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Working Paper

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ZEW Discussion Papers, No. 97-28

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Non technical summary

In industrialised countries a debate has been raging on technological change and foreign competition having both increased the demand for skilled and reduced the demand for unskilled labour faster than changes in supply from the educational and the training system. A central feature of the German labour market over the past 30 years has been the declining demand for less educated workers and the rising demand for highly-educated workers. Using data from the German Federal Bureau of Labour, the labour input is broken down into three types: graduates, employees with vocational training and workers with no degree. In all industries, the percentage of workers without any degree paying social security contributions declined from 36.4 percent in 1977 to 22.5 percent in 1996. On the other hand, the percentage of workers with a formal, vocational certificate and those with a university or technical university degree rose from 60.0 to 69.7 percent and from 3.7 to 7.8 percent, respectively, during the same period. Capital deepening also seems to have increased the relative demand for educated workers. Related research has found physical capital to be more complementary (or less substitutive) with skilled workers. Therefore, empirical evidence on substitutability among different types of labour is essential. If it is easy for industries to substitute among inputs, then the effectiveness of alternative policies should be very different than if complementarity were found.

In order to avoid imposing a priori restrictions on the own- and cross- price elasticities (roughly stated a percentage change in quantity associated with one percent change in input price) and to leave determination of the degree of substitutability to the data, we adapt the so called flexible functional form for the estimation. The factor demand system is estimated for five industries with semi-annual time-series data from 1977 to 1994. An objective of this paper is to analyse whether capital accumulation and technological change lead to increased skill formation. In particular, we compare the demand shift away from unskilled labour caused by technological change in the non-traded goods with the shift in the traded goods sector. For these reasons, we include one traded goods industry: manufacturing, and four non-traded goods sectors: energy, water & mining;

construction; wholesale & retail trade; banking & insurance.

Our primary finding is that the high, own-price elasticity of unskilled labour and technological change account for the bulk of the shift in demand away from unskilled labour. First, in four out of five sectors, the results indicate that the demand for unskilled labour is more responsive to wage-rate changes than labour demands for skilled or highly-skilled. In manufacturing, the own-price elasticity of demand for unskilled labour is estimated at −1.41, whereas the own-price elasticity for medium skilled and graduates is −0.48 and −0.42, respectively. Second, the results for the five sectors indicate that different types of labour are more highly substitutable for each other than for material or capital. In the majority of cases, low- and medium-skilled labour are substitutes. While the degree of substitutability is high in manufacturing and banking & insurance, these two types of labour are less substitutable in construction and energy, water & mining. Third, biased technological progress away from unskilled labour was found in all industries except banking & insurance. In manufacturing during the 1977-94 period, estimated unskilled job losses are quite large: two thirds of actual average annual decline of −2.8 percent of unskilled employment can be attributed to the technological change. Expressed in absolute terms, this figure is 915,000 full-time equivalent unskilled workers. Furthermore, biased technological change towards high-skilled labour is largest in manufacturing. In absolute terms, job creation caused by technological changes amounts to 50,000 graduates. Finally, for manufacturing, the material-unskilled labour and capital-unskilled labour substitutability are additional factors leading to the negative shift in demand for unskilled labour.

In manufacturing, we would need an output growth rate of 3.0 percent to stabilise unskilled employment at unchanged factor prices. In construction and wholesale & retail trade, the corresponding figures are 1.8 and 2.4 percent, respectively. When these calculations are performed assuming 2 percent wage-growth for all skill groups, an output growth rate of about 3.7 percent is needed to stabilise unskilled employment in manufacturing. Since this high output-growth rate appears unrealistic, the main alternative policy is limiting wage growth. Our calculations suggests that in manufacturing and construction, for a given output growth rate of 2 percent, the wage-growth rate of unskilled labour should be limited to 50 percent of the medium and high-skilled wage growth rate. During phases of economic downturn, the limit should be 20 percent of the medium and high-skilled wage-growth rate.

Abstract

In this paper, four commonly provided explanations for the shift in labour demand for different skill groups are investigated: the substitutability of inputs; the own-price sensitivity for different types of labour; the effect of economic growth and the impact of technological change. In general, the shift of demand away from unskilled labour can be explained by the large own-price elasticity of unskilled labour and by biased technological change. During the period of 1977-1994, the rate of biased technological progress against unskilled workers seems to be as large in the traded as in the non-traded goods industries. Furthermore, in three out of five sectors considered, technological change is biased towards high-skilled labour.

Keywords: technological change, heterogeneous labour

JEL Classification: D 24, J 23, O33.

The Demand of Heterogeneous Labour in Germany

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The first author acknowledges the financial support of the Deutsche Forschungsgemeinschaft (German Science Foundation) in the programme „Industrial Economics and Input Markets“. We thank Herbert S. Buscher, Bernd Fitzenberger, Wolfgang Franz, Stefan Klotz, François Laisney, Georg Licht, Friedhelm Pfeiffer, Winfried Pohlmeier and Viktor Steiner for helpful comments. We thank Carsten Baumann and Semka Thorwaldsen for proof-reading.

1. Introduction

In nearly all Western industrialised countries, the employment of higher skilled workers has increased faster than that of the lower skilled workers. In Germany, the decline in the demand for low-skilled workers has been even steeper than in other industrialised countries (OECD 1996, Papaconstantinou 1997). Using aggregate (one digit level) data from the Federal Employment Service (IAB), we define three skill categories on the basis of the highest formal qualification received. These three categories are assigned according to the outcome of the German vocational training system: workers without any formal vocational certificate are categorised as lower skilled or unskilled; workers with a certificate from the dual vocational training system, who have attained either an university level entrance degree ("Abitur") or secondary school degree, are categorised as medium skilled or skilled; and finally, workers with a university or technical university degree are categorised as highly-skilled workers. Employment of workers without any formal, vocational degree declined at an average annual rate of 1.9% between 1977 and 1996 in West Germany (see Table 1a-1b in the Appendix). In manufacturing, where the share of unskilled workers is above average, unskilled employment declined at an average annual rate of 3.1% over the same period. The situation for unskilled labour became even more severe after 1991. During the 1991-95 period, the number of unskilled workers in West Germany dropped by an average annual rate of −3.5%, from 5.8 to 4.8 million; in manufacturing, the rate was −6.1%.[1] This is consistent with the view that firms are more likely to hoard skilled labour rather than unskilled labour during the recessions ("skill labour hoarding"). For the economy as a whole, on the other hand, employment of workers with a formal, vocational certificate, and those with a university or technical university degree rose by 1.4% and 4.6% per year, respectively. Several explanations for this finding can be found in the literature: skill-biased technological change; substitution effects between different inputs, in particularly capital-unskilled substitutability (see Machin et al. 1996, Berman et al. 1994); increasing international competition with low-wage countries (see Fitzenberger,

[1] Data refer to full and part-time workers.

