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Structural Changes in the Demand for Labor

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Contents

Abstract

This paper investigates why labor demand has shifted away from low-skilled toward high-skilled labor in The Netherlands. We focus on the role of changes in relative wages and technological progress. A flexible functional form, proposed by Diewert and Wales, the Symmetric Generalized McFadden cost function, is estimated for the exposed and sheltered sectors. The estimates are based on time-series data for the period 1972-1993, which recently became available. Labor-saving technological change explains most of the displacement of low-skilled workers. The computed elasticities suggest that substitution between labor as a whole and capital is small. However, substitution plays a modest role in the shift from low-skilled toward high-skilled labor, especially in the sheltered sector. Skill-capital complementarity seems relevant in both sectors.

1 Introduction[1]

The educational level of employment in the Netherlands has increased dramatically in the last decades. Demand for low-skilled workers halved, while demand for high-skilled workers tripled between 1969 and 1993. As a consequence, unemployment hit low-skilled workers much harder. In the same period wage differentials decreased considerably. In 1969 a high-skilled worker earned 60% more than his low-skilled colleague did. This earnings differential decreased to a mere 10% in 1993.

Given these changes in wages and employment, substitution on the demand side seems a likely explanation for the structural upgrading of the workforce. Employers may have replaced increasingly expensive, low-skilled workers by relatively inexpensive, high-skilled workers.

Another plausible explanation for the shift in demand is labor-saving technological change. New technologics, e.g. the introduction of computers, may have increased the productivity of low-skilled labor relatively strong, American research (e.g. Berman, Bound, Griliches, 1994) points into this direction. In the US, and in contrast to the Netherlands, wage differentials rose sharply over the 1980's, while demand for educated labor continued to grow compared to the demand for unskilled labor. Substitution due to changes in relative wage costs cannot explain these patterns.

Two other possible explanations seem less plausible. First, changes in the growth pattern by industry have only a limited effect on the composition of employment. The increased demand for educated labor is due to shifts *within* rather than *between* industries. Own calculations (appendix C) show that between 1979 and 1989 almost 90 percent of the decline in employment share of low-skilled workers was caused by within industry shifts. Second, one could argue that the rapid growth in the educational level of the workforce could lead skilled workers to occupy unskilled jobs. Van Ours and Ridder (1994), however, find empirical evidence suggesting that job eviction of low-skilled and high-skilled workers is unimportant. Indeed, job competition occurs only between workers with an academic and a higher vocational education. Both categories are high-skilled.

In this paper we explore the role of substitution and labor-saving technological change. This research was undertaken in connection with the construction of a new macroeconomic model by CPB (Broer *et al*, 1996). However, the results have a policy relevance of their own. For example, when considering policies to fight high unemployment of low-skilled workers, policymakers would like to know how the demand for labor responds to price signals.

Empirical studies on the demand for different types of labor in the Netherlands are relatively scarce. Examples are Broer and Jansen (1989), Hebbink (1991) and Huigen

[1] Thanks are due to Peter Broer for helpful comments.

et al (1993). Lack of appropriate data is the main reason for this limited research. Well known is the missing data on capital, but also information on employment and wages by educational level was, until recently, available only for a few years. Recently, Statistics Netherlands and the CPB released new labor market data by educational level for the period 1969-1993 (CBS, 1996). This paper relies on these new data.

We distinguish between three factors of production: low-skilled labor, high-skilled labor and capital. We assume cost minimization, subject to a production function. Accordingly, factor demand is a function of factor prices, output and the parameters of the production function. These parameters are estimated and the results will be represented by elasticities.

In order to allow for differences in production structure by industrial scetor, we distinguish two broad catagories of industries; the exposed and the sheltered sector. The exposed sector is relatively capital intensive and contains agriculture, manufacturing and transport. Construction, trade, banking and other private services form the sheltered sector. We make estimates for both sectors.

This paper is organized as follows. Section 2 presents the model. The evolution of factor demand and factor prices is described in section 3. Section 4 discusses the estimation results and section 5 summarizes and concludes.

2 The model

2.1 Introduction

One of the most vexing problems facing applied economists in estimating factor demand relations is to find functional forms that are flexible, use only a small number of parameters and satisfy the theoretical restrictions implied by economic theory. For our purposes we require the estimated relations to satisfy the global concavity restriction. A (nested) CES function is globally concave but restrictive with respect to the substitution possibilities. For example, a nested CES function that aggregates low- and high-skilled labor into one production factor labor excludes the possibility of complementarity between high-skilled labor and capital. Moreover, this particular structure implies identical substitution between capital and both types of labor. A widely used form, the translog cost function, is flexible, but global concavity is not guaranteed. Diewert and Wales (1987) show that imposing this restriction may lead to biased estimates. We apply a functional form suggested by Diewert and Wales (1987, 1995), the so-called *Symmetric Generalized McFadden* (SGM) cost function. This function meets all our criteria. Recent applications of this specification can be found in Rask (1995), Coelli (1996) and Terrell (1996).

2.2 Long-run

We distinguish three production factors: low-skilled labor x_l, high-skilled labor x_h and capital x_k. Technology can be represented by a production function $y = f(x,t)$ where x is the vector of factor inputs ($x = [x_l, x_h, x_k]^T$), y is output and t is the time trend representing the state of technology. Given the vector of factor prices p ($p = [p_l, p_h, p_k]^T$) , costs are defined by $C = x^T p$. We assume cost minimization and constant returns to scale. Given these assumptions, Diewert and Wales (1987) propose the following functional form for the minimal cost per unit output:

$$c = \frac{C}{y} = g(p) + p^T\alpha + p^T\beta t + p^T\gamma t^2 \ , \tag{1}$$

$$\text{with} \qquad g(p) = \frac{1}{2}\frac{p^T\Xi\, p}{\theta^T p} \ , \tag{2}$$

where $\Xi = \|\xi_{ij}\|$ denotes a symmetric matrix and α, β, and γ are vectors of parameters. The vector θ is a predetermined vector of positive constants. All prices are normalized to unity and the time trend equals zero in a certain base year. In order to identify all parameters, some extra restictions are needed. We demand the Ξ matrix to satisfy the linear restriction $\Xi\iota = 0$, where ι is the unity vector. All rows of Ξ sum to zero. For practical reasons we pick the constants of the θ vector to sum to unity.

$$\Xi = \Xi^T \ , \quad \Xi\iota = 0 \ , \quad \theta^T\iota = 1 \ . \tag{3}$$

Diewert and Wales labelled this function the *Symmetric Generalized McFadden* (SGM) cost function. They show that this suggested form is flexible and satisfies the conditions implied by economic theory. The function is linear homogeneous in factor prices. Global concavity in the prices implies that matrix Ξ is negative semi-definite. If necessary this restriction can be imposed without destroying the flexibility of the functional form.

