Discussion Paper No. 01-43

What Drives the Vacancy Rate for Information Technology Workers?

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Non-technical summary

There is general consensus that the German labor market for information and communication technology (ICT) specialists has large numbers of unfilled positions. Particularly in the U.S. there has been a lively debate about the existence and the magnitude of the shortage of ICT workers. While industry representatives argue that there is a shortage of ICT workers, labor market analysts see a temporarily tight labor market. However, it is difficult to find a appropriate measure of occupational shortage. The number of vacancies is often used as a measure of ICT worker shortage. 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.

This paper provides the first systematic empirical evidence on the determinants of unfilled positions for ICT workers. The empirical evidence comes from a unique cross-sectional data set conducted in mid-2000. In particular, I investigate the impact of ICT penetration, as well as strategies to solve ICT worker shortages on both the probability that firms have vacancies and the number of vacancies. Vacancies are measured as unfilled positions during the first half of 2000 excluding those created by replacement demand. The major findings are the following: High turnover rates are not the main reason for the ICT worker shortage. 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 about 20 percent of total vacancies. The adjusted job vacancy rate for ICT workers varies between 5.7 percent in the ICT sector and 6.7 percent in the non-ICT sector. Both findings in combination with the fact that the majority of the firms reports higher vacancy duration for ICT workers than for non-ICT workers 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 positions indicate that the adjusted vacancy rate mainly depend on the initial stock of ICT workers, firm size as well as actions taken to solve the ICT worker shortage in the past but not on the penetration of ICT. In the ICT sector, the vacancy rate is significantly lower if firms made extensive use of the new ICT apprenticeship program established in 1997. 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. Furthermore, the probability that firms have unfilled positions for ICT workers depends positively on ICT penetration (such the percentage of workers using a computer on the job, use of CAD/CAE software and on the use of web customer relationship management). Finally, outsourcing of software development reduces the probability that firms have unfilled positions.

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What Drives the Vacancy Rate for Information Technology Workers?*

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Summary

This paper provides empirical evidence on both the magnitude and determinants of unfilled positions for information technology workers using cross-sectional data on 4150 German firms. Vacancies are defined as unfilled positions excluding those created by replacement needs during the first half of the year 2000. The share of unfilled positions created by replacement needs is only about 20 percent, indicating that high turnover rates are not the main reason for high vacancy rates. The adjusted job vacancy rate for ICT workers varies between 5.7 percent in the ICT sector and 6.7 percent in the non-ICT sector. The results of a generalized tobit model show that the adjusted vacancy rate mainly depends on the firm size, the share of ICT workers and actions taken in the past to solve the ICT worker shortage but not on the diffusion of ICT. In the ICT sector, the decision made in the past to train apprentices in the new ICT occupations seems to have reduced the current vacancy rate. In the non-ICT sector, a successful strategy to solve the ICT worker shortage appears to be increased internal training. Finally, in the non-ICT sector, the common practice of completely outsourcing software programming significantly reduces the probability of unfilled positions.

JEL J63, J21, O33
Unfilled positions, ICT workers, information technology
unbesetzte Stellen, IKT-Fachkräfte, Informationstechnologie

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Zusammenfassung

Dieser Beitrag beschäftigt sich mit der Anzahl und den Bestimmungsfaktoren unbesetzter Stellen für IKT-Fachkräfte in Deutschland. Datengrundlage ist eine repräsentative telefongestützte (CATI) Umfrage von 4150 Unternehmen für das Jahr 2000. Die Quote unbesetzter Stellen für IKT-Fachkräfte (ohne Stellen aufgrund Ersatzbedarfs) variiert zwischen 5,7 Prozent in der IKT-Branche und 6,7 Prozent in der Nicht-IKT-Branche. Der Anteil fluktuationsbedingt unbesetzter Stellen an allen unbesetzten Stellen beträgt 20 Prozent. Somit dürfte die Personalfluktuation der IKT-Fachkräfte nicht die Hauptursache für die hohe Quote unbesetzter Stellen sein. Regressionsergebnisse auf Basis verallgemeinerter tobit-Modelle zeigen, dass die Quote unbesetzter Stellen hauptsächlich von der Firmengröße, dem Anteil der IKT-Fachkräfte im Vorjahr sowie den Strategien zur Überwindung des IKT-Fachkräftemangels in der Vergangenheit abhängen, jedoch von der Diffusion der Informationstechnologie nicht beeinflusst werden. Hinsichtlich der Wahrscheinlichkeit unbesetzter Stellen zeigt sich, dass die Auslagerung der Software-programmierung an Fremdunternehmen zu einer geringeren Betroffenheit von unbesetzten Stellen für IKT-Fachkräfte führt.

