FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG

Lehrstuhl für VWL, insbes. Arbeitsmarkt- und Regionalpolitik
Professor Dr. Claus Schnabel

Diskussionspapiere
Discussion Papers

No. 14

Skill-Biased Technological Change, International Trade and the Wage Structure

ARND KÖLLING AND THORSTEN SCHANK

SEPTEMBER 2002

ISSN 1615-5831

Editor: Prof. Dr. Claus Schnabel, Friedrich-Alexander-Universität Erlangen-Nürnberg

Skill-Biased Technological Change, International Trade and the Wage Structure

New evidence on the determinants of the employment structure from linked employer-employee panel data for Germany

Arnd Kölling[a] and Thorsten Schank[b]

ABSTRACT: During the last two decades, the labour demand structure in Germany has experienced a decrease in the demand for the low skilled. Possible explanations for this trend are investigated in this study for West Germany (1994-1997) using a unique linked employer-employee panel data set for Germany. Estimation results of the conditional labour demand for three different skill types indicate that the major part of the skill structure is determined by wages, while we have found only minor impacts of a skill-biased technological change and of international trade.

Zusammenfassung: In den letzten beiden Jahrzehnten hat sich die Beschäftigtenstruktur in Deutschland zuungunsten der Un- und Angelernten entwickelt. Mögliche Ursachen für diesen Trend werden in der vorliegenden Studie auf der Basis eines neuen, aus Individual- und Betriebsdaten zusammengefügten Datensatzes, für West-Deutschland (1994-1997) untersucht. Schätzungen der bedingten Arbeitsnachfrage für drei verschiedene Qualifikationsgruppen zeigen, dass der größte Teil der Beschäftigtenstruktur von den Löhnen bestimmt wird, während nur geringe Einflüsse des technologischen Wandels und des internationalen Handels identifiziert werden.

KEYWORDS: labour demand, substitution, skill-biased technological change, labour hoarding, international trade, linked employer-employee data

JEL-CLASSIFICATION: J23, J31, O33, F16

[a] Dr. Arnd Kölling, Institut für Arbeitsmarkt- und Berufsforschung der Bundesanstalt für Arbeit, Regensburger Str. 104, D-90478 Nürnberg, arnd.koelling@iab.de

[b] Thorsten Schank Ph.D., Universität Erlangen-Nürnberg, Wirtschafts- und Sozialwissenschaftliche Fakultät, Lange Gasse 20, D-90403 Nürnberg, thorsten.schank@wiso.uni-erlangen.de

1. INTRODUCTION

During the last two decades, the labour demand structure in Germany and other OECD countries has experienced a decrease in the demand for low skilled and a rise in the demand for highly skilled employees (see Bellmann *et al.* 1996, 85pp, Koller & Haas 2001 for Germany and Machin & Van Reenen 1998 for other OECD countries). Since we do not observe the same development in the supply of labour, consequently the group of unskilled employees faces severe and rising unemployment problems. Projections of the German labour force, for example, predicts that this trend continues until the end of the first decade of the new millennium (see Weidig, Hofer & Wolff 1999, 58; Schüssler *et al.* 1999, 57pp). Mainly two reasons for this phenomenon are discussed. The first argument follows the notion of a "creative destruction" (Schumpeter 1942). Old equipment vanishes, while modern technology appears. This kind of technical progress is assumed to be skill-biased, leading to an increase in the share of highly skilled employees (Bound & Johnson 1992; Berman, Bound & Griliches 1994). The alternative argument rests on higher foreign competition due to the globalisation of markets. Competitors in low-wage countries damage the position of less skilled workers in industrialised high-wage economies (Freeman 1995). Besides these, capital-skill complementarities and the shift from manufacturing to non-manufacturing industries (see Fitzenberger 1999a, 4) and, very recently, organisational changes (Bresnahan, Brynjolfsson & Hitt 1999) are commonly referred to when explaining shifts in the skill structure of labour demand. It is often argued that the reduction in the demand for the low skilled could be counteracted by lowering their wages and that the rigid wage structure in continental Europe, as opposed to the United States and Great Britain, is at least partly responsible for the high unemployment rates of the unskilled.[1]

Both explanations, skill-biased technological change and increased foreign competition, determine long-run effects on the structure of labour demand. However, there are also shifts due to short-run behaviour of firms. The change in labour productivity during a business cycle is a stylised fact. During a recession, labour productivity decreases, while it increases during an economic upswing. One explanation for this procyclical movement is labour hoarding of skilled workers (Hamermesh 1993, 205). The demand for low skilled, on the other hand, is more sensitive to a firm's economic condition, because of lower hiring and firing costs of

[1] Following this argument, a lower unemployment rate of the unskilled would obviously be achieved at the expense of a rising wage inequality.

this group. Therefore, the structure of employment in a firm also depends on short-run effects due to the business cycle and the share of low skilled employees is assumed to be positively correlated with the business cycle.

This paper seeks to identify the different influences on the skill structure within a firm, using the LIAB, a linked employer-employee panel data set, which is unique for Germany. Our analysis is based on 880 West German plants for the time period from 1994 to 1997 and covers approximately 350,000 employees per year. It combines individual data from the official employment statistics of the Federal Employment Services with plant data from the IAB-Establishment Panel. The employment statistics provides us with detailed and precise information on personnel characteristics and the skill decomposition of a plant's workforce and of the (median) wage of each skill group, while we observe the economic activity of a plant (actual and expected output, different types of investment, export) and the level of the used technology from the IAB panel. Thus, we are able to estimate the demand for heterogeneous labour based on a rich and new data-set. Furthermore, taking advantage of the longitudinal character of the data, our analysis should produce reliable results since we are able to control for unobserved (time-invariant) plant heterogeneity, an inherent problem of many empirical specifications.

The paper is organised as follows. Section 2 reviews the theoretical and empirical literature on the structural changes in the firms' labour demand. In Section 3, we derive conditional labour demand functions for three different skill types of labour from a Generalised Leontief Cost Function. Section 4 describes the data, while the empirical specification is presented in Section 5. The estimation results are discussed in Section 6. Section 7 summarises.

2. A BRIEF OVERVIEW OF PREVIOUS STUDIES

Following the seminal article by Krueger (1993), the hypothesis of a skill-biased technological change became very popular. The literature provides two different explanations for the increase in the share of skilled employees due to technical progress. The first assumes a complementary relationship between human capital and physical capital. This leads to a higher demand for the highly skilled after a firm has implemented new technologies. Hence, the structure of the workforce shifts towards the skilled/highly skilled employees. Caselli (1999) distinguishes between different kinds of technological progress. Besides the skill-biased technological changes, there are sometimes de-skilling effects of new machines.