When imposing global concavity, we apply the following technique. The matrix Ξ is replaced by minus the product of a lower triangular matrix Ω times its transpose Ω^T

$$\Xi = -\Omega\Omega^T , \quad \Omega = \|\omega_{ij}\| , \quad \omega_{ij} = 0 \ \ \textit{for } i<j \ . \tag{4}$$

Using Shepard’s lemma, i.e. x = ∂C/∂p, the factor demand relations can easily be derived from the cost function (1), namely for the input-output ratios we can write:

$$\frac{x^*}{y} = g_p(p) + \alpha + \beta t + \gamma t^2 , \tag{5}$$

$$\text{with} \quad g_p(p) = \frac{\Xi p}{\theta^T p} - \frac{1}{2}\theta \frac{p^T \Xi p}{(\theta^T p)^2} . \tag{6}$$

The asterisk denotes a long-run variable. Each factor demand relation in the system given in (5) and (6) consists of three parts. The first term $g_p(p)$ represents the effect of prices; the second term α denotes the input-output ratio in the base year, while the third and fourth term $\beta\, t + \gamma\, t^2$ stand for the influence of technology.

2.3 Short-run

Equation (5) represents the long-run relation. It is unlikely that factor demand equals the long-run equilibrium in every time period because of habits persistence, adjustment costs, incorrect expectations and misinterpreted real price changes. We therefore assume a general first-order error correction model:

$$\Delta x = \Gamma_p y \Delta \frac{x^*}{y} + \Gamma_y [\frac{x^*}{y}]_{-1} \Delta y + \Lambda [x^* - x]_{-1} , \tag{7}$$

where the input-output ratios (x^*/y) stand for the long-run input-output ratios as given by equation (5), while Γ_y, Γ_p and Λ represent parameter matrices. We assume Γ_y *and* Γ_p to be diagonal. The dynamic equation consists of three terms. The first gives the impact effect of price changes; the second the impact effect of a production change; the last is the error correction term, that determines dynamic behaviour after the first year. When the impact effects of a price- and production-change are equal, *i.e.* $\Gamma_y=\Gamma_p=\Gamma$, equation (7) reduces to:

$$\Delta x \;=\; \Gamma\Delta x^{*} \;+\; \Lambda[x^{*}-x]_{-1} \;. \tag{8}$$

2.4 Elasticities

The factor input-output relations can be estimated. The estimated parameters can be used to compute the effect of prices and technology on factor demand. In particular, we will present the following elasticities:

$$\eta_{ij} \;=\; \frac{\partial \ln x_i^{*}}{\partial \ln p_j} \quad ; \quad \eta_{it} \;=\; \frac{\partial \ln x_i^{*}}{\partial t} \;, \quad i,\, j \;=\; l,\, h,\, k \;. \tag{9}$$

The elasticity η_{ij} represents the ordinary (compensated) elasticity of factor demand i with respect to the price of factor j; η_{it} stands for the relative change in factor demand i due to technical progress. It should be noted that the elasticities are derived for a given level of output and are not constant over time. According to a strong definition, two factors are complements if their cross price elasticity is negative, while two factors are substitutes if this elasticity is positive. According to a weaker definition, two factors are relative complements if their cross price elasticity is lower than other cross elasticities. Technical change is factor saving, neutral or using if $\varepsilon_{\mathrm{it}}$ is respectively negative, zero or positive.

In the base year when prices equal one and the time trend equals zero, expressions in (9) reduce to a simple function of the parameters of the cost function.

$$\eta_{ij}^{*} \;=\; \frac{\xi_{ij}}{\alpha_i} \;, \quad \eta_{it}^{*} \;=\; \frac{\beta_i}{\alpha_i} \;, \quad i,\, j \;=\; l,\, h,\, k \;, \tag{10}$$

where an asterisk denotes elasticities in the base year.

A commonly reported substitution elasticity in applied work is the *Allen substitution elasticity*. Characterized in terms of the price elasticities it reads:

$$a_{ij} = \frac{\eta_{ij}}{v_j} , \quad i, j = l, h, k , \tag{11}$$

where $v_j = (p_j x_j)/C$ is the cost share of factor *j*. Blackorby and Russell (1989) show that the Allen elasticity is no good generalization of the substitution elasicity as originally derived by Hicks in the two-dimensional case. Compared to the (cross) price elasticities, it adds no new information. A more natural generalization of the substitution elasticity in the two-factor case is the *Morishima elasticity*. This elasticity gives the percentage change in proportional factor inputs induced by a change in relative prices, keeping output and all prices but one constant.

$$m_{ij} = - \frac{\partial \ln (x_i/x_j)}{\partial \ln (p_i/p_j)} \Big|_{p_j} = \eta_{ji} - \eta_{ii} . \tag{12}$$

In general this elasticity is not symmetric. The percentage change in x_i/x_j depends upon how the price relative p_i/p_j is changed. It should be noted that in the two-dimensional case both the Allen elasticity and the Morishima elasticity reduce to the same value.