1. Introduction

There is general consensus that the German labor market for information and communication technology (ICT) specialists has large numbers of unfilled positions. This labor market shortage of ICT workers has recently received much attention among researchers and the general public alike. Particularly 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 also been examined. While industry representatives argue that there is a shortage of ICT workers, labor market analysts see a temporarily tight labor market (see Cappelli 2000, National Research Council 2000, Veneri 1999). Cappelli (2000), for instance, concludes that ICT worker 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 little evidence on the magnitude of unfilled positions and the extent of the ICT worker shortage. One exception is the study of GfK, ISI and IESE (2000) which investigates ICT worker shortage and ICT skill needs for software developers and programmers using data on 800 firms in a number of manufacturing and service industries. They found a very high unfilled job vacancy rate for software developers of about 17 percent in the ICT sector and 16 percent in the remaining industries. Using data from the IAB establishment panel 2000, Kölling (2001) investigates the extent and the determinants of unfilled positions for three different educational qualification groups as well as for workers with a university degree in engineering, computer science and mathematics. He finds that the extent of unfilled positions for highly skilled workers mainly depends on investment in information and communication technologies as well as on organizational change.

In the debate on the magnitude of the ICT worker shortage, the appropriate measure of occupational shortage is controversial. 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 labor shortage. Large vacancy rates of ICT workers, however, 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 worker or skill shortage (see Freeman and Aspray 1999). In particular, the growth in the usage of ICT throughout the economy is seen as the fundamental driver of this labor shortage or labor market tightness for ICT workers. This explanation is consistent with the fact that the increased usage of ICT has also 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 about 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 as well as the opening of the labor market to 20,000 information technology workers from outside the EU on a new temporary residence visa (German Greencard).

This paper examines determinants of the vacancy rate of ICT workers using cross-section data on 4,150 firms. Vacancies are defined as unfilled positions created by the firms' desired net

change of employment during the first half of the year 2000. Unfilled positions created by replacement needs are not included. The resulting adjusted vacancy rate serves as a measure of unmet labor demand for ICT workers. In addition, unfilled positions are compared to the number of newly hired ICT workers. In the literature, there are few employer surveys that distinguish between unfilled positions and filled positions, see e.g. the study of Van Bastelaer and Laan (1994) and Kölling (2001). 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, B2C and web customer service) as well as different outsourcing practices. Past activities to solve the ICT worker shortage, such as hiring university graduates with a non-ICT background or workers trained by information technology training programs, as well as training of ICT apprentices may also influence the current vacancy rate. Generalized tobit models are used to take into account that a large fraction of firms in the sample does not have unfilled positions for ICT specialists.

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, the empirical results of the sample selection model are presented. Section 5 concludes the findings.

2. Empirical Modelling

2.1 Definition and measurement of the vacancy rate

The number of vacancies is often used as a measure of labor shortage. The job vacancy rate is a measure originally developed by the U.S. Bureau of Labor Statistics that was designed to measure unfilled labor demand. Here, job vacancies are defined as currently unfilled positions in the establishment that are immediately available to workers outside your firm and for which the firm is actively seeking to fill (Abraham 1983). A related concept that is relevant here is skill shortage. Green and Ashton (1992) introduced 'skill shortage' as difficulties in filling vacancies. Vacancies can also be defined as job openings with starting recruitment activities (see Farm 2000). Vacancies, however, suffer from a number of problems (see Abraham 1983, Franz and Smolny 1994). A high vacancy rate does not necessarily indicate a labor shortage. High turnover rates and a long time to fill positions requiring particular ICT skills lead to a large number of vacancies even if the supply of ICT workers is equal to the demand for them. Under certain simplifying assumptions, the vacancy rate for ICT workers, v, can be defined as (National Research Council 2000):

$$v = \frac{V}{N} = \left(\frac{S}{N} + \frac{\Delta N}{N} \right) \times D \qquad (1)$$

where the vacancy rate is calculated by dividing the stock of job vacancies for ICT positions, V, by the total ICT workforce, N.[1] The formula s=S/N denotes the separation rate measured as total number of separations of ICT workers as percent of the ICT workforce per year. Δ 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 (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 Pissarides (1990). In particular, the turnover as well as the 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).

It is well known that the turnover rate for ICT occupations is higher than the turnover rate for non-ICT occupations. For the U.S., the turnover rate in ICT positions by individuals with a bachelor's degree or higher (measured as changing employers or changing jobs with the same employer) is 19 percent per year during the period 1995 to 1997 (see National Research Council 2000). The comparable rate for non-ICT workers with an equivalent educational level is 11.7 percent. German figures based on the microcensus show similar tendencies. Based on the German microcensus 1997, the percentage of core-ICT workers who change employers in 1996 is 14 percent compared to 9 percent for non-ICT workers (both groups with a university degree). In addition, the turnover rate of ICT workers is higher in the ICT sector than in the non-ICT sector. Based on the German microcensus, the share of ICT workers (all educational qualification groups) who change employers in 1996 ranges between 13 percent in the non-ICT sector and 17 percent in the ICT sector. Therefore, a large fraction of vacancies can be attributed to the high turnover of ICT workers. For the U.S., the National Research Council (2000) suggested that 80 percent of the current stock of vacancies are due to turnover and the remaining 20 percent are due to net employment growth. For Germany, assuming a turnover rate of 20 percent, a growth rate of ICT workers of about 10 percent and an average time of four months to fill a position result in 33.300 vacancies for ICT occupations due to replacement needs and 16.700 vacancies due to employment growth over the course of the year, given the total estimate of about 495.000 workers in ICT occupations based on the 1999 German microcensus.

