What drives the vacancy rate for information technology workers?*

Martin Falk†

June 5, 2001

Abstract

This paper provides empirical evidence on both the magnitude and determinants of unfilled vacancies for information technology workers using cross-sectional data for 4150 German firms. Vacancies are defined as unfilled vacancies excluding vacancies created by replacement needs during the first half year of 2000. The share of unfilled vacancies created by replacement needs is only about 20 percent indicating that high turnover rates are not the cause of high vacancy rates. The adjusted job vacancy rate for ICT workers varies between 5.7 in the ICT sector and 6.7 in the non-ICT sector. Using generalized Tobit models, I find that variations in the vacancy rate are mostly determined by firm size, the initial stock of ICT workers and actions taken to solve the ICT worker shortage but not by the penetration of ICT. In the ICT sector, the decision to hire apprentices in the new ICT occupations in the past two years of the survey tends to reduce the current vacancy rate. In the non-ICT sector a successful strategy to solve the ICT skill shortage appears to be larger investments in training of the existing staff. Finally, the common practice to completely outsoure software development significantly reduce the probability of unfilled vacancies, in particular in the non-ICT sector.

Keywords: unfilled vacancies, ICT workers, information technology

JEL Classification: J63, O33

*I thank Viktor Steiner and Georg Licht for helpful comments. I also thank Werner Dostal (IAB) and Johannes Velling (BMBF) for helpful comments on the design of the questionnaire.

†Centre for European Economic Research, L7,1, D-68161 Mannheim; phone: (0621) 1235-153; fax: (0621) 1235-225; e-mail: falk@zew.de

1. Introduction

There is general consensus that the German labor market for information technology (ICT) workers is currently tight with large numbers of qualified ICT positions unfilled. This labor market tightness for ICT workers has recently received much attention among researchers as well as among the public. In particular in the U.S. there has been a lively debate about the existence and the magnitude of the shortage of ICT workers. The causes and effects have been examined as well. While industry representatives argue that there is a shortage of ICT workers, labor market analysts see, at most, a temporarily tight labor market (see Cappelli 2000, National Research Council 2000, Veneri 1999). Cappelli (2000), for instance, concludes that ICT skill shortage is only a temporary phenomenon resulting from market adjustments, particularly a lag in student responses to changing labor market conditions. For Germany there is a lot of anecdotal evidence but very little hard evidence on the magnitude of vacancies and skill shortages for ICT workers. One exception is the study of GFK, ISI and IESE (2000) that investigates skill shortages and skill needs for software developers and programmers using 800 firms in a number of manufacturing and service industries. The estimated number of immediately available vacancies for software programmers is about 28.000 covering in the year 2000.

One problem with this discussion is the appropriate measure of occupational shortage. In the literature there is no standard definition of an occupational labor shortage (Veneri 1999). The number of vacancies is often used as a measure of the difference between labor and supply. Vacancies, however, suffer from a number of problems. Most importantly, large vacancy rates of ICT workers are not surprising given the high turnover rate as well as the rather long time to fill positions for ICT workers.

Most authors agree that both supply and demand factors are responsible for the ICT skill shortages (see Freeman and Aspray 1999). Demand factors involve the general acceleration of the ICT capital stock in all sectors as well as the exceptionally rapid growth in the ICT sector (see Jorgenson and Stiroh 2000). This explanation is consistent with the evidence that increased use of ICT has increased the demand for highly skilled labor (see Bresnahan, Brynjolfsson and Hitt 2001). In addition, past activities influencing the supply of ICT workers may also explain some variation of the firms' current vacancy rate. In Germany much of the policy debate surrounding the ICT shortage problem has centered on actions of increasing supply of ICT labor, in particular the establishment of a

new ICT apprenticeship program in 1997.

This paper examines determinants of the vacancy rate of ICT workers using a unique Vacancy Survey. Vacancies are defined as unfilled vacancies created by the firms' desired net change of employment during the first half year of 2000. Unfilled vacancies created by replacement needs are not included. I argue that the adjusted vacancy rate may serve as a measure of unmet labor demand of ICT workers. In addition, unfilled vacancies are compared to occupied job openings measured as newly hired ICT workers. In the literature there are few employer surveys distinguishing between unfilled vacancies and occupied job openings except the study of Van Bastelaer and Laan (1994). Factors explaining the adjusted vacancy rates include indicators of ICT penetration, such as the percentage of workers using a computer, the number of computers per worker and the percentage of workers with internet access, the use of different software and web applications (such as B2B, BcB and web customer relationship management) as well as the practice of outsourcing. Past activities to solve ICT skill shortage such as hiring less qualified workers or workers with non-ICT background as well as the establishment of ICT apprenticeship programs may also influence the current vacancy rate. Our econometric work takes into account that a large fraction of firms in the sample does not have unfilled vacancies. Specially, I use generalized tobit models.

The layout of the paper is as follows. Section 2 outlines the empirical model and discusses different measures of vacancies, while section 3 describes and summarizes the data. In section 4, I present results for the probability that firms have unfilled vacancies as well as the vacancy rate based on the censored sample. Section 5 concludes.

