in eliminating a covariance relies on how good we specify predictors with systematic effect on wages and which might covariate with C_i. Fortunately we believe our data is rich enough to allow us include as many relevant predictors.

Results and Discussion

Here we will look in to regression results obtained from our log linear model. To begin with, log of annual wage is regressed on computer-use and other job attributes. Table 4 reports regression results for the sample as a whole and by gender.

Most of the variables have the expected signs. Earning positively varies with education and firm size, and the premium to computer use is about 15.4% and highly significant. To see if the same would transcend to the use of other office equipments at work we have included *cell phone-use, fax-use, calculator-use, and personal-organizer-use (organizer-use)*. Parallel to DiNardo and Pischke (1997) estimate of office tools, estimates to *cell phone-use* and *fax-use* exhibit a significant premium. The premium of using a fax and a cell phone is high enough that in the case of fax-use (18.3%) exceeds that of a computer use. Cell phone use acquires a 7% premium. A correlation coefficient also shows that there exists a very high co-variation between pc-use and fax-use at work; in fact highest (40%) relative to other variables included in the analysis.

To see if the general tendency is shared by both male and female workers equally, the bigger sample is split by gender. Regression estimates from the female sub-sample show that female computer users earn about 21% more to those who do not while the sign and magnitude of the rest of the coefficients remain fairly similar to that obtained from the pooled data. On the other hand no significant (both at 5%&10% level of significance) relationship is detected between pc-use and wage for our male sample. So far our regression results seem to gainsay what our descriptive statistics points; such that a higher return is attached to female computer-users in contrast to males.

In accordance with the explanations given at the introductory section we put restriction on time worked and wage limit such that only those working fulltime throughout the year and non-students are sampled in order to focus on the hourly gross wage equivalent. This is more in line with previous studies where focus was made on hourly wage. Conditional on the restrictions on time worked an employee is unlikely to earn less than 100,000NOK; consequently gross annual wage will be limited to a minimum of 100,000 NOK. Sample elements earning less than this threshold are eliminated as outliers. Due to multiple restrictions the sample size is reduced to 1668.

