Computer Use and the Employment Status of Older Workers – An Analysis Based on Individual Data*†

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Abstract

This paper analyzes the determinants of computer use by male employees and estimates the impact of computer use on the employment status for older workers, based on individual data from the German Socio-Economic Panel (GSOEP). In line with previous research on the diffusion of new technologies, a strong and negative relationship between the age of workers and computer use is found. The correlation of educational level and occupational status on computer use is significantly positive. However, the estimated impact of computer use on the change in employment status of older workers becomes insignificant when controlling for individual and firm-specific characteristics.

JEL-Classification: J14, J26, O33
Keywords: computer use, older workers, employment status

***Data availability:** The analyses of this paper are based on the Socio-Economic Panel (GSOEP) data provided by the German Institute for Economic Research (DIW).

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1 Introduction

In recent years, increasing life expectancy and decreasing natality have caused an aging of populations in industrialized countries worldwide. This trend can be seen in Germany, too, and it is also expected to show up in the German employment structure. This is not the case, however. To a large extent older workers use the possibilities of early retirement and hence the average age of the German work force is stagnating.[1] In West Germany, between 1970 and 2000 the labor force participation rate of men aged 60 to 64 has sharply declined by 37 percentage points (from 70% to 33%) and the rate of men aged 55 to 59 has decreased by 10 percentage points to 78% (Clemens, Künemund, and Parey, 2003). This reflects the propensity among older workers to retire early. On the other hand, the participation rates of male workers between 30 and 45 years remained relatively stable over time and amounted to more than 90% up to the year 2000 (Statistisches Bundesamt Deutschland, 2001[2]).

One explanation for this trend are several reforms of the German pension system in this period, which have opened up various possibilities to retire early (see, for example, Berkel and Börsch-Supan, 2003, and Arnds and Bonin, 2003, for a discussion). In addition, the rapid diffusion of information and communication technologies (ICT) across German firms is often cited as a possible reason for this development in the labor market. The use of computers on the job has become common practice. At the end of 2004 about half of German employees predominantly worked with a computer at the workplace, as a ZEW-survey shows (ZEW, 2005). But it is the age group of the 50 to 60 year old workers that is found to have a smaller share of computer users than the other age groups in Germany in the 1980s and 1990s (Borghans and ter Weel, 2002). It might have been difficult for older workers to adopt to the new labor market requirements.

Taking computer use as a measure of new technologies, Weinberg (2004) analyzes the relationship between the experience of workers and their technology adoption. His findings indicate that the benefits of schooling are particularly strong at the beginning of the career. Therefore, consistent with most vintage human

[1] In West Germany, the average age of the labor force remained at about 38 to 39 years between 1970 and 1990 (in Germany in 2002: 40 years).

[2] The data were taken from German Statistical Yearbooks.

capital models, younger men find it easier to adopt to new technologies, especially when they are highly educated. However, their computer use declines with labor experience. But, Weinberg finds that computer use increases with experience for less educated men. His results suggest that new technologies can complement existing skills and can be adopted first by (older) workers that have experience with the old technology.

Friedberg (2003) finds that computer users have been retiring later than non-users in the 1990s. She presents two reasons for this finding. On the one hand, people who are assigned to invest in computer training retire later in order to use the acquired skills for a longer time. On the other hand, there are people who decide to retire later for any reason and who find it worthwhile to invest in computer training as for them enough time is left in order to amortize the investment. Bartel and Sicherman (1993) state that it makes a difference whether technological changes occur as a permanent process or as a shock. Older workers suffer particularly from the latter because their human capital abruptly depreciates and their experience cannot be used in the adoption process.

By using the share of computer users as a measure of new technology diffusion, this paper contributes to the research on the relationship between new technology use and the labor market participation of older workers by analyzing two main questions: Firstly, what are the factors determining the computer use of male employees? Secondly, are older workers more likely to stay in full-time employment if they use a computer at work?

The empirical analysis is based on individual data from the German Socio-Economic Panel (GSOEP) and shows that (i) the probability of using a computer on the job declines sharply as workers reach an age of 55 and older. (ii) Using a computer at home, the educational level as well as the occupational status have a highly significant and positive impact on the probability of using a computer at work. (iii) There is a positive partial correlation observable between computer use at work and the probability of continuing to work full-time in the analyzed sample of older workers within a two-year as well as within a four-year period. Using an instrumental variables approach and controlling for various other factors, the impact of computer use on employment status becomes insignificant, however. Therefore, among the analyzed age group (50 to 60 years in 1997) computer use at work does not seem to affect the probability of changing the employment status. (iv) Much more important for the probability of changing the employment status is the occupational status of older workers. For example: self-employed men have a significantly higher probability of continuing to work full-time than other men. (v) The educational level and the tenure of older workers show no significant relation with the probability of changing the employment status.

The remaining part of this paper is organized as follows: Section 2 gives a short overview on the results of previous studies. The empirical framework and the data are described in Section 3. Section 4 presents the results, and Section 5 concludes.

2 Background discussion

In the economic literature alternative hypotheses are discussed in order to explain why the labor force participation rate of older workers declines and why some workers retire earlier than others. In this section, first, studies are presented that concentrate on older workers' productivity as one of the factors that influence their employment situation. Then, after taking a look at studies that discuss the impact of computer technology on skill requirements in general as well as on wages, research results are summarized that concentrate on the relationship between computer use and employment status of older workers. In addition, important retirement regulations in Germany are described in brief.

Productivity of older workers

The labor productivity of workers varies with their age. Skirbekk (2003) presents various studies analyzing the pattern and the causal factors of these productivity differentials. Several individual and firm related characteristics determine the productivity of workers. As the weight of these causal factors is steadily changing due to biological or labor market reasons also productivity does not remain unchanged during working life. Several studies presented by Skirbekk (2003) find a decline of mental abilities with age after maximum values are reached in the 20s and early 30s. The decline becomes even sharper for older workers above the age of about 50. Part of this "technical skill obsolescence" (Rosen, 1975) may be compensated by longer experience and higher levels of job knowledge of older workers. However, as there are changes in the market value of skills due to technological progress, cognitive abilities (such as learning, or adjusting to new ways of working) become crucial, while a long work experience may become less essential ("economic skill obsolescence", see Rosen, 1975). Thus, the relative labor productivity of older workers declines. Lazear (1979) shows that in an imperfect labor market for employers it is optimal to pay older workers above their marginal productivity (and younger workers less than their marginal productivity). However, this gives employers an incentive to send older workers into early retirement ("retirement push"). The trend towards early retirement in Germany is facilitated by institutional regulations, such as, for example, by allowing women, part-time employees, unemployed or disabled persons to leave the workforce years before they reach the regular retirement age ("retirement pull").