1996, for Germany); and high minimum wages (Drèze and Sneessens 1994).

In this paper, we focus on four explanations for the shift in labour demand pertaining to the various skill groups: skill-biased technological change, capital-skill complementarity, price sensitivity of different types of labour demands, as well as the impact of production growth on the different inputs. Our main hypothesis is that both capital accumulation and technological change lead to increased skill formation. Flexible cost or profit functions provide the tools needed to understand the shift in demand away from unskilled labour and towards skilled labour. Flexible functional forms do not impose a priori restrictions on the elasticities of substitution and leave the determination of the degree of substitutability to the data. We use the quadratic demand system for modeling the input demand relationships in order to be able to impose the price concavity restriction without violating the flexibility properties of the cost function (see Diewert and Wales, 1987). The concavity of the cost function in prices is a property which is inherited from the assumed optimisation behaviour of production units and it ensures that the factor demand equations are negatively sloped. The factor demand system is estimated for five industries with semi-annual time-series data from 1977 to 1994. We further investigate if the biased technological change away from unskilled labour and towards high skilled labour is as large in the non-traded goods sectors as in the traded goods sector. Therefore this study includes not only the manufacturing sector but also the sectors energy, water & mining; construction; wholesale & retail trade; banking & insurance. Each sector is characterised by a different skill structure. While manufacturing, construction and, to a lesser extent, wholesale & retail trade employ abundant unskilled labour (between 27 to 31 percent of total employment), in the remaining sectors the share of unskilled labour is much lower (about 18 percent). Banking & insurance and energy, water & mining are characterised by a high proportion of graduates. In 1994, the share of graduates was 7.5 and 8.6 percent, respectively.

The results of several studies (Kugler et al. 1989, Bergström and Panas 1992, Machin et al. 1996, Betts 1997) provide empirical support for the link between demand for skills and new technology. In work closely related to ours, Betts (1997) and Bergström and Panas (1992) use a translog cost function approach to estimate substitution between white-collar workers, blue-collar workers and capital. According to their results, capital-skill complementarity cannot be rejected (Bergström and Panas 1992 for Sweden) and skill biased technological change is detected (Betts 1997 for Canada). As in most other econometric studies (see also e.g. Fitzroy and Funke 1995a and Kugler et al. 1989), the authors rely on the white/blue collar distinction to measure skills. Using data from 1960-86 for four manufacturing industries in Germany, Kugler et al. (1989) find the substitutability between equipment and blue-collar workers is greater than the substitutability between equipment and white-collar workers. They also find that technological change is biased against blue-collar workers and towards white-collar workers. Some weaknesses remain in their analysis: the assumption of constant returns to scale, the neglect of materials as input factor in the production process and the fact that some own-price elasticities are found to be positive. Including materials as production factors does not only permit to avoid a specification bias (see e.g. Basu and Fernald, 1997), but is also interesting as such. First, it allows to study the substitution pattern between unskilled workers and materials. Second, materials, as defined by the German statistical office, account for imports, services and subcontracting which indirectly reflects a sector's potential to delocalize parts of its production.

Using data from the 1977-92 period for 32 manufacturing industries in West Germany, Fitzroy and Funke (1995a) find that the capital elasticity of labour is greater for blue-collar than for white-collar. The results, however, are not robust due to the distinction white/blue-collar labour on the one hand and unskilled and skilled labour on the other hand. If skills are defined as skilled blue-collar and skilled white-collar workers, then capital-skill complementarity is rejected. For Germany, Entorf (1996) finds that on average non-neutral technological change causes an employment restructuring of -1.2 percent of unskilled manual workers and between -2.8 and -4.4 percent for the unskilled clerical staff. According to the author, the skill-hoarding argument is more important than technological change in explaining the falling demand for unskilled labour. Furthermore, the estimated elasticity of substitution between unskilled and skilled labour lies near 1.0 for blue-collar and between 0.5 to 1.5 for white-collar workers. However, Entorf (1996) does not include the capital stock (or its user cost) as an explanatory variable in the determination of input demands.

Recent studies for countries other than Germany exhibit results that are rather different from those obtained for Germany. For France, Sneessens and Shadman-Mehta (1995) find no support for the capital-skill complementarity hypothesis. In comparing four countries (Great Britain, the United States, Norway and Sweden), Machin et al. (1996) found that only Sweden has experienced sizeable skill-biased technological change. In fact, Sweden is the only country which has experienced stable conditions for both wage dispersion and unemployment, which suggest that the impact of technological change may well depend on labour market institutions.[2] In Germany, the role played by institutions appears central, particularly in the determination of wages. The evidence of a stable wage spread between unskilled and medium skilled, analysed by Fitzenberger (1996) could lead firms to correct this rigidity in their choice of technology. The resulting possible trade-off between earnings inequality and employment has recently been analysed by Steiner and Wagner (1997) for German manufacturing industries, who show that reductions in the relative earnings of unskilled workers would counter the decline in relative employment only in a limited extend. In this paper, we also consider non manufacturing sectors in assessing the impact of wages, output and technological change on heterogeneous labour skills.

The paper proceeds as follows: the next section delineates the econometric model of the factor demand. Section 3 describes the data. In Section 4, we present the empirical findings and some policy implications. Section 5 concludes.

2. The modelling framework

The most widely used method for estimating multifactor demands is to fit the factor demand equations derived from the cost function by Shephard's lemma. The translog and generalised Leontief functions have been applied extensively in estimating price elasticities, but do not often satisfy the concavity in prices.

[2] The declining role of trade unions in the UK and the US could lead to more flexibility, which compensates for the negative impact of technological change on the demand for unskilled labour.