In the 1920ies, the use of assembly lines did not lead to an increase in the required skills. By contrast, individual operations at the workplace were split into small pieces. Thus, the required skills were lowered and more workers were able to work with this technology. On the other hand, the use of information technology (IT) and microelectronics since the 90ties has probably been skill-biased since they require very special capabilities and therefore, more human capital.

The second explanation for a skill-biased technological change refers to the different abilities to adapt to a new technology or to an unknown labour environment (Bartel & Lichtenberg 1987). Because highly skilled employees are able to learn faster and perform better with new machines than the low skilled, it is more attractive for the employer to hire skilled instead of unqualified workers.

The paper of Krueger (1993) initiated a vast body of literature on the effects of technological changes on the structure of labour demand, which support the hypothesis of a skill-biased technological change. Empirical studies for Germany find evidence for a skill-biased technological change (e.g. FitzRoy & Funke 1998, Kaiser 2000, Falk & Seim 1999, Falk & Koebel 2000). The work of Lindbeck & Snower (2000) deals with organisational changes that abolish the tayloristic system of work and also and simultaneously shifts the demand for labour in favour of the highly skilled. These organisational changes may be the result of technical progress, but Leigh & Gifford (1999) find that the introduction of new equipment leads to higher training efforts rather than organisational transformations. Entorf, Gollac & Kramarz (1999) and Entorf & Kramarz (1997) also find a demand bias towards highly skilled labour but the effect reduces after introducing unobserved plant heterogeneity to the model. Also, it is the experience with modern technology, not only the use, that is rewarded by the employer. Fitzenberger (1999a, 137pp.) receives differentiated results, as he distinguishes between several instruments for modern technologies. Also, he divides capital into two different kinds (equipment and plant) and discriminates manufacturing from non-manufacturing industries. Depending on the variables used, the influence on the skill groups differ, but an overall trend towards highly skilled after the introduction of new equipment in the firm is always found.

On the other hand, several studies could not confirm a relationship between higher qualification and technological progress or find other explanations for the shift in the skill structure. Bellmann & Schank (2000) do not find complementarities between capital and human capital in Germany. In the paper of DiNardo & Pischke (1997), the wage structure changes because of the competition on the product market. If firms which use modern technology are able to pay higher wages for skilled employees, then all firms are forced to pay more for these workers, otherwise their employees would quit. The results of Haskel & Heden (1999) suggest a lower demand for manual workers, if investment in computers takes place. Finally, Robinson & Manacorda (1997) find evidence that a great part of the structural changes in the labour force is pictured by the alterations in the supply of labour. However, skill-biased technological progress is probably induced by an increased supply of highly skilled employees (Acemoglu 1998).

The alternative to this technical or organisational based explanation of the change in the skill structure is international trade. Foreign competition leads to higher productivity pressure on the establishments (Freeman 1995). When firms from low-wage countries appear on the market, wages of less skilled workers must decrease or the share of low skilled in the firm declines. Machin & Van Reenen (1998) and Berman, Bound & Machin (1998) do not support this assumption, but they find that skill-biased technological change takes place not only on the national, but also on the international level. Zeira (1998) claims that the adoption of new technologies is profitable for countries with a high productivity. Hence, producers in countries with a low level of productivity may not find it profitable to use new technologies. For Germany, Fitzenberger (1999b) finds that trade is a possible explanation reduces the demand of low skilled, whereas skill biases technological change increases the demand for highly and medium skilled workers.

The explanations of a falling employment share of the unskilled discussed so far deal with long-run changes in labour demand, but there is also evidence of short-run alterations. Different adjustment costs or efficiency wages lead to differences in the adjustment behaviour for different skill groups during a business cycle (cf. Hamermesh 1993, 205; Saint-Paul 1996, 45pp). The hiring and firing of employees with high replacement cost are expected to take place at a lower rate; and generally, it is assumed that these costs rise with skill. Therefore, the demand for unskilled employees is awaited to fluctuate with a higher rate through a business cycle and its share in total employment should be larger during a boom than during a recession. Therefore, the proportion of low skilled varies pro-cyclical while the proportion of high skilled varies counter-cyclical. Technical progress or international trade lead to a direct substitution of low skilled through highly skilled employees. This process is independent of the business cycle; thus, we should distinguish between both effects in our empirical investigations. In the next section, a labour demand model is derived to estimate short-run and long-run effects on the structure of a firm's workforce.

3. A Functional Framework for Heterogeneous Labour Demand

In the following, we use a cost function to derive the demand for heterogeneous labour, where the labour input is stratified into three categories (unskilled, medium skilled and highly skilled employees; see the data description for the actual categorisation). We assume capital, *K,* to be a quasi-fixed factor of production. Following the considerations in the previous section, we assume that modern technologies, *IT*, the export behaviour, *EXP*, and labour hoarding, *LH,* influence the demand for the different skill groups. Thus, the variable production cost, *C*, which are necessary to produce a certain output level, *Y,* can be summarised as:

$$C = C(w_1, w_2, w_3, Y, K, IT, EXP, LH). \tag{1}$$

We also seek to identify short-run effects on the demand for labour in this study. Therefore, one could argue, that the model has to be specified as a dynamic labour demand model. There are two reason, why a dynamic formulation does not fit the needs of the model. Firstly, the assumptions about the costs of adjustment and the production function in these models are rather restrictive and questionable (cf. Hamermesh 1993, 232pp.). Secondly, empirical results for Germany suggest that the adjustment processes for heterogeneous labour is almost completed within one year (cf. Kölling 1998, 175pp.). Since we use yearly data in this study, employment dynamics should not affect the results.

We choose a Generalised Leontief cost function to derive the demand for heterogeneous labour (Diewert 1971). Together with the Translog specification (Christensen, Jorgenson & Lau 1973), the Generalised Leontief belongs to the most common flexible functional forms, which are linear second-order approximations to arbitrary cost functions. They are preferred to the Cobb-Douglas or CES-functions because they do not restrict the substitution elasticities of the input factors to be equal to one or to be constant. We select the following Leontief cost function:

$$C = Y\sum_i\sum_j \alpha_{ij}\sqrt{w_i w_j} + Y^2\sum_i \beta_i w_i + \sum_i\sum_k \gamma_{ik} Z_k w_i + u_i \qquad \text{i,j} = 1,...,3, \quad \text{k} = 1,....,4; \tag{2}$$

where w_i denotes the wage of group i and where we have used *Z* as a column vector consisting of *K, IT, EXP* and *LH*, with z_k defining the *k*-th element of this vector. The condition $\alpha_{ij}=\alpha_{ji}$ ensures equal cross partial derivatives $(\partial^2 C/\partial w_i \partial w_j = \partial^2 C/\partial w_j \partial w_i)$. Applying *Shepard's Lemma* – i. e. $\partial C/\partial w_i = N_i$ – yields the conditional demand functions for the different types of labour:

$$N_i = Y\alpha_{ii} + Y\sum_{i\neq j}\alpha_{ij}\sqrt{\frac{w_j}{w_i}} + \beta_i Y^2 + \sum_k \gamma_{ik} Z_k \qquad \text{i,j}=1,...3, \quad \text{k}=1,...4. \qquad (3)$$

The own-wage elasticities of the respective labour groups are given by the following formula:

$$\eta_{N_i w_i} = \frac{-.5Y\sum_{j\neq i}\alpha_{ij} w_j^{.5}}{N_i w_i^{.5}} \ . \qquad (4)$$

Since the cost function is assumed to be concave, the own wage has a non-positive impact on the demand for each group $\left(\frac{\partial^2 C}{\partial w_i} = \frac{\partial N_i}{\partial w_i} \leq 0\right)$.

