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Workers' skill level and information technology: evidence from German service firms

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Workers' Skill Level and Information Technology Evidence from German Service Firms*

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Abstract

This paper analyses the link between human capital and information technology (IT) in the service production process. The analysis is based on 1994 cross-sectional data for 1929 German firms drawn from the first wave of the Mannheim Service Innovation Panel (MIP-S). Factor demand functions are used to analyse the determinants of the firm-specific skill structure. The empirical evidence indicates that firms with a higher IT investment to sales ratio employ a larger fraction of high-skilled workers. The relationship between IT investment and medium-skilled labour is rather weak while the unskilled labour share is negatively related to the IT investment to sales ratio. Using a translog production function to assess the productivity of different input factors, we find that human and information capital provide the most powerful contributions to output in the service sector.

Keywords: Information technology, skills, labour demand, service sector

JEL Classification: J23, O33, L8

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A non-technical summary

While in the 1960s the public opinion feared that computer-controlled machines would eventually replace blue-collar workers, many people nowadays are afraid that information technology (IT) could replace the middle management. Similarly, transaction cost theory implies that the number of managers could be sharply cut due to the introduction of IT (Malone and Rockart 1991). Thus, theoretical analyses as well as informal evidence suggest that the prevalent spread of IT in all types of enterprises may affect the skill structure within firms. Service firms are heavy users of information technology. In particular, knowledge-intensive service activities such as software, R&D and technical consulting, as well as business services have a relatively high share of information technology in total output. Among all sectors, the service sector is prone to be severely affected and to experience the most significant changes from the rise of IT.

Empirical work on the link between information technology and skills has used both establishment and industry data. However, due to data limitations, a large number of studies have focused on manufacturing rather than service sectors. Empirical results at the firm level for the US suggest that a higher demand for information technology is associated with a higher skill level of the workforce or a higher proportion of skilled workers. Studies based on industry data show that the increase in the share of white-collar workers is positively correlated with the industries' initial IT to total investment ratio.

This paper analyses the link between information technology and workers' skill level for the German service sector. Our results show that information technology has a small, but significant impact on the employment share of university graduates. This finding implies that firms with higher IT investment to sales ratios employ a larger fraction of university graduates after controlling for firm size, industry affiliation, exporters and R&D performers. However, the quantitative effect is rather weak. A 50% increase in the IT investment to sales ratio would only lead to a rise in the university graduates share from 14.9 to 15.2%. The impact of IT investment on the university graduates share is strongest for skill-intensive service activities (business services, computer and R&D labs). Furthermore, the employment share of unskilled labour is, as expected, negatively related to the IT investment to sales ratio. Using a translog production function to assess the productivity of different input factors, we find that both human and information capital make significant output contributions.

1. Introduction

While in the 1960s public opinion feared that computer-controlled machines could eventually erode the demand for blue-collar workers, the 1990s have witnessed a public apprehension that information technology (IT) may replace the middle management (Drucker 1988). A basic theoretical justification at the microeconomic level for this notion can be found by pointing to the lower marginal and total costs exhibited by IT capital relative to human capital. The differences in cost would suggest a substitution of IT capital for the more expensive management and clerical workers, assuming similar marginal products of IT and human capital. Similarly, transaction cost theory implies that the number of managers could be cut sharply due to the introduction of IT (Malone and Rockart 1991). Thus, theoretical analyses as well as informal evidence suggest that the prevalent spread of IT in all types of enterprises may affect the skill structure within firms. In the US, 80% of IT expenditures are invested in the service sector (Brynolfsson 1992), German figures show similar tendencies. Within the service sector, wholesale trade, the finance and insurance industries, and business services have shown the highest adoption rates of IT (McFetridge 1992). Due to the significant role of IT, the service sector is prone to be severely affected and to experience the most significant changes from the rise of IT.

The link between both information- and communication capital and the skill structure has been empirically analysed by a number of studies (for a survey of the literature, see Chennells and Van Reenen 1998). The majority of studies relies on industry-level data to relate the rate of change in the employment share of skilled labour - rather than the level of the employment share - to the industry's initial IT to total investment ratio. In contrast to the public opinion's fears mentioned above, a common finding indicates the complementarity of IT capital and skilled labour. Berman, Bound and Griliches (1994) as well as Autor, Katz and Krueger (1997) provide US evidence at the four-digit SIC level that the change in the cost share of skilled labour is positively related to the industry's initial investment in computers. Haskel and Heden (1999) present similar firm-level results for the UK while Duguet and Greenan (1997) provide evidence that the change in the skill structure is related to the introduction of process and product innovations using French firm level data. Our analysis of the determinants of firm-level skill intensity is closely related to the approach presented by Bresnahan, Brynjolfsson and Hitt (1998). The authors estimate a firm-level demand function for IT capital based on a panel of 311 US companies separating the work force into college-educated workers and professionals. Their findings suggest that if a firm increases its work force's skill level by one standard deviation (increase of 25%), its demand for IT capital will rise by approximately 13.5%. The authors conclude that skill-IT complementarity is the dominant factor in explaining the demand for skilled labour.

A related area of the literature examines the output contribution of information technology in a production function framework. The results shown by the various studies, however, do not paint a consistent picture. Estimates of the output elasticity of IT capital range from 0.05 (Brynolfsson and Hitt 1995) or 0.10 (Lichtenberg 1995) to 0.5 (Licht and Moch 1997). The first two studies use an unbalanced panel of 200-400 large U.S. firms, of which a third are service providers, taken from the IDG/computerworld surveys on IT spending. Licht and Moch (1997) show evidence of a much higher output-elasticity of IT equipment based on IT usage data from the International Data Corporation Germany's 'IT survey' conducted for a sample of 790 German firms. Using similarly disaggregated data for 60 US business units, Loveman (1994), on the other hand, estimates that the contribution of information capital to final output is negligible.

As an alternative approach, Lichtenberg (1995) and Dewan and Min (1997) focus on the marginal rate of substitution between different types of skills (including IT labour), IT capital, and other factors of production. Lichtenberg (1995) finds that one IT worker can be substituted for six non-IT workers. In contrast, Dewan and Min's (1997) results indicate an elasticity of substitution of approximately one between IT capital and other factors of production (capital and non-differentiated labour).

In this paper we hope to side-step some of the problems which may have contributed to the inconsistencies in the above studies by focusing explicitly on the service sector to provide some more indicative evidence of the contributions of IT to both productivity and the firm's input mix. The motivation for the choice of sector is twofold. The sectoral distribution of IT suggests vastly differing degrees of importance of IT by sector and motivates a more detailed study of those sectors in which IT capital is highly concentrated. In addition, a detailed study of the service sector can enhance our understanding of the empirical regularities of the tertiary sector, an area where research has been limited despite the sector's growing importance in most industrialised countries' economies.

In the first part of the paper, the determinants of the skill structure will be examined. Following Bresnahan et al. (1998), we investigate the link between IT and skill intensity rather the relationship between the change in skill intensity and the initial IT level. The data is drawn from the 1995 Mannheim Service Innovation Panel (MIP-S) which has previously been analysed by Licht and Moch (1997) and Kaiser (1998). Due to data limitations we will focus primarily on the subsample of West German firms and exclude the East German firms from most of our analysis. Since the data set includes detailed firm-specific characteristics such as firms' organisational structure and innovative activity, this paper provides new insights into the determinants of heterogeneous firms' skill decompositions. The second part of the paper focuses on the return to human capital and IT investment. We apply a flexible functional form to estimate the production function. In contrast to Brynolfsson and Hitt (1995), we divide the labour used in the production process into three separate skill classes where high- and medium-skilled labour is measured by, respectively, the number of university graduates and vocational school graduates employed by a firm.

The layout of the paper is as follows. Section 2 outlines the econometric model. Section 3 describes and summarises the data. In sections 4 and 5, we present the results for the factor demand equations and the production function. Section 6 concludes.

2. Econometric Model

2.1. Factor Share equations

2.1.1. Model specification

To investigate the link between information technology and the skill intensity of the firm, we employ factor demand equations. Many econometric studies of the complementarity of IT and skilled labour have used a variable cost function framework to examine whether skill intensity and technology are positively correlated in a given cross-section (Doms et al. 1997). We apply a similar set-up defined over two quasi-fixed factors of production; IT investment (IT) and non-IT investment (K) and three variable inputs; university graduates (H), vocational school graduates (M), and workers without degree including apprentices (U). Using a translog cost function and under homogeneity of degree one in prices and homotheticity, Shepard's lemma implies the following cost shares for the three types of labour (see Chennells and Van Reenen 1998):

$$\frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i X_i}{C} = S_i = \alpha_i + \sum_{j=U,H} \beta_{ij} \ln(P_j/P_M) + \beta_{iK} \ln(K/Q) + \beta_{iIT} \ln(IT/Q) + u_i$$

where C denotes the firm's total cost, P_i the price of input i ($i = H, U$), and X_i the conditional factor demand for input i. S_i is thus the cost share for the two types of labour and Q denotes total sales in nominal prices as a proxy for output. We normalise by the factor price of medium-skilled labour, P_M. Note that the medium-skilled labour equation has been dropped because the cost shares sum to unity. The parameters β_{iK} and β_{iIT} measure the effects of the non-IT capital to sales ratio (K/Q) and the IT capital to sales ratio (IT/Q) on the labour cost shares. A positive coefficient on the investment to output ratio in the university graduates share equation ($\beta_{HK} > 0$) indicates, for example, that capital is a complement to skilled labour. Similarly, a positive coefficient on the IT capital to output ratio indicates skill-technology complementarity. If both $\beta_{HIT} > 0$ and $\beta_{UIT} < 0$, then technology is skill-biased. Assuming a constant investment to capital ratio, the investment to output ratio is taken as a proxy for the capital to output ratio in the two investment sectors, IT and non-IT.