Table 4. OLS results

INDEP. VAR.	ALL	MALE	FEMALE
Gender	0.116 (3.97)**	__	__
Age	0.183(26.04)**	0.174(17.89)**	0.186(17.52)**
Age squared	-0.002(22.2)**	-0.002(15.2)**	-0.002(14.9)**
Student	-0.144(4.63)**	-0.145(3.29)**	-0.126(2.79)**
Months worked	0.030(6.08)**	0.033(4.45)**	0.028(3.96)**
Computer-use	0.143(3.58)**	0.081(1.45)	0.191(3.24)**
Cell phone use	0.067(2.42)*	0.066(1.67)	0.048(1.19)
Fax-use	0.152(5.05)**	0.133(3.23)**	0.168(3.73)**
Calculator-use	0.033(1.09)	0.067(1.59)	-0.005(0.12)
Organizer-use	0.006(0.24)	0.019(0.49)	-0.002(0.07)
Upper & post secondary	0.308(7.47)**	0.257(4.76)**	0.362(5.67)**
Tertiary - Intermediate	0.368(7.58)**	0.253(4.04)**	0.514(6.61)**
1stDegree – Advanced research	0.427(7.54)**	0.318(4.36)**	0.573(6.35)**
Fulltime	0.477(14.13)**	0.618(10.46)**	0.408(9.42)**
Full & part-time	0.165(1.59)	0.321(1.77)	0.108(0.82)
Supervise <=5persons	0.058(1.62)	0.058(1.30)	0.055(0.92)
Supervise >5persons	0.080(2.01)*	0.124(2.53)*	0.020(0.30)
Between 20 & 99 employees	0.178(5.71)**	0.147(3.55)**	0.201(4.20)**
Between 99 & 499 employees	0.224(6.10)**	0.171(3.54)**	0.274(4.80)**
Between 499 & 999 employees	0.281(4.36)**	0.273(3.37)**	0.285(2.69)**
>999 employees	0.251(4.76)**	0.252(3.52)**	0.248(3.14)**
Mining & Quarrying	0.530(5.25)**	0.551(4.97)**	0.324(1.05)
Manufacturing	0.147(2.65)**	0.152(2.09)*	0.205(1.94)
Electric, gas & water supply	0.126(0.86)	0.123(0.76)	0.225(0.68)
Construction	0.206(2.84)**	0.210(2.48)*	-0.026(0.12)
Trade, hotel & restaurant	0.144(3.11)**	0.195(2.84)**	0.123(1.82)
Transport, Storage & communication	0.137(2.23)*	0.138(1.71)	0.168(1.55)
Financial Intermediation	0.183(2.22)*	0.162(1.33)	0.237(2.04)*
Real estate, renting & business	0.212(4.42)**	0.213(3.12)**	0.218(2.85)**
Public admin. & Defense	-0.009(0.18)	-0.002(0.02)	0.007(0.08)
Education	-0.020(0.42)	-0.039(0.52)	0.004(0.06)
Other activities	0.028(0.43)	0.022(0.23)	0.057(0.58)
Legislators & other managers	0.084(1.60)	0.052(0.85)	0.152(1.52)
Professionals	0.017(0.42)	0.054(0.99)	-0.012(0.18)
Clerks	-0.159(2.93)**	-0.167(1.94)	-0.119(1.58)
Service & Marketsales	-0.084(1.89)	-0.110(1.75)	-0.029(0.43)
Crafts & related	-0.028(0.42)	-0.059(0.83)	-0.272(1.24)
Plant operators & assemblers	0.063(0.94)	0.014(0.20)	0.221(1.18)
Elementary occupations	-0.287(4.15)**	-0.330(3.47)**	-0.216(2.07)*
Allscore	0.001(2.18)*	0.002(3.09)**	0.000(0.22)
Constant	6.449(36.96)**	6.455(27.79)**	6.562(24.37)**
N	**3183**	**1651**	**1532**
R-sq.	**0.64**	**0.65**	**0.61**

Absolute value of t statistics in parentheses
*significant at 5%; ** significant at 1%

Note: Reference category: women, part-time, less than upper secondary, without supervisory responsibility, firm size <20 employees, health and social work (industry), technicians and associate professionals (occupation).

Regression estimates, as reported in table 5, for all and the sub-samples (by gender) are completely different estimates; in fact opposite of what our previous estimates (in table 4) indicated. The effect of computer-use on wage for our composite sample is reduced by more than half to about 7.3%. A contrasting result is also obtained for the male and female sub samples. The male sample earning over 100,000NOK in annual wages is found to be significant with an 8.2% premium while no relation was detected for females earning above the mentioned threshold. The fact that computer premium is high in the case of female subgroup relative to the remaining subgroups is that many female observations lie under the 100,000NOK annual wage limit where the proportion of non computer users to computer users is nearly 50%. Most of these lie in very low income levels hardly justifiable for a fully employed worker who has worked for the whole year. In fact a similar exercise (not reported) shows that computer-use-income relationship disappears for annual wage levels as low as 40,000NOK. A parallel line of reasoning applies also to the male group. The relatively high concentration of computer users at very low income levels is responsible to the downward bias. The combined effect is implied by a sizable change in the coefficient after wage limit is set to >=100,000NOK and lesser noise (lower standard error).

Moreover, coefficients to other office equipments such as use of fax which earlier was found to account for as high as 18% earning differential and happened to be highly correlated with computer-use exhibit no significant relationship in this last case.