Another problem with vacancies as a measure of labor shortage is that vacancies might exclude a large number of discouraged vacancies, i.e. jobs that employers would like to fill but have given up recruiting for. Abraham (1983), however, suggests 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 positions during the first half of the year 2000. This definition is similar to those used in the IAB establishment panel (see Kölling 2001). In particular, firms

[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).

are asked if they have been willing to hire ICT workers but suitable applicants have not been available. This implies that the number of hiring decisions is greater than the number of actually hired ICT workers. In other words, if firms do not succeed in hiring a new worker during this period, an open position becomes vacant. Firms are then asked about the number of unfilled positions. This measure of vacancies does not include vacancies that were immediately filled or filled within the six-month period. Instead, this measure of unfilled positions mainly consists of longer duration vacancies as well as hard-to-fill vacancies and therefore provides a measure of unmet labor demand. Since the measure of unfilled positions in this survey is based on a flow concept, it is difficult to compare the vacancy rate to those reported in previous vacancy surveys. Farm (2000), however, points out that the stock of vacancies during any given 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 positions.

The flow of vacancies during a period of time equals the flow of occupied jobs, FV_O, and the flow of unfilled jobs, FV_U, both measured during the first half of the year 2000:

$$FV = FV_O + FV_U \tag{2}$$

Occupied job positions 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 the high employee turnover of ICT workers rather than to net employment growth, particularly in the ICT sector. Therefore, it is important to distinguish between vacancies created by the firms' desired net change of employment, $FV_{U,G}$, and vacancies created by replacement needs, $FV_{U,R}$,

$$FV = FV_{U,R} + FV_{U,G} \tag{3}$$

The ratio of unfilled positions 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 needs may be smaller than the share created by net employment growth. One explanation for this hypothesis is that many separations are anticipated and replacements are 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 share of ICT workers in the previous year, the percentage change of ICT workers in the previous year, the use of different software and web applications, outsourcing activities as well as

strategies implemented to solve the ICT worker shortage in the past. The following specification will be used to examine the determinants of the adjusted vacancy rate:

$$FV_{U,G}/N = \beta_0 + \beta_{1j}\Delta N/N + \beta_{2j}N/E + \beta_{3j}COMP/E + \beta_{4j}E^{COMP} + \beta_{5j}E^{WEB} + \beta_{6jf}SW_f + \beta_{7jg}WEB_g + \beta_{8jh}STRAT_h + \beta_{9jl}OUTS_l + \beta_{10jm}Z_m + \varepsilon_j \quad (4)$$

where j refers to the industry.

The variables are defined as

$FV_{U,G}/N$	ratio of unfilled positions for ICT workers to total ICT workers (excluding unfilled positions created by replacement needs)
$\Delta N/N$	annual percentage change of ICT workers between 1999 and 2000
N/E	share of ICT workers in 1999 (excluding ICT apprentices) (percent)
$COMP/E$	number of computers in 2000 divided by total employment in 1999
E^{COMP}	percentage of workers using a computer on the job in 2000 (percent)
E^{WEB}	percentage of workers with internet access in 2000 (percent)
SW_f	f=1,...,5 different software applications
WEB_g	g=1,...,7 different web-related activities
$STRAT_h$	h=1,..,8 strategies to solve the ICT worker shortage during the last two years
$OUTS_l$	l=1,..,8 types of ICT outsourcing, completely or partially
Z_m	1,...,6 firm size classes; 1,...,8 industry dummies

The right-hand variables are the number of ICT workers as a percentage of total workers, N/E, ICT penetration indicators (such as the percentage of workers who use a computer, the number of computers per worker, the percentage of workers with internet access and the use of different web and software applications). The remaining variables are strategies to solve the shortage problem in the past, $STRAT_h$, outsourced ICT-activities, $OUTS_l$, as well as a set of appropriate control variables, Z_m.

One should note that between 87 percent of the firms in the non-ICT sector and 58 percent of the firms in the ICT-sector do not have unfilled positions for ICT workers and thus register zero observations (based on the unweighted sample). A tobit model estimated by ML or a censored regression model estimated by semi-parametric methods would be appropriate. However, the use of the tobit model imposes the restriction that the regressors have the same impact on the probability of observing unfilled positions and the rate of unfilled positions as they occur. It could be hypothesized that the probability of vacancies increases with firm size but the vacancy rate decreases with increasing firm size given that firms have unfilled positions. In addition, the performance of the semi-parametric censored regression model is quite poor when the percentage 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 or sample selection model (known as tobit type II). This model consists of an index or a selection equation, a structural equation and a threshold index linking both equations. The selection equation concerning whether or not firms have unfilled positions is given by:

$$d^* = x_1\beta_1 + u \quad (5)$$

where the threshold index is defined as d=1 if d*>0 and d=0 if d*≤ 0. The threshold structural equation is defined as

$$v^* = x_2\beta_2 + e \tag{6}$$

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

$$e,u \sim N(0,0,\sigma^2,\rho) \tag{7}$$

v* denotes the latent (non-observed) endogenous variable and v denotes 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 positions, 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). This 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). In particular, exogenous variables are necessary that explain whether or not unfilled positions occur but not how many vacancies exist. In empirical studies using firm data, it is often difficult to find exclusion restrictions and justify them based on theoretical considerations. The approach adopted here is to estimate a most general specification 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 shows that the practice of completely outsourcing software development is a valid exclusion restriction. If the correlation coefficient, ρ, is found to be insignificant, the vacancy rate function is estimated using OLS on the restricted sample. Furthermore, I use logarithms of the vacancy rate rather than the untransformed vacancy rate. This may reduce the skewness of the vacancy rate (see Figure 1 in the appendix).