Since factor prices (i.e. wages by skill classes) are generally not available at the firm level, one can employ the skill-specific employment shares to proxy the unknown cost shares.[1] Furthermore, assuming that relative wages (P_H/P_M) or (P_U/P_M) are constant within industries, the effects of relative wages can be captured by industry dummies. The general specification used in the following empirical implementation relates the employment shares of each skill class, E_i, to the log IT expenditure to total sales ratio, the log non-IT expenditure to total sales ratio, as well as a set of appropriate control variables:

$$E_i = \alpha_i + \beta_{iK} \ln(K/Q) + \beta_{iIT} \ln(IT/Q) + \sum_{j=1}^{9} \beta_{ijK} (\delta_j \ln(K/Q)) + \sum_{j=1}^{9} \beta_{ijIT} (\delta_j \ln(IT/Q)) + \sum_{j=1}^{9} \beta_j \delta_j + \sum_{m=1}^{4} \beta_m \delta_m + \sum_{n=1}^{3} \beta_n \delta_n + u_i \quad (2.1)$$

[1] Industry-level information on wages for different skill groups could be obtained from wage and salary statistics. However, only wholesale and retail trade, transport and banking and insurance are covered by the official German wage statistics.

where $i = H, M, U$; $j = 1,...,9$ refer to service industries; $m = 1,...,4$ denote size classes; and $n = 1,...,3$ are performance indicators (see more detailed description below). d is a dummy indicator which equals one if the firm is a member of industry j, has size class m, or qualifies for performance indicator n. To test whether the investment impact on any given employment share varies by industry, we include interaction effects of the IT investment or non-IT investment to sales ratios and the industry dummies. As a normalisation, we excluded one of the industry and size classes each in the estimation. Since factor prices are not included, it is not necessary to impose the conditions of symmetry and linear homogeneity in factor prices. Consequently, each employment share equation can be estimated separately by OLS. However, the degree of substitutability between different types of labour and information technology cannot be ascertained when employment shares are used and factor prices are not available. A positive IT coefficient in the employment share equation for graduates then simply indicates that firms with higher IT investment to sales ratios have a higher skill intensity.

Appropriate control variables, n, which may affect the skill composition of a firm's labour force include information on the firm's export orientation, participation in R&D and ownership form (part of industrial conglomerate). In particular, export orientation represents a good control variable because the exporting activity of German firms is concentrated in skill-intensive goods and services.

2.1.2. Censoring and sample selection issues

When estimating employment share equations, several econometric difficulties arise, including: (1) censoring of the employment shares, (2) zero values for both types of investment and (3) outliers due to reporting errors.

Employment shares are bounded between 0 and 1 such that OLS estimates will be inconsistent and a truncated regression model may be employed instead. Furthermore, the observed data contain some clusters of zero- or one-values for one or more variables. Those variables might be censored either in the upper tail ('on the right') or in the lower tail of the distribution ('on the left'). In this particular application, the three employment shares are censored from both sides of the distribution. Thus, the censored regression model may be more appropriate than the truncated regression model. In the basic censored regression model, the true underlying dependent variable, y^*, is a function of a set of independent variables, x:

$$y^* = \beta' x + \varepsilon \qquad \varepsilon \sim \mathcal{N}(0; \sigma^2) \tag{2.2}$$

while the actually observed value of the dependent variable, y, is given by:

$$y = \begin{cases} L & y^* \leq L \\ y^* = \beta' x + \varepsilon & L < y^* < U \\ U & y^* \geq U \end{cases}$$

where U and L denote the upper and lower censoring bounds, respectively. The values for y^* if $y^* \leq L$ or $y^* \geq U$ are unobserved. Equation 2.2 is a variant of the Tobit model which allows for censoring in both tails of the distribution. If the residuals are normally distributed, equation 2.2 can be estimated by maximum likelihood methods. The assumptions of the standard Tobit model include censoring on one side of the distribution and the homoscedasticity of the disturbance terms. Homoscedasticity will be violated though, if the variance is, for example, proportional to one of the regressors or its square. In this case, the ML-estimator of the Tobit model is inconsistent. We will correct for potential heteroscedasticity by using a multiplicative heteroscedastic Tobit model which specifies the variance of the error terms as $var(\varepsilon_i) = \sigma_i^2 = \sigma^2 \exp(\gamma' z_i)$. In this specification, z is a set of independent variables that possibly coincides with the explanatory set of variables, x. In the current application, all variables except for the constant are included in the heteroscedasticity function and the heteroscedastic model is tested against the homoscedastic base model using a likelihood ratio test (see Greene 1997).

Another way to estimate the employment share equations follows the generalised Heckman approach ('Type 2 Tobit model'). The two-step Heckman method is related to, but less restrictive than the Tobit model since the parameters explaining the firm's decision to employ a high-, medium-, or unskilled worker are not constrained to equal to those explaining the level or employment share of each of the skill classes. The two-stage method consists of a Probit selection equation and the structural equation:

$$\begin{aligned} z_1^* &= \alpha_1' v_1 + \varpi_1 \\ z_1 &= \begin{cases} 1 & z_1^* > 0 \\ 0 & z_1^* \leq 0 \end{cases} \\ y &= \beta' x_1 + \varepsilon_1 \quad L < y^* < U \end{aligned} \tag{2.3}$$

where v_1 is vector consisting of firm size and sector dummies, the logs of the IT investment to sales ratio and the investment to sales ratio, and other control variables. One shortcoming of this approach is that there a few potential variables which explain the firm's decision to employ a worker of a certain skill and not the employment share. We use firm size as the identifying variable in the sample selection model. The estimates of the Probit selection equation for the employment decision are used to construct an estimate for the inverse Mills ratio which is included as an explanatory variable in the estimation of the structural model. Note, that we do not account for censoring in the upper tail of the distribution in the two-step estimation procedure. However, the high-skilled employment share equals to one only for very few firms.

The second estimation problem concerns the multiple zero values observed for both types of investment. Potential solutions include the use of the level rather than the logarithm of the IT to sales ratio or the replacement of zero expenditures by a small, but positive value. Observations with zero values could also be excluded, but then the estimation of the employment share equations must account for the selection bias thereby induced. We proceed to jointly estimate the employment share equation and the investment decision by extending the standard Tobit model to the sample selection Tobit model:

$$
\begin{aligned}
z_2^* &= \alpha_2' v_2 + \varpi_2 \\
z_2 &= \begin{cases} 1 & z_2^* > 0 \\ 0 & z_2^* \leq 0 \end{cases} \\
y^* &= \beta_2' x_2 + \varepsilon_2 \\
y &= \begin{cases} L & y^* \leq L \text{ and } z_2 = 1 \\ y^* = \beta_2' x_2 + \varepsilon_2 & L < y^* \text{ and } z_2 = 1 \end{cases}
\end{aligned}
\tag{2.4}
$$

where a correlation between both error terms is allowed ($Corr[\varepsilon_2; \varpi_2] = \rho$). The variables in the employment share equation can only be observed when $z_2 = 1$ (i.e. nonzero values for either IT or non-IT investment). We initially estimate a Probit model which identifies factors influencing the decision for a firm to invest in IT or non-IT capital. The inverse Mills ratio is then used as a correction in the second stage employment share Tobit regression. This two-stage least squares procedure provides consistent, but inefficient estimates of the sample selection Tobit model. Efficient estimates are obtained via full information maximum likelihood methods using the two-stage least square results as starting values.

A further estimation problem is the presence of outliers. This will be addressed by LAD estimation of the employment share equations based on a restricted sample (excluding zero values for both types of investment as well as zero values for university graduates). For comparison reasons, an additional sample selection model is estimated. Here the selection rule follows a discrete choice model explaining non-zero investment expenditure as well as non-zero values for university graduates.

2.2. The Production function

2.2.1. Model specification

We use the production function framework to examine the contributions of IT capital and human capital to output. The functional form used in this paper is the translog production function with five input variables. In its logarithmic transformation, the relation between inputs and output can be written as (omitting the firm subscript for convenience):

$$\ln Y = \alpha_0 + \sum_i \alpha_i \ln X_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j \tag{2.5}$$

where X_i and X_j are stock measures of inputs, Y denotes output. One advantage of the translog functional form over the Cobb-Douglas production function is that the output elasticities are not restricted to be the same across all types of firm. Starting from the translog production function, several restrictive functional forms are nested and can be statistically tested, for example the Cobb-Douglas production function imposes the restrictions of $\gamma_{ij} = 0 \; \forall i, j$ in equation 2.5. The output elasticity with respect to input i which measures the percentage increase in output in response to a unit increase in the input variable is computed as the derivative of the production function with respect to the logarithm of i. For the translog functional form, the output elasticity is thus a function of input i, as well as the remaining inputs into production, j:

$$\eta_i = \frac{\partial \ln Y}{\partial \ln X_i} = \alpha_i + \sum_j \gamma_{ij} \ln X_j \tag{2.6}$$

The Wald test is used to test the non-linear hypothesis that the output elasticity is significantly different form zero. We apply the translog production function defined over the five inputs into production; the three labour skill classes, H, M, and U; and two types of capital, IT and K.

2.2.2. Estimation techniques

The unbiased and consistent estimation of the production function is complicated by the following econometric and data problems: (1) the use of flows as proxies for capital stocks, (2) omitted variable bias due to missing material inputs, (3) endogeneity of inputs, and (4) the role of outliers.

The production function specified above is based on stock measures of all inputs to account for the fact that past investments in capital make contributions to output in the current period. To derive a stock measure of capital inputs into production, most commonly a weighted average of past levels of investment is computed. Unfortunately, the MIP-S dataset employed in this study does not contain measures of the net capital stock or past investment flows at a disaggregated level for IT and non-IT capital. We therefore use investment flows as a proxy for the IT and non-IT capital stocks. Some justification for this choice of proxies is provided by the following evidence. The national accounts provides information on the overall net capital stock for 14 service industries. In a descriptive regression of the investment to sales ratio and the net capital stock to sales ratio, we find a strong positive relationship. The Pearson correlation coefficient is 0.97 and significant at the 1% level. The regression estimated by OLS yields:

$$\frac{I}{Q} = \underset{(4.8)}{0.052} + \underset{(14.8)}{0.056}\frac{C}{Q} \quad \text{adj. } R^2 = 0.94; OBS = 14:$$

where I denotes total investment at current prices, Q gross output and C the net capital stock at current prices. Assuming a constant share of IT expenditures out of total investment, the flow values of IT and non-IT capital may provide accurate proxies of the underlying capital stocks. In the case of IT capital, current expenditures may be very close to the discounted accumulation of past IT expenditures due to the high rate of depreciation of computer capital. Since investment flows can only serve as appropriate proxies for the unobserved capital stock in the case where the ratio of investment to capital stock is relatively stable, we are not able to extend our analysis to East German firms where the stability of this relationship breaks down.