2. Empirical Modelling

2.1. Definition and measurement of the vacancy rate

One problem with the discussion of occupational shortage or tightness is the appropriate measure. The number of vacancies is often used as a measure of the difference between labor and supply. The job vacancy rate is a measure originally developed by the U.S. Bureau of Labor Statistics that was designed as a measure of unfilled labor demand. Here, job vacancies are defined as current unfilled job vacancies in the establishment which are immediately available to workers outside your firm and for which the firm is actively seeking (Abraham 1983). A related concept that is relevant here is skill shortage. Green and Ashton (1992) intro-

duced 'skill shortage' defined as difficulties in filling vacancies. Vacancies can also be defined as job openings with starting recruitment activities (see Farm 2000). A high stock of vacancies may indicate both matching problems and recruiting problems. Vacancies, however, suffer from a number of problems (see Muysken 1994, Abraham 1983). High vacancy rates do not necessarily indicate a shortage, rather this signals that some adjustment has to take place. High turnover rates and long time to fill positions requiring particular ICT skills mean that vacancies exist even if the supply of ICT worker is equal to the demand for them. A highly qualified software developer, for instance, will not seldom switch jobs every year or two (National Research Council 2000). Under certain simplifying assumptions, the vacancy rate for ICT workers, v, can be defined as (National Research Council 2000):

$$v = \frac{V}{N} = (\frac{S}{N} + \frac{\Delta N}{N}) \times D \tag{2.1}$$

where the vacancy rate is calculated by dividing the stock of job vacancies for ICT positions, V, by the total ICT workforce.[1] s=S/N denote the separation rate measured total number of separations of ICT workers as percent of the ICT workforce per year. The flow of separations consists of both quits and layoffs. $\Delta N/N$ is the rate of net growth in employment of ICT workers per year and D is the average time to fill an open position for ICT workers (measured in years). The total flow of newly hired workers equals the flow of separations and the change in employment ($H = S + \Delta N$). According to the law of large numbers the relationship above may only hold in large firms, as emphasized by Pissaridies (1990). In particular, the turnover as well as average time to fill an open position can be influenced by a number of factors such as management practices and recruiting effort (see Cappelli 2000).

Given the definition of the vacancy rate as a function of the occupational turnover and the net employment growth rate it is obvious that the vacancy rate is higher in the ICT sector than in the non-ICT sector. It is also easy to see that vacancies are not a good measure of unmet labor demand for ICT workers. Consider for example a turnover rate of 20 percent and an average time to fill a position of three months. This turnover rate translates into 50.000 vacancies for ICT occupations over the course of the year without an increase in the demand

[1] The job vacancy rate can also be computed by dividing the number of job vacancies by the sum of employment and vacancies (see Abraham 1983).

for ICT workers given a total estimate of about 495.000 ICT occupations based on the 1999 German micro census. Another problem with vacancies as a measure of labor shortage is that vacancies might exclude a large number of discouraged vacancies, i.e. jobs which employers would like to fill but have given up recruiting for. Abraham (1983), however, suggested that the downward bias of excluding discouraged vacancies is relatively low. Furthermore, start-up firms are usually not represented in the Vacancy Surveys. A priori one might expect such firms to have large vacancy rates.

Our definition of vacancies differs from previous vacancy surveys. Vacancies are defined as the presence of unfilled jobs during the first half of the year 2000. In particular, firms are asked whether they are willing to hire ICT workers but suitable applicants are not available given that the number of hiring decisions is greater than the number of actual hired ICT workers. In other words, if firms do not succeed in hiring a new worker during this period a job opening becomes an unfilled vacancy. Firms are then asked about the number of unfilled vacancies. This measure of vacancies does not include vacancies that were immediately filled. Instead, the measure of unfilled vacancies mainly consists of longer duration vacancies as well as hard-to-fill vacancies and therefore provides a measure of unmet labor demand. Therefore unfilled vacancies will mainly consist of hard-to-fill vacancies that are primarily caused by recruiting problems rather than by matching problems. Since the measure of unfilled vacancies in this survey is based on a flow concept, the vacancy rate could not compared to previous vacancy surveys. Farm (2000), however, pointed out that the stock of vacancies during a quarter is mainly determined by the inflows and outflows during this quarter, while the influence of the vacancy stock in the beginning of the quarter is relatively low. Therefore, flows are likely to be a good proxy of the stock of unfilled vacancies.

Total vacancies during a period of time equal the flow of occupied jobs, FV_O, and the flow of unfilled jobs (that remained unfilled during the period), FV_U, both measured during the first half of year 2000:

$$FV = FV_O + FV_U \tag{2.2}$$

Occupied job openings should be equal to the flow of newly hired workers, H, during the period of time. As already suggested, a substantial fraction of vacancies can be attributed to high employee turnover of ICT workers rather than to net employment growth, in particular in the ICT sector. Therefore, it is important to distinguish unoccupied job openings into vacancies created by the firms' desired

net change of employment, $FV_{U,G}$ and vacancies created by replacement needs, $FV_{U,R}$:

$$FV_U = FV_{U,R} + FV_{U,G} \tag{2.3}$$

The ratio of unfilled vacancies for ICT workers created by the firms' desired net change of employment of ICT workers, $FV_{U,G}/N$, serves as our measure of unmet labor demand for ICT workers. This allows us to compare high job turnover firms with low job turnover firms. The fraction of unfilled jobs created by replacement demand may be smaller than the share created by net employment growth. One explanation is that many separations are anticipated and replacements being made before the corresponding job becomes unfilled (see Farm 2000).

2.2. Empirical specification

Factors explaining the adjusted vacancy rates include indicators of ICT penetration, the initial share of ICT workers, growth rate of ICT workers, the use of different software and web applications, outsourcing activities as well as strategies implemented to fill empty positions in the past. The following specification will be used to examine the determinants of the vacancy rate:

$$\begin{aligned} V_U &= \beta_0 + \beta_{1j}\Delta N/N + \beta_{2j}E^{ICTW} + \beta_{3j}COMP/E + \beta_{4j}E^{COMP} + \beta_{5j}E^{WEB} + \\ &\quad \beta_{6fj}SW_f + \beta_{7jg}WEB_g + \beta_{8jh}STRAT_h + \beta_{9jl}OUTS_l + \beta_{10jl}Z_m + \epsilon_j \end{aligned} \tag{2.4}$$

where j refers to the industry. The variables are defined as:

$\Delta N/N$	annual percentage change of ICT workers between '99 and '00
E^{ICTW}	share of ICT workers in 1999 (excl. ICT apprentices) (%)
$Comp/E$	computers per worker in 2000
E^{COMP}	percentage of workers using a computer on the job (%)
E^{WEB}	percentage of workers with internet access (%)
SW_g	f=1, ...,5 different software applications
WEB_f	g=1,...7, different Web–related activities
$STRAT_h$	h=1,..,8 past strategies to solve ICT skill shortages
$OUTS_l$	l,=1,..8, different types of ICT outsourcing
z_m	1,...,6 firm size classes, 1,...,8 industry dummies

The righthand variables are the initial stock of ICT workers as a percentage of total workers, E^{ICTW}, ICT penetration indicators (such as the percentage of workers using a computer, the number of computers per worker and the percentage of workers with internet access as well as the use of different web applications), the use of different software as well as web applications, SW_f and WEB_g, past strategies to solve the shortage problem, $STRAT_h$, the use of ICT outsourcing, $OUTS_l$, as well as a set of appropriate control variables, z.