The cross wage elasticities are given by:

$$\eta_{N_i w_j} = \frac{.5Y\alpha_{ij} w_j^{.5}}{N_i w_i^{.5}} \ . \qquad (5)$$

Two groups are substitutes, if the derivative of N_i with respect to w_j is positive $\left(\frac{\partial N_i}{\partial w_j} > 0, \, i \neq j\right)$ and complements, if this derivative is negative. Finally, labour demand

elasticities with respect to output and with respect to any of the *Z*-variables can be calculated as:[2]

$$\eta_{N_i Y} = \frac{Y(\alpha_{ii} + \sum_{j\neq i}\alpha_{ij} w_j^{.5} w_i^{-.5} + 2Y\beta_i)}{N_i} \qquad (6)$$

and

$$\eta_{N_i Z_k} = \frac{\gamma_{ik} Z_k}{N_i}. \qquad (7)$$

We are not only interested in the impact of any exogenous variable on the employment levels, but also in the effect of any exogenous variable on the employment shares of each skill group. These can be calculated via the following expression:[3]

$$\frac{\partial(N_i/N_\bullet)}{\partial x} = \left(\frac{\partial N_i}{\partial x}N_\bullet - \sum_j \frac{\partial N_j}{\partial x}N_i\right)\frac{1}{(N_\bullet)^2} = \frac{\partial N_i}{\partial x}\frac{1}{N_\bullet} - \sum_j \frac{\partial N_j}{\partial x}\frac{N_i}{(N_\bullet)^2} \quad \text{i,j}=1,...,3; \qquad (8)$$

---

[2] By contrast, the derivation of the impact of the *Z*-variables in a Translog system also relies on coefficients which occur only in the cost function.

[3] The qualitative impact of a variable on the employment share is not directly obvious from the qualitative impact of a variable on the employment levels.

where $N_{\bullet} = \sum_{j=1}^{3} N$ is total employment within a plant and x denotes any of the right-

hand side variables of our model. Note that this formula depicts the marginal effect (the impact of a change in a right-hand side variable on the employment share of a particular skill group), but the extension to a semi-elasticity or an elasticity is straightforward.

4. The Matched Employer-Employee Data-Set (LIAB)

The use of matched employer-employee data has recently become popular as it allows a more detailed analysis of economic relationships. In particular, various analysis of the labour market can benefit from the availability of employer-employee data.[4] In this paper, we use the LIAB, which combines the employment statistics of the German Federal Employment services with plant level data from the IAB-Establishment Panel.

The employment statistics (cf. Bender, Haas & Klose 2000) cover all employees and trainees subject to social security and exclude, among others, a part of the civil servants ("Beamte"), the self-employed, family workers, students enrolled in higher education and those in marginal employment. For 1995, the employment statistics cover nearly 79% of all employed persons in Western Germany and about 86% in Eastern Germany.

The employment statistics are collected by the social insurance institutions for their purposes according to a procedure introduced in 1973 and are made available to the Federal Employment Services. Notifications are prescribed at the beginning and at the end of a person's employment in a plant. In addition an annual report for each employee is compulsory at the end of a year. Misreporting is legally sanctioned. The employment statistics contain information on an employee's occupation, the occupational status and gross earnings up to the contribution assessment ceiling and on individual characteristics like sex, age, nationality, marital status, number of children and qualification. Each personnel record also contains the establishment identifier, the industry and the size of the plant.

Starting in 1993, the IAB-Establishment Panel (cf. Kölling 2000) is drawn from a stratified sample of the plants included in the employment statistics, where the

---

[4] A survey of matched employer-employee data sets can be found in Abowd and Kramarz (1999).

strata are defined over 16 industries and 10 plant sizes (large plants are oversampled), but the sampling within each cell is random. In 1993, the sample started with 4,265 plants, covering 0.27% of all plants in West Germany (2 million) and 11% of total employment (29 million). In 1996, the Eastern German establishment panel started with 4,313 establishments representing 1.10% of all plants (391 thousand) and 11% of total employment (6 million). Altogether, the number of establishments interviewed increased until the year 2001 up to 15,000, in order to make regional analysis on the federal state level feasible.

The IAB-Establishment Panel is created for the needs of the Federal Labour Services to provide further and detailed information about the demand side of the labour market. Therefore, information on the decomposition of the workforce and its development through time constitutes a major part of the questionnaire. Further questions include training, working time, business activities and establishment policies. Other topics, for instance, questions on innovations or flexibility of labour, are asked biennially or triennially. In addition, each year provides information on particular topics; in 2000, for example, this has been the lack of skilled employees.

The LIAB is created by linking the employment statistics and the IAB-Establishment Panel through a plant identifier which is available in both data sets. This matched employer-employee data-set, which is unique for Germany, comprises currently the years 1993-1997.

5. THE EMPIRICAL SPECIFICATION

Based on Equation (3), we estimate the following system of employment-output ratios:

$$\frac{N_{ipt}}{Y_{pt}} = \alpha_{ii} + \sum_{i \neq j} \alpha_{ij} \sqrt{\frac{w_{jpt}}{w_{ipt}}} + \beta_i Y_{pt} + \sum\nolimits_k \gamma_{ik} \frac{Z_{kpt}}{Y_{pt}} + \varepsilon_{ip} \qquad i, j = 1, \ldots, 3; \;\; k = 1, \ldots 4; \tag{9}$$

where p denotes plants and *t* indexes the year of observation. In addition, we have divided Equation (3) by output, since it seems reasonable that the error variance of the skill groups is correlated with the output level (see, for example, Parks 1971). This would cause biased estimates of the standard errors when estimating a system of labour inputs themselves. A common problem of earlier studies based on cross-sectional data is unobserved plant heterogeneity. To sweep out any unobserved (and time-invariant) effects, we apply the within transformation to Equation (9):[5]

$$\frac{N_{ipt}}{Y_{pt}} - \frac{1}{T}\sum_t \frac{N_{ipt}}{Y_{pt}} = \sum_{i \neq j} \alpha_{ij} \left(\sqrt{\frac{w_{jpt}}{w_{ipt}}} - \frac{1}{T}\sum_t \sqrt{\frac{w_{jpt}}{w_{ipt}}} \right) + \beta_i \left(Y_{pt} - \frac{1}{T}\sum_t Y_{pt} \right) + \sum_k \gamma_{ik} \left(\frac{Z_{kpt}}{Y_{pt}} - \frac{1}{T}\sum_t \frac{Z_{kpt}}{Y_{pt}} \right) + \varepsilon_{ipt} - \frac{1}{T}\sum_t \varepsilon_{ipt} \quad i,j = 1,\ldots,3;\ k = 1,\ldots 4; \tag{10}$$