Another limitation of the data concerns the lack of firms' material expenditures. Materials are, however, important factors of production in the service sector. Based on sectoral data, the share of materials in total output ranges from 35% in banking and insurance to 86% in wholesale trade.[2] To account for the

[2] See table 7-3 in the appendix.

missing explanatory variable, total wage costs are used as an alternative proxy for value added instead of sales.

Since the MIP-S dataset is derived from survey responses, the extent of erroneous responses to the survey questions and resulting large outliers has to be considered. The role of outliers will be investigated by employing median regression models. In median regression models, estimates are obtained by minimising the sum of the absolute rather than the sum of the squared residuals so that outliers are discarded in the estimation process.

Finally, the direct approach to estimating the production function has been criticised because it ignores the simultaneity created by the input and output decisions (Griliches and Mairesse 1997). The problem of simultaneity can be solved by instrumental variable (IV) estimation. Appropriate instruments for firm level data include the predetermined input levels from previous periods (Griliches and Hausman 1986, Mairesse and Hall 1995). However input levels from previous periods are currently not available and this particular problem will only be addressed as future waves of the MIP-S data set become available.

3. Data description

Our empirical analysis is based on the first wave of the Mannheim Service Innovation panel (MIP-S) which contains information for 1994. This survey has been conducted to examine the innovation behaviour of service firms (for details see Licht and Moch, 1997). Approximately 2550 firms participated in the first wave of the service panel of which 1629 firms are located in the West and 924 in the East (see table 7-2 in the appendix). The key variables covered by the study are sales, investment, the skill structure of the workforce and a large number of quantitative and qualitative dummy variables (product and process innovations, effects of innovation, R&D activities, importance of external sources of knowledge).

Skill is measured by the employee's level of educational qualification. The original data base distinguishes between five skill classes: (1) polytechnic or university graduates with engineering or natural science degrees, (2) polytechnic or university graduates with economics or social science degrees, (3) technical college graduates ("Fachschulabschluß"), (4) vocational school graduates, and (5) workers without any advanced degree or apprentices. To obtain meaningfully sized skill classes, we combined (1) and (2) into the high-skilled class (university graduates,

H) and (3) and (4) into medium-skilled labour (workers with vocational degree, M). The total workforce is the sum of the three skill groups. Output is measured by total sales in nominal prices. Expenditures on materials are not available. IT is defined by 1994 investment in information and communication technology. IT includes expenditures on computers, peripheral equipment, and software. Total gross investment is also provided. In order to avoid double counting, we subtract IT investment from total investment to obtain non-IT investment.

Incomplete information on gross investment, IT investment, employees by skill class, or firm characteristics led to a reduction of the sample to 1231 West German firms (for details see table 7-2 in the appendix). Furthermore, we excluded observations dropped that contained imputed data. Imputed values for employment and sales reduced the sample size to 1219 in the West and 713 in the East. Finally, three obvious outliers (investment to sales ratio exceeds 200 %, 400 % in the East) were removed from the sample (see table 7-2 in the appendix for details).

The data set contains a significant number of entries for which investment or IT investment equals zero. Out of the total sample of 1218 firms, 273 report zero expenditures for either total investment or IT investment, of which 89 firms report zero expenditures for both total and IT investment. 96 out of 273 firms report positive total investment, but zero expenditures for IT expenditures. The remaining 88 firms report positive IT expenditures, but zero total investment expenditures such that IT expenditures exceed total investment expenditures. In these cases, the resulting negative non-IT investment has been replaced by DM 1. The large number of firms (88 out of 1218) which report zero total investment figures, but non-zero IT investment indicates the presence of reporting errors.

Table 3-1 reports averages and standard deviations of the key variables used for the estimation. Descriptive statistics are reported separately for the East and West German samples. Since sample weights are not used, the sample is not representative and should be interpreted with caution.[3] 15 % of the sample report a university or higher technical college degree as their highest level of education. The corresponding figure for East German firms is 23 %. The proportion of medium-skilled labour is 60 % with a median of 65 % while unskilled workers account for approximately 25 % of the workforce.

[3] Although a non-response analysis is done at the ZEW, sample weights are not used to calculate adjusted ratios.

Table 3.1: Summary Statistics

Variable(x)	Mean†	Median	Std. dev	Min.	Max.	x=0 (%)	x=1 (%)
West German firms (n=1218)							
High-skilled labour, H	37	3	269	0	8000	27.7	
Medium-skilled labour, M	315	20	3370	0	107000	2.1	
Unskilled labour, U	186	6	1693	0	52000	24.4	
Gross investment (Mill DM)	13.4	0.25	168	0	5563	14.5	
IT investment (Mill DM)	2.2	0.05	32	0	1063	15.2	
H share (%)	14.9	5.6	21.7	0	100.0	27.7	0.5
M share (%)	59.6	65.0	28.3	0	100.0	2.1	8.6
U share (%)	25.5	15.2	28.1	0	100.0	24.4	0.8
Non-IT inv., % of sales	5.2	1.0	12.4	0	132.0	14.5	
IT inv., % of sales	1.3	0.3	2.9	0	42.0	15.2	
East German firms (n=711)							
High-skilled labour, H	29	4	198	0	4000	16.2	
Medium-skilled labour, M	86	17	295	0	4350	2.8	
Unskilled labour, U	49	3	209	0	3330	34.0	
Gross investment (Mill DM)	5.6	0.25	23.6	0	300	13.2	
IT investment (Mill DM)	0.56	0.04	5.8	0	150	14.9	
H share (%)	22.8	10.4	26.6	0	100.0	16.2	0.7
M share (%)	57.6	64.8	29.2	0	100.0	2.8	7.3
U share (%)	19.6	8.9	26.6	0	100.0	34.0	1.4
Non-IT inv., % of sales	15.4	2.1	37.4	0	302.0	12.5	
IT inv., % of sales	2.0	0.5	5.9	0	94.0	14.5	

† The means given in the table are arithmetic means.
Source: Mannheim Service Innovation Panel 1995.

We observe the low levels of investment relative to total sales which are characteristic of service sector firms. Despite the rapid IT accumulation that has been taking place in the service sector, the unweighted average of IT investment as a percentage of gross sales amounts to 1.3% in 1994 corresponding to about 17% of total average investment.

Table 3-2 contains information on firms' industry affiliation, size classes, export behaviour and innovation variables. A number of firm-specific heterogeneity control variables are included in the regression equations, among them sector and size dummies. Firm size is defined by number of employees and firms are divided into five size classes: the reference group has less than 10 employees, the three medium-sized classes are defined as 10-19, 20-49, and 50-249 employees, while large firms are defined to have more than 250 employees. About 17% out of 1218 West German firms have less than 10 workers. In 1994, 36% of West German and 23% of East German firms belonged to a corporate group. The share of exporting firms is 24%. The service sector is broken down into 10 subsectors. Among the service firms, some regrouping of industries was found to be necessary. Industries with a large number of firms such as market services are split up into computer and related software (NACE 72); R&D labs and technical consultants (NACE 731, 742, 743); business consultants, legal services, and accounting (NACE 741); and other business activities including cleaning and advertising (NACE 744-746, 748, 633, 641).

Table 7-5 in the appendix shows the sectoral breakdown of IT and non-IT investment, both in % of total sales. As mentioned before, sample weights based on a non-response analysis are not used. Computer and R&D labs as well as business services possess the expected higher IT intensity than the remaining sectors. Wholesale and retail trade exhibit very low IT investment to sales ratios, a result which should be interpreted with some caution. One reason for the low IT investment to sales ratio may be the high share of material inputs in these sectors. Wholesale trade, transport, and community services (in particular sewage, sanitation) can also be classified as capital-intensive industries.

Table 3-4 reports the skill decomposition at the sectoral level. The service sector can be differentiated on the basis of knowledge intensity expressed as an industry's proportion of workers with a university or higher college degree out of total workers. The most skill-intensive sectors are the computer/software and R&D laboratories and technical consulting sectors, as well as business services (consultants, legal services, accounting). In these sectors, the share of university

Table 3.2: Summary Statistics (Dummy Variables, percentage share of total)

	West (OBS=1218)	East (OBS=711)
Sector distribution (NACE classification in parenthesis)		
Wholesale trade (51)	17.6	11.8
Retail trade and repairs (50; 52)	12.9	10.3
Transport (61; 62; 63; 64; excl. 632; 641)	12.9	14.3
Banking and insurance (65; 66; 67)	17.0	11.0
Real estate activities and renting (70; 71)	6.2	9.4
Computer and related software (72)	6.8	4.8
R&D labs, technical consultants (731; 742; 743)	4.9	16.0
Business consultants, legal, accounting (741)	6.2	4.4
Other business activities, cleaning, advertising (744 – 746; 748; 633; 641)	13.5	13.4
Other community services, sewage, sanitation (900 – 924)	2.1	4.5
Size distribution in terms of total employees, L:		
Size 1: $L < 10$	17.2	22.0
Size 2: $10 \leq L < 20$	18.6	14.3
Size 3: $20 \leq L < 50$	18.8	22.6
Size 4: $50 \leq L < 250$	24.5	28.9
Size 5: $L \geq 250$	21.0	12.1
Other indicators:		
R&D performer	18.1	13.4
Exporter, 1994	24.3	8.6
Part of industrial conglomerate, 1994	36.6	23.8

Notes: The means given in the table are arithmetic means. Performance indicator dummies: exporter = 1 if firm has earned positive revenues from exports for 1994. Part of industrial conglomerate = 1 if firm is parent to or subsidiary of another firm in 1994. R&D = 1 if firm is occasionally or continuously engaged in R&D activities.