Table 5. Regression results for wage>=100,000NOK where restrictions are imposed on variations in time worked *(working fulltime & whole year, & non students only*)

INDEP.VAR.	ALL	MALE	FEMALE
Gender	0.164(9.98)**		
Age	0.046(9.06)**	0.051(7.52)**	0.039(4.90)**
Age squared	-0.00(7.47)**	-0.00(6.33)**	-0.00(3.83)**
Computer-use	0.070(2.64)**	0.079(2.28)*	0.037(0.88)
Cell phone-use	0.064(3.91)**	0.093(4.01)**	0.024(1.04)
Fax-use	0.012(0.67)	-0.004(0.17)	0.038(1.45)
Calculator-use	0.003(0.15)	0.005(0.20)	-0.003(0.13)
Organizer-use	0.004(0.29)	0.013(0.61)	-0.005(0.26)
Upper & Postsecondary	0.007(0.29)	0.015(0.49)	-0.002(0.04)
Tertiary - Intermediate	0.064(2.29)*	0.057(1.54)	0.098(2.20)*
1st Degree–Advanced research	0.148(4.64)**	0.148(3.54)**	0.165(3.23)**
Supervise <=5persons	0.049(2.61)**	0.058(2.43)*	0.032(1.02)
Supervise >5persons	0.129(6.48)**	0.115(4.53)**	0.162(4.96)**
Between 20 & 99 employees	0.040(2.30)*	0.036(1.58)	0.047(1.73)
Between 99 & 499 employees	0.103(5.12)**	0.102(3.89)**	0.108(3.35)**
Between 499 & 999 employees	0.140(4.35)**	0.168(4.04)**	0.089(1.75)
Between 20 & 99 employees	0.146(4.95)**	0.150(3.91)**	0.117(2.47)*
Mining and Quarrying	0.591(11.72)**	0.600(9.72)**	0.395(3.14)**
Manufacturing	0.208(7.05)**	0.197(4.72)**	0.218(4.33)**
Electric, Gas & water supply	0.232(3.33)**	0.201(2.48)*	0.346(1.84)
Construction	0.176(4.55)**	0.165(3.36)**	0.112(0.92)
Trade, Hotels & Restaurants	0.131(4.47)**	0.147(3.34)**	0.093(2.22)*
Transport, Storage & Communication	0.218(6.40)**	0.209(4.42)**	0.276(4.58)**
Financial Intermediation	0.247(5.49)**	0.277(4.21)**	0.248(3.91)**
Real estate, Renting & Business	0.225(8.00)**	0.229(5.52)**	0.207(4.91)**
Public admin. & Defense	0.019(0.67)	0.015(0.35)	0.028(0.66)
Education	-0.003(0.11)	-0.019(0.42)	0.027(0.75)
Other activities	0.079(2.07)*	0.045(0.85)	0.134(2.29)*
Legislators & managers	0.091(3.60)**	0.082(2.63)**	0.125(2.68)**
Professionals	0.028(1.31)	0.000(0.00)	0.087(2.63)**
Clerks	-0.130(4.40)**	-0.178(3.68)**	-0.069(1.81)
Service & Marketsales	-0.080(2.87)**	-0.083(2.16)*	-0.056(1.35)
Crafts & related	-0.113(3.32)**	-0.111(2.88)**	-0.212(1.84)
Plant operators & assemblers	-0.116(3.32)**	-0.128(3.18)**	0.035(0.34)
Elementary occupations	-0.185(3.51)**	-0.126(1.81)	-0.233(2.90)**
Allscore	0.001(5.27)**	0.001(4.35)**	0.001(2.40)*
Constant	10.737(85.90)**	10.764(64.47)**	10.985(56.45)**
N	**1668**	**1077**	**591**
R-squared	**0.50**	**0.45**	**0.43**

Absolute value of t statistics in parentheses
*significant at 5%; ** significant at 1%

Note: Reference category: women, part-time, less than upper secondary, without supervisory responsibility, firm size <20 employees, health and social work (industry), technicians and associate professionals (occupation).