As can be seen, we subtract from each variable the within-plant mean. After adding time dummies, this Equation system is estimated by the Seemingly Unrelated Regression (*SUR*) method in STATA V7.0. The *SUR* method assumes that the error terms between the labour inputs of one plant are correlated, but not those of different plants.

For the analysis of this paper, information from the employment statistics on wages and on the number of employees in each skill group (unskilled, medium skilled and highly skilled) has been aggregated at the establishment level. We have combined two variables of the employment statistics to classify employees by skill. Workers are categorised according to their occupational status (unskilled, skilled/trained, master craftsmen). Since the employment statistics contains only one occupational status for salaried employees, we have categorised this group according to their qualification (without apprenticeship and without A-levels, with apprenticeship and/or A-levels, with a degree from higher education).

The information on daily wages is censored at the top, since there is a contribution assessment ceiling for payments to the social security. Therefore, we have carried out twelve Tobit regressions (for each year and for each skill group separately) of the daily wage on a set of other variables from the employment statistics (nationality, age, gender, number of children, family status, occupation and industry dummies).[6] Figures 1a-1c contain the distributions of the actual and the predicted wages for each skill group, separately for workers and for salaried

---

[5] Because of this transformation, all time-invariant variables are swept out. For this reason, we have not included controls for industry classification.

[6] For 1997, for example, the regressions are carried out with ca. 1.0 million observations for the unskilled (6,609 censored), 2.1 million observations for the skilled (187,877 censored) and 0.5 million observations for the highly skilled (233,241 censored). The regression ouputs are available from the authors upon request.

employees.[7,8] It is evident that a large percentage of highly skilled employees receive wages which are above the contribution ceiling for social security payments. Within each skill group, the mean wage of salaried employees is slightly higher than that of workers. However, the distributions for both types of workers look roughly similar within each skill group, in particular for unskilled and for highly skilled employees.[9] We have used the predicted wages to calculate the median wage per plant and per skill group. Therewith, we avoid a bias in the coefficients due to censored information on wages and we have also eliminated any potential endogeneity of the wages, since the variables used to predict the wages can be regarded as exogenous.

These plant specific variables (for each skill group the estimated median wage and the number of employees) are added to the IAB-Establishment Panel, from which we obtain the other information which is needed to estimate the system of input-output ratios given in the Equation system (6). We use (yearly) turnover instead of value added as a proxy for output, since the data on intermediate inputs contains missing values for about one third of all plants. Turnover are measured in millions DM and are deflated by a sectoral price index obtained from the statistical office. Since the information refers to turnover in the previous year, we believe that the problem of endogeneity of turnover is minimised. The capital stock is approximated by the sum of investment expenditure in the last two years and is also measured in millions DM. Further, we include dummy variables which respectively indicate whether a plant has invested in (i) property and buildings, (ii) in production units and (iii) in information and communication technology. The latter can be regarded as a proxy for the use of new technologies in the plant and, in addition to this, we use another dummy variable which is equal to one if uses up-to-date equipment to produce goods or to provide services. The importance of international trade and globalisation for a plant is measured as the percentage of exports in the turnover of the previous year. Labour hoarding is approximated by the expected relative change of turnover compared to the previous year. If the value is positive, the share of unskilled is expected to rise.

Agriculture, the mining and energy sector, the banking and insurance sector and the public sector are excluded because their measure for turnover is not

---

7 The top and bottom 1% of each distribution are not included in the figures.

8 The graphs refer to the first year in the data-set, 1993, but the same pattern emerges for each year.

9 For salaried skilled employees, we observe a much higher spike at the social security ceiling than for skilled workers.

comparable to that of other sectors. We have included only plants with an (average) employment size of at least 10, taking account of the fact that small plants have different substitution possibilities. After the within-transformation, plants with only one observation have no impact on the regression results and have consequently been dropped from the analysis. This leaves us with a sample size of 2470 observations and 880 West German plants covering the time period 1994 until 1997.[10] The descriptive statistics of the variables used are summarised in Table 1.

6. Estimation Results

Tables 2 and 3 report parameter estimates of *constrained seemingly unrelated regression* analysis of Equation (10), which was performed separately for manufacturing and for services. We can already infer from the parameter estimates that for both subgroups unskilled and medium skilled employees are substitutes and that the unskilled and the highly skilled are not affected by each other's wage. While medium skilled and highly skilled employees are substitutes in the manufacturing sector, they are complements in the service sectors. As we have mentioned above, when estimating a *Leontief* cost function, the impact of a right-hand-side variable –other than wages and output- on the labour demand for group *i* is directly given by the respective coefficient. In both sectors, capital and medium skilled employees are complements with similar quantitative relationships (i.e. the point estimate for services lies in the 95% interval of the respective estimate for manufacturing), but the demand for unskilled as well as for highly skilled employees remain unaffected by a change in the capital stock. The same pattern arises, if a plant increases its export share, which rises significantly only the number of medium skilled employees. With respect to the different types of investment, we observe distinct impacts for the two subsamples. Investment in information and technology affects only labour demand in the service sector, where both the number of unskilled and medium skilled employees in a plant shrink after the implementation of new (or further) information and technology equipment. By contrast, investment in production units as well as in property and buildings rises labour demand in manufacturing for all but one skill groups, whereas all estimated parameters for the service subsample turn out to be insignificant. Upgrading the technical level of the machinery (such that it becomes up-to-date) in the service sector influences the demand for the three skill types in the opposite (albeit expected) direction: the number of unskilled employees falls,

---

[10] Since we need two years of the IAB panel to generate our proxy for capital, the regression sample does not include 1993, although the IAB panel starts in 1993.

while the number of medium skilled and highly skilled employees rises. On the other hand, whether or not the technical level of machinery is up-to-date has no importance for the labour demand in manufacturing. For both subsamples, we find that the expected change in output influences the demand for all groups positively, with highly skilled employees being the least affected.