3 Factor demand and factor prices between 1969 and 1993

3.1 Data

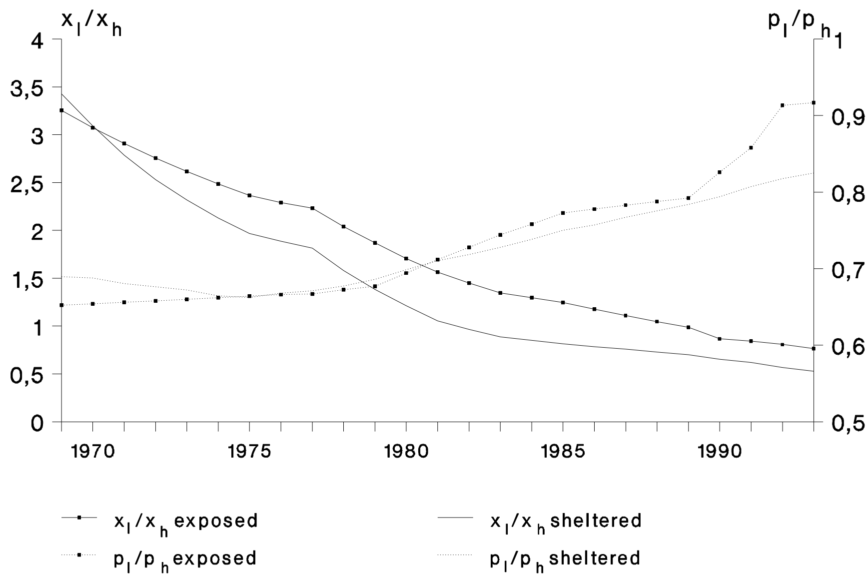
To estimate the system of input-output ratios, we need data on prices and quantities of all factor inputs. Low-skilled labor is defined as labor with a primary and extended education. High-skilled labor involves labor with secondary, higher vocational and university education. *Statistics Netherlands* (CBS, 1995) provides data on employment and wages by education for the period 1969-1993. We rely on time series from 1972 onwards.

The stock of capital is constructed through the accumulation of investments, assuming a constant depreciation rate. The cost of capital poses a particular problem. One could use the user cost of capital according to Jorgenson (1986), but the quality of this approximation is probably quite poor and likely to cause bias in estimation. Alternatively, we assume the value of output to equal the total cost of production. Using this accounting identity, we can derive the cost of capital from value added, the costs of other inputs and the stock of capital. Prices and quantities are corrected for shifts in working time. Appendix A gives a more detailed discussion of the definitions and the data used.

3.2 *Employment and wages in the 1969-1993 period*

Before discussing our estimation results, we first take a closer look at the development of employment and wages between 1969 and 1993. Figure 1 shows the evolution of the employment ratio x_l/x_h and the wage ratio p_l/p_h of low-skilled and high-skilled workers in the exposed and sheltered sectors. In both sectors the employment ratio shows a strong downward trend, the employment of low-skilled labor declines relative to high-skilled labor. In the exposed sector this ratio changed from 3.3 in 1969 to 0.8 in 1993. In the sheltered sector this decline was even stronger, *viz* from 3.4 to 0.5. The wage ratio shows an upward trend, wages of low-skilled workers rose relative to those of high-skilled workers. In the exposed sector the wage ratio increased from 0.65 in 1969 to 0.92 in 1993. The sheltered sector experienced a more modest change in wage ratio from 0.69 to 0.82.

Figure 1 *Employment and wage ratio*



From these figures one could make a first guess of the substitution elasticity between low- and high-skilled workers. This elasticity can be defined as the percentage change in the employment ratio divided by the percentage change in wage ratio. For the exposed sector this would lead to a substitution elasticity of 4. For the sheltered sector the figures suggest an elasticity of 11. These values are unrealistically high. It should be noted, however, that this first guess neglects the possible effects of biased technological change and the substitution with other input factors (capital), that could be different for the two types of labor.

Table 1 gives the annual percentage changes in output, factor demand and real factor prices for both the exposed and sheltered sectors.

Table 1 *Annual percentage changes in output, factor demand and factor prices*

	Exposed	Sheltered
Quantities		
Low-skilled	−3.71	−3.17
High-skilled	2.32	4.63
Capital	2.29	3.91
Output	2.81	2.38
Real prices[a])		
Low-skilled	4.58	1.90
High-skilled	3.16	1.15
Capital	0.25	−1.10

[a] Real prices are defined as p_x/p_y, where p_y is the price of output

Again, this table shows the strong decline in low-skilled labor. Surprisingly, the negative growth rate is roughly the same in the exposed and the sheltered sectors, although there are large differences in the development of prices in the two sectors. This suggests differences in substitution in both sectors. Another possibility is a minor role for substitution and identical labor-saving technological progress in the exposed and sheltered sectors. The growth rates for capital and high-skilled labor are the same, especially in the exposed sector, despite the fact that high-skilled wages rose more than the cost of capital. This suggests skill-capital complementarity.

4 Results

4.1 Introduction

This section presents results obtained from estimating the system of factor demand relations, given by (5), (6) and (7). We estimated the model both for the exposed (manufacturing, transport) and the sheltered sectors (trade, market services and construction). Next, to all equations a disturbance term was added. This disturbance is assumed to have a multivariate normal distribution. Estimation of equation (7) may result in heteroscedasticity in the error term. So, the equation is scaled with the production level to make the assumption of homoskedasticity of the disturbances more plausible. We used Instrumental Variables to estimate the parameters. This technique is chosen because of the (possible) endogeneity of prices and output in macroeconomic demand relations and the possible measurement error in cost of capital.

There are 12 long-run parameters to be estimated; three independent parameters in the Ξ matrix and three parameters in the α, β and γ vector each. The general dynamic specification adds another 15 paramers to the model. It turned out to be impossible to estimate all parameters simultaneously. Therefore we proceed as follows. We first estimate the static equations. Next we estimate the dynamic structure, given these long-run parameters. In another round we re-estimate the long-run parameters, given the dynamic structure and so on. We repeat this procedure until convergence is reached.

The base year at which all prices are set to unity is arbitrary and is obtained by scaling the data. We select 1990 to be this point. For each input the original prices are divided and the original quantities are multiplied by the original price in 1990. The vector θ is a vector of nonnegative constants which may be chosen by the researcher. We choose the parameters θ_i to be equal to the average cost share. For both sectors global concavity was enforced.