Various specifications

To reflect on the consistency and persistence of our estimates we present OLS estimates of computer-use for various log linear models. Following the bottom-up approach we start out with basic regressors and build our model up by including successive variable-categories to see how the model in general and more specifically computer-use estimate responds to new variable inclusion. This exercise will also help us see how critical it is to bring *allscore* (an average across literacy skills scores) in to the model in reducing the upward bias claimed to exist due to unobservable skills heterogeneity. Many previous researches on this subject do not explicitly treat literacy skills scores as predictors.

Tables 7a and 7b summarize regression results of computer-use from various specifications. As one goes from one model to another, that is as more and more variables are included in to the model estimates to computer-use do decline significantly. This is what one would expect if computer use at work is positively correlated with previously omitted variables. Prior to imposing a wage limit, the female column exhibits high premium and is significant as stipulated earlier in table 4, while all categories are consistently declining as more variables join in to the model.

Congruent to the results in table 5, for the wage limit >=100,000NOK computer productivity for the female group is lower than its male counter part at all levels and eventually disappears in the last two models. The large divergence in extent of estimates between the first three columns and their respective estimates in the second three columns is attributable to the high computer non-use concentration of females at very low annual gross wages.

Further, we duplicate table 7a by taking a better approximate to minimum annual wage for a person working fulltime (wage>=180,000NOK) and get table 7b. Table 7b clearly shows that computer premium is unstable. The return to using a computer at work diminishes to none in the last specification and literacy skills become critical for the male subgroup. This merely indicates that computer-use estimate has been a reflection of the other skills which were gloomy or treated as unobservable in many previous works.

Table 7a. OLS computer-use estimates for various models (*working fulltime, through out the year and non students*)

Models	All wages			Wage>=100,000.00NOK		
	All	**Male**	**Female**	**All**	**Male**	**Female**
Model#1	.420(.035)**	.380(.047)**	.466(.052)**	.276(.025)**	.294(.0311)**	.232(.041)**
Adj R-squared	0.596	0.600	0.561	0.278	0.194	0.162
Model#2	.325(.037)**	.256(.051)**	.397(.055)**	.223(.027)**	.231(.035)**	.192(.043)**
Adj R-squared	0.604	0.611	0.566	0.301	0.226	0.189
Model#3	.207(.038)**	.172(.052)**	.242(.056)**	.140(.027)**	.161(.036)**	.104(.043)**
Adj R-squared	0.619	0.622	0.586	0.347	0.269	0.260
Model#4	.207(.038)**	.177(.053)**	.229(.057)**	.149(.026)**	.172(.034)**	.093(.042)**
Adj R-squared	0.625	0.633	0.588	0.427	0.370	0.324
Model#5	.185(.038)**	.151(.053)**	.215(.057)**	.136(.026)**	.151(.034)**	.089(.042)**
Adj R-squared	0.632	0.637	0.595	0.439	0.383	0.334
Model#6	.150(.040)**	.101(.055)	.192(.059)**	.082(.027)**	.097(.035)*	.037(.042)
Adj R-squared	0.636	0.642	0.597	0.479	0.421	0.393
Model#7	.143(.040)**	.081(.056)	.191(.059)**	.070(.024)*	.079(.035)*	.037(.042)
Adj R-squared	0.636	0.644	0.597	0.487	0.430	0.398
Sample Size	**3183**	**1651**	**1532**	**1668**	**1077**	**591**

Standard deviation in parentheses
* Significant at 5%; ** significant at 1%

Where in **model#1** lnwage is regressed on independent variables: computer-use, gender, age, agesq, student, fulltime, fuldel & months worked
Model#2 == model#1 + (cell phone-use, fax-use, calculator-use & organizer-use)
Model#3 == Model#2 + Education dummies
Model#4 == Model#3 + Industry dummies
Model#5 == Model#4 + Firm size dummies
Model#6 == Model#5 + supervise <=5persons, supervise >5persons + occupation dummies
Model#7 == Model#6 + allscore

Table 7b. OLS computer-use estimates for various models (*working fulltime, through out the year and non students; wage>=180,000*)