Source: Mannheim Service Innovation Panel 1995.

graduates lies between 30 and 45 % (on Micro Census basis as well as MIP-S data set). Banking and insurance as well as real estate and community services can be classified as medium-skill-intensive industries. Finally, wholesale and retail trade, transport and other business services (cleaning, advertising) can be classified as low-skill-intensive. Wholesale and retail trade and other business service activities tend to have a majority of medium- and unskilled labour. A comparison of the high-skilled share and IT investment to sales ratio provides informal evidence that the sectors which are skill-intensive are the ones that use IT intensively.

The survey's response rate is relatively low which suggests that firms participate selectively. Since the questionnaire contains a number of innovation-related questions, it is possible that the sample is disproportionally comprised of innovators. However, comparable indicators of IT or communication investment at the sectoral level are not available so it is difficult to quantify whether innovators are oversampled.[4]

To examine the representativeness of the MIP-S survey participants, the average skill structure in the 1995 wave of the German Labour Force Survey ('Micro Census'), a survey at the level of the individual, is examined by adding across participants who are employed in one of the service sector industries. Table 3-4 compares the skill structure of the two datasets and reports only minor differences in the high-skilled shares. Across sectors, however, the share of unskilled workers in the MIP-S firm dataset exceeds the corresponding figures in the German Micro Census considerably.

[4] In general, sectoral information for IT expenditures is not available. For the total economy, EITO reports a IT/GDP ratio of around 2.1 % for Germany for 1997. This ratio doubled to 4.2 % when communication technology is included.

Table 3.3: Qualification strucure in German service industries

	Qualification Structure (% share of total work force)							
	MIP-S '95[a]				Micro Census '95[a,b]			
	H[c]	M	U	Obs.	H	M	U[d]	Obs.
West German firms								
Wholesale trade	9.4	65.6	25.0	214	7.7	76.4	15.8	5765
Retail trade, repairs	4.0	72.6	23.5	157	5.0	78.1	16.9	19669
Transport	4.3	51.8	43.9	157	6.2	75.2	18.6	4556
Banking/insurance	14.7	71.9	13.5	207	11.5	78.9	9.6	7118
Real estate/renting	14.9	64.0	21.1	76	12.3	73.6	14.1	1102
Computer/software	44.7	44.6	10.7	83	39.4	52.8	7.7	1087
R&D labs/consult.	44.8	42.9	12.2	60	39.0	52.1	8.7	5499
Business services	32.3	53.6	14.2	75	34.5	55.7	9.8	2965
Other bus. services	8.8	48.3	42.9	164	10.0	67.9	22.1	5513
Community services	16.0	43.1	40.8	25	17.6	53.2	29.2	3904
Total Service Sector	14.9	59.6	25.5	1218	18.7	65.8	15.5	101338
East German firms								
Wholesale trade	10.4	66.2	23.5	84	17.4	77.1	5.6	850
Retail trade, repairs	12.8	70.7	16.5	73	7.1	84.8	8.2	4504
Transport	5.2	66.1	28.7	102	6.1	90.7	3.2	1096
Banking/insurance	20.7	67.6	11.7	78	19.2	75.5	5.3	925
Real estate/renting	17.8	70.2	11.9	67	19.5	78.1	2.4	375
Computer/software	55.1	41.1	3.8	34	52.4	39.7	7.9	111
R&D labs/consult.	58.7	35.4	5.9	114	44.7	49.9	5.4	986
Business services	31.0	51.5	17.5	31	35.6	55.7	8.6	426
Other bus. services	11.5	52.1	36.5	95	8.9	82.2	8.9	1328
Community serv.	14.1	45.8	40.1	32	30.4	62.3	7.3	922
Total Service Sector	22.7	57.6	19.6	711	15.9	77.2	6.9	11523

[a] Data refers to 1994. [b] The statistics are based on the German Micro Census Public Use File which contains 70 % of the complete Micro Census. The German Micro Census is based on a 1% sample of the German population. The survey is limited to employed workers during the survey reference week April 1995. Employment shares by educational category are calculated as the proportion of total workers (including self-employees) in each of the three educational categories. [c] Means weighted by employment in parenthesis. [d] Apprentices included

Source: Mannheim Service Innovation Panel 1995, Micro Census Public Use File.

4. Determinants of the skill structure

In order to quantify the main factors behind a firm's skill intensity, the employment shares are regressed against the potential determinants discussed above.

As noted earlier, 28 % of the 1218 West German sample firms do not employ high-skilled labour causing the university graduates employment share to be censored below. Initially, we do not exclude firms with either zero non-IT or IT investment expenditures, but instead replace zero values by DM 1. Table 4-1 reports the resulting maximum likelihood estimation results for two variants of the Tobit model, as well as the two-stage estimation method for the sample selection model. The first two columns show the results for the Tobit models, where column (1) contains the results for the standard homoscedastic model and column (2) allows the disturbances to be heteroscedastic. Since the LR test-statistic of approximately 455 indicates that the heterocedasticity model cannot be rejected, the interpretation of the Tobit results is concentrated on the heterocedasticity model. For both Tobit specifications marginal effects are computed. Columns (3) and (4) show the results for the sample selection model. For the two-step Heckman model we do not consider censoring in the upper tail of the distribution which may not introduce a serious bias since the graduates share equals to one for only six of the sample firms. We first estimate a Probit model which identifies the factors influencing the firm's decision of whether to employ university graduates. The coefficients on firm size are positive and significant at the five-percent-level, suggesting that the probability of employing university graduates depends on the firm size (see column 3 in Table 4-1). In contrast, all of the firm size dummies are insignificant in both of the Tobit models. Note that the inverse Mills ratio is significant when added as an independent variable in the structural equation.

The main result is the significant, positive relationship between the share of university graduates and IT investment. The IT investment effect remains significant and robust across all specifications and is mirrored in the results for the East German subsample (see appendix). These results thus suggest that an increase in the IT investment to sales ratio would raise a firm's skill intensity. Turning to the size of the IT impact on the university graduates share, a consistently low value is found for the IT semi-elasticity across all models which is somewhat surprising. The IT semi-elasticity based on the sample selection model is slightly larger than the IT semi-elasticities based on OLS for the restricted sample (OLS results not shown due to space limitations). The IT impact increases from 0.006 to 0.008 when the inverse Mills ratio is included in the restricted sample's estimation. The estimated coefficients of the sample selection model, however, differ only slightly compared to the standard Tobit model which is reasonable since the firm size dummies are the only variables which appear in the Probit selection equation, but not in the structural equation.[5] The sample selection model's IT coefficient of 0.008 translates into a relatively small elasticity of 0.054 %.[6] Thus an increase in the IT investment to sales ratio by one standard deviation (50 %) would only raise the average firm's high-skilled labour share by 0.03 percentage points from 14.9 % to 15.2 %. For East German firms, the IT impact is slightly smaller. An IT coefficient of around 0.006 translates into an elasticity of the high-skilled employment share with respect to the IT investment to sales ratio of 0.03 % (see table 7-5). All in all, the low quantitative effects of IT and non-IT investment on the university employment share suggest that other - unobservable - factors may play an important role in explaining skill intensity at the firm level.

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[5] According to Leung and Yu (1996) the critical point of the performance of the Heckman's estimator is collinearity between inverse Mill's ratio and the right hand variables in the structural equation. However, the low R^2 of approximately 0.023 of a regression of the inverse Mills ratio on the right hand variables in structural equation indicates that collinearity is not a problem.

[6] The elasticity is computed as $\varepsilon_{H;IT/Q} = \beta_{IT}/\bar{s}_H$ where β_{IT} denotes the estimated IT coefficient in the sample selection model and $\bar{s}_H$ is the sample mean of the high-skilled labour share based on the full sample (obs= 1218), thus $\varepsilon_{H;IT/Q} = 0.008/0.149$.

Table 4.1: Tobit models for the university graduates employment share (West)

	Tobit		Het. Tobit[a]		Sample selection model: Structural model		Sample selection model: Probit Selection ($H > 0$)	
	marg. eff.[b]	t-st.	marg. eff.[b]	t-st.	coeff	t-stat	marg. eff.[b]	t-st.
itq	0:09	5:6	0:06	4:4	0:08	3:4		
iq	¡0:03	¡2:3	¡0:02	¡1:9	¡0:04	¡2:6		
itq£computer	0:20	2:9	0:50	3:6	0:35	3:8		
itq£tech. cons.	0:43	4:5	0:66	4:3	0:67	4:4		
itq£bus. scvs.	¡0:12	¡1:9	0:23	1:6	¡0:18	¡2:1		
itq£computer	¡0:10	¡2:5	¡0:11	¡2:1	¡0:10	¡1:9		
Wholesale trade	¡0:50	¡3:3	¡0:51	¡3:8	¡0:74	¡3:1	¡:19	¡3:7
Retail trades	¡0:94	¡5:7	¡0:88	¡8:8	¡1:50	¡5:7	¡:25	¡5:2
Transport	¡1:00	¡5:9	¡0:80	¡6:2	¡1:58	¡5:8	¡:30	¡5:8
Real estate	0:06	0:3	0:01	0:0	0:18	0:6	¡:05	¡0:7
Computer	2:06	4:9	:364	6:0	:365	6:4	:23	2:5
Tech. cons.	:395	8:2	:517	7:1	:597	8:1	:17	1:8
Business svcs.	0:56	1:5	2:31	3:7	1:10	2:1	:06	0:6
Other bus. svcs	¡0:43	¡2:7	¡0:60	¡4:9	¡0:76	¡3:1	¡:20	¡4:3
Comm. svcs.	0:06	0:2	¡0:15	¡0:3	0:57	1:1	¡:17	¡2:1
10 · L < 20	0:08	0:6	0:47	2:3			:10	2:9
20 · L < 50	0:08	0:5	0:35	1:7			:13	3:3
50 · L < 250	0:12	0:8	0:49	2:6			:32	8:0
L ¸ 250	0:07	0:4	0:41	2:2			:53	10:9
Exporter	0:39	3:7	0:21	2:3	0:56	3:4	:13	3:7
Ind. Conglom.	0:29	3:1	0:16	2:3	0:39	2:5	:10	3:1
R&D	0:49	4:3	0:14	1:7	0:75	4:2	:18	3:6
Inv. Mills Ratio					2:23	8:7		
Constant	0:86	4:2	0:33	1:3	0:97	3:7	:02	2:0
Log likelihood	¡103:3		123:5				¡509:2	
Pseudo/Adj.R^2	:747				:465			
Observations	1218		1218		881		1218	

Notes: Lower case variables denote logarithms. Obs. summary for the Tobit models: 337 left-censored obs. with $E_H = 0$ and 6 right-censored obs. with $E_H = 1$. Zero values for ITQ or IQ have been replaced by DM 1. Reference group for sector dummies is banking/insurance, for size classes size 1. [a] The coefficients of the heteroscedasticity terms have been omitted. [b] Displayed coefficients are marginal effects, the partial derivatives of expected value with respect to the vector of characteristics.