One should note that 80 percent of the firms do not have unfilled vacancies of ICT workers and thus register zero observations. A tobit model estimated by ML or by semi-parametric methods would be appropriate. However, the use of the tobit model imposes the restriction that coefficients are the same among the censored and uncensored sample. This means that a tobit model would be unable to differentiate between the impact of firm size on the presence of vacancies and how many vacancies given that the firm reports at least one unfilled vacancy. It could be hypothesized that the probability of unfilled vacancies increases with firm size but the vacancy rate given that firms have unfilled vacancies decreases with firm size. In addition, the performance of semi-parametric censored regression models is quite poor when the number of censored observations is very high. In this application 80 percent of firms report zero vacancies. Another way to handle censoring at zero is to use Heckman's generalized tobit model (known as tobit type II). This model consists of an index or selection equation, a structural equation and a threshold index linking both equations. The selection equation concerning whether or not firms have unfilled vacancies is given by:

$$d^* = x_1\beta_1 + u \tag{2.5}$$

where the threshold index is defined as $d = 1$ if $d^* > 0$ and $d = 0$ if $d^* \leq 0$. The threshold structural equation is defined as

$$v^* = x_2\beta_2 + e \tag{2.6}$$

where $v = v^*$if $d = 1$ and 0 else. The error terms are assumed to follow a bivariate normal distribution with correlation ρ and zero mean:

$$e, u \sim N(0, 0, \sigma^2, \rho) \tag{2.7}$$

v^* denotes the latent (non-observed) endogenous variable and and v denoted the corresponding observed vacancy rate. x_2 and x_1 are vectors of explanatory variables and β_1 and β_2 are vectors of parameters. d^* is a latent variable that

represents binary censoring and d is the observed value (1 if firms report unfilled vacancies, else 0). The generalized tobit model can be estimated consistently by Heckman's two step estimation procedure or by FIML. One major problem with this approach is to identify the coefficients in the second stage (structural equation). That means that at least one variable included in the first step (probit model) should not appear in the second step (estimated by OLS or FIML). Specifically, exogenous variables are necessary that explain the presence of unfilled vacancies but not how many vacancies exists. In empirical studies using firm data it is often difficult to find exclusion restriction and justify them based on theoretical considerations. The approach adopted here is to estimate a most general approach relying upon functional form to achieve identification. In the next step various subsets of variables have to be excluded from the second stage of the estimation. Likelihood ratio tests are then used to test the validity of the exclusion restriction. Preliminary regression show that that the practice of completely outsourcing of software development is valid exclusion restriction. If the correlation coefficient, ρ, is found to be insignificant, then I estimate the vacancy rate function using uncensored samples only. The resulting truncated regression model can be estimated by maximum likelihood. Since truncation of the sample will be likely to result in a left-skewed vacancy rate I use logarithms of the vacancy rate. This may reduce the skewness of the vacancy rate and make the vacancy rate normally distributed.

2.3. Hypotheses

In the following I advance seven hypotheses concerning the determinants of the adjusted vacancy rate, which we proceed to evaluate in the following empirical work:

Hypothesis 1. The adjusted vacancy rate for ICT workers once the firm registers at least one unfilled vacancy depends negatively on the initial share of ICT workers.

Hypothesis 2. The vacancy rate will be lower if employers have been successfully implementing strategies to fill empty positions in the past such as the willingness to employ inexperienced university graduates with non-ICT background or to hire apprentices in the four ICT professions, or make larger investments on internal training.

Hypothesis 3. The current vacancy rate may also be lower if firms contract out ICT activities.

Hypothesis 4. Both the propensity as well as the vacancy rate should be strongly positively related to the diffusion of ICT.

Hypothesis 5. The vacancy rate decreases with firm size given the impact of other control variables.

Hypothesis 6. The vacancy rate for firms with unfilled vacancies may be lower in the ICT sector than in the non-ICT sector.

Hypothesis 7. The vacancy rate for firms with unfilled vacancies may be increasingly positively related to the firms' employment growth rate in the preceding year.

Hypothesis 1 states that the vacancy rate for ICT workers depends negatively on the initial share of ICT workers in total. This reflects the fact that firms with an initially low level of ICT workers are beginning to expand their ICT workforce and therefore have higher vacancies rates. Hypotheses 2 is about actions implemented in the past to address the labor shortage problem of ICT workers. Employers have many options to solve the skill shortage, including hiring less qualified workers, recruiting workers outside traditional ICT occupations or hiring of workers who had completed a public training program, making larger investments on internal training and retraining, contracting out ICT tasks or cutting back production. Past activities of increasing supply of ICT workers may be more effective in reducing the current vacancy rate than actions implemented to reduce the amount of work. In particular, the vacancy rate will be lower if employers are willing to offer high salaries to applicants, or to employ inexperienced university graduates with non-ICT background, or to establish apprenticeship training programs or of they are making larger investments on internal training and retraining of ICT workers. According to hypothesis 3, firms with outsourcing of ICT activities are less likely to report unfilled vacancies. Outsourcing of software development has become a common practice. Hypothesis 4 states that unfilled vacancies may be related to factors driving the demand for ICT workers such as the penetration of different types of information and communication technologies. Both the propensity as well as the level of unfilled vacancies should be strongly positively related to the diffusion of ICT. This can be explained by the fact that ICT occupations are directly related to the use of information and communication technologies. For instance, many web applications require qualified ICT workers to develop and maintain them. Hypothesis 4 states that the vacancy rate decreases with firm size given the impact of other control variables. This may be related to the fact that employees in small firms receive smaller salaries than in larger, well established firms (National Research Council 2000). Furthermore, the vacancy rate for

firms with unfilled vacancies may be lower in the ICT sector than in the non-ICT sector. In some sectors such as manufacturing, trade as well as transport firms with unfilled vacancies may have a higher vacancy rate due to inflexible pay scales and the non-existence of stock options and equity stakes (Hypothesis 6). Finally, hypothesis 7 states that the vacancy rate for firms with unfilled vacancies may be increasingly positively related to the firms' employment growth rate in the preceding year.