Tables 4 and 5 list the wage and output elasticities which have been calculated according to Equations (4)-(6).[11] For both sub-samples, we observe that the own-wage elasticity decreases (in absolute values) with skill, but the differences are statistically insignificant for manufacturing. By contrast, there is a huge variation in the estimated own wage elasticities for the service sector. While the demand for unskilled workers rises by 27% if their wages decrease by 10%, we find that the group of the highly skilled employees is not influenced by their own wage. For each sector, differences in the output elasticities between the three skill groups are statistically not significant.[12] Except for the medium skilled in the service sector, all elasticities are statistically not different from one, implying constant returns to scale.

Tables (6) and (7) report the impacts on the share of the respective skill groups, which have been calculated according to Equation (8). Since the numbers denote actual changes of the shares (rather than share elasticities), each row sums up to zero. It is evident, that the skill structure is largely driven by wages. The other variables, which exhibit significant impacts on the skill structure, do mainly have the expected sign. In both subgroups, investment in information and technology increases the share of the highly skilled and medium skilled employees at the expense of the unskilled. In the service sector (only), the same pattern is observed if the technical standard of the machinery becomes up-to-date. Rising the capital stock reduces the share of the unskilled in both subgroups. The expected effect of an anticipated change in output – i.e. a shift towards the share of the unskilled – occurs only in the service sector; though it is very small, if output is expected to

---

[11] The elasticities have been calculated at the actual sample means (of manufacturing respectively services) of N_i, w_i and *Y*. We have used the average residual of each employment equation as an estimate for the α_{ii}, which is necessary to compute the output elasticities. We will not discuss the (semi-)elasticities of the Z-variables, since their qualitative effect is already obvious from the estimated coefficients reported in Tables 2 and 3.

[12] A test on $\eta_{\text{Unskilled}-\text{Y}} = \eta_{\text{Medium Skilled}-\text{Y}}$ delivered for manufacturing the statistic $\chi^2(1) = 1.13$ *(* (*p-value:* 0.287) and for services the statistic $\chi^2(1) = 0.01$ (*p-value:* 0.932). A test on $\eta_{\text{Medium Skilled}-\text{Y}} = \eta_{\text{Highly Skilled}-\text{Y}}$ delivered for manufacturing the statistic $\chi^2(1) = 1.57$ (*p-value:* 0.21) and for services the statistic $\chi^2(1) = 0.12$ (*p-value:* 0.726).

double in the current year, for example, then the share of the unskilled increases by 0.4%.

7. Summary

A decrease in the demand for unskilled employees is a stylised fact in the economic literature; and explanations for this ongoing trend include the skill-biased technological change and the impact of a rising international trade. On the other hand, it is often argued that a less rigid wage structure could reduce unemployment of the unskilled. The empirical evidence on these hypothesis is mixed, often relying on incomplete data. This study has used the LIAB**,** a unique, linked employer-employee data-set for Germany, to investigate the determinants of the employment structure within a plant. Our analysis has used information of 880 West German plants between 1994 and 1997, which cover approximately 350,000 employees per year. Based on a Generalised Leontief cost function, we have estimated conditional labour demand functions for unskilled, medium skilled and highly skilled employees, where the regressions have been carried out separately for manufacturing and the service sector. The panel structure of the data has allowed to control for unobserved plant heterogeneity, a fundamental problem of many studies on this issue, which rely on cross-sectional data. We have also endogenised the wages, and the richness of our data-set provided us with a set of appropriate instruments.

We have identified a within-plant skill-biased technological change via the impact of capital, investment in information and technology and upgrading of the technical level of the machinery. This effect is stronger in the service sector, but even there it is relatively small. The degree of international trade, which we have measured as the percentage of exports in total sales, is also found to have only a weak impact on the skill structure within a plant. The major part of the skill structure is determined by the wages and – for the service sector – by output. A 5% reduction of the wages of the unskilled, for example, rises the demand for this group by 2.9% in manufacturing and by 13.4% in the service sector. This reassures claims that a less rigid wage structure could reduce unemployment of the unskilled. The own wage elasticities decrease with skill -although the differences are not significant for manufacturing- which confirms earlier results for Germany from FitzRoy & Funke (1998). We have found a labour hoarding effect – i.e. a shift towards the unskilled if output is expected to rise - only in the service sector, but again the effect of our proxy for labour hoarding is quite small.

To conclude, our results show that the major part of the skill structure is determined by wages, while we have found only minor impacts of a skill-biased technological change, of international trade and of short-run effects due to the business cycle.

REFERENCES

Abowd, J. & Kramarz, F. (1999): The Analysis of Labor Markets using Matched Employer-Employee Data. In: Ashenfelter, H. & Card, D. (eds.): Handbook of Labor Economics, Amsterdam, Vol. 3B, 2629 - 2710.

Acemoglu, D. (1998): Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality. The Quarterly Journal of Economics, 113, 1055 - 1089.

Bartel, A. & Lichtenberg, F. (1987): The Comparative Advantage of Educated Workers in Implementing New Technology. The Review of Economics and Statistics, 69:1, 1 - 11.

Bellmann, L., Düll, H., Kühl, J., Lahner, M. & Lehmann, U. (1996): Patterns of Enterprise Flexibility in Germany. Contribution to OECD's "Flexible Enterprise" Project conducted on the behalf of the Federal Ministry of Education, Science, Research and Technology. Institute for Employment Research of the Federal Employment Services. Nuremberg.

Bellmann, L. & Schank, T. (2000): Innovations, Wages and Labour Demand for Heterogeneous Labour: New Evidence from a Matched Employer-Employee Data-Set. IZA-Discussion Paper No. 112, Bonn.

Bender, S., Haas, A. & Klose, C. (2000): IAB Employment Subsample 1975 - 1995. IZA-Discussion Paper No. 117, Bonn.

Berman, E., Bound, L. & Griliches, Z. (1994): Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures. The Quarterly Journal of Economics, 109:2, 367 - 397.

Berman, E., Bound, L. & Machin, S. (1998): Implications of Skill-biased Technological Change: International Evidence. The Quarterly Journal of Economics, 113, 1245 - 1279.

Bound, J. & Johnson, G. (1992): Changes in the Structure of Wages in the 1980s: An Evaluation of Alternative Explanations. The American Economic Review, 82, 371 - 392.

Breshnahan, T., Brynjolfsson, E. & Hitt, L. (1999): Information Technology, Workplace Organization and the Demand for Skilled Labour: Firm-Level Evidence. NBER Working Paper 7136.

Caselli, F. (1999): Technological Revolutions. The American Economic Review, 89:1, 78 - 102.

Christensen, L., Jorgenson, D. & Lau, L. (1973): Transcendental Logarithmic Production Frontiers. Review of Economics and Statistics, 55, 28 - 45.