The estimation results are given in Appendix B, The computed long-run elasticities are described in section 4.2 to 4.4. The dynamic properties are discussed in section 4.5. Section 4.6 compares our results with earlier empirical work.

4.2 Long-run elasticities

Table 2 contains the elasticities as defined in (5) as well as the price elasticity for labor as a whole (ε_{aa}). The elasticities are evaluated in the base year 1990. In the exposed sector elasticities are below unity, indicating only modest effect of prices on employment. In the sheltered sector elasticities are higher. In both sectors, own price elasticities decrease with skill, indicating that the (direct) negative effect of an increase in wages is sharper for low- than for high-skilled labor. From the cross price elasticities it follows that the two types of labor are substitutes in both sectors. However, substitution in the sheltered sector is considerably higher than in the exposed sector. According to the strong definition, high-skilled labor is complementary with capital in the sheltered sector, the price elasticity is negative. In the exposed sector this elasticity is positive but smaller than the cross elasticity between low-skilled labor and capital. Substitution between low-skilled labor and capital is modest, especially in the exposed sector. The computed own labor demand elasticities are small, indicating hardly any substitution between labor as a whole and capital; the cross price elasticity between labor and capital (minus the own-labor demand elasticity) ranges from 0.03 in the sheltered sector to 0.06 in the exposed sector.

Table 2 *Price elasticities and elasticities of technological change*[a]

	Exposed sector		Sheltered sector	
Price elasticities[b]				
η_{ll}	–0.88	(3.1)	–2.10	(8.2)
η_{lh}	0.83	(2.9)	1.92	(8.5)
η_{lk}	0.05	(1.4)	0.18	(5.1)
η_{hl}	0.65	(2.9)	0.91	(8.4)
η_{hh}	–0.67	(2.9)	–0.84	(8.8)
η_{hk}	0.02	(0.7)	–0.06	(4.0)
η_{kl}	0.04	(1.4)	0.13	(5.7)
η_{kh}	0.02	(0.7)	–0.09	(4.3)
η_{kk}	–0.06	(6.5)	–0.04	(5.9)
η_{aa}	–0.06		–0.03	
Elasticities of technological change[c]				
ε_{lt}	–0.027	(2.6)	–0.029	(4.8)
ε_{ht}	–0.017	(2.1)	–0.012	(4.0)
ε_{kt}	–0.009	(7.3)	0.013	(9.9)

[a] Absolute t-values between parentheses; elasticities are evaluated in the base year 1990

[b] Price elasticiteis are defined as $\eta_{ij} = \partial \ln x_i^*/\partial \ln p_j$

[c] Elasticities of technological change are defined as $\eta_{it} = \partial \ln x_i^*/\partial t$

From these elasticities one can compute the employment effects of a decrease in wage costs in the market sector, the exposed and sheltered sector together. Given employment and elasticities in the base year, a 10% overall decrease in wages, without any change in other prices and output, increases low-skilled employment by 1.2% (corresponding to 20 000 labor years). Due to complementarity with capital, an overall change in wages has a small (negative) effect on high-skilled employment. The employment effects of a specific change in wages are much different. A 10% decrease in wage costs for low-skilled labor *only* leads to an increase in employment for low-skilled by 15.4% (250 000 labor years), while due to substitution the demand for high-skilled labor decreases by 8.1% (178 000 labor years). Again it should be stressed that the elasticities are derived given a constant output. When output effects are take into account, total employment effects can be much higher. Technological progress is not affecting all inputs in the same way, it is strongly labor-saving for low-skilled labor. Due to exogenous technological change the demand for low-skilled labor is reduced by almost 3% in the base year in both the exposed sector and the sheltered sectors. One might argue that there is a collinearity between the time trend and the prices. The flexible way in which technological progress is modelled takes account of most of the variation in prices, leading to low estimates for the substitution parameters. However, estimating the model under the constraint of no technical change, we do not find substantially higher estimates for the substitution elasticities. This suggest that collinearity between price and time effects is rather small. It should be noted, that the null hypothesis of no technological change is rejected for both sectors.

Table 3 *Morishima elasticities*[a]

	Exposed sector	Sheltered sector
m_{lh}	1.53	3.01
m_{lk}	0.92	2.23
m_{hl}	1.50	2.76
m_{hk}	0.69	0.75
m_{kl}	0.11	0.22
m_{kh}	0.08	–0.02

[a] $m_{ij} = \eta_{ji}-\eta_{ii}$, for i,j = h,k,l; elasticities evaluated in the base year 1990

Morishima elasticities are presented in Table 3. These elasticities can easily be derived from the (cross) price elasticities in Table 2.

Changing the wage ratio has a strong effect on the employment ratio of low- and high-skilled workers. In both sectors the values of the corresponding Morishima elasticities are larger than 1. This finding corresponds with the crude quesstimates in section 3.2. Due to neglectance the influence of technological change the reported values in section 3 were higher, however.

The Morishima-values are asymmetic. It matters how a change in price ratio is induced. A change in the price ratio caused by a change in the cost of capital has a much lower effect on the relative factor demand ratio than an identical change induced by a change in wages. This corresponds, of course, with the low value of the own price elasticity of capital.

4.3 *Decomposition of the shift in employment*

Table 4 attributes changes in employment as determined by the long-term relations (1) to changes in output, prices and technology. In accordance with the reported elasticities, the strong technological change determines the decrease in long-term employment of low-skilled workers. In the exposed sector a growth rate of output of at least 4.3% is necessary to stabilise low-skilled employment at unchanged factor costs. In the sheltered sector the required growth rate would be 3.4%. Changes in prices add only a minor part to the shift in demand. Substitution plays a relative more important role in the growth of high-skilled employment.