We directly start with a functional form which can be constrained easily in this respect, the normalized quadratic cost function (see Diewert and Wales, 1987):

$$c(p_t, z_t; \alpha) = p_t' A_p + \frac{1}{2}(\theta' p_t)^{-1} p_t' A_{pp} p_t + p_t' A_{pz} z_t + \frac{1}{2}(\theta' p_t) z_t' A_{zz} z_t, \qquad (2.1)$$

where α denotes the technological parameters to be estimated. Given the available data, we define the vector of inputs as $x_t = (m_t, k_t, h_t, s_t, u_t)'$ and the corresponding prices as $p_t = (p_{mt}, p_{kt}, p_{ht}, p_{st}, p_{ut})'$, where the labour input h_t denotes highly skilled workers, s_t denotes the medium skilled and u_t the less skilled or unskilled group. In addition, m_t denotes material and k_t capital. The net capital stock is assumed to be variable. Other explanatory variables entering the cost function are the level of production y_t and a time trend t denoting the impact of technical change. These variables are regrouped in a vector $z_t = (y_t, t)$. The matrices of parameters to be estimated, $A_p = [\alpha_p]$, $A_{pp} = A'_{pp} = [\alpha_{pp}]$, $A_{pz} = [\alpha_{pz}]$ and $A_{zz} = [\alpha_{zz}]$, are of size 5×1, 5×5, 5×2 and 2×2, respectively. The term $\theta' p_t$ appearing in equation (2.1) is introduced to guarantee that the cost function is linearly homogeneous in prices. The vector θ, of size of 5×1, is chosen to be equal to x_T / c_T so that $\theta' p_t$ corresponds to a Laspeyres price index for total costs, normalized to one in the basis period for which $t = T$. As underlined by Diewert and Wales (1987), this arbitrary choice of θ does not affect the flexibility properties of c. In addition to linear price homogeneity, the price symmetry property is directly imposed on equation (2.1). Furthermore, for all parameters of the matrices A_{pp} and A_p to be identified, 5 additional equality constraints must be imposed on A_{pp}:

$$(1, \ldots, 1) A_{pp} = 0. \qquad (2.2)$$

Diewert and Wales show that the price concavity property of the cost function is equivalent to the negative semi-definiteness of A_{pp}. One advantage of retaining a quadratic cost function is that despite these restrictions, the form of equation (2.1) remains flexible, i.e. it can still provide a local approximation for an arbitrary cost function as well as its first and second order derivatives. Since the unconstrained estimated model does not necessarily satisfy the price concavity condition, the concavity restrictions are imposed using a Cholesky decomposition of matrix A_{pp} as described in Koebel (1997).

The system $x^*(p_t, z_t; \alpha)$ of input demands corresponding to the above cost function is obtained through application of Shephard's lemma:

$$\begin{aligned} x^*(p_t, z_t; \alpha) &= A_p + (\theta' p_t)^{-1} A_{pp} p_t - \frac{1}{2} (\theta' p_t)^{-2} \theta p_t' A_{pp} p_t \\ &\quad + A_{pz} z_t + \frac{1}{2} \theta (z_t' A_{zz} z_t). \end{aligned} \tag{2.3}$$

Furthermore, as in all other studies of labour demand, changes in labour supply are assumed to affect all sectors in a similar way.[3] In the empirical part of the paper, own-price and cross-price elasticities are estimated together with the output elasticity of input demand and impacts of non-neutral technological change. The price elasticities of input i are conventionally defined as:

$$\epsilon_{ij} = \frac{\partial i^*}{\partial p_j} \frac{p_j}{i^*}, \quad i, j = m, k, h, s, u.$$

Two inputs are substitutes if the cross price elasticity is significantly positive ($\epsilon_{ij} > 0$ for $i \neq j$). On the other hand, two inputs are complements if $\epsilon_{ij} < 0$. The Morishima elasticity of substitution between two variables, defined as

$$\sigma_{ij}^M = -\frac{\partial (i^*/j^*)}{\partial (p_i/p_j)} \frac{(p_i/p_j)}{(i^*/j^*)}, \quad i, j = m, k, h, s, u,$$

can be obtained from the own-price and cross price elasticities as:[4]

$$\sigma_{ij}^M = \epsilon_{ji} - \epsilon_{ii}.$$

The output elasticities of input demand are given by:

$$\epsilon_{iy} = \frac{\partial i^*}{\partial y} \frac{y_t}{i^*}, \quad i = m, k, h, s, u.$$

These output elasticities are positive for normal goods. If ϵ_{iy} is negative, the input x_i is said to be inferior. The inclusion of a time trend in the factor demand equations allows consideration of the impact of technical change on input demand i^*:

$$\epsilon_{it} = \frac{\partial i^*}{\partial t} \frac{1}{i}, \quad i = m, k, h, u, s.$$

[3] Since we have no information on qualification of workers within different age classes, this issue is not considered here.

[4] See Blackorby and Russell (1989) for further discussion on the signification and interpretation of Morishima and other kind of elasticities.

The technology is said to be biased towards factor i if $\epsilon_{it} > 0$ and biased against factor i if $\epsilon_{it} < 0$. The technology is input i neutral if $\epsilon_{it} = 0$.

3. The data

The econometric analysis is carried out for five aggregate sectors of economic activity in West Germany: manufacturing; energy, water & mining; construction; wholesale & retail trade; banking & insurance. In 1994, approximately 60 percent of all workers paying social security contributions were employed in these five sectors.

All data are available semi-annually from 1977 to 1994. The sources, however, are different. The gross value of production, material and the net capital stock are obtained from national accounts. The material deflator is calculated by dividing material expenditures by material at constant prices. The user costs of capital are computed using the investment price $p_{\triangle kt}$, the nominal interest rate r_t and the depreciation rate δ_t :

$$p_{kt} = (1 + r_t)\, p_{\triangle kt} - (1 - \delta_t)\, p_{\triangle kt+1}.$$

The depreciation rate is calculated as $\delta_t = 1-(k_t-\Delta k_t)/k_{t-1}$, where Δk_t denotes gross investment at constant prices. Semi-annual interest rates are drawn from the Deutsche Bundesbank (long-term interest rate for public sector bonds).

Employment data are provided by the German Federal Employment Office (Institut für Arbeitsmarkt- und Berufsforschung). They contain information on employment by skill category and by industry for all employees paying social security contributions. For the 1987-94, period the employment variable is available at quarterly frequency. Semi-annual data are simple averages of the quarterly figures. Skill group 1 (also called high skilled) is made up of workers with a university or polytechnical degree, group 2 (medium skilled) of those having completed vocational training and the remaining group 3 (unskilled) of individuals without formal qualifications, also including apprentices. Employment is transformed to full-time equivalent employees.[5] For approximately 5% of the employees, the occupational degree is not available (see Table 1a and 1b in the Appendix). Therefore, 2/3 of these workers were added to the unskilled group and 1/3 to the skilled group. Finally, for the 1977-87 period, annual data for each skill group are interpolated according to the semi-annual pattern of the total employment series.