Diewert, W. (1971): An Application of the Shepard Duality Problem: A Generalised Leontief Production Function. Journal of Political Economy, 79, 481 - 507.

DiNardo, J. & Pischke, J.-S. (1997): The Returns to Computer Revisited: Have Pencils Changed the Wage Structure Too? The Quarterly Journal of Economics, 112:1, 291 - 303.

Entorf, H., Gollac, M. & Kramarz, F. (1999): New Technologies, Wages, and Worker Selection. Journal of Labor Economics, 17:3, 464 - 491.

Entorf, H. & Kramarz, F. (1997): Does Unmeasured Ability Explain the Higher Wages of New Technology Workers? European Economic Review, 41, 1489 - 1509.

Falk, M. & Seim, K. (1999): Workers' Skill Level and Information Technology: Evidence from German Service Firms. In: Bellmann, L. & Steiner, V. (eds.): Panelanalysen zu Lohnstruktur, Qualifikation und Beschäftigungsdynamik. Beiträge zur Arbeitsmarkt- und Berufsforschung 229, Nuremberg, 79 - 116.

Falk, M. & Koebel, B. (2000): A Dynamic Heterogenous Labour Demand Model for German Manufacturing. Applied Economics, 33:3, 339 - 348.

Fitzenberger (1999a): Wages and Employment Across Skill Groups. ZEW Economic Studies 6, Heidelberg.

Fitzenberger (1999b): International Trade and the Skill Structure of Wages and Employment in West Germany. Jahrbücher für Nationalökonomie und Statistik 219:1&2, 67 - 89.

FitzRoy, F. & Funke, M. (1998). Skills, Wages and Employment in East and West Germany. Regional Studies, 32:5, 459 - 467.

Freeman, R. (1995): Are Your Wages Set in Beijing? Journal of Economic Perspectives, 9:2, 15 - 32.

Hamermesh, D. (1993): Labor Demand. Princeton NJ.

Haskel, J. & Heden, Y. (1999): Computers and the Demand for Skilled Labour: Industry- and Establishment-Level Panel Evidence for the UK. The Economic Journal, 109, C68 - C79.

Kaiser, U. (2000): New Technologies and the Demand for Heterogenous Labour. Economics of Innovation and New Technology, 9:5, 465 - 486.

Kölling, A. (1998): Anpassungen auf dem Arbeitsmarkt. Eine Analyse der dynamischen Arbeitsnachfrage in der Bundesrepublik Deutschland. Beiträge zur Arbeitsmarkt- und Berufsforschung Vol. 217, Nuremberg.

Kölling, A. (2000): The IAB-Establishment Panel. Schmollers Jahrbuch, Journal of Applied Social Science Studies, 120:2, 291 - 300.

Koller, L. & Haas, A. (2001): Grundauszählung aus der IAB-Regionalstichprobe 1975-1997 nach persönlichen und betrieblichen Merkmalen, mimeo.

Krueger, A. (1993): How Computers Have Changed the Wage Structure: Evidence from Microdata, 1984 - 1989. The Quarterly Journal of Economics, 108:1, 33 - 60.

Leigh, D. & Gifford, K. (1999): Workplace Transformation and Worker Upskilling: The Perspective of Individual Workers. Industrial Relations, 38:2, 174 - 191.

Lindbeck, A. & Snower, D. (2000): Multitask Learning and the Reorganization of Work: From Tayloristic to Holistic Organization. Journal of Labour Economics, 18:3, 353 - 376.

Machin, S. & Van Reenen, J. (1998): Technology and Changes in Skill Structure: Evidence from Seven OECD Countries. The Quarterly Journal of Economics, 113, 1215 - 1244.

Parks, R. (1971): Price Responsiveness of Factor Utilisation in Swedish Manufacturing, 1870-1950, The Review of Economics and Statistics, 53(2), 129 - 139.

Robinson, P. & Manacorda, M. (1997): Qualifications and the Labour Market in Britain: 1984 - 94. Skill Biased Change in the Demand for Labour or Credentialism? Centre for Economic Performance, Discussion Paper No. 330, London.

Saint-Paul, G. (1996): Dual Labor Markets. Cambridge MA, London.

Schüssler, R., Spiess, K., Wendland, D. & Kukuk, M. (1999): Quantitative Projektion des Qualifikationsbedarfs bis 2010. Beiträge zur Arbeitsmarkt- und Berufsforschung Vol. 221, Nuremberg.

Schumpeter, J.A. (1942): Capitalism, Socialism and Democracy. New York.

Weidig, I., Hofer, P. & Wolff, H. (1999): Arbeitslandschaft 2010 nach Tätigkeiten und Tätigkeitsniveau. Beiträge zur Arbeitsmarkt- und Berufsforschung Vol. 227, Nuremberg.

Zeira, J. (1998): Workers, Machines, and Economic Growth. The Quarterly Journal of Economics, 113, 1091 - 1117.

Table 1: Descriptive statistics of regression sample

	Manufacturing		Services	
Variables	Mean	Std. Dev.	Mean	Std. Dev.
N_u	238	418	143	401
N_m	297	459	208	332
N_h	65	130	32	84
w_u	144	16.5	131	21.4
w_m	180	17.4	165	20.1
w_h	251	32.4	234	33.5
Y (mill. DM)	223	469	193	307
K (mill. DM)	23.9	64.2	27.5	77.4
Export Share	.254	.251	.042	.132
$\frac{\Delta Y^{Expected}}{Y} * 100$	.019	.104	.022	.107
Investment Dummies:				
IT	.679	.467	.703	.457
Production Units	.839	.369	.672	.470
Property, Buildings	.295	.456	.363	.481
Dummy: Technical Level of Machinery Up-to-Date	.211	.408	.243	.429

Note: The subscripts u, m and h denote unskilled, medium skilled and highly skilled respectively.

Table 2: Constrained seemingly unrelated regressions for different skill groups, manufacturing

	Unskilled	Medium skilled	Highly Skilled
$Y\sqrt{w_m / w_u}$	1.066***		
	(2.67)		
$Y\sqrt{w_h / w_u}$	-0.026		
	(-0.18)		
$Y\sqrt{w_u / w_m}$		1.066***	
		(2.67)	
$Y\sqrt{w_h / w_m}$		0.260**	
		(2.03)	
$Y\sqrt{w_u / w_h}$			-0.026
			(-0.18)
$Y\sqrt{w_m / w_h}$			0.260**
			(2.03)
Y^2	-0.0006***	-0.0007**	-0.0002***
	(-5.61)	(-2.34)	(-2.63)
C	0.070	0.526***	0.036
	(1.53)	(4.51)	(1.41)
Export Share	4.858	15.214*	2.777
	(1.45)	(1.78)	(1.48)
$\frac{\Delta Y^{Expected}}{Y} * 100$	0.003***	0.006***	0.001**
	(2.97)	(2.60)	(2.06)
Investment-Dummies			
IT	-0.200	1.311	0.289
	(-0.61)	(1.56)	(1.58)
Production Units	0.614**	1.605**	0.192
	(2.03)	(2.07)	(1.13)
Property, Buildings	1.947***	3.329**	0.563*
	(3.24)	(2.16)	(1.67)
Dummy: Technical Level of Machinery Up-to-Date	0.415	-0.869	0.014
	(0.94)	(-0.77)	(0.06)
χ^2	83.34***	70.63***	34.91***

Note: [a] Parameters constrained to be the same on: $Y\sqrt{w_m / w_u}$ and $Y\sqrt{w_u / w_m}$; $Y\sqrt{w_h / w_u}$ and $Y\sqrt{w_u / w_h}$; $Y\sqrt{w_h / w_m}$ and $Y\sqrt{w_m / w_h}$.