3. Data description and summary statistics

In mid 2000 ZEW and INFAS collected data from 4411 employers using a stratified random sample design based on 'Creditreform' , the largest German credit rating agency. The survey is designed by the ZEW in cooperation with INFAS as well as the Federal Ministry of Education and Research. The survey is conducted by telephone using CATI techniques. The response rate is 43 percent. To check for a possible bias due to unit non-response I calculate unit non-response rates across both firm size and sectors. Unreported results show that average non-response rates are quite similar across one-digit industries as well as firm size.

The survey is not representative of the entire economy but nationally representative for both the manufacturing and the service sector. The survey is stratified by industry, size and region and respondents were drawn from a variety of industrial sectors (not just the ICT sector). In particular the survey covers manufacturing, retail and wholesale trade, transport, banking and insurance and business services representing a population of about 19 million workers. The key variables in this study include different vacancy measures and different information technology indicators (computers per worker, percentage of workers using a computer on the job and percentage of workers with internet access), ICT outsourcing activities and strategies against the shortages of ICT workers, as well as the use of software applications (use of data management systems, ERP systems, CAD, use of e-mail and electronic data exchange).

Approximately 4411 firms participated in the first wave. Excluding firms with less than 5 employees led to a reduction of the sample to 4149 firms. Incomplete information on the ICT indicators reduced the sample by 370 firms. For the number of ICT workers as well as unfilled vacancies the share of missing values is generally low. Approximately less than 0.5 percent of firms did not report their number of ICT workers.

The firms are first asked whether they hired ICT workers and if so how many ICT workers in the first half year of 2000. Both firms with or without hirings are asked whether they are willing to hire ICT workers but suitable applicants are not available during the first half year 2000. If so, the respondent is asked to specify 'the number of vacancies for ICT workers that have been unfilled during the first half year 2000'. The definition of ICT workers is rather broad and includes the following job titles: computer programmers, computer software engineers, system analysts, network administrators, computer support specialists, telecommunication engineers, telecommunication technicians, hardware engineers, computer science teachers and training specialists, database administrators and managers.

Table 1 presents summary statistics for the share of ICT workers, the vacancy rate as well as ICT penetration indicators. Summary statistics are calculated using sample weights where missing values on each variable are imputed using 'trimmed' means across sectors or predictions of using predicted values from probit regressions.[2] Approximately 5.9 percent of the firms reported unfilled positions for ICT workers during the first half year 2000. Subtracting unfilled vacancies created by replacement vacancies slightly decreases the percentage of firms to 5.2 percent. The share of unfilled vacancies for ICT workers in the first six months of the year 2000 as percentage of total ICT workers is 7.8 percent. A vacancy rate of 8 percent is quite high given the unemployment rate of ICT occupations of about 4.5 percent (based on microcensus 1997). When national surveys of vacancies have been conducted in the past the job vacancy rate has been in the 1.0 to 2.0 percent range (see Abraham 1983). When vacancies due to replacement demand are excluded, the vacancy rate decreases slightly from 7.8 to 6.3 percent. That means that 80 percent of the unfilled vacancies are created by the firms desired change in net employment and 20 percent are due to turnover. Since vacancies with a long duration are overrepresented, the low proportion of vacancies due to turnover might be expected.

Figure 3.1 shows the distribution of the adjusted vacancy rate as well as the logarithm of the adjusted vacancy rate based on the censored sample. While the adjusted vacancy rate is skewed to the left, the logarithm of adjusted vacancy rate tends to be normally distributed. Firms are also asked about the length of duration of ICT positions in relation to non-ICT positions. Not surprisingly

[2] The weights are constructed using information on the number of workers by both industry, size class and region drawn from the Employment Register of the Federal Labor Office.

Table 1: Summary statistics (means)

	all sectors obs: 4149	ICT-sector obs: 640	non-ICT sector obs: 3509
unfilled vacancies (1/0)	5.9	25.5	4.6
unfilled vacancies ex. replacement vac. (1/0)	5.2	24.2	4.1
unfilled vacancy rate, %[a]	7.8	6.9	8.5
adjusted vacancy rate,%[a]	6.3	5.7	6.7
share of newly hired ICT workers, %[a]	9.2	10.6	8.1
growth rate ICT workers, %[a]	8.6	13.6	5.0
ICT workers (1/0)	33.6	94.7	28.6
% of ICT workers[a]	4.7	27.6	2.9
computers per worker, %[a]	64.5	120.7	61.7
% of workers using a computer[a]	44.0	60.0	43.2
% of work. with internet access[a]	31.4	75.6	29.5
	use of software applications (1/0)		
database manag., widespread	31.6	44.1	30.9
database manag. occasional	39.5	41.7	39.4
ERP software, widespread	25.4	18.0	25.8
ERP software, occasional	36.3	53.1	35.3
CAD/CAE, widespread	12.6	8.8	12.8
CAD/CAE, occasional	19.7	17.9	19.8
E-mail, widespread	38.5	84.7	35.8
	use of web applications (1/0)		
Web-marketing, widespread	18.5	23.0	18.2
Web-marketing, occasional	36.7	60.1	35.4
Web-ordering, widespread	10.4	37.7	8.8
Web-ordering, occasional	40.1	45.5	39.8
web customer relations. manag., widespread	22.2	65.3	19.6
web customer relations. manag., occasional	42.3	25.6	43.3
electronic banking, widespread	36.3	51.2	35.5
electronic banking, occasional	13.3	18.8	13.0
web recruiting, widespread	17.5	29.2	16.8
web recruiting, occasional	5.7	15.5	5.2