Data for monthly average gross earnings per employee are taken from the Lohn- und Gehaltsstatistik. According to the level of formal qualification and the difficulty of employment tasks, three groups for blue-collar and five groups for white-collar workers are distinguished.[6] Wage data are constructed in multiple steps. In the first step the Beschäftigtenstatistik is matched with the Lohn- und Gehaltsstatistik. "Unskilled labour wages" refers to category III for the blue-collar group and the category V for the white-collar group. Wage data in both categories contain employees without any formal degree. "Skilled labour wages" refers to category I (vocational training and foreman) for the blue-collar group and categories III and IV for the white-collar group. The highest skill group refers to "professional and managerial workers" (category II white-collar). The data source also contains the employment structure for the various types of employees. In the second step, the gross wage for each skill group is calculated as a weighted average of the different groups as well as for men and woman (weighted by employment shares). In the third step, the gross wages are transformed to labour costs by adding the employers' contribution to social security. We then check the sum of the three different types of labour costs against total labour costs obtained from the national accounts. The labour costs calculated at the sectorial level cover approximately 95 percent of labour costs reported in the national accounts. Finally, the wages are transformed to wage indices normalized to the midpoint value (1985:2). These transformations generate p_{ht}, p_{st} and p_{ut}.

[5] Employment is measured in full-time equivalents. Part-time workers are weighted with one half, trainees by one third. For the different skill groups, data on working hours are not available.

[6] Data for the category I of the group white-collar labour (managers) is not available. The average gross earnings include all amounts regularly paid to the employee (fixed or freely arranged wages, additional regular and non-regular allowances and bonuses for efficiency, social welfare, etc.). The wage refers to full time workers.

The quantities of capital stock, output, and material are annualised and all prices are normalized to one for 1985:2. Finally, all series are seasonally adjusted.

Figure 1 (see Appendix) shows the evolution of employment for different skill groups and the net capital stock at constant prices. As can be seen from this figure, for all sectors the quantities of graduates demanded grew at a faster rate than all other inputs. Concerning the graduates, the magnitude of the shift was largest in banking & insurance, where the number of graduates jumped by 250 percent over the 1977-1994 period. In banking & insurance, it is likely that the rapid growth of computer technology has made graduates increasingly important. The number of graduates employed in manufacturing grew by 80 percent. The downward trend for unskilled labour was most pronounced in manufacturing and in energy, water & mining. While in wholesale & retail trade and in banking & insurance, unskilled labour declined by 16 and 20 percent, unskilled employment shrank even more (by 40 percent) in the manufacturing sector. Furthermore, unskilled labour appears more cyclically sensitive than skilled employment. During the second oil-price induced recession and after 1991, we observe an accelerating deterioration in unskilled employment. Looking at the capital stock, it can be seen that capital accumulation is the most important in banking & insurance. Here, the net capital stock nearly doubled between 1977 and 1994. This is consistent with the high investments in office computers during the last years in this sector.

The decreasing demand for less qualified labour is matched by relatively stable wages across different types of labour. Table 2 of the Appendix present the manufacturing-wide price index for each labour category. Since the relative prices of different types of labour and both material and capital across sectors are rather similar, only manufacturing input prices are reported. During the 1977-1994 period, labour costs increased by 120 percent for graduates and 110 percent for unskilled and medium-skilled labour.[7] In contrast, the material deflator increased by only 40 percent and the user costs of capital by 90 percent. During the 1977-80 period, the material price grew at a faster rate than other factors, which reflects the impact of the second oil shock.

Expressed in relative prices, the wages of different types of labour rose 50 to 65 percent faster than the material price during the 1977-1994 period. Furthermore, high-skilled wages rose 15 percent faster in relation to the user costs of capital, whereas unskilled wages rose 8 percent more. Since relative prices between different types of labour and other input prices are rather similar, it is not likely that the substitution pattern could explain a large part of the changes in the labour composition.

4. Empirical results

The system of five input demands (2.3) divided by the output level, to which a residual vector ν_t is added, is used for estimating the parameter vector α :

$$x_t/y_t = x^*\left(p_t, y_t, t; \alpha\right)/y_t + \nu_t. \tag{4.1}$$

For the 1977:2-1994:2 period, the factor demand equations for three types of labour, for material and for capital are estimated with the iterative *SUR* method, assuming that the vector ν_t has zero mean and constant variance. In the first step, the concavity unconstrained model is estimated. Since concavity violations are detected in many cases, in the second stage the constrained parameters of the matrix A_{pp}, satisfying concavity, are estimated using the minimum distance procedure as described in Koebel (1997). This violation in the unrestricted model is frequently observed in empirical analyses using heterogeneous labour skills (see

[7] A closer look at the sectoral relative wages fails to suggest a clear pattern. In banking & insurance, the wages of high-skilled labour grew at a slightly faster rate than semi-skilled or unskilled labour. The opposite holds for wholesale & retail trade, where high and medium-skilled wages grew less rapidly than unskilled wages. In the two remaining sectors, skilled wages rose slightly more than unskilled or high-skilled wages. However, in general, relative wages were stable during the period. Finally, we check the evolution of relative wages against IABS-data (Institut für Arbeitsmarkt und Berufsforschung-Stichprobe), which have kindly been provided by Bernd Fitzenberger. In three out of five sectors, except energy, water & mining and construction, the evolution of relative wages drawn from the two sources is similar.

for example Kugler et al. 1989) and could be caused by the high collinearity of input prices.

The complete model consists of 28 free parameters which have to be estimated on the basis of 5 × 36 observations. The fit of the model is rather good, especially for the three labour demand equations; for the material equation the fit is somewhat lower than for the three labour demand and capital demand equations. Significant first order autocorrelation was detected in several equations.[8]

4.1 The impact of output, technological change and prices on input demands

Table 3 presents the impacts of technological change and the output elasticities of input demand. All elasticities are calculated at the midpoint value in 1985:2. These elasticities are, in the majority of cases, significant at the one percent level. The main result is that a large part of the shifting demand towards graduates and away from unskilled labour is explained by the time trend. If one maintains the assumption that technological change effects can be captured by the trended residual, then technological change is, in general, non-neutral and skill-biased, especially against low-skilled workers and in favour of high-skilled workers. In manufacturing, the estimated −1.9 percent biased technological change away from unskilled labour is quite large.[9] This means that more than two thirds (68 percent) of the average annual decline of 2.8 percent in unskilled employment over the period 1977-1984 can be attributed to technological change. When expressed in absolute terms, this figure amounts to 915,000 full-time equivalent unskilled workers. All other industries (except for banking & insurance) also exhibit technological bias against unskilled labour. For the total 1977-94, period estimated unskilled job losses due to technological change are 280,000 in wholesale & retail trade, 110,000 in construction, and 28,000 in energy, water and mining. It is interesting to note that the bias against unskilled labour, measured in relative terms, seems to be as large in trade-affected manufacturing as in non-trade-affected industries (see Table 3).

[8] Detailed results are available upon request.

[9] We follow the common practice assuming that technological change put forward failing everything else.