[b] Dependent Variables: N_i / Y where *i* denotes unskilled (*u*), medium skilled(m) or highly skilled (*h*).

[c] Estimation of Equation (9) , i.e. all variables are divided by *Y* and then the within-transformation is applied.

[d] 1955 observations. Time dummies additionally included. */ **/ *** denotes significance at the 10/ 5/ 1% level.

[e] Hausman-Test against specification without within-transformation: x^2 (33) = 105.90, p-value: 0.000.

Table 3: Constrained seemingly unrelated regressions for different skill groups, services

	Unskilled	Medium skilled	Highly skilled
$Y\sqrt{w_m / w_u}$	3.336*** (2.99)		
$Y\sqrt{w_h / w_u}$	0.178 (0.40)		
$Y\sqrt{w_u / w_m}$		3.336*** (2.99)	
$Y\sqrt{w_h / w_m}$		-0.577* (-1.77)	
$Y\sqrt{w_u / w_h}$			0.178 (0.40)
$Y\sqrt{w_m / w_h}$			-0.577* (-1.77)
Y^2	-0.0006 (-1.12)	-0.001*** (-2.72)	-0.0002 (-1.62)
C	0.122 (0.46)	0.750*** (3.70)	0.150*** (2.85)
Export Share	17.174 (0.89)	25.817* (1.76)	5.043 (1.32)
$\frac{\Delta Y^{Expected}}{Y} * 100$	0.026*** (6.66)	0.021*** (7.02)	0.002** (2.54)
Investment-Dummies			
IT	-5.889*** (-4.12)	-3.024*** (-2.79)	0.011 (0.04)
Production Units	-1.153 (-0.76)	0.267 (0.23)	0.398 (1.33)
Property, Buildings	1.620 (1.13)	1.015 (0.93)	0.276 (0.97)
Dummy: Technical Level of Machinery Up-to-Date	-3.299** (-2.07)	5.451*** (4.51)	1.581*** (5.03)
χ^2	91.85***	136.08***	58.66***

Note: [a] 515 observations.
[b] See Table 1, footnotes a-e.
[c] Hausman-Test against specification without within-transformation: x^2 (33) = 257.41, p-value: 0.000.

Table 4: Employment elasticities for different skill groups, manufacturing

	Unskilled	Medium skilled	highly skilled
Elasticities			
Wages:			
Unskilled	-.572**	.378***	-.035
Medium skilled	.588***	-.500***	.397**
Highly Skilled	-.017	.122**	-.362**
Output	1.262***	1.608***	1.091***
Capital	.003	.020***	.006
Export Share	.005	.013*	.011
$\frac{\Delta Y^{Expected}}{Y} * 100$	.00002***	.00004***	.00003**
Semi-Elasticities			
Investment Dummies:			
IT	-.0008	.004	.004
Production Units	.003**	.005**	.003
Property, Buildings	.008***	.011**	.009*
Dummy: Technical Level of Machinery: Up-to-Date	.002	-.003	.0002

*/ **/ *** denotes significance on the 10/ 5/ 1% level.

Table 5: Employment Elasticities for different skill groups, services

	Unskilled	Medium skilled	Highly skilled
Elasticities			
Wages:			
Unskilled	-2.684***	1.383***	.404
Medium skilled	2.524***	-1.064**	-1.467*
Highly Skilled	.160	-.319*	1.063
Output	1.873	1.749*	1.178
Capital	.023	.099***	.129***
Export Share	.005	.005*	.007
$\frac{\Delta Y^{Expected}}{Y} * 100$	.0004***	.0002***	.0001**
Semi-Elasticities			
Investment Dummies:			
IT	-.041***	-.014***	.0003
Production Units	-.008	.001	.012
Property, Buildings	.011	.005	.009
Dummy: Technical Level of Machinery: Up-to-Date	-.023**	.026***	.049***

*/ **/ *** denotes significance on the 10/ 5/ 1% level.

Table 6: Impacts on the employment share of different skill groups, manufacturing

	Unskilled	Medium skilled	Highly skilled
$\frac{\partial\left(N_i / \sum N_j\right)}{\partial X / X}$			
Wages:			
Unskilled	-.210**	.222***	-.012
Medium skilled	.209***	-.262***	.053*
Highly Skilled	.001	.040*	-.041**
Output	-.061	.096	-.035
Capital	-.007***	.008***	-.001***
Export Share	-.0017	.0016*	.0001
$\frac{\Delta Y^{Expected}}{Y} * 100$	-4.0e-06	4.0e-06*	-4.6e-08
$\frac{\partial\left(N_i / \sum N_j\right)}{\partial X}$			
Investment Dummies:			
IT	-.0012***	.0010***	.0002***
Production Units	-.00057	.00069*	-.00012*
Property, Buildings	-.0006	.0007	-.0001
Dummy: Technical Level of Machinery: Up-to-Date	.00098	-.0011**	.00010

Note: calculated with parameters reported in Table (1) and at sample means of the respective variables.

*/ **/ *** denotes significance on the 10/ 5/ 1% level.

Table 7: Impacts on the employment share of different skill groups, services

	Unskilled	Medium skilled	Highly skilled
$\frac{\partial\left(N_i / \sum N_j\right)}{\partial X / X}$			
Wages:			
Unskilled	-.922***	.870***	.052
Medium skilled	.853***	-.710**	-.143**
Highly Skilled	.069	-.160	.091
Output	.047	.0008	-.048
Capital	-.019*	.014	.005
Export Share	-.000088	-.000026	.00014
$\frac{\Delta Y^{Expected}}{Y} * 100$	.00004**	-.00003***	-.00001***
$\frac{\partial\left(N_i / \sum N_j\right)}{\partial X}$			
Investment Dummies:			
IT	-.0067***	.0047**	.0020***
Production Units	-.0025	.0014	0011
Property, Buildings	.0014	-.0015	-.0001
Dummies: Technical Level Of Machinery Up-to-Date	-.012***	.012***	.003***

Note: Calculated with parameters reported in Table (2), at sample means of the respective variables.