It should be noted that the specification presented above is based on several restrictive assumptions. The use of outsourcing of ICT activities as an exclusion restriction can be criticized because outsourcing itself is a choice variable. In principle, one may add a selection equation explaining the decision to outsource. Unfortunately, it is difficult to find variables explaining the decision to outsource but not the existence of unfilled positions. Note that all firms were independently asked about their outsourcing decision and the extent of the ICT worker shortage. Furthermore, the question on outsourcing does not refer to a specific time period. There might also be a simultaneity problem between the strategies to solve the ICT worker shortage and the current vacancy rate. Since the strategies refer to the past two years of the survey, the direction of causality has been assumed to run from strategies implemented in the past to current unfilled positions. Note also that all firms (with or without vacancies) have been asked about their strategies to solve the ICT worker shortage in the past. A final point concerns the specification of the univariate probit model. The absence of unfilled positions can be simply explained by the fact that firms do not generally employ ICT workers or that firms decide not to hire ICT workers within the six month period. Note that both the

hiring of ICT workers within the six month period and the presence of unfilled positions are final outcomes of the decision to open a position. Both decisions may also depend on different factors. While the presence of unfilled positions may be related to local supply factors, such as the local unemployment rate of ICT workers, the decision to open a position may depend on demand factors. In this situation the bivariate probit model with partial observability suggested by Poirier (1980) may be more general than a univariate probit model. However, variables such as the local unemployment for ICT workers or local relative wages are very difficult to get.

2.3 Hypotheses

In the following, seven hypotheses concerning the determinants of the adjusted vacancy rate are formulated that will be evaluated in the following empirical work:

Hypothesis 1. The probability of unfilled positions is lower if firms are completely outsourcing their ICT activities.

Hypothesis 2. Both the propensity of unfilled positions as well as the vacancy rate itself should be strongly positively related to the diffusion of ICT.

Hypothesis 3. The vacancy rate will be lower if employers have successfully implemented strategies to solve the ICT worker shortage in the past, such as the training of apprentices in the new ICT occupations or increased internal training.

Hypothesis 4. The adjusted vacancy rate for ICT workers depends negatively on the share of ICT workers in the previous year.

Hypothesis 5. The vacancy rate decreases with increasing firm size.

Hypothesis 6. The vacancy rate for firms that have unfilled positions may be lower in the ICT sector than the vacancy rate in the non-ICT sector.

Hypothesis 7. The vacancy rate for firms that have unfilled positions may be increasingly positively related to the firms' employment growth rate of ICT workers in the previous year.

Hypothesis 1 states that firms with outsourced ICT activities are less likely to report unfilled positions. The outsourcing of software development has become a common practice. In particular, firms in the non-ICT sector are expected to outsource software projects. Hypothesis 2 states that unfilled positions 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 positions 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 usage of information and communication technologies. For instance, qualified ICT workers are required for the development and maintenance of many software and web applications. Hypothesis 3 is about actions implemented in the past to address the labor shortage problem of ICT workers. Employers have many options to solve the ICT worker shortage, including hiring less qualified workers, recruiting workers outside traditional ICT occupations or hiring workers who have completed a public training program

in major information technology applications such as SAP courses, increased internal training, contracting out ICT tasks or cutting back production. Strategies aiming to increase the supply of the 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 train apprentices in ICT occupations or if they increase internal training. According to hypothesis 4, the vacancy rate for ICT workers depends negatively on the share of ICT workers in the previous year. 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. Hypothesis 5 states that the vacancy rate decreases with increasing firm size. 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).[2] Furthermore, the vacancy rate for firms with unfilled positions may be lower in the ICT sector than in the non-ICT sector. Some sectors such as manufacturing, trade and transport firms with unfilled positions may have a higher vacancy rate due to inflexible pay scales and the lack of stock options and equity stakes (Hypothesis 6). Finally, hypothesis 7 states that the vacancy rate for firms with unfilled positions may be increasingly positively related to the firms' employment growth rate in the previous year.

3. Data description and summary statistics

In mid-2000, INFAS collected data from about 4,400 firms using a stratified random sample of about 10,500 firms based on 'Creditreform', the largest German credit rating agency. This corresponds to a response rate of about 43 percent. The survey was designed by the ZEW in cooperation with INFAS as well as the Federal Ministry of Education and Research (BMBF). The survey was conducted by telephone using CATI techniques. 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 of both the manufacturing and the service sector. The survey is stratified by industry, size and region. The firms 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. Government, non-profit institutions, the health sector as well as the construction sector are not included in our survey. The industry affiliation of the firms is identified using the question of which product groups or services generate the highest revenues. The definition of the ICT sector is as close as possible to that of the OECD.[3]

[2] For further evidence on the positive wage-firm size relationship see Schmidt and Zimmermann (1991).