Table 3:[a] Impact of technological change and output elasticities (at midpoint)

	traded goods	non-traded goods sectors			
	manufacturing	energy, water & mining	construction	wholesale & retail trade	banking & insurance
ϵ_{mt}	0.002 (4.7)	0.003 (7.6)	0.001 (1.7)	-0.003 (-3.0)	0.006 (3.3)
ϵ_{kt}	0.001 (1.0)	0.011 (21.5)	-0.006 (-4.5)	0.006 (2.3)	0.015 (12.4)
ϵ_{ht}	0.012 (9.5)	0.013 (32.8)	0.003 (1.8)	-0.003 (-0.8)	0.009 (4.6)
ϵ_{st}	-0.001 (-1.0)	-0.001 (-1.2)	-0.003 (-3.6)	-0.009 (-5.5)	0.008 (6.5)
ϵ_{ut}	-0.019 (-17.7)	-0.013 (-13.2)	-0.012 (-7.7)	-0.022 (-8.0)	0.002 (0.7)
ϵ_{my}	1.02 (21.5)	0.57 (12.3)	1.74 (19.7)	1.31 (16.7)	1.06 (13.5)
ϵ_{ky}	-0.21 (-4.4)	0.10 (1.5)	0.11 (0.7)	-0.62 (-2.4)	-0.02 (-1.8)
ϵ_{hy}	0.59 (7.1)	-0.20 (-3.9)	0.61 (4.0)	1.05 (3.4)	0.91 (11.3)
ϵ_{sy}	0.56 (8.7)	0.09 (1.0)	0.43 (3.7)	0.63 (3.8)	-0.01 (-0.2)
ϵ_{uy}	0.64 (6.9)	-0.50 (-3.5)	0.65 (3.2)	0.91 (3.4)	-0.27 (-2.8)

[a] t-values in parentheses.

In regard the bias towards educated labour due to technological change, remarkable differences can be found across industries. In manufacturing, the bias of technological change towards high-skilled workers is estimated at 1.2 percent. This means that 33 percent of the average annual increase of 3.6 percent can be explained by technological change. The results for energy, water & mining are similar. In contrast, for the remaining sectors, technological change cannot explain the bulk of the shift in demand towards graduates. In banking & insurance, the bias towards high-skilled labour was 0.9 percent per year. Thus only a small proportion of the average annual increase of 7.4 percent can be attributed to technological change. Thus, we conclude that biased technological change towards high-skilled labour is largest in manufacturing. In this sector, job creation caused by technological changes amounts to 50,000 graduates in absolute terms.

The results for medium-skilled labour are mixed. Whereas in wholesale & retail trade and construction, technological change is biased against medium-skilled labour, in banking & insurance, technological change is biased towards medium-skilled labour. In energy, water & mining, wholesale & retail trade, banking & insurance, technological change is biased towards capital.

The calculations for the elasticity of input with respect to output are also given in Table 3. We find that the number of graduates employed rises as output increases. This is especially pronounced in banking & insurance and wholesale & retail trade. In manufacturing, construction and wholesale & retail trade, unskilled employment is quite responsive to output variation. Some output elasticities of input demand are negative, especially for unskilled employment and capital. For energy, water & mining growth in production seems to be possible with less labour input. In banking & insurance, unskilled labour is also inferior.

Table 4 presents own- and cross-price elasticities derived from the estimated parameters. They are evaluated at the midpoint values, the second half of 1985. The t-statistics are given in parentheses. Almost half of the own- and cross- price elasticities are statistically significant at a five percent level. As can be seen, the magnitude of price elasticities varies widely in magnitude (0 to -1.4 for the own-price elasticities and -0.46 to 1.2 for the cross-price elasticities). Considering own-price elasticities first, several general comments are in order. First, the demand for unskilled labour is more responsive to wage rate changes than the demand for medium-skilled labour. Second, the own-price elasticity of unskilled labour is also larger in absolute value than the own-price elasticity for graduates. The highest own-price elasticity is found in manufacturing ($\epsilon_{uu} = -1.41$). That means a one percent decrease in the wage rate of unskilled labour would increase the employment of unskilled labour workers by approximately 27,000, given an initial level of 2 million in 1994. In contrast, medium- and high-skilled labour is much less responsive to wages; own-price elasticities are -0.48 for medium-skilled labour and -0.42 for graduates. Using a panel of manufacturing industries, Fitzroy and Funke (1995b) find a wage elasticity for unskilled labour of -1.46. Sneessens and Shadman-Mehta (1995) also discover that the negative effects of wage increases would be sharper for unskilled labour than for skilled labour.

In the remaining sectors, unskilled labour is also more price responsive than medium-skilled labour. The own-price elasticity for the unskilled ranges from -0.25 in energy, water & mining to -1.20 in banking & insurance. The own-price elasticities of capital and material are negative but insignificant in nearly all cases. This means that rising material or capital prices reduce the input demand by only a small proportion.

Table 4 also presents cross-price elasticities. Cross-price effects for both material and capital and the three types of labour are generally quite small. In contrast, elasticities between different types of labour suggest significantly greater substitutability. In nearly all cases, different types of labour are substitutes. Medium-skilled labour and workers with no degree show significant substitutability in all sectors, except wholesale & retail trade. The values of cross-price elasticity of unskilled with respect to medium-skilled labour price, ϵ_{us}, are 1.06 in manufacturing, 0.79 in banking & insurance, 0.42 in construction and 0.22 in energy, water & mining. In contrast, the cross price elasticity of medium-skilled labour with respect to p_h is negative when significant i.e. for energy, water & mining and for construction.

As for capital-skill complementarity, which states that physical capital is a complement for skilled labour, but a substitute for unskilled labour, we find only little evidence for this assumption. In manufacturing, the cross-price elasticity of unskilled labour with respect to the price of capital is insignificant. Since the substitution of capital for unskilled labour is low, capital subsidies or taxes will have no effect on demand for the unskilled. Out of the remaining sectors, capital and unskilled labour are substitutes only in construction ($\epsilon_{uk} = 0.21$). The finding of a low ϵ_{uk} is surprising in light of empirical studies on homogeneous labour (see Hamermesh 1993).