*/ **/ *** denotes significance on the 10/ 5/ 1% level.

Figure 1a: Actual and predicted wages of unskilled employees, 1993, individual-level data

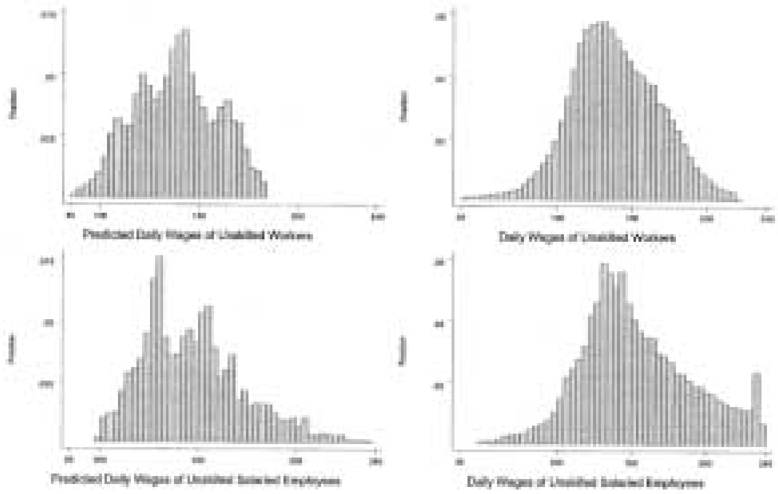


Figure 1b: Actual and predicted wages of skilled employees, 1993, individual-level data

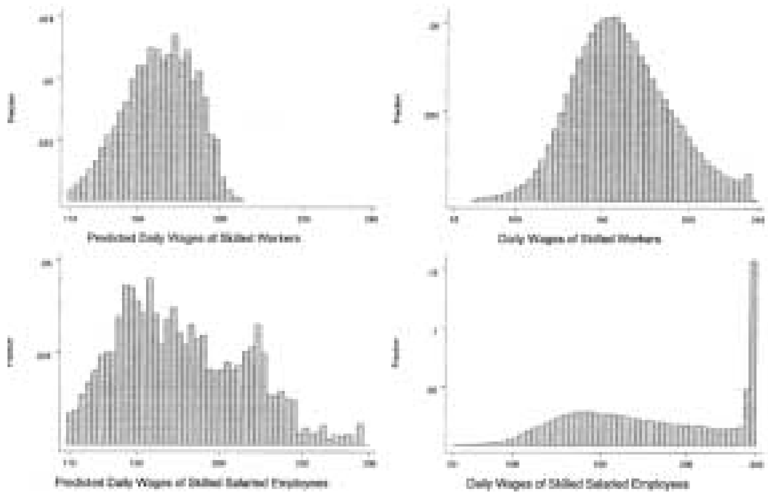
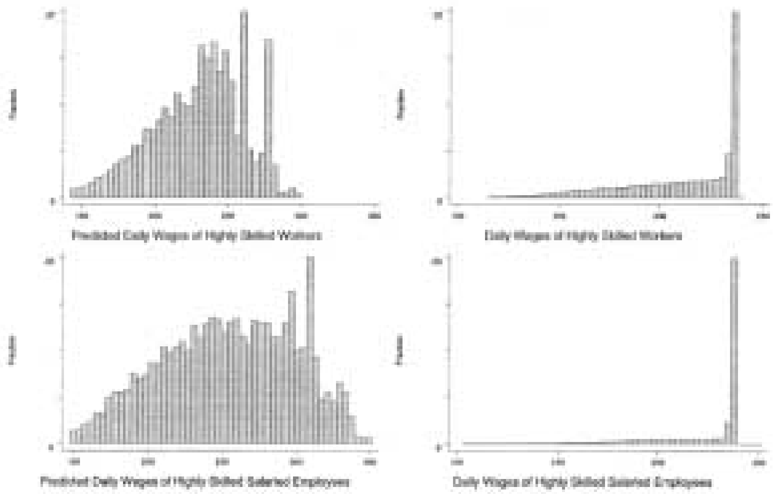


Figure 1c: Actual and predicted wages of highly skilled employees, 1993, individual-level data



In der Diskussionspapierreihe sind bisher erschienen:

Previously published Discussion Papers:

1	Addison J.T., Schnabel C., Wagner J.	Die *mitbestimmungsfreie Zone* aus ökonomischer Sicht	05/2000
2	Jahn E.J., Wagner T.	Substitution and Crowding-Out Effects of Active Labour Market Policy	06/2000
3	Wegener T.	Institutionelle Aspekte der Regionalisierung von Wirtschafts- und Strukturpolitik	09/2000
4	Kölling, A., Schnabel, C., Wagner, J.	Bremst das Schwerbehindertengesetz die Arbeitsplatzdynamik in Kleinbetrieben?	01/2001
5	Schnabel, C., Wagner, J.	Verbreitung und Bestimmungsgründe verschiedener Formen der Arbeitnehmerpartizipation in Industriebetrieben	06/2001
6	Jahn E.J., Wagner T.	Labour's Law?	06/2001
7	Niederalt, M., Schnabel, C. Kaiser, Chr.	Betriebliches Ausbildungsverhalten zwischen Kosten-Nutzen-Kalkül und gesellschaftlicher Verantwortung – Einflussfaktoren der Ausbildungsintensität von deutschen Betrieben	11/2001
8	Kohaut, S. Schnabel, C.	Tarifverträge – nein danke!? Einflussfaktoren der Tarifbindung west- und ostdeutscher Betriebe	12/2001
9	Jahn, E.J.	Brauchen wir einen allgemeinen Kündigungsschutz?	02/2002
10	Addison, J.T., Bellmann, L., Schnabel, C., Wagner, J.	German Works Councils Old and New: Incidence, Coverage and Determinants	05/2002
11	Jahn, E.J. Wagner, T.	A Hiring Subsidy for Long-Term Unemployment in a Search Model with PES and Random Search	05/2002
12	Goerke, L. Schnabel, C.	On Strike Insurance	06/2002
13	Kölling, A. Schnabel, C. Wagner, J.	Establishment Age and Wages: Evidence from German Linked Employer-Employee Data	06/2002
14	Kölling, A. Schank, T.	Skill-Biased Technological Change, International Trade and the Wage Structure	09/2002

An updated list of discussion papers can be found at the homepage:
http://www.arbeitsmarkt.wiso.uni-erlangen.de/

Eine aktualisierte Liste der Diskussionspapiere findet sich auf der Homepage:
http://www.arbeitsmarkt.wiso.uni-erlangen.de/