[3] The ICT-sector includes the following industries: office machinery and computers (300), wire and cables (313), radio, television and communication equipment (321-323), instruments and appliances (332), industrial process control equipment (333), wholesale of office machinery (51641), retail sales

Approximately 4400 firms participated in the first wave. The exclusion of 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 positions 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 were first asked whether they hired ICT workers, and if so, how many ICT workers they hired in the first half of the year 2000. Both firms with or without hirings were asked whether they were willing to hire ICT workers but suitable applicants were not available during the first half year 2000. If so, the respondent was asked to specify 'the number of positions for ICT workers that were unfilled during the first half of the year 2000'. The definition of the ICT workers is rather broad and mainly covers ICT specialists of 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 whereas missing values on each variable are imputed using 'trimmed' means across sectors or predictions based on predicted values from probit regressions.[4] Approximately 5.9 percent of the firms reported unfilled positions for ICT workers during the first half of the year 2000. Subtracting unfilled positions created by replacement vacancies slightly decreases the percentage of firms to 5.2 percent. The share of unfilled positions for ICT workers in the first six months of the year 2000 as percentage of total ICT workers is 7.8 percent.[5] A vacancy rate of 7.8 percent is quite high given the unemployment rate of ICT occupations of about 4 percent (based on microcensus 1997). When national surveys of vacancies were conducted in the past, the job vacancy rate was in the 1.0 to 2.0 percent range (see Abraham 1983). When vacancies due to replacement needs are excluded, the vacancy rate decreases slightly from 7.8 to 6.3 percent. That means that 80 percent of the unfilled positions are created by the firms' desired change in net employment and 20 percent are due to replacement needs. Since vacancies with a long duration are overrepresented, the low proportion of vacancies due to replacement needs might be expected.

Figure 1 in the appendix shows the distribution of the adjusted vacancy rate as well as the distribution of the logarithm of the adjusted vacancy rate based on the selected sample including firms with at least one unfilled position. While the adjusted vacancy rate is skewed to the left, the logarithm of the adjusted vacancy rate tends to be normally distributed.

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of optical and photographic goods, computers and software (52484), telecommunications (642), renting of office machinery and computers (7133), and software and data processing (72).

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

[5] Note that this number differs slightly from those reported in Licht et al. (2001). The discrepancy can be explained by the different coverage of industries and firm size classes. In contrast to Licht et al. (2001) these calculations are restricted to the manufacturing and the service sector as well as to firms with 5 or more workers.

Table 1: Summary Statistics (means)

	all sectors obs: 4149	ICT sector obs: 640	non-ICT sector, obs: 3509
unfilled positions (1/0)	5.9	25.5	4.6
unfilled positions exclud. replacement vacancies, (1/0)	5.2	24.1	4.1
vacancy rate, percent [a]	7.8	6.9	8.5
vacancy rate excl. replacement vacancies, percent[a]	6.3	5.7	6.7
share of newly hired ICT workers, percent[a]	9.2	10.6	8.1
percentage change in ICT workers[a]	8.6	13.6	5.0
ICT workers (1/0)	33.6	94.7	28.6
ratio of ICT workers to total workers, percent [a]	4.7	27.6	2.9
computers per worker, percent[a]	51.3	84.0	49.1
percentage of workers using a computer[a]	43.2	62.0	42.0
percentage of workers with internet access[a]	27.8	51.1	26.2
	usage of software applications (1/0)		
database management, widespread	31.6	44.1	30.9
database management, 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
	usage 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 service, widespread	22.2	65.3	19.6
web customer service, 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]Continuous variables are weighted using information on the number of employment in each cell as the share of total employment based on the Employment Register of Social Security.
Source: ZEW-INFAS IT-Survey 2000.

continued Table 1:

	all sectors	ICT sector	non-ICT sector
activities to solve the ICT worker shortage in the past two years (1/0)			
increased internal training, often	9.5	29.4	8.3
increased internal training, occasional	8.8	25.9	7.8
overtime, often	11.6	31.0	10.4
overtime, occasional	6.9	22.9	5.9
hiring workers who completed a public training program, often	2.0	12.2	1.4
hiring workers who completed a public training prog., occasional	4.2	11.6	3.8
hiring university graduates with a non-ICT background, often	1.4	5.1	1.2
hiring university graduates with a non-ICT background, occ.	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 ICT work, often	6.8	14.4	6.3
contracting out ICT work, 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 administration, completely	32.5	11.8	33.7
system administration, 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

Firms are also asked about the time it takes to fill ICT positions relative to non-ICT positions. In the ICT sector, it is not surprising that it takes more time to fill open positions for ICT workers than for non-ICT occupations. 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 constitute half of the 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 can be translated 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 in the non-ICT sector for the year 1996. Furthermore, the percentage change in the number of ICT workers is 8.6 percent between 1999 and 2000.[6]