Notes: Dummy variables are weighted by sample weights. [a]The remaining variables are weighted using information on the number of employment in each cell as a share of total employment based on the Employment Register of Social Security.

continued table 1:

	all sectors	ICT-sector	non-ICT sector
activities to fill empty positions in the past two years (1/0)			
increased training existing staff, often	9.5	29.4	8.3
increased training existing staff, occas.	8.8	25.9	7.8
overtime, often	11.6	31.0	10.4
overtime, occasional	6.9	22.9	5.9
hiring worker who completed a public train. prog,. often	2.0	12.2	1.4
hiring worker who completed a public train. prog., occas.	4.2	11.6	3.8
hiring graduates from non-ICT fields & train them, often	1.4	5.1	1.2
hiring graduates from non-ICT fields & train them, occas.	2.8	12.3	2.3
hiring ICT apprentices, often	2.3	16.4	1.4
hiring ICT apprentices, occasional	2.1	9.1	1.7
contracting out, often	6.8	14.4	6.3
contracting out, occasional	6.8	15.2	6.3
raising wages to job applicants, often	1.1	3.8	1.0
raising wages to job applicants, occasional	5.8	20.8	4.9
ICT-outsourcing (1/0)			
system admin., completely	32.5	11.8	33.7
system admin., partially	28.4	17.4	29.0
support help desk, completely	26.8	9.3	27.9
support help desk, partially	27.1	26.2	27.1
software programming, completely	43.3	20.9	44.6
software programming, partially	18.2	18.0	18.2
ICT-training, completely	30.9	9.9	32.1
ICT-training, partially	24.1	36.5	23.4
ICT tasks/fields (1/0)			
hardware	6.0	15.3	5.5
software development	19.1	56.2	17.0
system administration	24.4	58.3	22.4
database management	19.9	49.7	18.1
e-Commerce	18.5	46.2	16.8
ERP software	18.7	37.8	17.6
ICT training	17.4	54.6	15.2
ICT support, help desk	16.5	55.7	14.2
telecommunication	13.2	24.3	12.5

Notes: See Table 1.

Figure 3.1: Distribution of the adjusted vacancy rate (univariate kernel density estimation), censored sample (obs.=652)

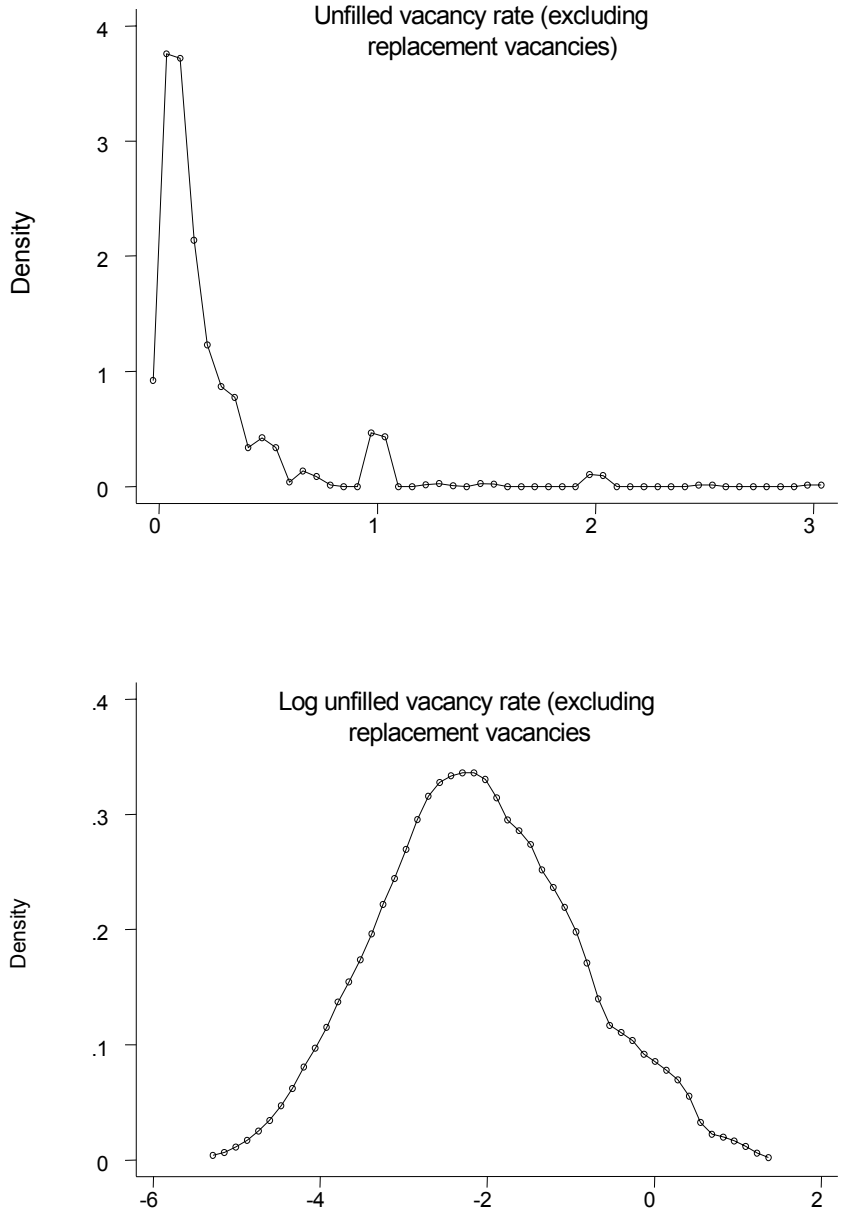

Figure 3.2:

in the ICT sector open positions for ICT workers take more time to fill. 43 percent of the firms responded that ICT positions take more time to fill than non-ICT positions but only 10 percent responded that the average time is shorter (unreported results). Furthermore, the share of ICT workers as a percentage of total employment ranges between 27.6 percent in the ICT sector and 2.9 percent in the non-ICT sector. Based on the German microcensus 1997, the shares of core ICT occupations (computer scientists, computer engineers and system analysts) in total employment range between 1.3 percent in the non-ICT sector and 13.7 percent in the ICT industry. This is consistent with the finding that the core ICT occupations constitutes half of total ICT workforce (see National Research Council 2000). The share of newly hired ICT workers in the first six months of the year 2000 as a percentage of total ICT workers ranges between 10.6 in the ICT sector and 8.1 percent in the non-ICT sector. This translates into a gross hiring rate of 21 and 15.6 percent per year, respectively. These estimates are consistent with the calculations based on the German microcensus 1997. Here the shares of newly hired workers in ICT occupations range between 18.8 percent in the ICT sector and 11.3 percent for the non-ICT sector for the year 1996. Furthermore, the estimated growth rate of ICT workers between 1999 and 2000 is 8.6 percent.[3]

Table 1 also contains information on the three main information technology indicators. The number of computers (PCs, mainframes as well as terminals) per total workforce amounts to 65 percent in 2000. Approximately 44 percent of employees are using a computer on the job for at least half of their working time. Based on the German socio economic Panel, 1997, a survey at the individual, 52 percent are working with a computer on the job (see Haisken De New and Schmidt 1999). This is also close to the corresponding share based on the German microcensus with about 54 percent (see Statistics Germany 2001). The difference between the our data set and the two other data set may be related to the limited coverage of our survey. Government, non-profit institutions, the health sector as well as the construction sector are not included in our survey. One third of the employees in the sample now has Internet access. Our survey also requested information on the use of different software and web applications, and if so the level of use on a 2 point scale from small use to heavy use. In 2000, 65 percent of German firms report a use of ERP systems. The number of firms using e-mail systems, data management/data warehouse software applications is 76 and 72 percent, respectively. Finally, table 1 contains information on ICT outsourcing

[3]Based on the microcensus the annual growth rate of core ICT occupations is 5.4 percent between 1993 and 1997. The difference may be related to the different time period.

(two types: partially and completely) and whether firms are specialized in different ICT activities. Outsourcing of ICT activities is a very common practice, in particular in the non-ICT sector. For instance, 46 percent of the firms responded that software programming is completely outsourced.

Regarding the actions to fill empty positions for ICT workers the preferred practices appears to be overtime hours as well as increased training of the existing staff in the last two years of the survey. (33 percent often, 27 percent occasional). In the ICT industry, hirings of apprentices in ICT professions as well as hirings of workers who had attended a public training program is also important. This newly establishsed ICT apprenticehip program has been very successful. In mid 2000 the number of ICT apprentices enrolled in the new apprenticeship program including the first apprentices already graduated already exceeds 40.000. Few firms employed workers who have completed a public training program or raised wages to job applicants in the past two years. The latter finding can be explained by the fact that employers may be reluctant to raise wages to newly hired workers because of the requirement to maintain pay scales (see National Research Council 2000).

Table 2 presents summary statistics for the censored sample (firms with at least one unfilled vacancy). Besides overtime hours, the preferred practice appears to be training existing staff (33 percent often, 27 percent occasional). 16 percent of the affected firms are often recruiting workers with a university degree in non-ICT fields and training them. Approximately 25 percent of the firms responded that apprentices in the four ICT professions are often hired. This new ICT apprenticehip program has been very successful. In mid 2000 the number of ICT apprentices enrolled in the new apprenticeship program including the first apprentices already graduated already exceeds 40.000. 15 percent of the firms respondend that wages to job applicants are often raised in the past two years of the survey.

4. Determinants of the vacancy rate

Table 3 presents the results for generalized tobit model estimated by FIML. The upper panel contains the factors that might influence the probability of unfilled vacancies (excluding replacement vacancies) using the full sample and the lower panel the factors explaining the adjsuted vacancy rate using the censored sample. Separate regressions are presented for the entire sample, for the ICT sector and for the non-ICT sector. The results indicate that the correlation coefficient of the

Table 2: Summary Statistics censored sample (means)

	all sectors obs.=652	ICT-sector obs.=249	non-ICT sector obs.=403
log adjusted vacancy rate	−2.09	−2.23	−1.99
adjusted vacancy rate, %	27.3	19.5	32.1
vacancy rate, %	24.4	17.7	28.4
growth ICT workers, %	12.7	14.8	11.5
share of ICT workers, %	24.4	51.4	8.1
share of newly hired ICT workers, %	10.2	12.2	9.0
actions to fill empty positions for ICT workers in the last two years (1/0)			
increased training existing staff, often	33.2	33.7	33.0
increased training existing staff, occasional	27.1	27.4	26.7
overtime, often	70.7	71.4	70.4
overtime, occasional	17.7	19.8	16.4
hiring of trained workers, often	10.6	14.3	8.4
hiring of trained workers, occasional	26.1	29.0	24.4
hiring of workers w. non ICT background,wp.	15.9	18.4	14.5
hiring of workers w. non ICT background, occ.	27.1	34.9	22.4
hiring of ICT apprentices, often	24.5	28.6	22.2
hiring of ICT apprentices, occasional	17.2	16.3	17.2
outsourcing ICT work, often	31.0	18.3	38.7
outsourcing ICT work, occasional	27.2	24.2	31.7
Higher pay offers, often	14.7	14.2	14.9
Higher pay offers, occasional	31.2	32.9	30.1
outsourcing of ICT (0/1)			
ICT-Training, completely	17.5	7.1	23.9
ICT-Training, partially	60.3	58.8	61.2

Notes: All numbers are unweighted.