Computer technology and skill requirements of jobs

Using different definitions and measures of technology, empirical studies mostly support the notion of a skill-biased technological change. An extensive analysis regarding this topic is presented by Acemoglu (2002). Chennells and van Reenen (2002) survey economic research on the effects of technological change, such as the diffusion of computers, on skills, wages and employment. They find evidence of a positive correlation between technology and the demand for skills.

Recent papers concentrate on the reasons of the shifts in the type of skills demanded in the labor market. One of the reasons may be changes in the skill composition within jobs. Autor et al. (2002, 2003) analyze the impact of technological changes on the design and the skill requirements of jobs using data for the U.S. They find that computers are introduced in particular "to automate tasks that can be described in terms of rules-based logic" (Autor, Levy, and Murnane, 2002, p. 445). At the same time, this technological change leads to a re-organization of those tasks that are not computerized. The authors support the widespread theory that computers and education act as complements, and that computerization therefore leads to an increase in the relative demand for highly skilled labor. Spitz (2003) describes the changes in the occupational structure of employment due to the diffusion of IT and analyzes the changes in skill requirements among occupations, using data of German employees. Her findings support the hypothesis that IT capital substitutes repetitive tasks and that it complements analytical, interactive and computational skills. Therefore, a shift in the task composition of occupation due to IT capital leads to an increase in the demand for more highly educated labor.

The relationship between changes in skill requirements of jobs due to innovation and the age structure of the workforce is not clear. Aubert, Caroli, and Roger (2004) point out that, on the one hand, as older workers are more experienced and have a higher level of knowledge they should benefit from the increasing demand for highly skilled labor. On the other hand, the impact of technological progress on older workers may be negative if it leads to a depreciation of a given stock of human capital ("economic skill obsolescence")[3]. However, the results of Weinberg (2004) suggest that for less educated workers new technologies can complement existing skills and can be adopted first by (older) workers that have experience with the old technology. Bartel and Sicherman (1993) conclude that older workers most notably suffer from technological shocks as they lead to an abrupt depreciation of knowledge. Permanently high rates of technological progress can be better accompanied by continued training activities and may therefore be a minor problem.

Computer use and wages

Developing a model to explain how computer technology has changed the labor market, Borghans and ter Weel (2004) conclude that it is not the task composition of a particular job that changes after the introduction of computers at the workplace. Rather the relative time needed to perform the tasks changes as the time requirements for tasks taken over by a computer are reduced. Relative costs of doing a certain task are higher for highly paid workers. Therefore, firms seem to upgrade their workforce, as they gain more when they give those highly-skilled workers a computer in order to reduce the time they need to perform a task. This result is consistent with the finding presented in other research papers that

[3]For a comprehensive description of the causes, models and estimations of skill obsolescence see de Grip and van Loo (2002).

workers who use a computer are already better paid before the introduction of this new technology. In the estimations of the determinants of computer use below, wage is one of the explanatory variables. In line with the finding given above the correlation turns out to be significantly positive. But there is no clear evidence from the data that the causality goes in this direction.

DiNardo and Pischke (1997) point in a similar direction. Comparing data for Germany and the U.S. they find a significantly positive correlation between computer use and wages but express some skepticism regarding the notion that computer use directly raises a worker's productivity. Rather, the return to computer use can also be attributed to unobserved heterogeneity. Also Entorf and Kramarz (1997) come to this result by analyzing the impact of computer-based new technologies on productivity and wages based on the French Labor Force survey. Computer users were more productive and already earned higher wages before they got a computer. In addition, they find that after the introduction, those highly paid workers benefit not from mere use of a computer, but their higher unobserved ability leads to higher wages due to the workers' productivity gain when acquiring experience in using them.

Focusing on the differences between older and younger workers, Borghans and ter Weel (2002) analyze the determinants of computer use as well as the relationship between computer skills and wages within different age groups. They use British data and conclude that computer use does not depend on age. Instead, it is mainly determined by the wage level. Highly paid workers are more likely to use a computer than low-paid workers. Two important reasons for this result are that the benefits from the amount of time saved by using a computer as well as the benefits of additional training are higher for employees who earn higher wages (and have a higher qualification). Although the regression results show that younger workers have more computer skills than older workers, Borghans and ter Weel (2002) state that this finding does not matter for the workers, because they find no labor-market returns to computer skills in terms of wage premia: Workers who use the computer for a longer period of time receive the same wages, regardless of their level of computer skills. Thus, they conclude, older workers should not have more trouble in adapting to a computerized work environment.

Computer use and the retirement decision of workers

The relationship between computer use of workers and their retirement decision is described by Friedberg (2003). Using U.S. data she concludes that not only the age of workers but also impending retirement affects the decision of using a computer on the job and, in addition, that computer users retire later than non-users. Moreover, Friedberg (2003) finds that the relationship between computer use and retirement is mutual. Workers who choose to invest in computer training retire later, and workers who decide to retire later are more likely to invest in further training and acquire computer skills. By analyzing cohorts, Friedberg (2003) shows that the rate of computer use was essentially flat over most ages up to an age of 53. Only for people in their late fifties and sixties the shares of computer users decreased when they approached retirement although they had previously kept pace with the younger workers. The analysis implies that computer use causes later retirement: It "raised the likelihood of continuing to work by up to 25-30%. These effects are strongest for workers in their late fifties" (Friedberg, 2003, p. 527).

The reduction in the labor force participation of older workers due to technological progress is also analyzed by Ahituv and Zeira (2000). Using data for the U.S., they conclude that the labor supply of older workers is negatively correlated with the average rate of technological progress across sectors due to an "erosion effect". Older workers tend to reduce training efforts because their career horizon is short, and hence technological changes lead to an erosion of their human capital. Young workers get an advantage in knowledge and become more productive. In the end this leads to a fall in relative income of older workers and they tend to reduce their labor supply by using the possibility to retire early.