Table 4 Determinants of long-term employment[a]

	Annual growth rate	Decomposition		
	Long-run employment	Output	Technical progress	Substitution
Exposed sector				
Low-skilled	−3.4	2.3	−4.3	−1.4
High-skilled	2.4	2.3	−1.8	1.9
Sheltered Sector				
Low-skilled	−3.4	2.0	−3.4	−2.0
High-skilled	3.9	2.0	1.0	0.9

[a] Percentage values; growth rates are averages over the period 1973-1993

4.4 *Elasticities over time*

The reported elasticities refer to the base year. However, elasticities are not constant over time. Table 5 contains the price elasticities in the first and the last sample points for both sectors. Figure 2 and 3 show the evolution of the elasticities of technological change.

Especially the own and cross price elasticities of low-skilled labor show a large increase in absolute values. This increase is (partly) caused by the strong decline of low-skilled employment . Given the SGM-specification the employment effect in labor years of a price change is fairly constant. The relative effect, however, increases with the fall in the size of employment.

The strong variation in the elasticities of technology is partly caused by the way technology is taken care of in this specification. The additive quadratic term in the factor demand relations even causes some elasticities to change sign over the sample period. For example, this is the case for the effect of technological progress on high-skilled labor in the sheltered sector. Without any strong indication about major changes in technology this seems not plausible.

Table 5 *Price elasticities in 1973 and 1993*

	Exposed sector		Sheltered sector	
	1973	1993	1973	1993
η_{ll}	–0.31	–1.07	–0.85	–2.66
η_{lh}	0.31	1.00	0.81	2.45
η_{lk}	0.00	0.07	0.04	0.21
η_{hl}	0.54	0.72	1.22	0.98
η_{hh}	–0.61	–0.72	–1.18	–0.91
η_{hk}	0.07	0.00	–0.04	–0.07
η_{kl}	0.00	0.06	0.10	0.15
η_{kh}	0.06	–0.01	–0.06	–0.12
η_{kk}	–0.06	–0.05	–0.04	–0.03

Figure 2 *Technological progress; exposed*

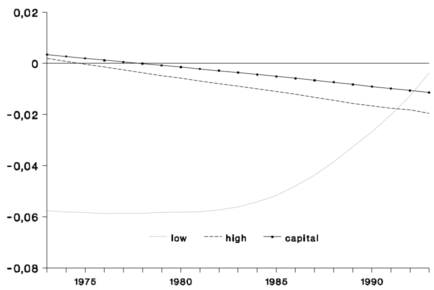
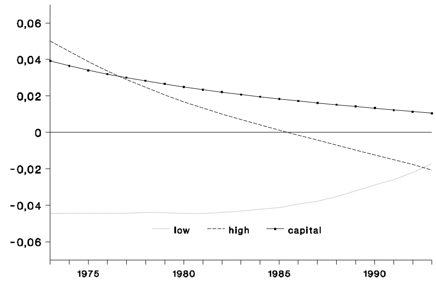


Figure 3 *Technological progress; sheltered*



4.5 *Dynamic parameters*

So far, the dynamic parameters as given by the Γ and Λ matrices in equation (7) have been ignored. Table 6 and Table 7 give for the exposed and the sheltered sectors the estimated values of these matrices, as well as some usual statistics. The Λ-parameters denote the error-correction coefficients. A necessary condition for the dynamic system to be stable is that the eigenvalues of the Λ matrix (in absolute value) are between zero and two. For both sectors this condition is met. All diagonal elements are positive as one would expect. An actual input-output ratio below the long-run ratio leads to an increase in factor demand in the next period.

The dynamic results are not satisfactory in all respects. Firstly, for high skilled labor and capital in the sheltered sector the short-run price effects are larger than the long-run effects, *viz* γ_{ph} and γ_{pk} are greater than one. For low skilled labor in this sector we see that a production change causes overshooting, γ_{yi} is greater than one. However, overshooting can be explained as forward looking behavior in inflationary or growth situations.

Secondly, the short-run production effect on investment seems high in the exposed sector. The capital coefficient is about 4 in the exposed sector. Combined with the estimated impact coefficients 0.78, this will lead to large investment fluctuations following production changes.

Table 6 *Dynamic parameters exposed sector*

	$\Delta(x_l/y)$		$\Delta(x_h/y)$		$\Delta(x_k/y)$	
γ_{pi}	0.74	(15.5)	0.78	(1.3)	0.89	(3.1)
γ_{yi}	0.31	(3.1)	0.82	(5.7)	0.78	(9.0)
λ_{il}	0.25	(1.4)	−0.33	(1.5)	−1.38	(1.6)
λ_{ih}	0.22	(1.4)	0.29	(1.3)	−0.13	(0.2)
λ_{ik}	0.03	(0.3)	0.27	(2.5)	1.38	(3.4)
R^2	0.94		0.60		0.93	
DW	1.88		1.73		2.30	

Table 7 Dynamic parameters sheltered sector

	$\Delta(x_l/y)$		$\Delta(x_h/y)$		$\Delta(x_k/y)$	
γ_{pi}	0.89	(6.7)	1.18	(3.2)	1.33	(21.8)
γ_{yi}	1.19	(9.6)	0.14	(0.9)	0.28	(10.3)
λ_{il}	0.46	(4.9)	−0.32	(3.9)	−1.19	(6.9)
λ_{ih}	−0.13	(1.1)	0.43	(4.0)	0.15	(4.7)
λ_{ik}	0.37	(5.5)	0.12	(1.7)	0.11	(6.9)
R^2	1.00		0.99		1.00	
DW	2.40		1.76		1.92	

4.6 Comparison with other results

Hamermesh (1993) surveys (mainly American) studies on labor demand. Although empirical work on price elasticities shows a wide range of estimates, some general conclusions can be drawn. Studies that assume labor to be homogeneous yield estimates somewhere between −0.15 and −0.75 for the own-demand elasticity. Studies that allow for heterogeneous labor suggest that capital and skill are relative complements and own-wage demand elasticities decrease with skill. Our results on the substitution pattern only partly fit this picture. The direct price elasticity for high-skilled labor is (in absolute value) smaller than for low-skilled labor and the cross price elasticities indeed suggest a (weak) skill-capital complementarity. However, the own-demand elasticity is considerably lower than suggested by Hamermesh. The important role for technological progress in reducing demand for low-skilled labor is in line with Berman, Bound and Griliches (1992) and Shadman-Mehta and Sneessens (1995).