Besides, in three out of five sectors capital is a substitute for graduates; the estimates of ϵ_{hk} range between 0.22 in construction and some 0.10 in both wholesale & retail trade and banking & insurance. In three out of five sectors, unskilled-capital substitutability does not exceed the graduates-capital substitutability. Since capital does not appear more complementary (or less substitutive) to skilled workers, capital-skill complementarity is rejected. One explanation for the rejection of the capital-skill complementarity could be the assumption that capital is variable. In effect, the model is based on perfect expectations and instantaneous adjustment to long-run equilibrium. When lags in capital adjustments or costs of adjustment exist, this assumption may prove troublesome. In partial equilibrium models treating capital as quasi-fixed, the variable cost function for

Table 4:[a] Price elasticities (at midpoint value)

	traded goods	non-traded goods sector			
	manufacturing	energy, water & mining	construction	wholesale & retail trade	banking & insurance
ϵ_{mm}	-0.006 (-0.5)	-0.038 (-7.3)	-0.107 (-2.0)	-0.001 (-0.3)	-0.012 (-0.4)
ϵ_{mk}	-0.004 (-0.6)	0.022 (6.9)	0.015 (0.9)	0.001 (0.5)	0.005 (0.8)
ϵ_{mh}	-0.004 (-2.3)	0.008(4.1)	0.056 (1.3)	-0.004 (-1.3)	0.003 (0.7)
ϵ_{ms}	0.023 (0.3)	0.014 (6.4)	0.019 (0.6)	0.012 (0.4)	-0.010 (-0.5)
ϵ_{mu}	0.012 (2.0)	-0.001 (-0.1)	0.067 (2.0)	-0.037 (-0.2)	0.014 (0.8)
ϵ_{km}	-0.041 (-0.6)	0.094 (7.1)	0.178 (0.9)	0.043 (0.5)	0.021 (0.8)
ϵ_{kk}	-0.027 (-0.5)	-0.095 (-8.0)	-0.313 (-2.5)	-0.029 (-0.7)	-0.015 (-1.8)
ϵ_{kh}	-0.014 (-1.2)	0.006 (0.9)	0.054 (2.0)	0.012 (2.1)	0.021 (6.6)
ϵ_{ks}	0.013 (0.3)	0.009 (1.3)	-0.375 (-2.1)	-0.037 (-0.7)	-0.021 (-1.1)
ϵ_{ku}	0.070 (1.8)	-0.008 (-2.2)	0.455 (2.4)	0.011 (0.4)	-0.005 (-0.3)
ϵ_{hm}	-0.161 (-2.3)	0.047 (4.1)	0.257 (1.3)	-0.159 (-1.3)	0.070 (0.7)
ϵ_{hk}	-0.058 (-1.2)	0.010 (0.9)	0.221 (2.0)	0.108 (2.1)	0.100 (6.6)
ϵ_{hh}	-0.418 (-1.9)	-0.170 (-3.1)	-0.697 (-6.1)	-0.126 (-0.3)	-1.226 (-3.2)
ϵ_{hs}	0.166 (0.5)	-0.073 (-2.7)	-0.458 (-2.2)	0.062 (0.2)	-0.063 (-0.1)
ϵ_{hu}	0.472 (1.1)	0.186 (3.4)	0.677 (3.0)	0.115 (0.8)	1.196 (4.6)
ϵ_{sm}	0.010 (0.3)	0.115 (6.4)	0.038 (0.6)	0.022 (0.4)	-0.021 (-0.5)
ϵ_{sk}	0.006 (0.3)	0.017 (1.3)	-0.067 (-2.1)	-0.015 (-0.7)	-0.010 (-1.1)
ϵ_{sh}	0.020 (0.5)	-0.009 (-2.7)	-0.021 (-2.2)	0.028 (0.1)	-0.006 (-0.1)
ϵ_{ss}	-0.481 (-4.5)	-0.174 (-8.4)	-0.118 (-1.4)	-0.022 (-3.6)	-0.206 (-1.8)
ϵ_{su}	0.444 (3.6)	0.051 (2.5)	0.167 (1.9)	0.012 (0.3)	0.237 (2.6)
ϵ_{um}	0.138 (2.1)	-0.005 (-0.2)	0.343 (2.0)	-0.021 (0.2)	0.097 (0.8)
ϵ_{uk}	0.078 (1.8)	-0.067 (-2.2)	0.207 (2.3)	0.014 (0.4)	-0.008 (-0.3)
ϵ_{uh}	0.128 (1.1)	0.107 (3.4)	0.076 (3.0)	0.017 (0.8)	0.366 (4.6)
ϵ_{us}	1.062 (3.6)	0.222 (2.5)	0.422 (2.0)	0.042 (0.3)	0.789 (2.6)
ϵ_{uu}	-1.409 (-3.7)	-0.256 (-2.5)	-1.049 (-4.3)	-0.052 (-0.5)	-1.244 (-4.0)

[a] t-values in parentheses.

material and labor is specified as $c^{pe}(p_{mt}, p_{ut}, p_{st}, p_{ht}, k_t, y_t, t; \alpha)$ where the superscript pe denotes partial equilibrium. We estimated a partial equilibrium model based on c^{pe}, and the result exhibited some evidence for capital-skill complementarity, especially in banking & insurance. However, the required convexity condition of the cost function with respect to capital was frequently violated by the unconstrained estimation.[10, 11]

Furthermore, most of the elasticities between material and different types of labour are close to zero. An interesting exception is the substitutability between unskilled labour and material in manufacturing and construction. Material can be substituted for unskilled labour, a fact which could indirectly reflect the impact of foreign competition on the skill structure of the labour force. Indeed, if firms respond to increasing import competition by moving low-skill, labour-intensive activities abroad, then it is likely that material and unskilled labour act as substitutes. In other words, semi-finished goods (made using foreign labour) are substituted for domestic, unskilled labour. For U.S. manufacturing industries, Revenga (1992) finds evidence that cheaper materials affect employment. In construction, the substitutability between material and unskilled labour could be explained by the fact that unskilled workers are substituted by contract workers from Southern and Eastern Europe; subcontracting with a foreign firm is a common type of outsourcing practice in this sector. Of course such statements are speculative since the aggregation level of inputs does not allow to distinguish imports from the remaining material.

4.2 Further comparative statics and policy implications

To shed further light on the implications of the estimates, we also conduct some calculations in which different scenarios for output growth and wage growth are considered. For this purpose, we use the first order Taylor approximation to derive the amount of growth necessary to keep the level of unskilled labour

[10] Besides, in three out of five sectors the derivative of the variable cost function with respect to capital was positive.