The coefficients on the interaction terms between the sector dummies and the IT or non-IT investment to sales ratio are statistically significant in three cases rejecting a uniform investment impact on the university graduates employment share. For sectors which have historically been IT intensive, namely computer/software and R&D labs, we find that IT investment is associated with greater skill intensity. For the computer industry, the IT interaction coefficient lies between 0.020 and 0.050, depending on the model specification, causing the IT elasticity for the sector to exceed the average IT elasticity by 13 to 36%. The implied total IT elasticity thus ranges from 0.10 to 0.16%. For R&D activities and technical consultants, our findings imply an excess over the average IT elasticity of 29 to 44% based on IT slope coefficients ranging from 0.043 to 0.066. The implied total IT elasticity thus lies between 0.12 and 0.14%. The IT slope coefficient for business services implies that IT has an insignificantly smaller effect on the graduates employment share than the average of the other sectors.

The remaining explanatory variables have the expected sign. The negative relationship between the non-IT investment to sales ratio and the graduates share highlights the fact that capital-intensive industries employ a smaller fraction of university graduates. The size of the coefficient on the non-IT investment to sales ratio is, however, rather small, and ranges from -0.006 to -0.003 across model specifications. Thus, a 50% increase in the investment ratio would imply a decline in the high-skilled employment share from 14.9 to 14.7% based on the estimated sample seclection model.

For the 24% of firms which export in 1994, we find that exporting reinforces the positive relationship found between IT investment and the employment of high-skilled labour. This finding is consistent with our conjecture that exporting firms concentrate extensively on human-capital-intensive products relative to firms that do not engage in exporting activities. The coefficient on the ownership dummy indicates that firms in an industrial conglomerate use more skill-intensive labour than their counterparts. A firm's R&D activities may also induce it to employ a more skilled labour force as the positive coefficient on R&D engaging firms shows.

Almost 18% of the firms in the sample continuously or occasionally engage in R&D.[7]

In our estimation of the high-skilled share equation, we have not yet accounted for the large share of firms that report zero expenditures for IT or non-IT investment. Consequently, the coefficients for IT and non-IT investments in the standard Tobit or sample selection model (see table 4-1) may be biased towards zero. Note that 15.5% of West German firms report IT investments of zero and 14.7% report zero non-IT investment. Excluding firms which report zero expenditures for either IT or non-IT investment reduces the sample size to 945. Simply eliminating the non-investing firms introduces a selection bias into the analysis. Therefore, we apply a Tobit sample selection model (see equation 2.4). The selection rule follows a discrete choice model to characterise those firms that report non-zero values for IT or non-IT investment. The results for the Tobit sample selection model and the Probit selection equation are displayed in table 7-6 in the appendix. Compared to the Heckman two-step estimation using the high-skilled labour selection rule, the simultaneous estimation of the Probit selection equation and the Tobit model yields only minor differences. For instance, the IT coefficient based on the sample selection Tobit model of around 0.018 is quite similar to the coefficient based on standard Tobit model. The IT interaction coefficient for business services, however, is significantly positive in the sample selection Tobit model. Similarly to previous models, the coefficients on R&D, exporters and industrial conglomerate are statistically significantly and very close to previous results without an investment decision rule.

To investigate the importance of outliers, we estimate the high-skilled share equation using LAD methods based on a restricted sample consisting solely of firms with both positive investment and high-skilled workers. Column 1 of table 4-2 shows a sample selection model investigating the firm's decision to invest in both IT and non-IT capital and to employ high-skilled workers.

[7] In a previous version of the paper we include dummies for process and product innovations as well as a dummy variable for organisational change. Since these variables are indicators of the technological change rather the technological level, we excluded these dummy from the share equations.

Table 4.2: Sample selection and LAD models excluding zero demands for IT and non-IT investment and high-skilled labour

	Sample selection model				OLS[a,b]		LAD[a,c]	
	Selection equation		Structural model[a]					
	marg. eff.	t-stat	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat
itq			0.017	3.6	0.017	3.7	0.006	1.9
iq			−0.005	−2.1	−0.004	−1.6	−0.004	−2.4
itq×comp.			0.099	4.8	0.101	5.0	0.115	4.4
itq×tech. cons.			0.073	3.3	0.066	2.8	0.104	2.1
itq×bus. svcs.			0.029	1.2	0.023	0.8	0.079	1.3
iq×computer			−0.009	−1.4	−0.009	−1.1	−0.021	−1.5
Wholesale trade	−0.216	−4.1	−0.066	−2.6	−0.013	−0.7	−0.033	−1.8
Retail trade	−0.204	−3.6	−0.121	−4.4	−0.071	−5.0	−0.048	−3.8
Transport	−0.286	−5.0	−0.146	−5.0	−0.073	−4.1	−0.048	−3.8
Real estate	−0.072	−1.0	0.002	0.1	0.022	0.8	0.025	0.8
Computer	0.191	2.4	0.606	6.2	0.568	5.4	0.614	3.4
Tech. cons.	0.195	2.3	0.611	6.2	0.532	4.8	0.746	3.4
Business svcs.	0.110	1.5	0.298	2.9	0.245	2.0	0.475	2.1
Other bus. svcs.	−0.222	−4.0	−0.075	−2.8	−0.018	−1.0	−0.036	−2.7
Comm. svcs.	−0.172	−1.6	0.043	0.7	0.099	1.7	0.015	0.1
$10 \leq L < 20$	0.102	2.1			−0.070	−2.0	−0.054	−1.4
$20 \leq L < 50$	0.198	4.0			−0.110	−3.5	−0.127	−6.1
$50 \leq L < 250$	0.409	8.3			−0.161	−5.3	−0.147	−6.8
$L \geq 250$	0.604	10.7			−0.193	−6.4	−0.165	−7.7
Exporter	0.141	3.6	0.069	4.0	0.037	2.5	0.011	0.9
Ind. Congl.	0.101	3.0	0.044	2.6	0.016	1.3	0.018	2.2
R&D	0.209	4.5	0.080	4.1	0.034	2.3	0.036	3.6
Inverse Mills ratio			0.219	8.1				
Constant	−0.142	−2.8	0.093	2.4			0.232	8.0
Pseudo/Adj. R^2	0.291		0.508		0.504		0.334	
Observations	1218		742		742		742	

Notes: Lower case variables denote logarithms. Dependent variable is the university graduates employment share. Further information about the independent variables can be found in the notes to Table 4-1. [a]Sample excludes zero values for H, IT and non-IT investment. [b]OLS estimates corrected for heteroscedasticity. [c]LAD estimates are based on bootstrapped estimates of the variance-covariance matrix of the estimators.

The remaining columns in table 4-2 report LAD results for the restricted sample based solely on firms which report positive investment and high-skilled employment shares. We again find the effect of IT to be significantly positive, but rather small. Compared to the baseline OLS model, the IT coefficient shrinks by a half when the LAD regression method is used.

Table 4-3 shows the estimates for un- and medium-skilled labour. Since estimation based on the two-stage Heckman model yields similar results, only the estimates for the heteroscedastic Tobit model are shown. Except for R&D labs and computer/software industries, the IT investment to sales ratio is not significantly related to the medium-skilled employment share. For computing firms and for R&D labs, a higher IT investment to sales ratio is associated with a lower medium-skilled employment share.

Table 4.3: Heteroscedastic Tobit Models for medium-skilled and unskilled employment shares (OBS= 1218)

	Medium-skilled labour				Unskilled labour			
	Share equation		Heterosc. Terms		Share equation		Heterosc. Terms	
	marg. eff.	t-stat	coeff.	t-stat	marg. eff.	t-stat	coeff.	t-stat
itq	−.002	−0.7	−.009	−0.9	−.007	−2.4	−.018	−1.4
iq	.002	0.7	−.010	−1.3	.002	1.3	−.009	−1.2
itq×banking					.011	2.2	.013	0.5
itq×comp.	−.041	−2.6	.133	2.6				
itq×consult.	−.029	−1.9	−.053	−0.7				
itq×oth. bus. svcs.	.025	2.1	−.008	−0.3	−.017	−1.8	.003	0.1
iq×comp.	.015	1.8	.028	1.2				
iq×comm. svcs.					.090	2.9	−.122	−1.6
Wholesale trade	−.105	−4.9	−.398	−4.5	.014	0.3	−.366	−3.2
Retail trade	−.035	−1.6	−.518	−5.8	−.001	0.0	−.586	−5.3
Transport	−.263	−7.9	−.636	−7.2	.148	3.2	−.657	−6.1
Real estate	−.109	−3.4	−.528	−5.4	−.019	−0.4	−.505	−4.3
Computer	−.394	−4.3	.268	3.2	−.114	−2.3	.206	1.2
Tech. consult.	−.436	−5.9	.265	2.9	−.063	−1.4	.195	1.1
Business svcs.	−.253	−7.5	.642	5.9	−.043	−1.0	.573	3.0
Other bus. svcs.	−.133	−1.7	.215	1.8	.034	0.5	.261	1.3
Community svcs.	−.380	−4.9	1.137	3.4	.452	4.9	.491	2.7
$10 \leq L < 20$	−.004	−0.1	−.008	−0.1	.132	3.9	.180	1.0
$20 \leq L < 50$	.016	0.5	.350	3.0	.154	4.7	.132	0.7
$50 \leq L < 250$	−.021	−0.7	.497	2.3	.221	6.6	.616	2.5
$L \geq 250$	−.070	−2.1	.319	1.4	.276	7.5	−.178	−0.4
Exporter	−.024	−1.4	−.014	−0.2	−.001	−0.1	.041	0.6
Ind. Congl.	.015	0.9	−.025	−0.4	−.031	−2.3	−.131	−2.1
R&D	.007	0.4	−.144	−2.1	−.023	−1.5	−.110	−1.4
Constant	.742	14.9			−.063	−1.3		
Pseudo R^2	.294				.311			
Het. Test	164.7				167.2			

Notes: Lower case variables denote logarithms. Dep. var.: column (1) share of workers with vocational degree, column (2) share of workers without advanced degree. Obs. summary for the medium-skilled employment share: 25 left-censored obs. with $E_M = 0$ and 105 right-censored obs. with $E_M = 1$. For the unskilled share equation: 297 left-censored obs. with $E_U = 0$ and 10 right-censored obs. with $E_U = 1$.