As mentioned above, empirical studies on the demand for heterogeneous labor in the Netherlands are scarce. Differences in methodology and data prevent a detailed comparison of the results across studies. However, none of the studies on the Netherlands fully confirm the ’stylized facts’ as reported in Hamermesh. In line with our results, both Broer and Jansen (1990) and Hebbink (1992) find that labor-saving technological change plays a major role in reducing the demand for unskilled labor. Regarding the price elasticity of labor demand, the evidence is mixed. To illustrate, Gelauff, Haan and Okker (1986) report an elasticity close to zero. Draper (1989), however, finds a value of -0,2. Hamermesh suggests that measurement error in the price of capital biases the estimate of the elasticity of labor demand towards zero. This bias might explain why studies that use the real price of labor as a determinant

(Draper, 1989) find a higher demand elasticity than studies that adept the price ratio of labor and capital as an explanatory variable (Gelauff, Haan and Okker, 1986).

5 Summary and conclusions

Focusing on the role of substitution and technology in explaining the structure of employment in the Netherlands, we estimated a system of factor demand relations. Three production factors are distinguished, low-skilled labor, high-skilled labor and capital. We employ time-series data for the period 1972-1993, which became available only recently. We use a functional form, that is flexible, globally concave and relatively easy to estimate. We provide estimates for both the exposed and the sheltered sectors.

The computed price elasticities indicate that the pattern of substitution does not differ very much between the exposed and sheltered sectors. Substitution between low- and high-skilled labor is relatively strong, especially in the sheltered sector. For the market sector as a whole, a 10% decrease in wage costs for low-skilled workers *only* would in the market sector lead to a rise in low-skilled employment by 15.4%, high-skilled employment would decrease by 8.1%. There is hardly any substitution between high-skilled labor and capital (skill-capital complementarity) and only modest substitution between low-skilled labor and capital. The resulting own-labor demand elasticity is small. Technological change plays an important role. Indeed, the greater part of the reduction in demand for low-skilled labor can be attributed to asymmetric labor-saving technological change. Our estimates should be interpreted with caution, as the results are only partly in line with earlier empirical work. The small elasticity of labor demand may be due to measurement errors in the price of capital. Also it should be noted that, partly due to the specification used, elasticities vary considerably over time.

It remains not very satisfactory to ‘explain’ the major part of the change in employment by an exogenous time trend. Further research should aim to incorporate technological change in a more sophisticated way.

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A Definitions and data used

This appendix defines skill level and industrial sector as used in this research. It explains the data used. Table A.1 and Table A.2 contain time series for all data used.

Skill level

Employment is distinguished by skill. We approximate the skill level of workers by the (highest) level of education attained. This in contrast to much work where the manual/non-manual distinction is used as a proxy for unskilled/skilled work. Low-skilled labor is defined as labor with a *primary* and *extended education*. High-skilled labor involves labor with *secondary*, *higher vocational* and *university* education.

We focus on the shifts in employment. Both the shares of primary and extended primary workers declined over the sample period, while the shares of secondary, higher vocational and university workers rose. Therefore it seems reasonable to combine the two former categories. One might argue that, when addressing labor market problems of the unskilled, it is useful to narrow this category to the primary level only. Only 8 percent of the workers fall in this group, however. For practical reasons we want both groups to be of comparable size.

Industrial sector

We restrict our analysis to the market sector. We distinguish two broad groups of industries: the *exposed* and the *sheltered* sectors. The exposed sector contains agriculture, manufacturing and transport. Construction, trade, banking and the other private services form the sheltered sector.

Time series Project Labor and Education (Tijdreeksproject Arbeid en Opleiding)

Empirical work is limited by the availability and quality of data. For the estimation of input-output relations one needs data on quantities and prices of all factor inputs, *i.e.* labor by skill and capital. Until recently, for the Netherlands, there existed no time series for employment and wages by skill level. Therefore, Statististics Netherlands (CBS) and CPB in a joint project –*Tijdreeksproject Arbeid en Opleiding* (CBS, 1996) – have made an effort to fill this gap. For the period 1969-1993 consistent time series for employment and wages by educational level and industrial sector have been constructed, merging all information available. Although this data set is a major innovation compared to data used in earlier empirical work, we should express some caution regarding the quality of the data. The time series were based on several data sources, often differing in methodology and definitions used. Strong assumptions had to be made to combine different sources. Furthermore, the data sources used cover only a limited number of years and values for missing years have been obtained by inter- and extrapolation. For this reason we restrict our analysis to the 1972-1993 period.

Employment and wages

We rely heavily on the data from the above mentioned Tijdreeksproject (TP). However, some information is missing, *e.g.* employment figures for self-employed workers are not complete and earnings for this category are not available. Furthermore, data from TP do not exactly match the data from the National Accounts (NA). We assume self-employed workers to have the same education and (imputed) wage as employees. To obtain employment figures by skill level we take the shares from TP and combine them with total employment from NA. Wages by skill are computed by combining the ratio of hourly wages from TP with the total wage sum from NA.

The stock of capital

There exists no aggregate time-series on the value of the capital stock. The *Kapitaal-goederenstatistiek* (CBS) contains data for only a few years. Statistical problems prevent comparison of these values over the years. However, using time-series on investments and the value of the capital stock in a base year, it is possible to compute the stock of capital. We distinguish between buildings and equipement. For each category in the exposed and the sheltered sector we use the following equation for the accumulation of investments:

$$x_{k,t} = x_{k,t-1}(1-\delta) + i_t \quad . \tag{A.1}$$

Capital is denoted by $x_{k,}$ investements are denoted by i, the index t stands for time. For ease of notation indices for sector and type of capital are left out. We assume the scrap rate δ to be constant over time. Scrap rates are based on average lifetimes as given in the *Kapitaalgoederenstatistiek*. For the exposed sector we use a scrap rate of 0.02 for buildings, for equipment this rate is 0.04. For the sheltered sector these rates are 0.03 and 0.11, respectively. From the same source we take the value of the stock of capital in the year 1991 as the base value. Buildings and equipment are added up to form the total stock of capital.