Using data of older men in the U.S. labor force between 1966 and 1983, Bartel and Sicherman (1993) distinguish between high rates of technological change in particular industries, on the one hand, and technological shocks, on the other hand. They conclude that workers in industries with high rates of technological change retire later because they have to perform permanent on-the-job training, that keeps their skills up-to-date. However, an unexpected technological shock leads to an abrupt depreciation of human capital and thus to a drop in the retirement age of workers. Hence, permanently high rates of technological change cause a postponement of retirement, whereas technological shocks lead to earlier retirement.

My paper contributes to the research on the retirement decision of older workers in correlation with their computer use. The main hypothesis is that computer use has a positive impact on the older workers' probability of continuing to work full-time.

Retirement regulations in Germany

In Germany[4], workers face several possibilities to leave work before the regular retirement age, either because they want to leave or because their employers induce them to go. Some of the most important regulations are described in this section.

Since the middle of the 1970s the retirement age in Germany has become more flexible. This is mainly due to reforms of the German pension system, most notably the reform of 1972. Since then, older workers face different legitimate possibilities to work part-time and to retire before the regular retirement age (65 for men and women). In the following years these regulations led to a reduction in the average age of retirement of men (women) from 62.2 (61.6) years in 1973 to 59.8 (60.5) years in 2000 (Clemens et al., 2003).

In East Germany, a new temporary retirement regulation was applied between 1990 and 1992 (after the German reunification). The impact of this regulation on the East German labor market was strong and influential for many years (see Ernst, 1996, for a description). In 1992 and 1999 reforms were launched in order to simplify the old age pension system. These reforms aim to stop the early retirement trend by abolishing exceptions for unemployed, for part-time employees and for women and thus by increasing their "normal" retirement age to 65 (Berkel and Börsch-Supan, 2003). However, the changes do not abolish all financial incentives to retire early.

[4]For an overview about the regulations and their effects on the labor force participation of older workers in different European and non-European countries, see Schleife (2004).

For the older workers of the year 1997 who are analyzed in this paper mainly the 1972 legislation is relevant as the reform of 1992 was not fully phased in.[5] However, their retirement behavior up to the year 2001 was to some extent already influenced by the reduction of possibilities to retire early.

3 The data

The analysis of the employment status change of older workers in Germany is based on the Socio-Economic Panel (GSOEP) data. The GSOEP (Haisken-DeNew and Frick, 2003) is a representative longitudinal survey of private households collected by the German Institute for Economic Research (DIW). Annually, since 1984, the same individuals have been asked for the development of their living and working conditions. Since the German reunification in 1990, East German households have been added to the survey.

The data analyzed in this paper were taken from the waves conducted in 1997, 1999 and 2001. Those were three of the four years (1997, 1999, 2000, 2001) in which questions concerning computer use at work were asked. The questions in 1997 and 2001 were: ‘Do you use a computer or the Internet in your occupation or training? And if you do so: since when?’[6] This information is used in a first step to find out who uses computers at work. I analyze the determinants of computer use of men employed full-time in 1997. Besides the age of workers this multivariate analyses includes several demographic, job-related and firm-related characteristics.

In a second step, the impact of computer use on the change in the employment status of older workers between 1997 and 2001 depending on whether or not they used a computer in the workplace in 1997 is studied. This four-year period is

[5] A relatively long transitional period was implemented with these reforms. Therefore, some rules of the old pension system will continue to be effective until 2017.

[6] The exact questions were: ‘Benutzen Sie beruflich - oder in einer Ausbildung - einen Computer und das Internet? Computer: ja = 1 / nein = 2, falls ‘ja’: seit welchem Jahr? Internet: ja = 1 / nein = 2, falls ‘ja’: seit welchem Jahr?’ The questions of the years 1999 and 2000 were less precise. In this study the information about Internet use has been ignored. In addition, any computer use data that is used in this study is taken from the 1997 SOEP wave.

chosen in order to observe a sufficiently large group of individuals undergoing a change in employment status. However, in order to detect computer use effects on employment status in the short run the changes between 1997 and 1999 are examined additionally. The employment status of the people analyzed is 'employed full-time' in 1997. In 2001 (and 1999 respectively) it can either be still 'employed full-time', or it can be changed and the people are 'employed part-time', 'retired' or 'unemployed'[7]. Men who declared to be unemployed but had no hope to find and were not looking for a new job are defined as 'retired'[8]. In addition, there is one man in the analyzed sample who declared to be retired but is still looking for a job. This man is defined to be 'unemployed'.

I restrict the analysis of this paper to males between the ages of 50 and 60 in 1997. Men in their early fifties oftentimes already face prejudices from the employers' side concerning the productivity of older workers and may have problems to stay in their job. Therefore, the lower threshold of 50 was chosen. Thus, the analyzed dataset also comprises male workers in their fifties who are in certain circumstances allowed to reduce their working time in accordance with various early retirement regulations in Germany (see Section 2). The maximum age of 60 in the year 1997 implies that the workers had not yet reached the regular retirement age of 65 in 2001. The sample is restricted to males because only a very small share of women of this age group is working full-time. In addition, only people who responded to the survey questions about their computer use in 1997 are included in the analyses.

The GSOEP wave of the year 1997 covers more than 13,000 individuals aged 16 years and older. According to the group of workers to be analyzed, the sample was restricted to 3,638 individuals in the first part of the paper analyzing the determinants of computer use. The analysis of an employment status change is made for older workers only. That reduces the sample to 581 men for whom the relevant criteria are met.

The main limitation of the data is that only little information is given about the reasons for leaving work or being unemployed. One hardly knows whether people

[7]This division was chosen under the assumption that for the analyzed older age group part-time employment is a form of smooth transition into retirement.

[8]The recipience of pension or Social Security income was not considered when defining retirement.

retire voluntarily or not, or whether they stay unemployed voluntarily or not because only a few of the interviewed people answered the according questions. In addition, there may be a selection bias, as only people who work full-time in 1997 are considered (see Section 4.1), since there is no information on whether or not people who do not work have professional experience with computers.