selection equation and the structural equation is significantly different from zero in the non-ICT sector equation but in the ICT sector equation. In the former equation ICT penetration as well as outsourcing of software programming are significant in the first stage probit equation but not in the second stage equation and could therefore used as identifying variables for the structural equation. In the ICT sector equation, however, it is difficult to find exclusion restrictions. In this case OLS regression using the censored sample would be approbriate. Since the signs and significance for the coefficients based on the structural equation of the generalized tobit model are generally similiar to those based on OLS regression interpretation focusses on the generalized tobit model. The empirical results indicate that the degree of ICT penetration is significantly positively related to the probability that firms have unfilled vacancies during the first six months in 2000. In fact, the three ICT penetration indicators are jointly significant from zero in the probit equation including all sectors (p-value$<$0.01). Separate regressions for the ICT and non-ICT sector indicate that the probability that firms have unfilled vacancies depends on different ICT penetration indicators. The number of computers per worker appears to be a significant predictor in the ICT sector but not in the non-ICT sector. The percentage of workers using a computer is only significant in the non-ICT sector. The use of CAD/CAE software applications as well as the use of web applications such as web customer relationship management as well as web recruiting also increase the probability that a firm has unfilled vacancies, in particular in the non-ICT sector. The finding of a strong relationship between the propensity of unfilled vacancies and technology use stands in contrast to Haskel and Martin (1999). Using U.K firm data they find that most technology indicators have little impact on skill shortage except for word processing. However, they are unable to distinguish between ICT workers and non-ICT workers. Furthermore, outsourcing of software programming decrease the propensity of unfilled vacancies in the non-ICT sector. The probability that a firm has unfilled vacancies is significantly higher for firms that are specialized in software development but this effect is only significant in the non-ICT sector. The coefficients on the sector dummies indicate that the probability that firms have unfilled vacancies is higher in banking and insurance as well as the ICT sector than in the remaining sectors.[4] Finally, in the ICT sector increased training of the existing staff reduces the probability of unfilled vacancies.

Regarding the determinants of logarithm of the vacancy rate I find that the most important determinants are both firms and the initial stock of ICT workers

[4]Firm and sector effects are not listed in Table 4 due to space limitations.

relative to total workers. Unreported results show that both variables jointly contribute to 0.40 to the adjusted R-squared of about 0.46. The percentage of ICT workers in total employment is significantly negative suggesting that firms with a high initial stock of ICT workers in 1999 relative to total employment have a lower ICT vacancy rate. Consistent with hypothesis 5 I find that the vacancy rate decreases with firm size. This is consistent with Abraham (1983) who finds that large units tend to have lower vacancy rates for homogeneous labor. In the ICT sector, the growth rate of ICT workers between 1999 and 2000 has a positive effect but this is not significant at the 5 percent level. Conversely, in the non-ICT sector I find a significantly negative coefficient indicating that firms with a higher employment growth rate in the past have a lower current vacancy rate. Surprisingly, I find that the penetration of ICT is not a major determinant of the adjusted vacancy rate. In fact, the three ICT penetration indicators (percentage of workers using a computer, the number of computers per worker as well as the percentage of workers with internet access) are all insignificant at conventional significance levels (p-value =0.146). Although the data does not support the hypothesis that the vacancy rate increases with a higher penetration of ICT, the other hypotheses listed above do receive some support. In particular, the use of web applications such as electronic banking tends to increase the ICT vacancy rate. More importantly, the results indicate that the willingness to establish jobs for apprentices in ICT-occupations in the past as well as increased training activities of the existing staff reduces the magnitude of the vacancy rate. In the ICT sector, ICT apprentices often hired in the past two years of the survey reduces the vacancy rate by about 32 percent compared to fims without hirings. In the non-ICT sector, firms training their existing staff often have lower vacancy rates. In this sector, the practice of hiring apprentices within the new ICT apprenticeship program to solve the skill shortage for ICT workers is not significant. Firms with outsourcing of ICT-related activities do not have a lower vacancy rate except firms with outsourcing of ICT-related training. In the non-ICT sector outsourcing of system administration activities reduces the vacancy rate of ICT workers by 28 percent. Raising wages for applicants in the past two years of the survey is not significant at the five percent level and was therefore excluded from the regression.

5. Conclusions

This paper provides first systematic evidence on the determinants of unfilled vacancies for information and communication technology workers. The empirical

evidence comes from a unique cross-sectional data set conducted in mid-2000. In particular, I investigate the impact of penetration of ICT as well as strategies to solve ICT skill shortages on both the probability that firms have unfilled vacancies and the level of vacancies. Vacancies are measured as unoccupied job openings during the first half of 2000 excluding vacancies created by replacement demand.

The major findings are as follows. High turnover rates are not the cause of skill shortages for ICT workers. The share of vacancies created by the firms desired net change of employment with about 80 percent is considerably larger than the share of replacement vacancies with 20 percent of total vacancies. This means that a large proportion of all reported unfilled job vacancies are the result of the firms' desire to expand employment and output rather than high quit or layoff rates. The adjusted job vacancy rate for ICT workers varies between 5.7 in the ICT sector and 6.7 in the non-ICT sector. Both findings in combination with the fact that the majority of the firms report higher vacancy duration for ICT occupation than for non-ICT occupations provides powerful evidence of a true labor shortage for ICT workers.

The empirical results on the determinants of the adjusted vacancy rate given that firms have unfilled vacancies indicate that variations in the adjusted vacancy rate are mostly determined by the initial stock of ICT workers, firm size as well as actions implemented to fill empty positions. The vacancy rate decreases with firm size and is significantly negatively related to the initial share of ICT workers in total employment indicating a catch-up effect. In the ICT sector, I find that the vacancy rate is significantly lower if firms hired apprentices in the four ICT occupations. Another successful strategy introduced to solve the skill shortage appears to be training existing staff to fill empty positions, in particular in the non-ICT sector. Actions such as recruiting workers with a university degree from non-ICT background and outsourcing in the past two years of the survey also tends to reduce the current vacancy rate but are not significant at the 10 percent level.