[11] In partial equilibrium frameworks, capital-skill complementarity is characterised by $\partial h^{pe}/\partial k_t \geq 0$ (e.g. Fitzroy and Funke, 1995a). Strictly speaking, this is not comparable with $\epsilon_{hk} = (\partial h^*/\partial p_{kt})(p_{kt}/h_t) \leq 0$. Indeed, $\partial h^*/\partial p_{kt} = (\partial h^{pe}/\partial k_t)(\partial k^*/\partial p_{kt})$, a term which can be insignificant while $\partial h^{pe}/\partial k_t$ is significantly positive if $\partial k^*/\partial p_{kt}$ is not significant.

demand unchanged:

$$\begin{aligned}
\Delta u_t &= \sum_j \frac{\partial u^*}{\partial p_{jt}} \Delta p_{jt} + \frac{\partial u^*}{\partial y_t} \Delta y_t + \frac{\partial u^*}{\partial t} = 0 \\
\Leftrightarrow \Delta y_t &= -\frac{\left(\sum_j \frac{\partial u^*}{\partial p_{jt}} \Delta p_{jt}\right) + \partial u^* / \partial t}{\partial u^* / \partial y_t} \\
\Leftrightarrow \frac{\Delta y_t}{y_t} &= -\sum_j \frac{\epsilon_{uj}}{\epsilon_{uy}} \frac{\Delta p_{jt}}{p_{jt}} - \frac{\epsilon_{ut}}{\epsilon_{uy}}. \qquad (4.2)
\end{aligned}$$

Similarly, we can calculate the rate of wage growth which would be required to maintain the level of unskilled labour; by solving $\Delta u_t = 0$ in $\Delta p_{ut}/p_{ut}$ it follows that

$$\frac{\Delta p_{ut}}{p_{ut}} = -\sum_{j=m,k,h,s} \frac{\epsilon_{uj}}{\epsilon_{uu}} \frac{\Delta p_{jt}}{p_{jt}} - \frac{\epsilon_{uy}}{\epsilon_{uu}} \frac{\Delta y_t}{y_t} - \frac{\epsilon_{ut}}{\epsilon_{uu}}. \qquad (4.3)$$

Five scenarios are considered. First, we calculate how much output must grow in order to stabilise unskilled employment at constant factor prices (scenario A): $\Delta p_{jt}/p_{jt} = 0$ in equation (4.2). As can be seen, the required growth rate of output is then equal to the ratio of the technological change elasticity of unskilled labour to the output elasticity of unskilled labour. However, the assumption of zero wage growth, underlying the above result, seems implausible. We extend the preceding comparative static computation in order to account for wage growth and calculate the output growth necessary for stabilising the employment for unskilled labour for a scenario B in which nominal wage growth for all skill groups amounts to 2 percent and no other price changes. In Scenarios C, D and E we ask which wage growth for the unskilled would maintain the level of unskilled labour while medium and highly-skilled wages grew at a 2 percent rate and prices of the two other inputs, materials and capital remain unchanged (which seems rather realistic, see Table 2 in the Appendix). In each scenario C, D and E, we assume respectively an output growth rate $\Delta y_t/y_t$ of 0, 2.0 and 2.5 percent. The results of these simulations are reported in Table 5.

As can be seen in Table 5, in manufacturing, a permanent annual output growth rate of 3.0 percent would stabilise unskilled employment assuming zero wage growth. In construction and wholesale & retail trade, the corresponding figures are 1.8 and 2.4 percent. In the two remaining sectors, unskilled labour would not benefit from output growth (because unskilled labour is inferior in these two sectors; however, the share of unskilled labour is rather small, 19 percent in 1994). Of course, a zero wage growth rate seems unrealistic. An even higher output growth is necessary to stabilise unskilled employment if one assumes that all wages grow at 2 percent (scenario B). For manufacturing, an output growth of 3.7 percent is needed to stop the decline in unskilled employment. Note that the elasticities are evaluated for the second half of the year 1985.

Table 5: Policy scenarios: Stabilizing unskilled employment by output growth (A,B) or limiting wage growth (C,D,E), percent change

	output growth		nominal wage growth		
	A	B	C	D	E
Manufacturing	3.0	3.7	0.3	1.2	1.5
Energy, Water & Mining	-2.6	-2.3	-2.5	*	*
Construction	1.8	3.5	-0.2	1.1	1.4
Wholesale & Retail Trade	2.4	2.4	*	*	*
Banking & Insurance	0.8	0.0	2.0	1.6	1.5

* This impact was not computed for this sector because the own price elasticity was not significantly different from zero or unskilled labor was inferior.

Since this output growth is rather unrealistic, we calculate how much the wage growth rate for unskilled labour should be to stabilise unskilled employment for different scenarios for output growth. In manufacturing, the nominal wage growth rate of unskilled labour should be limited to 0.3 percent per year for a constant output level (Scenario C). With 2% output growth and 2% nominal growth for medium and highly-skilled labour, nominal unskilled wage growth limited to 1.2% would stabilise the demand for unskilled labour. Thus, our calculations suggest that in manufacturing, for a given output growth rate of 2 percent and a given medium and highly-skilled nominal wage growth rate, the wage growth rate of unskilled labour should be limited to 60 percent of the wage growth rate for higher qualifications. During phases of economic downturns (with

$\Delta y_t / y_t = 0$) this limit should be 15 percent.

5. Conclusion

The econometric study focuses on four determinants of labour demand for different skills: own wage elasticity, substitution possibilities, impact of output growth and of biased technological change. First, the demand for unskilled labour is more price elastic than the demand for medium-skilled labour. This is one explanation for demand shifts away from unskilled labour. Particularly in manufacturing, unskilled labour is considerably more responsive to wage-rate changes ($\epsilon_{uu} = -1.41$). A one percent increase in the skill group wages would reduce unskilled employment by 1.4 percent, whereas skilled and high-skilled employment would only be reduced by 0.4 percent. Second, our results do not confirm a common finding that unskilled labour is more easily substituted for capital than skilled labour. Only in manufacturing and construction is there some evidence of capital-unskilled substitutability, although in manufacturing the degree of substitutability is low ($\epsilon_{uk} = 0.07$) and insignificant. Third, the demand shift away from unskilled labour could be explained by the substitutability relationship between material and unskilled workers. For manufacturing and construction, we find that materials are substitute for unskilled labour ($\epsilon_{um} = 0.14$ and 0.34, respectively). In manufacturing, despite some temporary falls in the input prices of capital and material both unskilled labour-capital substitutability and unskilled labour-material substitutability only explain a very small part of the shift in demand away from low-skilled employment.

Furthermore, we find that labour substitution is much greater between unskilled and medium-skilled workers than between graduates and the unskilled. However, since the relative prices of various types of labour remained do not vary to a great extend over time, the substitution pattern could not explain the observed changes in the labour market composition. A large part of the shifting demand towards graduates and away from unskilled labour is explained by the time trend. Usually, technological progress is an assumption put forward after all other explanations fail. If one maintains this hypothesis, then technological change is largely biased against unskilled labour and towards high-skilled workers. In manufacturing, energy, water and mining, construction, wholesale & retail trade, the rate of biased technological change away from unskilled labour at constant relative wages and production ranges between 1.2 and 2.2 percent. The results indicate that the shift away from unskilled employment is as large in the traded goods as in the non-traded-goods sectors.