Moreover, the unskilled labour share is significantly negatively related to the IT investment to sales ratio. The negative relationship between the IT investment to sales ratio and unskilled labour, on the one hand, and the positive relationship between the IT investment to sales ratio and high-skilled labour, on the other hand, indicate a complementarity between IT capital and the skill structure of a firm's labour force. Accumulation of IT capital favours skilled labour. We also find that the coefficient on the non-IT investment to sales ratio is not significant at the five-percent-level for both medium- and unskilled labour shares. Exporting firms and firms that are part of a larger corporate group use less unskilled labour which is in line with a concentration on skill-intensive products by these firms.

The results for the three employment share equations were tested for robustness. First, we included quadratic investment terms in each employment share equation, finding only a weak significance of the quadratic log IT share. Second, we used the log IT investment to total wage cost ratio instead of the log IT investment to sales ratio as a second proxy for value added. In some sectors, total wage cost is a better proxy for value added than total sales, but the results for the IT coefficients remain robust. A last point concerns the causalitiy of the relationship between information technology and the high-skilled share since the firm's choice of IT investment and skill structure may be jointly determined. This simultaneity problem is, however, difficult to address on the basis of cross-sectional data and we will postpone a further investigation of these issues until the second wave of the MIP-S is available.

5. Output contributions of human capital and IT

As stated in section 2, two specifications for the production function will be investigated, the Cobb-Douglas production function as well as the translog production function. Output is a function of the five inputs, nine sector dummies and three dummy variables for exporters, R&D and ownership.

Two samples are used, the full sample of 1218 firms and a restricted sample excluding firms with zero expenditures for both types of investment and high-skilled labour. In addition, one could exclude firms that do not employ either medium-skilled or unskilled workers. This would reduce the sample size to 586 firms. However, since the size and significance of the input-output elasticities were remarkably similar to the results from the larger samples, the results are not displayed.

Results for the Cobb-Douglas specification using a sample selection model are reported in table 7-8. In addition, the CD-production function is estimated by a median regression model and the resulting standard errors are based on bootstrapped estimates of the variance-covariance matrix of the estimators. Estimates from the median regression model are obtained by minimising the sum of the absolute rather than the sum of the squared residuals. This approach aims to correct for possible outliers which are likely to arise in a firm level dataset. Both the sample selection model as well as the median regression model of the CD production function yield parameters for the different types of labour, non-IT investment and IT investment which have the expected signs and are significant at conventional levels. Except for the input-output elasticity of vocational school graduates, the regression results are thus not overly sensitive to the use of different specifications.

The estimation results for the translog production function are shown in table 5-1 contrasting a translog production function for the full sample with a sample selection model which explains the decision to employ at least one high-skilled worker and to invest in both IT and non-IT investment. Not surprisingly, the inverse Mills ratio is not significant since the translog production function contains quadratic terms which are good proxies for firm size, the identifying variable in the selection equation. The general results have been tested against restricted functional forms, and the test-statistics for homogeneity of degree one and the Cobb-Douglas functional form are reported. The chi-squared statistic of 407 for the specification test of a Cobb-Douglas versus translog functional form allows us to reject the appropriateness of the Cobb-Douglas specification. Similarly, linear homogeneity in inputs is rejected.

The output elasticities reported in table 5-1 have been evaluated at the mean of the inputs, thus $\eta_i = \alpha_i + \sum_j \gamma_{ij} \ln(\overline{X}_j)$. All output elasticities are positive and statistically significant. Although some of the estimated parameters are insignificant, the corresponding explanatory variables have not been excluded from the analysis to sustain the elasticities' flexibility across firms and sectors. Our results justify the assumption of a strictly quasi-concave production function. Under quasi-concavity, the Hessian matrix $D^2Y = D^2 f(H;M;U;IT;K)$ has to be negative definite. The percentage of observations which satisfy this regularity condition is approximately 50 %.[8] Monotonicity of the production function, i.e. positive firm-specific input-output elasticities, is satisfied by 55 % of the observations. 250 out of 1218 firms show negative non-IT investment-output elasticities based on the simple OLS model. For IT investment and unskilled labour, negative output elasticities were found for 15 % of total observations. For high- and medium-skilled labour, negative output elasticities were found in 5.5 and 1.7 % of total observations. As expected, the results for the restricted sample significantly reduce the set of negative output elasticities. Since the Breusch-Pagan heteroscedasticity statistic indicates that the residual variance depends on the explanatory variables, t-statistics are based on heteroscedasticity-consistent standard errors. To conserve space, we report only input-output elasticities based on the sample mean and the distribution of the input-output elasticities (see figures in the appendix).

The key results can be summarised as follows. Both IT expenditures and high-skilled labour make significant contributions to output as indicated by an IT elasticity of 0.14 and a high-skilled labour elasticity of 0.16 (based on the full sample and evaluated at sample means).[9] Thus, a 1 % increase in IT would raise the output level by 0.14 %. Concerning the non-IT factors, medium-skilled labour (vocational school graduates as well as foremen and technicians) is the most important production factor. The output elasticity of vocational school graduates is 0.49 while the contribution of non-IT capital to output is about 0.08. Output elasticities show a considerable variability across firms (see figures in the appendix). Moreover, R&D is associated with a higher productivity level.

[8] The determinants are calculated for each data point.

[9] The relative high value of the output elasticity of IT capital may partly be due broad definition of IT (including software and communication equipment) as well as the omission of materials as an input into production.

Table 5.1: Production function estimates, translog specification (West)

	TL production function		Sample Selection Model			
			Structural model[d]		Selection equation	
	coeff.	t-stat[a]	coeff.	t-stat	coeff.	t-stat
β_H	0.160	8.6	0.136	3.7		
β_M	0.490	22.1	0.424	10.0		
β_U	0.132	9.0	0.083	3.6		
β_K	0.080	7.4	0.138	6.8		
β_{IT}	0.139	9.2	0.220	7.4		
Wholesale trade	−0.974	−9.2	−1.128	−7.4	−0.216	−4.1
Retail trade	−1.215	−10.6	−1.260	−7.6	−0.204	−3.6
Transport	−1.659	−13.8	−1.808	−10.0	−0.286	−5.0
Real estate/renting	−1.082	−7.7	−1.325	−7.2	−0.072	−1.0
Computer/software	−1.898	−13.0	−2.044	−11.8	0.191	2.4
R&D / tech. consult.	−1.945	−12.3	−2.089	−11.2	0.195	2.3
Business services	−2.057	−14.4	−2.312	−13.9	0.110	1.5
Other business svcs	−1.885	−16.2	−1.655	−10.0	−0.222	−4.0
Community services	−1.547	−7.0	−1.424	−4.6	−0.172	−1.6
Size 2: $10 \le L < 20$	3.372	18.9			0.102	2.1
Size 3: $20 \le L < 50$	−0.101	−1.0			0.198	4.0
Size 4: $50 \le L < 250$	0.019	0.2			0.409	8.3
Size 5: $L \ge 250$	−0.037	−0.3			0.604	10.7
Exporter	−0.110	−1.3	0.193	2.0	0.141	3.6
Ind. Conglomerate	0.238	3.3	0.167	1.9	0.101	3.0
R&D	0.172	2.6	−0.116	−1.1	0.209	4.5
Inverse Mills Ratio			−0.177	−0.6		
Constant	3.304	16.8	3.23	7.2	−0.142	−2.8
Spec. test 1[b]; test 2[c]	312.96	72.9				
Adj-R^2	0.808		0.828			
Observations	1218		742		1218	

Notes: Dependent variable is log sales. IT and K denote IT investment and non-IT investment. respectively. H, M, and U denote university graduates, vocational school graduates and unskilled workers. Zero values for IT and K have been replaced by 0.000001 = DM 1. Zero values for H, M, or U have been replaced 0.1. Technology is given by: $\ln Q = \alpha_0 + \sum_i \alpha_i \ln X_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln X_i \ln X_j$. Displayed elasticities are based on the Wald-statistic to test the hypothesis of $H_0 : \epsilon_x = \partial \ln Q / \partial X = 0$. The reference groups are banking and insurance for the sector dummies and size 1 for the size classes. [a] Displayed t-statistics are based on the White estimator of the covariance matrix of the OLS estimator. [b] Specification test, Cobb-Douglas vs. translog specifications, $\gamma_{ij} = 0 \; \forall i; j$. The critical value is given by $\chi^2[15]_{95} = 25.0$. [c] Test for homogeneity of degree one, $\sum_i \alpha_i + \sum_i \sum_j \gamma_{ij} = 1$. The critical value is given by $\chi^2[6]_{95} = 12.6$.

Since most other studies are based on a narrow definition of information technology, quantitative comparisons of our results with those of Brynjolfsson and Hitt (1995) are not meaningful. Furthermore, for a number of reasons the output elasticities of non-IT and IT investment should be regarded with caution. First, as noted by Hall and Mairesse (1995), the use of flow rather than stock data tends to overestimate the output elasticities.