Table 1 also contains information on the three main information technology indicators. The number of computers (PCs, mainframes as well as terminals) per total worker amounts to 51 percent in 2000. Approximately 43 percent of employees are using a computer on the job for at least half of their working time. Based on the German socioeconomic Panel, 1997, a survey at the individual level, 52 percent are working with a computer on the job (see Haisken-DeNew and Schmidt 1999). This is also close to the corresponding share based on the German microcensus of about 54 percent.[7] The difference between our data set and the two other data sets may be due to the different coverage of our survey. Approximately 28 percent of the employees in the sample now have internet access. Our survey also requested information on the use of different software and web applications, and if used, the level of usage on a 2 point scale from small use to heavy use. In 2000, 61 percent of German firms report a use of ERP systems. The number of firms using CAD/CAE applications, data management/data warehouse software applications is 32 and 71 percent, respectively. Finally, Table 1 contains information on ICT outsourcing (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, 43 percent of the firms responded that software programming is completely outsourced. Regarding the actions to solve the ICT worker shortage in the past, the preferred practices appear to be overtime hours as well as increased internal training in the last two years of the survey. In the ICT industry, training of apprentices in ICT occupations and hiring workers who had attended a public training program in major ICT applications are also important. The newly established

[6] Based on the microcensus the annual growth rate of the core ICT occupations is 5.4 percent between the period 1993-1997.

ICT apprenticeship 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 exceeded 40.000. Conversely, few firms hired workers who have completed a public training program in ICT applications. Similarly, few firms 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: Summary Statistics

	all sectors	ICT sector	non-ICT sector
	Obs.=649	Obs.=249	Obs.=400
log adjusted vacancy rate	-2.09	-2.23	-1.99
adjusted vacancy rate, percent	27.3	19.5	32.1
vacancy rate, percent	24.4	17.7	28.4
percentage change in ICT workers, percent	12.7	14.8	11.5
share of ICT workers, percent	24.4	51.4	8.1
share of newly hired ICT workers, percent	10.2	12.2	9.0
actions to solve the ICT worker shortage in the last two years (1/0)			
increased internal training, often	33.2	33.7	33.0
increased internal training, occasional	27.1	27.4	26.7
overtime, often	70.7	71.4	70.4
overtime, occasional	17.7	19.8	16.4
hiring trained workers, often	10.6	14.3	8.4
hiring trained workers, occasional	26.1	29.0	24.4
hiring university graduates, non-ICT fields, often	15.9	18.4	14.5
hiring university graduates, non-ICT fields, occasional	27.1	34.9	22.4
training ICT apprentices, often	24.5	28.6	22.2
training 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 (1/0)	
ICT training, completely	17.5	7.1	23.9
ICT training, partially	60.3	58.8	61.2

Notes: All numbers are unweighted.
Source: ZEW-INFAS IT-Survey 2000.

[7] See Statistics Germany 2001, 'Leben und Arbeiten in Deutschland, Ergebnisse des Mikrozensus, 2000'. Source: http://www.statistik-bund.de/presse/deutsch/pk/2001/mikro2000b.htm

Table 2 presents summary statistics for the selected sample (firms with at least one unfilled position). As expected, the adjusted vacancy rate for firms with at least one unfilled position is quite high ranging between 20 percent in the ICT sector and 32 percent in the non-ICT sector. 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. Approximately 25 percent of the firms responded that they often trained apprentices in the four ICT occupations. 15 percent of the firms responded that wages to job applicants have often been raised within the last two years of the survey.

4. Determinants of the vacancy rate

Table 3 presents the results for the generalized tobit model estimated by FIML. The first part of the table contains the factors that might influence the probability of unfilled positions (excluding replacement vacancies) using the full sample. The second part of the table contains the factors explaining the adjusted vacancy rate using the selected sample (firms with at least one unfilled positions excluding those created replacement needs). 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 between the error terms of the selection equation and the structural equation is significantly different from zero in the non-ICT sector equation but not in the ICT sector equation. In the former equation, ICT penetration and outsourcing of software programming are significant in the first stage probit equation but not in the second stage equation and could therefore be used as the identifying variables for the structural equation. In the ICT sector equation, however, it is difficult to find convincing exclusion restrictions. In this case, OLS regression using the selected sample would be appropriate. Since the sign and significance levels for the coefficients based on the structural equation of the generalized tobit model are generally similar to those estimated by OLS using the restricted sample, interpretation focuses 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 positions 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 the non-ICT sector indicate that the impact of ICT penetration is more pronounced in the non-ICT sector. Here, the percentage of workers using a computer, the use of CAD/CAE software applications as well as the use of web applications such as web customer service increase the probability that a firm has unfilled positions. The finding of a positive relationship between the propensity of unfilled positions and some indicators of ICT penetration stands in contrast to Haskel and Martin (1999). Using U.K. firm data, they found that most technology indicators have little impact on the probability of skill shortage, except word processing. However, they are unable to distinguish between the ICT workers and the non-ICT workers. Outsourcing of software programming decreases the propensity of unfilled positions in the non-ICT sector. Furthermore, the probability that a firm has unfilled positions is significantly

higher for firms with software development activities 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 positions is higher in banking and insurance as well as in the ICT sector than in the remaining sectors. Finally, in the ICT sector increased internal training reduces the probability of unfilled positions.