4 Results

4.1 Estimating the determinants of computer use

Table 8 in the Appendix shows the shares of computer users and non-users of the analyzed group of full-time employees in 1997 according to various individual and firm-related characteristics[9]. There are large differences in the shares of computer users between workers aged 55 years and older and those who are younger than 55. Whether this is a result of age itself or e.g. of the educational or occupational composition of the workforce in the respective age group is studied in this section. Hence, the determinants of computer use of full-time workers are analyzed here, particularly considering the oldest age group.

Computer use is measured by a binary variable taking the value 1 if the employee uses a computer and the value 0 if he does not. The impact of the different individual and job-related characteristics on the probability of using a computer is analyzed in four steps.[10] At first, only age group dummies are included in the regression. In a second step, education and occupational status are added in order to find their impact on computer use. Hourly wage, PC use at home, region and nationality are additionally included and analyzed in specification (3). The fourth specification finally contains firm-specific determinants (firm size, industrial sectors).

[9] Additionally, Table 8 contains the share in the sample for every characteristic.

[10] As the use of a computer at the workplace is observable for employed people only, the analyzed sample is supposed to be a non-random sample. This may cause a sample selection bias in the estimations. The attempt to use a Heckman correction for being employed had to be abandoned as no adequate instrument variables were found. Thus, the possibility of a sample selection bias has to be kept in mind when interpreting the results.

Assuming that the latent propensity of computer use at work y_i^*, representing the utility of using a computer, depends on individual and job-related characteristics X_i and on normally distributed unobserved factors ε_i in the form

$$y_i^* = X_i\beta + \varepsilon_i,$$

the observed computer use y_i is

$$y_i = \begin{cases} 1 & if \quad y_i^* > 0 \\ 0 & if \quad y_i^* \leq 0 \end{cases}$$

and the probability of computer use can be depicted as

$$Pr(y_i = 1|X_i) \quad = \quad Pr(y_i^* > 0|X_i) \quad = \quad \Phi(X_i\beta)$$

where Φ is the cumulative normal distribution function.

The results of the four probit estimations are presented in Table 1. As mentioned above, specification (1) includes only age group dummies and it shows that the probability of using a computer at the workplace is lowest for the youngest and the oldest age group of full-time workers compared to those who are 25 to 34 years old.

As there may exist age differences between educational levels and occupational status categories[11], the impact of those factors has to be considered when analyzing the effect of age on computer use. Including education and occupation in a regression additionally shows how they directly affect the probability of using a computer at work. Many economic studies ascertain a positive relationship between the highest achieved educational level of workers and their use of new technologies. For example, it is found by Borghans and ter Weel (2002) using data of Germany, Great Britain and the United States, and by Entorf, Gollac, and Kramarz (1999) analyzing French data. Eight education variables are therefore considered in specification (2) to test this presumption on the basis of the GSOEP

[11] Hirsch, Macpherson, and Hardy (2000), for example, find substantial entry barriers for older male and female workers in occupations with steep wage profiles, pension benefits, and computer usage.

data. Furthermore, seven occupational status categories are included. As can be seen in Table 1, education and occupation show the expected and significant relationship to the probability of using a computer at work: for higher levels of education and occupational status the probability of using a computer is higher. Having included education and occupation, the negative marginal effect of the oldest age group regarding computer use increases from 10% to 17% (the effect of the youngest age group is no longer significant). Thus, within-education and within-occupation age differences largely explain the age differences in computer use.

Borghans and ter Weel (2002) as well as Entorf and Kramarz (1997) find a positive correlation between computer use and wage. They conclude that workers who use a computer have already earned higher wages before the introduction of new technologies. Those workers are assumed to have a higher unobserved ability. Moreover, using a computer at home is assumed to be highly correlated with using a computer on the job (see e.g. Haisken-DeNew and Schmidt, 1999, and Table 8 in the Appendix) and is therefore included in specification (3). Table 8 in the Appendix also shows that the use of computers differs by nationality (German, Non-German) and by region (East Germany, West Germany). In order to find out whether the differences are significant in a multivariate setting, these variables are additionally included in specification (3) (see Table 1). The results of the regression confirm that there is a significantly positive correlation between the hourly wage and computer use at work. It leads to an increase of the negative marginal effect of the oldest workers (to 19%[12]). As expected, using a computer at home is highly correlated with using a computer at work. It increases the probability of using a computer at work by 36% on average. However, to a large extent using a computer at home explains the observed age effect and it reduces the marginal effect of age on computer use at work. Thus, older workers' probability of using a computer at work turns out to be 11% less than the probability of workers aged 25 to 34. The effects of region and nationality are insignificant.

Specification (4) depicted in Table 1 adds firm-related variables to the analysis. For those determinants already included in specification (3) it leads to very similar results regarding the direction and the significance of the effects. Compared to

[12]This is the result of specification (3) without taking 'computer use at home' into consideration. The results are not depicted here.

workers with an age of 25 to 34 years, workers of the oldest age group show a significantly smaller probability to use a computer at work again. Having an age of 55 to 64 years reduces the probability of using a computer at work by about 10%. This finding again supports the hypothesis that computer use is age dependent and that computer use is lower for workers who are near retirement. Specification (4) additionally shows that the probability of using a computer is significantly higher in large firms with 2,000 or more employees and in the industrial sectors 'credit, insurance, real estate' as well as 'data processing, R&D, business services', as compared to public sector firms.

Table 1: **The determinants of computer use at work of full-time workers in 1997**