The user cost of capital

Capital poses a particular problem. Its user cost is not a market price and is therefore not observed. Following Jorgenson (1986) the user cost of capital can be expressed as a function of the interest rate, tax parameters and the investment price

$$p_{k,t} = \frac{(1-wir_t - u\,ia_t)}{(1-u)}[(1-u_t)r_t + \delta + risk - \mathring{\pi}_t^{\,e}]\pi_t \quad , \tag{A.2}$$

$$\text{with} \qquad \mathring{\pi}^e_t = \alpha\mathring{\pi}^e_{t-1} + (1-\alpha)\mathring{\pi}_{t-1} \quad . \tag{A.3}$$

The corporate tax rate is given by u, *wir* stands for investment premiums and *ia* stands for certain fiscal tax facilities. The long-term interest rate is given by r, *risk* is a mark-up for risk. The price of investments is given by π and $\mathring{\pi}^e$ is the expected inflation of investment goods. The cost of capital as a whole can be obtained by weighing the cost of buildings and the cost of equipment with the stocks of both categories. We call this the *Jorgenson price* of capital $p_{k\text{-}j}$.

Theoretically, at least in the long-run, the value of output should equal total cost of production. In this approach we assume profit margins to be zero. Using this accounting identity, the cost of capital can be derived from value added, the cost of other inputs and the stock of capital

$$p_k = \frac{p_y y - p_l x_l - p_h x_h}{x_k} \quad . \tag{A.4}$$

For convenience of notation the index t is left out. We call this the *value-added* price of capital $p_{k\text{-}va}$. This leaves us with two definitions for the cost of capital. Both definitions are approximations of the ’true’ cost of capital. How to evaluate both measures? Which price to take? In Figure A.1 and A.2 both series are drawn. In computing the Jorgenson price acccording to (A.2) the researcher has a certain freedom in choosing the risk rate and in computing the expected price inflation of investments. We chose the parameters *risk* and α such that over the period 1969-1993 the Jorgenson price fitted the value-added price best.

Figure A.1 Capital prices; exposed

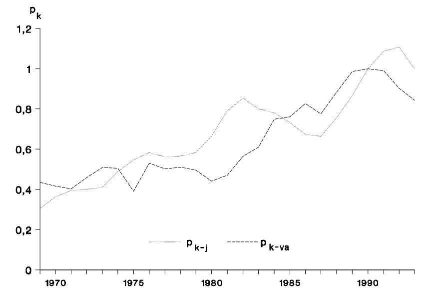
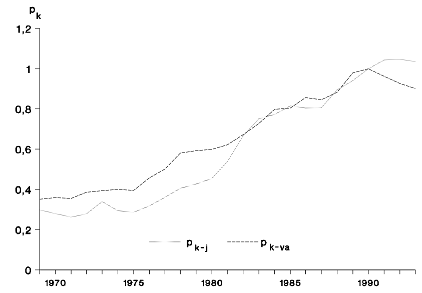


Figure A.2 Capital prices; sheltered



Despite the calibration of the Jorgenson price there are still large differences between both series for the cost of capital. Over the sample period, as one should expect, both series are more or less the same. The fluctuations in the Jorgenson price seem a bit larger. These fluctuations are caused by changes in the long-term-interest rate. In estimating the model, we experimented with both series. The Jorgenson price lowered the overall fit of the model. Moreover, using the Jorgenson price led to lower estimates for the substitiution between labor and capital. As Hamermesh points out (1993, p 79), measurement errors in the price of capital will bias this substitution toward zero. Probably, both series contain large measurement errors. However, based on these results, we assume the value-added price to be more reliable. This price we use in the estimations.

working time

Prices and quantities are corrected for changes in working time. Employment and wages refer to labor years. The effective input of labor falls and the effective price rises with reductions in the length of a labor year. However, shorter working hours increase the productivity. Therefore, effective labor falls less than proportional. The corresponding elasticity is less than one. Effective capital input and cost are also affected by the changes in working time, but only slightly. A reduction in working hours leads only to a small reduction in machine hours. For effective quantities and prices we use the following expressions

$$x_i = \tilde{x}_i \, ha^{\zeta_i}, \quad p_i = \tilde{p}_i / ha^{\zeta_i}, \quad i = l,h,k \quad , \qquad \text{(A.5)}$$

where *ha* stands for the (index of) working time. A tilde means uncorrected quantities and prices. The parameter ζ denotes the elasticity of effective quantities to working time. For both types of labor we assume an elasticity of 0.85. It is assumed that reductions in the working hours of labor reduce capital input with an elasticity of 0.15.

Table A.1 *Data exposed sector*[a]