Regarding the determinants of logarithm of the vacancy rate, the most important determinants are firm size and the ratio of ICT workers 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 ratio of ICT workers to total workers in 1999 have a lower ICT vacancy rate. Consistent with hypothesis 5, the vacancy rate decreases with increasing firm size. This is consistent with Abraham (1983), who found that large units tend to have lower vacancy rates. In the ICT sector, the percentage change in the number 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, the significantly negative coefficient indicates that firms with a higher employment growth rate in the previous year have a lower current vacancy rate. Surprisingly, the ICT penetration 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). The use of web applications such as electronic banking, however, tends to increase the ICT vacancy rate. Regarding the strategies to solve the ICT worker shortage, the results indicate that the earlier willingness to establish jobs for apprentices in ICT-occupations as well as increased internal training reduce the magnitude of the vacancy rate. In the ICT sector, firms that made extensive use of the new ICT apprenticeship program in the past two years of the survey reduce the vacancy rate by about 33 percent compared to firms without training of ICT apprentices.[8] In the non-ICT sector, firms that have increased internal training in the past have lower vacancy rates. Similarly, the earlier willingness to employ university graduates in non-ICT fields or workers with a non-ICT background also reduces the current vacancy rate but this effect is only significant at the 8 percent level. 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 24 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.

[8] 0.33=EXP(-0.40)-1.

Table 3: Heckman's sample selection model (FIML estimates)

	selection equation (prob. for unfilled positions)					
	all sectors		ICT sector		non-ICT sector	
	coeff.	t	coeff.	t	coeff.	t
share of ICT workers	1.153	6.4	1.054	3.2	1.444	4.4
# of computers per worker	0.106	1.7	0.153	1.1	0.054	0.6
percentage of workers using a computer	0.189	1.6	-0.375	-1.1	0.302	2.3
percentage of workers with 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 software programming, completely	-0.289	-3.6	-0.303	-1.2	-0.280	-3.2
web recruiting, widespread	0.684	7.7	0.970	3.0	0.624	6.2
web recruiting, occasional	0.365	4.7	0.498	1.9	0.314	3.5
web customer service, widespread	0.285	2.2	0.273	0.5	0.295	2.2
web customer service, occasional	0.209	1.7	0.303	0.6	0.214	1.6
increased internal training, often	-0.066	-0.9	-0.283	-2.1	0.011	0.1
increased internal training, occasional	0.122	1.6	0.099	0.6	0.132	1.5
training of ICT apprentices, often	0.192	2.3	0.003	0.0	0.279	2.8
training of 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
	size and industry dummies[a]					
5 – 9 employees	-0.746	-4.6	-0.689	-2.4	-0.887	-2.5
10 – 49 employees	-0.567	-5.1	-0.640	-3.0	-0.460	-2.9
50 – 99 employees	-0.380	-3.3	-0.360	-1.5	-0.335	-0.7
100 – 249 employees	-0.336	-3.4	-0.360	-1.7	-0.324	-0.7
250 – 499 employees	-0.120	-1.3	-0.198	-0.9	-0.074	-1.1
wholesale trade	-0.120	-0.7			0.121	0.7
retail trade	-0.185	1.1			0.195	1.1
transport	0.197	1.4			0.206	1.5
banking and insurance	0.416	3.8			0.414	3.5
ICT sector	0.256	2.6				
technical consultants, R&D	0.015	0.1			0.018	0.1
business services	-0.025	-0.2			0.033	0.2
constant	2.178	13.0	1.663	2.9	2.302	12.3

Notes: t-values are based on White's heteroscedasticity adjusted standard errors. [a]The omitted reference groups are firms with 500 or more workers as well as the manufacturing sector.

continued Table 3

	log adjusted vacancy rate					
	all sectors		ICT sector		non-ICT sector	
	coeff.	t	coeff.	t	coeff.	t
percentage change in 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
increased training, often	-0.221	-2.8	-0.271	-1.7	-0.202	-2.1
increased training, occasional	-0.026	-0.3	-0.078	-0.6	0.034	0.3
hiring graduates non-ICT fields, often	-0.016	-0.2	0.310	2.1	-0.230	-1.8
hiring graduates non-ICT fields, occasional	-0.154	-2.0	-0.108	-0.9	-0.146	-1.5
training of ICT apprentices, often	-0.127	-1.4	-0.402	-3.3	0.064	0.5
training of ICT apprentices, occasional	-0.143	-1.5	-0.214	-1.4	-0.139	-1.1
outsourcing system administration, completely	-0.215	-1.7	0.245	1.2	-0.335	-2.2
outsourcing ICT training, often	-0.224	-2.0	-0.259	-1.4	-0.219	-1.5
outsourcing ICT training, occasional	-0.203	-2.3	-0.230	-1.9	-0.198	-1.5
	size and sector dummies[a]					
5 – 9 employees	1.799	10.1	1.457	4.2	2.287	8.2
10 – 49 employees	1.547	12.1	1.120	4.1	1.890	10.0
50 – 99 employees	1.134	9.0	0.686	2.8	1.406	9.6
100 – 249 employees	0.750	5.9	0.405	1.9	0.952	5.6
250 – 499 employees	0.600	6.3	0.397	2.2	0.649	5.8
wholesale trade	-0.246	-1.1			-0.269	-1.3
retail trade	-0.215	-0.9			-0.241	-1.0
transport	0.251	1.3			0.266	1.4
banking and insurance	0.335	-2.7			-0.319	-2.6
ICT sector	0.173	-1.6				
technical consultants, R&D	0.194	1.3			0.156	1.0
business services	0.246	1.4			0.350	1.9
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
log σ	-0.129	-2.8	-0.218	-0.9	-0.146	-2.7
# of total observations (# of zero observations)	3872(3223)		599(350)		3273(2873)	

Notes: see Table 3.