dependent variable: computer use at work				
variable (reference group)	**(1)**	**(2)**	**(3)**	**(4)**
age (ref.: age 25-34)				
19-24	-.156 (.035)***	-.024 (.029)	.021 (.027)	.007 (.027)
35-44	.034 (.021)	-.011 (.016)	-.016 (.015)	-.014 (.015)
45-54	.040 (.023)*	-.028 (.018)	-.011 (.017)	-.014 (.017)
55-64	-.100 (.027)***	-.168 (.021)***	-.111 (.021)***	-.101 (.021)***
education (ref.: university degree)				
lower secondary education or less		-.212 (.153)***	-.099 (.031)***	-.111 (.032)***
other vocational education		-.230 (.183)***	-.123 (.035)***	-.133 (.035)***
apprenticeship		-.154 (.126)***	-.061 (.026)**	-.080 (.028)***
special. vocational school		-.132 (.173)***	-.083 (.032)**	-.092 (.033)***
technical school		-.065 (.150)**	-.015 (.030)	-.018 (.031)
civil servant school		-.049 (.211)	.033 (.045)	-.004 (.044)
polytechnical or college abroad^{i}		-.031 (.144)	.015 (.030)	.006 (.031)
occup. status (ref.: blue collar low-l.)				
blue collar high-level		.067 (.019)***	.013 (.020)	.022 (.019)
clerical worker low-level		.229 (.028)***	.124 (.030)***	.122 (.030)***
clerical worker high-level		.577 (.019)***	.396 (.031)***	.374 (.032)***
civil servant low-level		.371 (.033)***	.245 (.044)***	.217 (.047)***
civil servant high-level		.430 (.027)***	.300 (.043)***	.289 (.046)***
self-employed		.337 (.022)***	.217 (.031)***	.250 (.039)***
nationality (ref.: foreign)				
German			.024 (.020)	.029 (.020)
region (ref.: west)				
east			-.025 (.017)	-.013 (.017)
log hourly wage			.083 (.018)***	.057 (.019)***
computer use at home			.363 (.021)***	.335 (.020)***
firm size (ref.: 20 to 199 employees)				
less than 5				-.008 (.029)
5 to 19				-.005 (.021)
200 to 1,999				.029 (.018)
2,000 or more				.061 (.019)***

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Table 1: **continued table**

variable (reference group)	**(1)**	**(2)**	**(3)**	**(4)**
industry (ref.: public sector)				
agriculture, forestry, fisheries				-.095 (.049)*
mining, utilities				-.036 (.041)
building industry				-.094 (.028)***
manufacturing				.014 (.025)
wholesale, retail trade				.036 (.030)
hotels & restaurants				-.016 (.056)
transport, communications				-.053 (.029)*
credit, insurance, real estate				.115 (.050)**
data processing, R&D, business services				.090 (.044)**
other services				-.062 (.026)**
other sectors				-.027 (.045)
Pseudo-R^2	.010	.331	.459	.480
number of observations	3,638	3,595	3,133	3,042

Notes: Probit estimation, marginal effects.
***, **, * depict significance at the 1%, 5% and 10% level. Standard errors in parentheses.
^{i}) College abroad: In the data it is not clear what kind of degree is meant.
Source: Author's calculations based on GSOEP 1997.

As pointed out by Bartel and Sicherman (1993) older workers tend to retire sooner if technological shocks occur in the industrial sector they are working in. Those shocks lead to an abrupt depreciation of knowledge, and investments in training become less attractive for older workers as they near retirement. In order to find out how computer use of older workers responds to the levels and the changes in average computer use in the person's occupation and industry, these relationships are tested based on the GSOEP data using regression analysis. Specification (1) includes the levels of average computer use in occupation and industry as well as their interaction. Specification (2) additionally considers the changes in average computer use. The results for older workers (55 to 64 years) are compared to those of prime age workers (26 to 45 years). Table 2 depicts the marginal effects of the probit estimation.

Table 2: **The impact of levels and changes in average computer use**

dependent variable: computer use at work				
	(1)		**(2)**	
	age 26-45	age 55-64	age 26-45	age 55-64
average occupational computer use	.823 (.087)***	1.008 (.223)***	.873 (.089)***	1.058 (.226)***
change, 1994-1997			-.116 (.052)**	-.274 (.117)**
average industry computer use	.581 (.115)***	.493 (.336)	.705 (.176)***	.193 (.617)
change, 1994-1997			-.133 (.143)	.269 (.506)
occupation × industry average	-.271 (.181)	-.524 (.460)	-.277 (.181)	-.461 (.464)
number of observations	2229	427	2229	427

Notes: Probit estimation, marginal effects.
***, ** depict significance at the 1% and 5% level. Standard errors in parentheses.
All workers analyzed are employed full-time in 1997. Levels and averages are based on seven occupational status categories and twelve industries of workers aged 26 to 45. The estimation results of the workers aged 46 to 54 form a logical transition between the other two age groups and are available from the author on request.
Source: Author's calculations based on GSOEP 1994 and 1997.

As expected, a higher level of average computer use in an occupation highly increases the probability of using a computer for older and younger persons working in that occupation. However, recent increases in the average of occupational computer use make older workers significantly less likely to use a computer at work. This indicates an explanation for the relationship between technological change and impending retirement. An abrupt increase in the average occupational computer use leads older workers to fall behind in using new technologies. As skills depreciate quickly the incentive for older workers to invest in training shrinks, and the incentive for early retirement increases. The negative effect of changes in average occupational computer use on the probability of using a computer at work is observable for workers younger than 46, too, but it is less than half the effect observed for older workers. The level of average computer use in an industry is only influential for younger workers' computer use probability. Thus, contrary to the work by Bartel and Sicherman (1993) the effect of recent changes in the average of computer use by industry comes out to be insignificant for older workers when considering occupational and industry averages together.

4.2 Estimating the impact of computer use on the change in employment status

The main hypothesis to be tested in this section is that older workers who use a computer at work are more likely to remain employed full-time than non-users in the same age group.[13] Therefore the relationship between computer use and the change in employment status of male workers between 1997 and 1999 as well as between 1997 and 2001 is analyzed. The 581 workers in the dataset were all employed full-time in 1997. In 1999 and 2001 they were either still full-time workers or they had changed their status and became employed part-time, retired or unemployed. Table 3 shows the expected decline in the share of full-time employment and the expected rise in the shares of part-time employment and retirement as the workers grow older. The focus of the following analysis lies on the risk of older workers to be urged into early retirement, part-time employment or unemployment, especially if they do not adopt new technologies. The change of older workers from full-time into part-time employment is assumed to be a (voluntary or involuntary) decision for a transitional status before definitely going into retirement. This assumption is supported by the finding that especially the oldest age group takes place in part-time employment (see Table 3). Men who declared to be unemployed but had no hope to find and not were looking for a new job are defined as 'retired', and those who declared to be retired but are still looking for a job are defined as 'unemployed'.

[13]The workers analyzed in this section are aged between 50 and 60 years in 1997. Hence, they become 52 to 62 years old when observed in 1999 and 54 to 64 years old in 2001. The chosen age definition assures that the workers have not yet reached the regular retirement age in 2001.