In the lower-skilled labour intensive sectors such as manufacturing, construction and wholesale & retail trade our calculations on the basis of estimated output and price elasticities suggest that unskilled labour could be stabilised by an output growth rate between 1.8 and 3.0 percent per year at zero wage growth, or between 2.4 and 3.7 percent assuming a uniform wage growth of 2 percent. In two out of five sectors limiting wage growth is an adequate policy alternative. In manufacturing and construction limiting nominal unskilled wage growth to 60 percent of the growth in medium and high-skilled wage would stabilise unskilled employment. During phases of economic downturns as in the 1992-1994 period, this wage growth should be limited to 1/6 of the growth of more qualified workers.

An important policy objective for 4.6 million unskilled workers in Germany is the access to regular jobs and that these jobs provide an adequate income. Nevertheless, one main conclusion is that a slightly increasing wage dispersion could stabilise unskilled employment in manufacturing. The primary policy alternative is that the unskilled become skilled. Furthermore, subsidising (or taxing) capital has little effect on unskilled employment.

Appendix: Descriptive statistics

Table 1a: Employment structure in West Germany, all sector

	number of workers (in 1000)						rate of change (in percent)		
	L	L_u	L_s	L_h	L_o		$\Delta L_u/L_u$	$\Delta L_s/L_s$	$\Delta L_h/L_h$
1977	19880	6716	11034	689	1440	78-80	1.3	2.2	6.2
1980	20954	6983	11770	826	1375	81-85	-2.3	0.5	3.2
1985	20378	6213	12057	965	1144	86-90	-1.3	2.9	5.9
1990	22368	5824	13886	1284	1374	91-95	-3.5	0.8	3.8
1995	22597	4859	14462	1550	1727	95-96	-4.7	-0.9	3.7
1996	22344	4631	14331	1608	1774	78-96	-1.9	1.4	4.6

Note: This database includes only those wage workers who are legally required to pay social security taxes. The rate of change is the average annual growth rate. The variables are defined as follows: L_u: workers without any formal vocational certificate; L_s: workers with a certificate from the dual vocational training system; L_h: workers with a university or technical university degree; L_o: information on type of occupational degree not determinable. Source: Federal Employment Service.

Table 1b: Employment structure in West Germany, Manufacturing

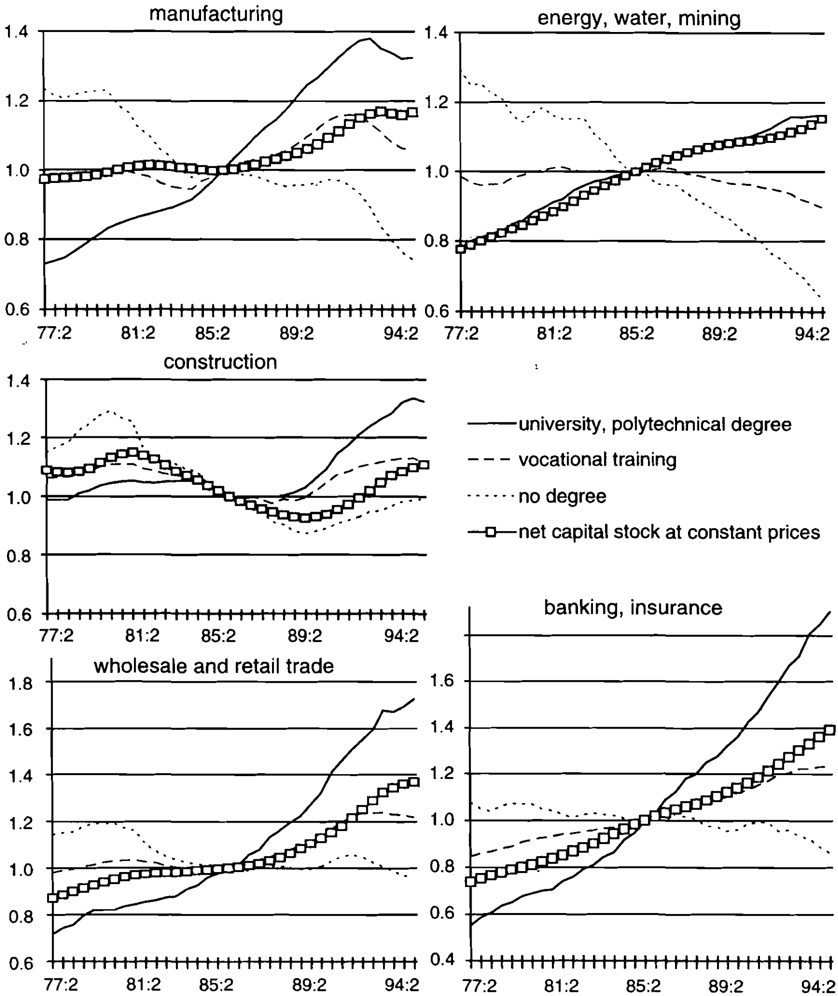
	number of workers (in 1000)						rate of change (in percent)		
	L	L_u	L_s	L_h	L_o		$\Delta L_u/L_u$	$\Delta L_s/L_s$	$\Delta L_h/L_h$
1977	8467	3394	4356	236	481	78-80	0.5	1.1	4.4
1980	8647	3440	4499	269	440	81-85	-3.4	-0.3	3.2
1985	7970	2884	4432	314	339	86-90	-1.3	2.8	5.6
1990	8555	2706	5078	413	358	91-95	-6.1	-1.3	1.1
1995	7508	1970	4747	436	356	95-96	-6.6	-2.2	2.4
1996	7281	1840	4642	446	352	78-96	-3.1	0.4	3.4

Notes: see Table 1a

Table 2: Prices and relative prices in the manufacturing sector

	p_m	p_k	p_h	p_s	p_u	p_m/p_u	p_k/p_u	p_h/p_u	p_s/p_u
1977:2	0.74	0.66	0.66	0.71	0.70	1.06	0.95	0.95	1.02
1980:2	0.90	0.85	0.80	0.84	0.83	1.08	1.03	0.96	1.00
1985:2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990:2	1.02	1.28	1.23	1.22	1.22	0.83	1.04	1.00	0.99
1994:2	1.02	1.27	1.47	1.45	1.45	0.70	0.88	1.01	1.00

Figure 1: Changes in employment by different skill groups (normalization to one in the second half year of 85)



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