5. Conclusions

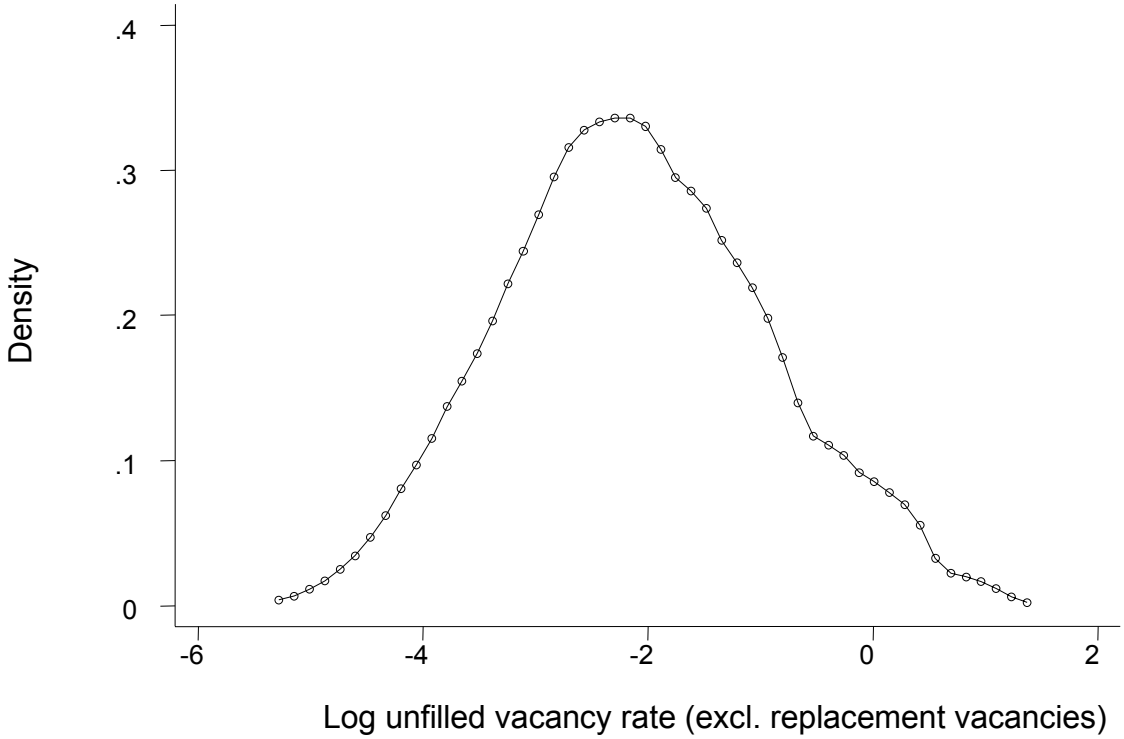
This paper provides first systematic evidence on the determinants of unfilled positions for information technology workers. The empirical evidence comes from a unique cross-sectional data set conducted in mid-2000. In particular, I investigated the impact of ICT penetration as well as the impact of strategies to solve the ICT worker shortage on both the probability that firms have vacancies and the rate of vacancies if unfilled positions exist. Vacancies are measured as unfilled positions during the first half of the year 2000, excluding vacancies created by replacement needs.

The major findings are as follows: High turnover rates are not the main reason for the ICT worker shortage. The share of vacancies created by the firms' desired net change of employment of 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 the result of high turnover rates. The adjusted job vacancy rate for the ICT workers varies between 5.7 percent in the ICT sector and 6.7 percent in the non-ICT sector. This finding, in combination with the fact that the majority of the firms report a higher vacancy duration for ICT occupations than 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 positions indicate that the adjusted vacancy rate mainly depends on the share of ICT workers in the previous year, on firm size and actions implemented to solve the ICT worker shortage in the past. The vacancy rate decreases with increasing firm size. The significantly negative relationship between the vacancy rate and the share of ICT workers in the previous year indicates a catch-up effect. In the ICT sector, the vacancy rate is significantly lower if firms are willing to train apprentices in the four ICT occupations more extensively than other firms. Another successful strategy introduced to solve the skill shortage appears to be increased internal training, particularly in the non-ICT sector. Furthermore, the probability that firms have unfilled positions for ICT workers depends positively on ICT penetration, in particular on the number of computers and the percentage of workers using a computer on the job, and on web applications such as web customer service. Finally, outsourcing of software programming reduces the probability of unfilled positions.

Appendix

Figure 1: Distribution of the adjusted vacancy rate (univariate kernel density estimation)



Notes: Firms with at least one unfilled position created by net employment growth. # of observations=649.

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