Our own previous results suggest, however, that the output elasticity of capital is not particular sensitive to the choice of flow or stock data. Second, the results are sensitive to the inclusion of firm effects. Using panel data, Brynjolfsson and Hitt (1995) report that the elasticity of IT capital drops from 10% to 5% once firm effects are included. A quantification of this factor will be undertaken once a MIP-S panel is available. A last concern arises out of the use of gross sales rather than value-added as our proxy for output. However, in one of the few studies that used data on both gross sales and value-added, Hall and Mairesse (1995) found only small differences in the estimated output elasticities based on value added rather than sales.

Table 7-7 in the appendix contrasts estimated input-output elasticities derived from the full-sample unrestricted OLS parameters for the translog production function using two alternative proxies for output, total sales and total wage costs. The greatest variation between the input-output elasticities based on total sales and the alternative specification using total wage costs is observed for university graduates and IT investment. The elasticity of IT capital drops from 0.16 to 0.08 when total wage cost is used as a proxy for value added.

6. Conclusions

This paper has presented a number of factor demand models to investigate the link between skill intensity and information technology at the firm level in service industries. Our econometric model allows for censoring at the lower and upper threshold parameters of the employment share. Tobit sample selection models are employed to account for zero values for both types of investment. We examine the sensitivity of the results with respect to model specification, sample selection and variable measurment. The most important result is the positive relationship between the share of high-skilled workers and information technology. Firms that have a higher proportion of information technology in total sales employ more university graduates. However, the size of the IT effect on the skill intensity is rather small. The results indicate little sensitivity to different models and specifications. Moreover, the investment ratio is negatively related to the high-skilled share indicating that capital-intensive firms employ less high-skilled workers. A more detailed study of the factors which affect firms' skill structure indicates that firms' export orientation, R&D or ownership characteristics have positive effects on the chosen skill intensity. The university graduates share is negatively related to firm size.

Moreover, we estimate the contribution of human and IT capital to output using a production function framework. The results for the translog production function show that the output contributions by university graduates and IT capital are approximately 0.14 and 0.16, respectively. Medium-skilled labour (vocational school graduates as well as foremen and technicians) is the most important production factor. In contrast, non-IT capital and unskilled labour play only a minor role in the service production process. Our results suffer from several shortcomings which we hope to address in future work, for example, the skill structure of the firm may largely be dependent on unobservable factors, as well as relative wages for different types of skills.

7. Appendix

7.1. Further descriptive statistics

Table 7.1: Definition of Service Sectors

Sector	3-dgt NACE	Description
Wholesale trade	511	Wholesale on a fee or contract basis
	513	Wholesale of food, beverages and tobacco
	514	Wholesale of household goods
	515	Wholesale of non-agricultural intermediate
	516	Wholesale of machinery, equipment & supplies
	517	Other wholesale
Retail trade	501	Sale of motor vehicles
	502	Maintenance and repair of motor vehicles
	503	Sale of motor vehicle parts and accessories
	504	Sale, maintenance and repair of motorcycles and related parts
	521	Retail sale in non-specialized stores
	522	Retail sale of food, beverages and tobacco
	524	Other retail sale of new goods
	525	Retail sale of second-hand goods
	526	Retail sale of mail order
Transport	602	Other land transport
	611	Sea and coastal water transport
	621	Scheduled air transport
	622	Non-scheduled air transport
	631	Cargo handling and storage
	634	Activities of other transport agencies
Financial Intermediation	651	Monetary intermediation
	652	Other financial intermediation
	660	Insurance
	671	Activities auxiliary to financial intermediation
Real Estate and Rental Activities	701	Real estate activities with own property
	702	Letting of own property
	703	Real estate activities on a fee or contract basis
	711	Renting of automobiles
	712	Renting of other transport equipment

Sector	3-dgt NACE	Description
Computing	721	Hardware consultancy and supply
	722	Software consultancy and supply
	723	Data processing
	724	Data base activities
	725	Maintenance and repair of office, accounting and computing machinery
	726	Other computer related activities
Research & development, technical consultants	731	Research & development on natural sciences, engineering
	732	Research & development on social sciences, humanities
	742	Architectural and engineering activities
Consulting (business scvs)	741	Legal, accounting, book-keeping and auditing activities
Other business services	744	Advertising
	745	Labour recruitment, provision of personnel
	746	Investigation and security activities
	747	Industrial cleaning
	748	Miscellaneous business activities
Community social and personnel services	900	Sewage and refuse disposal, sanitation
	911	Business, employers and prof. organizations
	913	Activities of other membership organizations
	921	Motion picture and video activities
	922	Radio and television activities
	923	Other entertainment activities
	924	News agency activities

Table 7.2: Missing values				
	West Germany		East Germany	
	Respondents	Missing values (%)	Respondents	Missing values (%)
Participating firms	1629		924	
University graduates, H	1433	12.0	835	9.6
Vocational school graduates, M	1477	9.3	849	8.1
Unskilled workers, apprentices, U	1470	9.8	852	7.8
Gross investment, inc. IT	1498	8.0	854	7.6
Inv. in communication and IT	1492	8.4	846	8.4
Exporter, 1994	1617	0.7	914	1.1
Part of ind. conglomerate, 1994	1614	0.9	916	0.9
R&D	1575	3.3	893	3.4
IT investment = 0, 1994	1498	8.0	854	7.6
Non-IT investment = 0, 1994	1492	8.4	846	8.4
Complete information (all variables)	1231		731	
Outliers[a]	1		2	
Imputed data (sales, employment)	12		18	
Observations used	1218	24.5	711	22.0

Notes: [a] Outliers are those observations for which non-IT investment to sales ratio exceeds 200 % and 400 % for East and West German firms, respectively.
Source: Mannheim Service Innovation Panel 1995.

Table 7.3: Share of material and labour expenditures in total output (West Germany 1994)

	Materials (%)	Labour (%)	Capital and gross profits (%)
Wholesale trade	86	9	5
Retail trade	82	13	5
Transport	50	29	21
Banking/insurance	35	31	34
Personal services	38	18	43
Market services	61	20	19

Source: National accounts. Own calculations

Table 7.4: IT and non-IT investment as percent of sales by sector

	West Germany				East Germany			
	Mean	Std. dev.	Max.	Obs.	Mean	Std. dev.	Max.	Obs.
IT investment								
Wholesale trade	0.5	1.0	7.1	214	0.5	1.0	6.0	84
Retail trade and repairs	0.6	1.3	11.3	157	1.1	3.8	31.3	73
Transport	0.8	1.6	11.9	157	0.9	2.0	15.4	102
Banking and insurance	1.1	2.8	26.1	207	1.4	5.8	5.0	78
Real estate and renting	1.4	3.7	26.0	76	3.0	12.6	94.2	67
Computer and software	3.3	3.2	15.9	83	7.1	11.8	58.1	34
R&D labs, Consultancy	3.0	4.0	25.0	60	3.6	4.7	33.3	114
Business services	2.6	4.3	32.3	75	2.6	2.7	10.0	31
Other business activities	1.0	3.5	41.7	164	1.1	2.4	16.7	95
Community services	1.9	3.9	17.3	25	1.1	3.2	18.5	32
Non-IT investment								
Wholesale trade	2.3	3.5	24.5	214	3.5	6.1	30.9	84
Retail trade and repairs	4.3	10.6	77.6	157	5.7	18.6	156.3	73
Transport	13.6	18.2	124.0	157	40.5	57.8	302.3	102
Banking and insurance	2.1	8.4	76.8	207	1.4	3.5	26.2	78
Real estate and renting	12.5	20.8	84.2	76	53.1	71.2	293.2	67
Computer and software	2.0	4.0	26.0	83	4.9	10.6	57.8	34
R&D labs, Consultancy	4.9	9.8	45.3	60	7.6	14.4	75.0	114
Business services	4.7	13.0	77.4	75	4.4	8.6	36.7	31
Other business services	2.7	6.4	55.3	164	6.8	16.3	132.8	95
Community services	15.3	28.4	131.8	25	19.4	25.4	104.2	32

Source: Mannheim Service Innovation Panel 1995

7.2. Further estimation results

Table 7.5: Tobit and sample selection models for the high-skilled employment share (East German firms)

	Tobit variants				Sample selection model			
	Tobit		Het. Tobit		Structural model		Selection equation	
	marg. eff.	t-stat	marg. eff.	t-stat	coeff.	t-stat	marg. eff.	t-stat
itq	.008	3.0	.004	1.5	.006	1.7		
iq	−.004	−1.8	−.002	−0.8	−.004	−1.7		
itq×retail trade	−.015	−2.3	−.003	−0.4	−.015	−1.8		
itq×banking	−.018	−2.1	.007	0.6	−.013	−1.4		
itq×computer	−.015	−2.3	.008	0.7	−.013	−1.5		
iq×transport	.011	2.1	.008	1.3	.013	1.9		
iq×banking	−.020	−3.3	−.023	−2.2	−.017	−2.5		
Wholesale trade	.163	2.4	.070	0.8	.098	1.2	−.001	−0.0
Retail trade	.069	0.9	.026	0.3	.019	0.2	−.006	−0.1
Transport	.117	1.7	.046	0.5	.027	0.3	−.118	−3.0
Real estate	.238	3.5	.103	1.1	.210	2.5	.005	0.1
Computer	.469	6.8	.445	3.7	.540	6.0	.268	5.4
Tech. consult.								
Business svcs.	.301	4.2	.168	1.5	.310	3.2	.028	0.5
Other bus. scvs.	.172	2.5	.042	0.5	.100	1.2	−.030	−0.8
Community svcs.	.207	2.9	.066	0.6	.168	1.9	.018	0.3
$10 \le L < 20$	.004	0.2	.063	1.9			.062	2.0
$20 \le L < 50$	−.034	−1.6	.062	2.1			.127	4.1
$50 \le L < 250$	−.044	−2.2	.062	2.0			.210	5.8
$L \ge 250$	−.048	−1.9	.068	2.1			.263	5.0
Exporter	.093	3.8	.036	1.0	.123	3.3	.062	1.4
Ind. Conglomerate	−.009	−0.5	−.005	−0.3	−.016	−0.6	.022	0.7
R&D	.057	2.7	.043	2.3	.067	2.1	.008	0.2
Inverse Mills Ratio					.340	5.8		
Constant	−.037	−0.6	0.02	0.3	−.050	−0.7	.032	1.0
Log likelihood	−724		860.2					
Pseudo/Adj. R^2	.93				.573			
Observations	711		711		596		711	

Notes: Lower case variables denote logarithms. Dependent variable is the university graduates employment share. Observation summary for the Tobit models: 105 left-censored observations with $E_H = 0$ and 10 right-censored observations with $E_H = 1$. Zero values for IT and I have been replaced by DM 1. Due to small sample sizes, the two sectors computer/software and R&D / technical consultants have been combined into one single sector. Banking/insurance was used as a reference group for the sector dummies and size 1 for the size classes. Further information about the independent variables can be found in the notes to Table 4-1.