Futhermore, I find that the probability that firms have unfilled vacancies for ICT workers depends positively on ICT penetration in particular on the number of computers share and the percentage of workers using a computer on the job and on web applications such as web customer relationship management. Finally, outsourcing of software development reduces the probability that firms have unfilled vacancies.

References

Abraham, K. G., 1983, 'Structural-Frictional vs. Deficient Demand Unemployment: Some New Evidence': *American Economic Review*, 73, 708-724.

Bresnahan, T., E. Brynjolfsson and L. Hitt, 2001, 'Information Technology, Workplace Organization and the Demand for Skilled Labor: Firm-level Evidence', forthcoming in: *Quarterly Journal of Economics*.

Cappelli, P., 2000, '*Is there a shortage of Information Technology workers*?' A Report to McKinsey and Company.

Farm, A, 2000, '*Job openings, hirings and unmet Demand: A New Approach to the Matching Function and the Beveridge Curve*', Swedish Institute for Social Research (SOFI), Stockholm University, http://www.sofi.su.se/

Freeman P. and W. Aspray, 1999. '*The Supply of Information Technology Workers in the United States*'. Computing Research Association, http://www.cra.org.

GFK, ISI and IESE (2000) '*Analyse und Evaluation der Softwareentwicklung in Deutschland*'. Studie für das Bundesministerium für Bildung und Forschung.

Green, F. and D. Ashton, 1992, 'Skill shortage and skill deficiency - a critique'. *Work, Employment & Society*, 6, 2, 287-301.

Haisken-DeNew, J. P. and C. M. Schmidt, 1999, 'Money for Nothing and Your Chips for Free? The Anatomy of the PC Wage Differential', IZA discussion paper, 86.

Haskel, J. and C. Martin, 1999, 'Technology, Wages and Skill Shortages: Evidence from UK Micro Data', mimeo, forthcoming in *Oxford Economic Papers*.

Jorgenson, D. W. and K. J. Stiroh, 2000, 'Raising the speed limit: US economic growth in the information age', *OECD working papers*, 87.

Muysken, J. 1994, 'Introduction', in: *Measurement and Analysis of Job Vacancies*, Avebury, Aldershot, 1-11.

National Research Council, 2000, '*Building a Workforce for the Information Economy*', Committee on Workforce Needs in Information Technology, Washington D.C., http://www.nap.edu/

Van Bastaer, A and J. Laan, 1994, 'The Job Vacancy Survey in the Netherlands', in Muysken j. (ed.). *Measurement and Analysis of Job vacancies*. Avebury.

Veneri. C. M., 1999, 'Can occupational labor shortages be identified using available data?' *Monthly Labor Review*, 122, 3, 15-21.

Table 3: Heckman selection model (FIML estimates)

	all sectors		ICT sector		non-ICT sector	
	coeff	t	coeff	t	coeff	t
	selection equation (unfilled vacancies=1,0 oth.)					
% share of ICT workers	1.153	6.4	1.054	3.2	1.444	4.4
# computer per worker	0.106	1.7	0.153	1.1	0.054	0.6
% workers using a computer	0.189	1.6	−0.375	−1.1	0.302	2.3
% workers w. internet access	0.044	0.4	0.384	1.3	0.000	0.0
CAD/CAE, widespread	0.224	2.6	0.021	0.1	0.287	2.6
CAD/CAE, occasional	0.208	2.9	0.049	0.2	0.275	3.2
outsourcing programming, compl.	−0.289	−3.6	−0.303	−1.2	−0.280	−3.2
web customer relations., wides.	0.285	2.2	0.273	0.5	0.295	2.2
web customer relations., occas.	0.209	1.7	0.303	0.6	0.214	1.6
training existing staff, often	−0.066	−0.9	−0.283	−2.1	0.011	0.1
training existing staff, occas.	0.122	1.6	0.099	0.6	0.132	1.5
ICT apprentices, often	0.192	2.3	0.003	0.0	0.279	2.8
ICT apprentices, occasional	0.127	1.4	−0.077	−0.4	0.205	1.9
activity: software development	0.437	5.7	0.542	2.4	0.422	4.7
activity: E-Commerce	0.200	3.2	0.077	0.6	0.246	3.4
	log adjusted vacancy rate					
growth rates ICT workers	−0.078	−2.0	0.288	2.6	−0.138	−4.8
% share of ICT workers	−0.905	−5.2	−0.543	−1.1	−1.636	−5.2
training existing staff, widesp.	−0.221	−2.8	−0.271	−1.7	−0.202	−2.1
training existing staff, occasional	−0.026	−0.3	−0.078	−0.6	0.034	0.3
new hirings & train them, often	−0.016	−0.2	0.310	2.1	−0.230	−1.8
new hirings & train them, occas.	−0.154	−2.0	−0.108	−0.9	−0.146	−1.5
ICT apprentices, often	−0.127	−1.4	−0.402	−3.3	0.064	0.5
ICT apprentices, occasional	−0.143	−1.5	−0.214	−1.4	−0.139	−1.1
outs. system admin, completely	−0.215	−1.7	0.245	1.2	−0.335	−2.2
outsourc. ICT training, often	−0.224	−2.0	−0.259	−1.4	−0.219	−1.5
outsourc. ICT training, occas.	−0.203	−2.3	−0.230	−1.9	−0.198	−1.5
constant	−2.493	−12.3	−2.730	−4.5	−2.415	−9.6
ρ	0.523	3.5	0.698	0.8	0.419	2.5
ln σ	−0.129	−2.8	−0.218	−0.9	−0.146	−2.7

Notes: The coefficients on the use of electronic banking as well as web recruiting are not reported due to space limitations. A constant in the probit equaton as well as size and sector dummies in both equations are also included but not reported. Number of observations is 3878, 600 and 3278 respectively. t-values are based on White's heteroscedasticity adjusted standard errors.