Table 3: **Employment status of older workers[i] in 1999 and 2001 by age group (quantities)**

employment status	1999		2001	
	age 52-57	age 58-62	age 54-59	age 60-64
employed full-time	305	169	268	106
employed part-time	0	5	3	17
not employed (retired)	22	61	52	115
not employed (looking for a job)[ii]	11	8	15	5
overall	338	243	338	243

Notes: [i]) Men who were employed full-time and between 50 and 60 years old in 1997.
[ii]) Including one man who declared to be retired.
Source: Author's calculations based on GSOEP 1997, 1999 and 2001.
Example: 47% (115 men) of the male workers who were 60 to 64 years old in 2001 and who were employed full-time in 1997 are retired in 2001.

In Table 4, a first idea of employment status differences between older computer users and non-users is given. Among the 336 non-users 39% (24%) have changed the status between 1997 and 2001 (between 1997 and 1999), among the 245 users only 30% (19%) have. Similar to Friedberg (2003) who uses a slightly different definition of changes in the employment status, computer users are statistically significantly less likely to retire than non-users. Without considering other co-variates the computer users' probability of leaving full-time employment in the four-year period is 14% (in the two-year period 8%) smaller than the probability of non-users. These results additionally indicate a declining impact of computer use over the years for the same cohort.

Table 4: **Employment status of older computer users and non-users* in 1999 and 2001**

employment status	in % of users	in % of non-users
still employed full-time in 1999	90	76
employment status change by 1999	10	24
still employed full-time in 2001	69	61
employment status change by 2001	31	39

Notes: *) Men who were employed full-time and between 50 and 60 years old in 1997. N(user)=245, N(non-user)=336.
Source: Author's calculations based on GSOEP 1997, 1999 and 2001.

4.2.1 OLS Estimates

In this subsection, the impact of computer use at work on the development of the employment status of older workers between 1997 and 1999 as well as between 1997 and 2001 will be examined in a multivariate analysis. Here, the development of the workers' employment status is measured by a dummy variable z. It takes the value 0 if workers kept the full-time status by 1999 (or by 2001 resp.). For workers who changed their employment status to being employed part-time, retired or unemployed (and looking for a job) in 1999 (2001 resp.), the value of z is 1. Besides the computer use characteristic of workers, their employment status decision depends on various individual and firm-related variables. This can be regarded as a linear probability model:

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_C x_C + u \qquad \text{with} \quad j = 1, 2, ..., C-1 \tag{1}$$

where β_C is the impact of using a computer at work. Table 5 shows the results of four OLS regression specifications that analyze the impact of computer use at work (x_C) on the employment status of older workers (z), controlling for various other characteristics (x_j). In the first specification only computer use at work is included to see the bivariate correlation. There is a negative and highly significant correlation between computer use and the probability of changing the employment status in 1999 as well as in 2001. Thus, as seen before, computer users are more likely to remain employed full-time than non-users, especially in the short run. Including age in the second OLS specification reduces the effect of computer use. It is still significant in the short-run, however, but it becomes insignificant in the long-run.

When including more demographic and job-related characteristics, such as nationality (German, Non-German), region (East, West), education, self-employment status, and log hourly wages (OLS-3), the correlation between computer use and the employment status change of older workers becomes smaller but is still significant for the two-year period. The correlation remains insignificant for the four-year period.

Controlling for firm-related variables (OLS-4), such as firm size and industry increases the correlation in the short-run. The results indicate that *within* industry differences in computer use explain much of the differences in the computer use effect on the employment status of older workers. Additionally, the results show that the impact of computer use declines over the years. By 1999, using a computer makes a worker 11.8 percentage points less likely to change the employment status, a strong effect. After four years, the observed effect is much smaller and no longer significant.

Self-employed workers are highly significantly less likely to change the employment status than workers in the other occupational groups. This result is not surprising as self-employed men are not eligible for retirement pension the way employees are. They have a big incentive to work longer as well as to work full-time in order to finance their life. Moreover, they cannot be dismissed by an employer for any reason.

The results of the OLS estimations differ from those given by Friedberg (2003). She finds a significant effect of computer use on the retirement decision for a period of four years (1992 to 1996) even after including other covariates. Thus, people who use a computer at the workplace choose to retire later. However, Friedberg uses a slightly different definition of the change in employment status and analyzes male *and* female workers.

Also Bartel and Sicherman (1993) describe the effects of various variables on the retirement decision. For example, self-employed workers retire later. This result is similar to the one given in this paper. On the other hand they find that schooling has a negative effect on the likelihood of retirement and tenure has a positive one. In contrast, the effects of education and tenure are insignificant in specification (4) of the employment status OLS-regression of this paper.

Table 5: **Linear probability model for the employment status change of older workers[i] between 1997 and 1999 as well as between 1997 and 2001**

	OLS-1	OLS-2	OLS-3	OLS-4
dependent variable: change in employment status 1997 → 1999				
computer use at work	-.142 (.030)***	-.127 (.029)***	-.093 (.041)**	-.118 (.042)***
age (ref.: age 50-54)				
age 55-60		.214 (.030)***	.213 (.033)***	.226 (.034)***
self-employed			-.105 (.048)**	-.200 (.097)**
also included[ii]			demographic and job-related characteristics	demographic, job-related and firm-related characteristics
dependent variable: change in employment status 1997 → 2001				
computer use at work	-.080 (.040)**	-.052 (.037)	-.058 (.050)	-.072 (.052)
age (ref.: age 50-54)				
age 55-60		.390 (.036)***	.388 (.040)***	.412 (.041)***
self-employed			-.173 (.062)***	-.351 (.107)***
also included[ii]			demographic and job-related characteristics	demographic, job-related and firm-related characteristics
number of observations	581	581	492	481

Notes: ***, ** depict significance at the 1% and 5% level. Robust standard errors in parentheses.
[i]) Men who were between 50 and 60 years old in 1997.
[ii]) Demographic characteristics: education, region, nationality; job-related char.: log hourly wage, tenure, tenure^2; firm-related char.: firm size, industry (see Table 8 in the Appendix for the categories).
Source: Author's calculations based on GSOEP 1997, 1999 and 2001.