Models	All	Male	Female
Model#1	.24(.024)**	.264(.030)**	.171(.039)**
Adj R-squared	0.223	0.136	0.086
Model#2	.175(.026)**	.197(.034)**	.115(.039)**
Adj R-squared	0.261	0.175	0.139
Model#3	.092(.026)**	.123(.034)**	.036(.039)
Adj R-squared	0.319	0.239	0.241
Model#4	.101(.024)**	.133(.032)**	.026(.038)
Adj R-squared	0.419	0.357	0.310
Model#5	.092(.024)**	.113(.032)**	.027(.036)
Adj R-squared	0.441	0.374	0.318
Model#6	.049(.025)*	.065(.032)*	-.005(.039)
Adj R-squared	0.470	0.417	0.362
Model#7	.035(.025)	.047(.032)	-.009(.038)
Adj R-squared	0.480	0.430	0.366
Sample Size	**1571**	**1036**	**535**

Standard deviation in parentheses
* Significant at 5%; ** significant at 1%

Where in **Model#1** lnwage is regressed on independent variables: computer-use, gender, age, agesq, student, fulltime, fuldel & months worked
Model#2 == model#1 + (cell phone-use, fax-use, calculator-use & organizer-use)
Model#3 == Model#2 + Education dummies
Model#4 == Model#3 + Industry dummies
Model#5 == Model#4 + Firm size dummies
Model#6 == Model#5 + supervise <=5persons, supervise >5persons + occupation dummies
Model#7 == Model#6 + allscore

Conclusions

This paper presents a proof in favor of DiNardo and Pischke (1997) who argued estimates associating computer-use to individual productivity (wage premium) reflect unobservable individual or job characteristics and is likely to disappear as more appropriate control variables are considered. We estimated an earnings function from a cross-sectional Norwegian data using OLS. Our findings indicate that computer-use estimates are fairly unstable and volatile. The positive wage premium diminishes as more control variables are considered both for the pooled sample and the sub samples by gender. At the outset there appeared to be a positive premium at low gross annual wage levels. But that disappears when a proper approximate to hourly wage is considered. Literacy skills become critical at this juncture depicting that estimates are mere reflections of unobservable individual differences in skills. This research finds no evidence either that there exists gender difference in computer premium.

Considering the timing of the survey computer is a ubiquitous office- as well as house hold equipment widely used. Although we don't deny the productivity impact of computers, workers use computers routinely every day like they do with pens and pencils irrespective of their status and type of work. Hence a strategy to measure the productivity effect of computer use at work from the observed wage differences between computer users and non users may not capture the effects we are interested in, making the productivity impact seem illusive. We feel thus an analysis geared at identifying individual productivity of a computer with out reference to what it is used for is less helpful.

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Appendices

Appendix1. Variable definitions

Lnwage	Log of gross annual wage (Dependent variable). The data was recorded in 2003 and reference was made to 2002.
Sets of independent variables	
Computer-use	Computer-use dummy assuming 1 if a person uses a computer at work and 0 if he/she doesn't
Other office equipments	
Fax-use	Fax-use dummy assuming 1 if a person uses a fax at work and 0 if he/she doesn't
Cell phone use	cell phone use dummy assuming 1 if a person uses a cell phone at work and 0 if he/she doesn't
Organizer-use	personal organizer use dummy assuming 1 if a person uses personal organizer at work and 0 if he/she doesn't
Calculator-use	Calculator use dummy assuming 1 if a person uses a calculator at work and 0 if he/she doesn't

Education dummies (four education dummies)
Less than upper secondary (reference group)
Upper secondary – postsecondary, non-tertiary
Tertiary and intermediate
First degree – advanced research degree

Job status dummies (three status dummies)

Supervise1	without supervisory responsibility (reference group)
Supervise <=5persons	Supervisory responsibility for up to 5 persons
Supervise >5persons	Supervisory responsibility for more than 5 persons

Firm size dummies (five dummies)
Firms employing less than 20 people (reference group)
Firms employing between 20 and 99 people
Firms employing between 100 and 499 people
Firms employing between 500 and 999 people
Firms employing more than 1000 people