Table 7.6: FIML and two-stage Least Squares estimates of the sample selection Tobit model (university graduates employment share, West German firms)

	FIML				2SLS	
	Investment selection		Structural model			
	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat
itq			.018	3.5	.013	3.3
iq			−.003	−1.3	−.002	−1.2
itq×computer			.096	4.9	.096	5.5
itq×tech. consult.			.085	4.0	.083	4.2
itq×business svcs.			.049	3.3	.044	2.5
iq×computer			−.013	−2.4	−.013	−2.4
Wholesale trade	−.421	−2.8	−.056	−2.0	−.059	−2.7
Retail trade/repairs	−.213	−1.3	−.115	−3.3	−.090	−4.1
Transport	−.332	−2.0	−.139	−4.1	−.108	−4.7
Real estate/renting	−.181	−0.9	.006	0.2	−.001	0.0
Computer/software	.225	1.0	.562	6.6	.565	6.7
R&D labs/tech. con.	.132	0.6	.670	7.1	.654	7.4
Business services	.248	1.1	.361	5.2	.345	4.3
Other business scvs	−.509	−3.2	−.044	−1.6	−.055	−2.5
Community services	.086	0.3	−.022	−0.6	.014	0.3
Size 2: $10 \leq L < 20$	.277	2.2				
Size 3: $20 \leq L < 50$	.610	4.4				
Size 4: $50 \leq L < 250$	.932	6.7				
Size 5: $L \geq 250$	1.163	7.2				
Exporter	.141	1.3	.067	4.0	.059	4.0
Ind. Conglomerate	.082	0.8	.041	2.5	.032	2.4
R&D	.463	3.2	.060	2.9	.070	4.1
Constant	.268	1.9	.160	3.8	.119	3.4
Inverse Mills Ratio					.155	4.1
Sigma			.195	43.4		
Rho = corr(ε_2; ω_2)			.270	1.0		
Observations	1218		945		945	

Notes: Dependent variable is the university graduates employment share. Selection is based on the firm's decision to invest in both IT and non-IT capital. Observation summary: 237 left-censored observations with ITQ and/or IQ = 0. Further information about the independent variables can be found in the notes to Table 4-1.

Table 7.7: Input-output elasticities based on different proxies for output using the translog production function

	Dependent variable			
	Log(sales)		Log(total wage costs)	
	coeff.	t-stat	coeff.	t-stat
β_H	0.157	4.0	0.219	9.1
β_M	0.407	9.5	0.389	13.0
β_U	0.059	2.5	0.149	10.3
β_K	0.123	6.3	0.044	4.0
β_{IT}	0.168	6.0	0.083	4.9
Adj. R^2	0.925		0.848	
Observations	1164		1164	

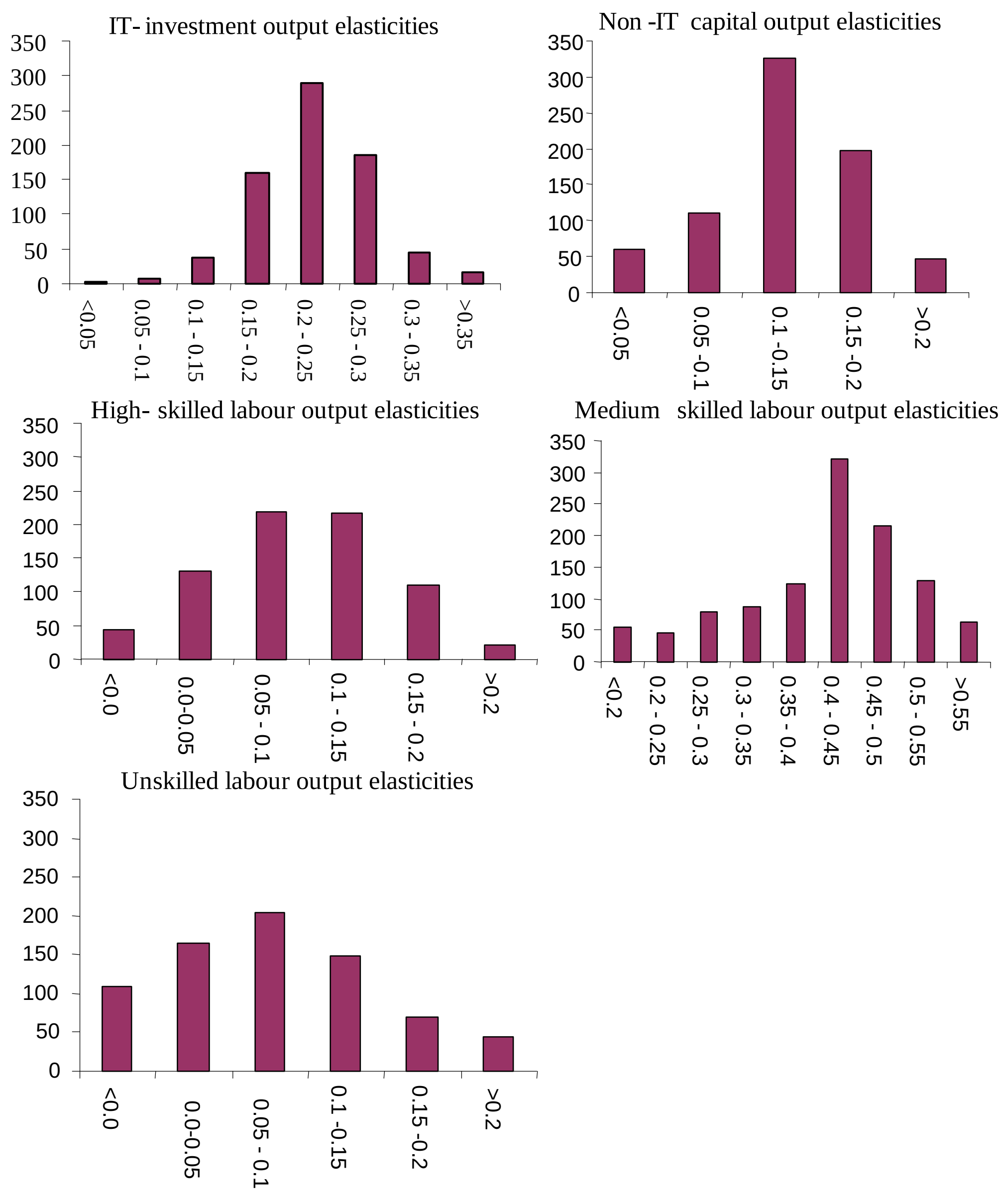
Notes: Observations for which total wage costs were missing were dropped reducing the sample size to 1164. Output elasticities are based on the estimated unrestricted translog specification parameters. IT and K denote IT investment and non-IT investment, respectively. H, M, and U denote university graduates, vocational school graduates and unskilled workers. Zero values for IT and K have been replaced by 0.000001 = DM 1. Zero values for H, M, or U have been replaced 0.1.

Table 7.8: Sample selection model and LAD of the CD Production function (West German firms)

	Sample selection model				Median regression	
	Selection equation		Structural Model			
	coeff.	t-stat	coeff.	t-stat	coeff.	t-stat[a]
Log (H)			0.183	5.2	0.148	3.2
Log (M)			0.330	9.2	0.362	7.5
Log (U)			0.088	4.3	0.034	0.9
Log (K)			0.045	4.1	0.047	4.2
Log (IT)			0.284	10.0	0.212	5.4
Wholesale trade	−0.216	−4.1	−0.866	−5.8	−1.077	−5.6
Retail trade	−0.204	−3.6	−1.024	−6.3	−1.159	−5.2
Transport	−0.286	−5.0	−1.407	−8.2	−1.740	−8.6
Real estate/renting	−0.072	−1.0	−1.015	−5.3	−0.969	−4.6
Computer/software	0.191	2.4	−2.186	−11.9	−2.116	−11.2
R&D / tech. consult.	0.195	2.3	−2.260	−11.4	−2.129	−10.4
Business services	0.110	1.5	−2.475	−13.7	−2.397	−13.2
Other business svcs.	−0.222	−4.0	−1.507	−9.7	−1.820	−7.6
Community svcs.	−0.172	−1.6	−1.188	−3.6	−1.062	−2.5
$10 \leq L < 20$	0.102	2.1			−0.055	−0.4
$20 \leq L < 50$	0.198	4.0			0.186	1.2
$50 \leq L < 250$	0.409	8.3			0.517	2.8
$L \geq 250$	0.604	10.7			0.883	3.7
Exporter	0.141	3.6	0.096	1.0	0.187	3.0
Ind. Conglomerate	0.101	3.0	0.115	1.2	0.129	2.0
R&D	0.209	4.5	−0.241	−2.2	0.015	0.1
Inverse Mills Ratio			−0.664	−2.7		
Constant	−0.142	−2.8	3.85	13.8	2.97	9.2
Pseudo/Adj. R^2	0.239		0.814		0.614	
Observations	1218		742		742	

Notes: Dependent variable is log sales. IT and K denote IT investment and non-IT investment, respectively. H, M, and U denote university graduates, vocational school graduates and unskilled workers. For the full sample, zero values for IT and K have been replaced by 0.000001 = DM 1. Zero values for H, M, or U have been replaced 0.1. [a] T-statistic are based on bootstrapped estimates of the variance covariance matrix of the estimators.

Figure 7.1: Distribution of input-output elasticities based on the restricted sample (west)



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