4.2.2 2SLS Estimates

As mentioned before, one of the main hypothesis to be tested in this paper is whether investing in computer training and using a computer on the job induces older workers to remain in full-time employment longer than otherwise, i.e. whether there is a causal effect of computer use on the employment status of older workers. However, two possible directions of causality have to be borne in mind when analyzing the relationship between computer use and employment status changes. On the one hand, computer training assignment may provide older employees the prospect of improved work opportunities. As a result, investments in training may induce older workers to delay retirement. On the other hand, the decision of delaying retirement may have other causes. That may give older workers an incentive to invest in training as for them enough time is left to amortize the effort. Thus, the decision to invest in training and to retire early is made simultaneously.

Hence, computer use is to be regarded as endogenous in (1) and the OLS estimation results in inconsistent estimators. An approach to estimate the model with x_C endogenous, is the two-stage least squares approach (2SLS) using instrumental variables. The idea is to find a variable (the instrument, h_1) that has an impact on the decision of using a computer but is otherwise uncorrelated with the decision of changing the employment status. Thus, computer use can be modelled as

$$x_C = \delta_0 + \delta_1 x_1 + \delta_2 x_2 + ... + \delta_{C-1} x_{C-1} + \theta_1 h_1 + r_C. \tag{2}$$

Including this reduced form equation for x_C in (1) gives

$$z = \alpha_0 + \alpha_1 x_1 + ... + \alpha_{C-1} x_{C-1} + \lambda_1 h_1 + v \tag{3}$$

with the coefficients $\alpha_j = \beta_j + \beta_C \delta_j$ and $\lambda = \beta_C \theta_1$, and the reduced form error $v = u + \beta_C r_C$. The instrumental variable used here is computer use at home.[14] Workers who use a computer at home already have some computer skills. Thus, for these workers the costs of on-the-job computer training will be smaller than for workers without these skills. Also for older workers nearing retirement age, this positively affects their decision to invest in on-the-job computer skills.

[14] When added along with the other covariates in a linear regression of employment status change 'computer use at home' is statistically insignificant. In addition, the Durbin-Wu-Hausman test was used to test for endogeneity of using a computer at work. Given the instrument 'computer use at home' the test shows significant evidence of endogeneity (t-values: 8.82 in 1999, 4.47 in 2001). Thus, OLS provides inconsistent estimates and 2SLS is performed in the following.

Table 6: **2SLS estimation of the employment status change of older workers**[i]**, First stage regressions**

dependent variable: computer use at work				
	2SLS-1	**2SLS-2**	**2SLS-3**	**2SLS-4**
computer use at home	.671 (.034)***	.668 (.034)***	.462 (.049)***	.463 (.048)***
age (ref.: age 50-54)				
age 55-60		-.031 (.034)	-.060 (.033)*	-.044 (.033)
also included[ii]			demographic and job-related characteristics	demographic, job-related and firm-related characteristics
$\mathbf{R}^2$	0.349	0.350	0.488	0.517
number of observations	544	544	492	481

Notes: ***, * depict significance at the 1% and 10% level. Robust standard errors in parentheses.
[i]) Men who were between 50 and 60 years old in 1997.
[ii]) Demographic characteristics: education, region, nationality; job-related char.: log hourly wage, tenure, tenure^2; firm-related char.: firm size, industry (see Table 8 in the Appendix for the categories).
Source: Author's calculations based on GSOEP 1997, 1999 and 2001.

As can be seen in the first stage of the 2SLS regression (Table 6) the instrument computer use at home is highly significantly correlated with computer use at work. As expected, workers who use a computer at home are much more likely to use a computer at work than the non-users at home.[15] This result does not change when additionally considering demographic, job-related or firm-related characteristics in the regression.

The second stage results of the 2SLS approach are reported in Table 7. The significance of the computer use effect observed in the short run OLS regressions (see Table 5) vanishes when including other demographic, job-related and firm-related characteristics. Thus, together with the insignificant effects in the four-year period the multivariate 2SLS approach does not provide any evidence that differences in the probability of changing the employment status between older workers result from their computer use at work. Other determinants explain the differences in computer use between workers changing their employment status and workers remaining full-time employed.

[15]This correlation was also observable when additionally considering younger age groups of full-time employed men (see Table 1).

The result of insignificant effects of computer use at work on the employment status of older workers fundamentally differs from the results of Friedberg (2003) who finds a significant correlation in her instrumental variables approach. However, she uses different instruments[16] and, as already mentioned, she uses a slightly different definition of employment status changes.

However, the 2SLS and the OLS approach lead to similar results regarding self-employed men. For both, the two-year period and the four-year period, self-employed men are significantly less likely to change their full-time employment status than workers with a different occupational status, presumably for the reasons discussed in section 4.2.1. The effect is even stronger in the longer period. The effect of age is highly significant and positive, as expected. Older workers have a higher probability to change the employment status and become retired or part-time employed, for example, as they near regular retirement age.

[16]The instruments used by Friedberg (2003) are the average computer use by prime-age workers in the same occupation and industry, and their changes over time. They could not be used in this paper because contrary to Friedberg's findings occupational dummies (and thus the mean of occupational computer use of prime age workers) show a significant effect on the probability of an employment status change (the second stage), and, additionally, the average of industry computer use shows no significant impact on older workers' probability of using a computer at work (the first stage) (see Table 2). A reason could be that Friedberg includes covariates in the regressions that result in insignificant coefficients of occupational status variables in the analyses.

Table 7: **2SLS estimation of the employment status change of older workers^{i}, Second stage regressions**

	2SLS-1	2SLS-2	2SLS-3	2SLS-4
dependent variable: change in employment status 1997 → 1999				
computer use at work	-.172 (.049)***	-.140 (.048)***	-.114 (.086)	-.112 (.084)
age (ref.: age 50-54)				
age 55-60		.219 (.031)***	.212 (.033)***	.223 (.034)***
self-employed			-.098 (.052)*	-.195 (.107)**
also included^{ii}			demographic and job-related characteristics	demographic, job-related and firm-related characteristics
dependent variable: change in employment status 1997 → 2001				
computer use at work	-.117 (.069)*	-.060 (.062)	-.009 (.109)	-.019 (.106)
age (ref.: age 50-54)				
age 55-60		.393 (.038)***	.393 (.041)***	.411 (.042)***
self-employed			-.169 (.069)**	-.373 (.107)***
also included^{ii}			demographic and job-related characteristics	demographic, job-related and firm-related characteristics
number of observations	544	544	492	481

Notes: ***, **, * depict significance at the 1%, 5% and 10% level. Robust standard errors in parentheses.
^{i}) Men who were between 50 and 60 years old in 1997.
^{ii}) Demographic characteristics: education, region, nationality; job-related char.: log hourly wage, tenure, tenure^2; firm-related char.: firm size, industry (see Table 8 in the Appendix for the categories). Almost all of these variables show insignificant coefficients.
Source: Author's calculations based on GSOEP 1997, 1999 and 2001.