Industry dummies (twelve major categories)
Mining and quarrying
Manufacturing
Electric, gas and water supply
Construction
Whole sale & retail trade, hotels and restaurants
Transport, storage and communications
Financial intermediation
Real estate, renting and business activities
Public administration and defense
Education
Health and social work (reference group)
Other community, social and personal service activities

Occupation Dummies (8 dummies)
Legislators, senior officials and managers
Professionals
Technicians and associate professionals (reference group)
Clerks
Service and marketsales workers
Crafts and related trades workers
Plant and machine operators and assemblers
Elementary occupations

Other worker characteristics

Gender	Gender dummy taking 1 for male and 0 for female
Age	Age of respondent
Agesq	Age squared
Months worked	Number of months worked in a year
Part-time	A dummy assuming 1 if a respondent worked part-time and 0 otherwise
Fulltime	A dummy assuming 1 if a respondent worked full-time and 0 otherwise
Fulltime & part-time	A dummy assuming 1 if a respondent worked both fulltime & part time equally and 0 otherwise
Student	A dummy assuming 1 if a respondent is student and 0 if otherwise

Literacy skills

Allscore	An average of literacy skill scores, namely prose literacy, numeracy, document literacy, and problem solving.
	Prose literacy: the knowledge and skills needed to understand and use information from texts including editorials, news stories, brochures and instruction manuals.
	Document literacy: the knowledge and skills required to locate and use information contained in various formats, including job applications, payroll forms transportation schedules, maps, tables and charts.
	Numeracy: the knowledge and skills required to effectively manage the mathematical demands of diverse situation.
	Problem solving: problem solving involves goal-directed thinking and action in situations for which no routine solution procedure is available. The problem solver has more or less well defined goal, but does not immediately know how to reach it. The incongruence of goals and admissible operators constitutes a problem. The understanding of the problem situation and its step-by-step transformation based on planning and reasoning, constitute the process of problem solving

Measurement of sills

For each domain, proficiency is denoted is denoted on a scale ranging from 0 to 500 points. Each score denotes a point at which a person has an 80 per cent chance of successfully completing tasks that are associated with a similar level of difficulty. For the prose and document literacy domains as well as numeracy domain, experts have defined five broad levels of difficulty, each corresponding to a range of difficulty while four broad levels of difficulty are defined for problem solving.[9]

Appendix2. Probit results (only coefficients are reported)

Indep.Var.	All	Male	Female
faxjob	1.061(8.67)**	1.188(7.12)**	0.892(4.06)**
edu2	0.087(0.59)	-0.117(0.61)	0.542(1.91)
edu3	0.394(1.97)*	0.221(0.81)	0.817(2.36)*
edu4	0.641(2.10)*	0.802(1.59)	0.721(1.59)
supervis3	0.677(3.08)**	1.031(2.93)**	0.303(0.98)
fsize2	0.368(2.59)**	0.308(1.60)	0.476(1.92)
fsize3	0.568(3.41)**	0.609(2.70)**	0.501(1.78)
fsize4	0.748(2.62)**	1.174(3.02)**	0.153(0.32)
indus5	0.585(2.53)*	0.755(2.05)*	0.487(1.37)
occup5	-1.040(5.46)**	-1.308(4.38)**	-1.017(3.46)**
occup6	-1.169(5.18)**	-1.416(4.96)**	-1.107(1.35)
occup7	-1.106(5.02)**	-1.329(4.72)**	-0.135(0.22)
occup8	-1.608(5.54)**	-1.891(4.59)**	-1.229(2.53)*
allscore	0.005(3.30)**	0.009(4.01)**	0.001(0.41)
Constant	-0.963(1.10)	-2.468(2.09)*	0.913(0.61)
Observations	1620	911	538

Absolute value of z statistics in parentheses
* Significant at 5%; ** significant at 1%

[9] For further details refer to statistics Canada and OECD 2005

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