5 Concluding remarks

Older workers are often assumed not to be able to keep pace with younger workers in adopting and using new technologies. Besides the existence of this skill gap the time to capture the returns to older workers' training investment is shorter. Thus, the incentive to invest in training may be lower for both older workers themselves and their employers. This may be an important reason why employers try to substitute older workers by deploying younger ones and use the possibilities of early retirement, or why older individuals have to work in traditional occupations and jobs with a large unemployment risk (Koller and Gruber, 2001). This paper attempts to analyze descriptively as well as econometrically the relationship between computer use and the employment status of older workers. It analyzes the characteristics of computer users, on the one hand, and whether or not older computer users have a higher probability of remaining employed full-time, on the other hand. For this purpose individual data of male workers are taken from the German SOEP waves 1997, 1999 and 2001.

As presumed, the age of workers has a significant impact on the probability of using a computer on the job. For older workers with an age of 55 to 64 years the impact is negative and it therefore implies a declining probability of computer use compared to younger workers, even after controlling for many other variables.

In many other studies (e.g. Friedberg, 2003, Entorf et al., 1999) it is stated that the educational level has an important influence on the probability of using a computer. The higher the level of education of workers, the higher the extent of computer use on the job. The analyzed group of full-time workers in this paper supports this relationship. However, the level of education shows almost no significant relation with computer use when analyzing workers aged 50 to 60 only.

The relationship between the occupational status of full-time workers and their probability to use a computer seems to be important. All but high-level blue collar workers (insignificant) show a significantly positive correlation with the probability of using a computer compared to low-level blue collar workers. The effect is higher for high-level clerical workers and high-level civil servants than for low-level clerical workers and low-level civil servants. A positive correlation is also found between hourly wages and computer use as stated by Borghans and ter Weel (2002) and Entorf and Kramarz (1997). In addition, as expected the relation with using a computer at home turns out to be highly significant and positive.

Further analyses focus on the question whether computer use has a significant causal effect on the employment status of older workers. In this study, the employment status of computer users and non-users aged between 50 and 60 in 1997 is compared to the employment status of 1999 as well as of 2001. Descriptive statistics show that computer non-users have a higher probability of changing their employment status from full-time employment to part-time employment, retirement or unemployment, especially in the short run. The bivariate correlation between computer use and employment status change leads to the same result.

However, further estimations using a multivariate approach lead to more specific conclusions for the group of older workers. On the one hand, OLS estimations find a significantly positive correlation between computer use and the probability of changing the employment status for the period of two years. The relation becomes insignificant in the long run, however. On the other hand, taking endogeneity of computer use at work into account the instrumental variables approach leads to insignificant coefficients of computer use at work for both periods after including several individual and firm-related characteristics. Being self-employed is one of the main determinants of an employment status change. For self-employed men the probability of remaining full-time employed is much higher than for all other kinds of occupations.

The analyses based on the GSOEP data thus support the negative relationship between the oldest employees and the probability of using a computer on the job. Additionally, it shows the expected positive correlation between computer use at home, hourly wage, as well as the level of education and/or occupation and the probability of using a computer on the job for all workers. However, the results of the study do not support the hypothesis that computer use on the job increases older workers' probability of remaining employed full-time up to the regular retirement age.

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Appendix

Table 8: **Computer use by various characteristics (in %)**[i]

	share[ii]	users	non-users	N
age				
19-24	0.06	30	70	200
25-34	0.32	46	54	1157
35-44	0.29	50	50	1058
45-54	0.22	50	50	796
55-64	0.12	36	64	427
nationality				
German	0.83	51	49	3021
Non-German	0.17	20	80	617
region				
East	0.27	41	59	966
West	0.73	48	52	2672
without any degree				
lower secondary education or less	0.16	20	80	564
upper secondary education				
other vocational education	0.06	14	86	232
apprenticeship	0.42	37	63	1507
specialized vocational school	0.05	52	48	168
technical/commercial college	0.08	59	41	305
civil servant school	0.03	79	21	106
tertiary education				
polytechnical or college abroad[iii]	0.09	77	23	314
university	0.12	86	14	415
occupational status				
blue collar low-level	0.18	10	90	653
blue collar high-level	0.30	20	80	1099
clerical worker low-level	0.06	42	58	203
clerical worker high-level	0.28	84	16	1010
civil servant low-level	0.03	71	29	113
civil servant high-level	0.05	83	17	166
self-employed	0.10	60	40	376
computer use at home				
yes	0.32	86	14	1109
no	0.68	23	77	2334

continued next page

Table 8: **continued table**

	share[ii]	users	non-users	N
firm size				
less than 5 employees	0.12	46	54	446
5 to 19	0.16	33	67	574
20 to 199	0.27	39	61	987
200 to 1999	0.21	47	53	758
2,000 or more	0.24	61	39	868
economic sector				
agriculture, forestry, fisheries	0.02	21	79	68
mining, utilities	0.03	52	48	97
building industry	0.15	22	78	534
manufacturing	0.33	44	56	1140
wholesale, retail trade	0.10	50	50	335
hotels & restaurants	0.02	28	72	53
transport, communications	0.07	40	60	241
credit, insurance, real estate	0.04	90	10	125
data processing, R&D, business services	0.05	80	20	158
other services	0.09	56	44	315
public sector	0.08	74	26	281
other sectors	0.02	31	69	83

[i]) Male workers who were employed full-time and less than 65 years old in 1997.
[ii]) Percentage in sample.
[iii]) College abroad: In the data it is not clear what kind of degree is meant.
Source: Author's calculations based on GSOEP 1997.
Example: A share of 51% of the German men declared to use a computer on the job.