	y	$\tilde{x}_l$	$\tilde{x}_h$	$\tilde{x}_k$	p_y	$\tilde{p}_l$	$\tilde{p}_h$	$\tilde{p}_{k-j}$	$\tilde{p}_{k-va}$	h
1969	82.657	1.465	0.450	380.5	0.520	0.237	0.300	0.305	0.435	1.176
1970	88.765	1.443	0.469	397.2	0.524	0.266	0.336	0.363	0.417	1.151
1971	91.234	1.405	0.483	411.3	0.553	0.301	0.379	0.395	0.404	1.131
1972	94.138	1.349	0.489	423.1	0.598	0.337	0.423	0.401	0.459	1.128
1973	100.831	1.315	0.503	437.9	0.641	0.390	0.489	0.411	0.508	1.111
1974	105.855	1.293	0.520	454.2	0.680	0.449	0.560	0.487	0.505	1.085
1975	100.572	1.245	0.526	466.7	0.727	0.504	0.627	0.547	0.391	1.068
1976	107.529	1.198	0.523	476.1	0.781	0.560	0.695	0.582	0.530	1.069
1977	108.904	1.164	0.522	489.3	0.801	0.606	0.751	0.563	0.503	1.067
1978	112.523	1.112	0.545	504.1	0.816	0.648	0.796	0.566	0.510	1.063
1979	116.329	1.074	0.574	519.4	0.827	0.688	0.840	0.583	0.495	1.057
1980	117.333	1.037	0.607	532.5	0.836	0.729	0.867	0.665	0.442	1.057
1981	120.368	0.981	0.628	540.7	0.842	0.764	0.887	0.792	0.469	1.056
1982	120.830	0.924	0.637	548.2	0.902	0.818	0.928	0.853	0.564	1.055
1983	122.963	0.872	0.648	557.1	0.917	0.856	0.950	0.800	0.610	1.047
1984	130.026	0.851	0.657	567.3	0.926	0.871	0.949	0.780	0.748	1.037
1985	132.403	0.851	0.682	580.6	0.944	0.894	0.956	0.731	0.761	1.020
1986	136.935	0.839	0.714	596.7	0.972	0.920	0.977	0.673	0.826	1.015
1987	138.003	0.823	0.742	610.7	0.973	0.941	0.993	0.663	0.775	1.012
1988	143.176	0.805	0.769	623.9	0.993	0.948	0.994	0.754	0.881	1.007
1989	150.145	0.790	0.800	639.4	1.005	0.955	0.996	0.866	0.985	1.001
1990	157.382	0.749	0.865	654.1	1.000	1.000	1.000	1.000	1.000	1.000
1991	161.225	0.740	0.879	668.0	1.009	1.067	1.027	1.087	0.989	0.999
1992	162.865	0.723	0.896	680.4	1.007	1.161	1.050	1.107	0.903	1.001
1993	162.408	0.686	0.896	691.6	0.994	1.193	1.075	0.998	0.842	0.998

[a] Output (y) and capital ($\tilde{x}_k$) values (billions) in prices 1990; employment ($\tilde{x}_l$, $\tilde{x}_h$) in labor years (millions); prices ($\tilde{p}_i$) and working time (h) normalized to unity in 1990.

Table A.2 *Data sheltered sector*[a]

	y	$\tilde{x}_l$	$\tilde{x}_h$	$\tilde{x}_k$	p_y	$\tilde{p}_l$	$\tilde{p}_h$	$\tilde{p}_{k\text{-}j}$	$\tilde{p}_{k\text{-}va}$	h
1969	99.678	1.508	0.440	112.9	0.326	0.248	0.285	0.298	0.351	1.166
1970	105.515	1.498	0.484	121.7	0.352	0.279	0.322	0.279	0.359	1.142
1971	109.702	1.460	0.524	129.3	0.380	0.316	0.368	0.262	0.355	1.122
1972	111.705	1.399	0.553	135.9	0.416	0.352	0.413	0.278	0.385	1.124
1973	117.042	1.363	0.588	142.9	0.452	0.403	0.477	0.339	0.394	1.106
1974	121.007	1.315	0.618	148.9	0.494	0.463	0.553	0.294	0.400	1.086
1975	120.355	1.268	0.645	153.6	0.545	0.517	0.620	0.286	0.395	1.061
1976	125.786	1.258	0.666	159.1	0.589	0.573	0.681	0.317	0.458	1.064
1977	129.694	1.252	0.690	165.9	0.634	0.625	0.739	0.360	0.501	1.062
1978	133.749	1.214	0.768	172.7	0.687	0.663	0.777	0.405	0.579	1.058
1979	136.544	1.177	0.852	179.6	0.725	0.696	0.806	0.427	0.592	1.053
1980	136.914	1.118	0.922	185.5	0.774	0.745	0.846	0.455	0.599	1.054
1981	132.536	1.012	0.960	189.2	0.814	0.775	0.866	0.539	0.622	1.048
1982	130.626	0.925	0.958	191.5	0.856	0.825	0.911	0.666	0.673	1.044
1983	129.581	0.861	0.969	194.7	0.891	0.860	0.938	0.751	0.727	1.037
1984	133.724	0.845	0.994	198.8	0.897	0.871	0.936	0.772	0.798	1.028
1985	137.621	0.839	1.032	204.9	0.903	0.892	0.944	0.815	0.804	1.013
1986	143.465	0.851	1.083	212.8	0.930	0.919	0.963	0.804	0.856	1.007
1987	147.277	0.856	1.133	222.7	0.939	0.933	0.965	0.805	0.845	1.003
1988	154.079	0.867	1.191	233.0	0.954	0.952	0.974	0.894	0.882	1.003
1989	162.596	0.879	1.256	244.0	0.976	0.965	0.977	0.941	0.978	0.999
1990	170.031	0.875	1.341	255.8	1.000	1.000	1.000	1.000	1.000	1.000
1991	174.818	0.870	1.408	268.6	1.023	1.051	1.034	1.043	0.961	0.996
1992	176.077	0.836	1.475	281.1	1.062	1.103	1.071	1.048	0.927	0.987
1993	176.648	0.807	1.531	289.7	1.095	1.147	1.104	1.034	0.901	0.985

[a] Output (y) and capital ($\tilde{x}_k$) values (billions) in prices 1990; employment ($\tilde{x}_l$, $\tilde{x}_h$) in labor years (millions); prices ($\tilde{p}_i$) and working time (h) normalized to unity in 1990

B Estimation results[a]

	exposed		sheltered	
			long-run parameters	
ω_{ll}	−4.96	(6.1)	6.96	(17.8)
ω_{hl}	4.68	(5.4)	-6.35	(18.3)
ω_{hh}	1.42	(11.8)	0.89	(8.6)
α_l	0.28	(37.2)	0.23	(26.2)
β_l (x100)	-0.75	(2.6)	-0.67	(4.3)
γ_l (x1000)	0.11	(6.6)	0.57	(9.8)
α_h	0.36	(60.0)	0.49	(32.3
β_h (x100)	−0.60	(2.2)	-0.61	(3.7)
γ_h (x1000)	−0.20	(1.4)	-0.66	(5.8)
α_k	0.37	(246.7)	0.33	(91.7)
β_k (x100)	−0.34	(7.4)	0.43	(10.7)
γ_k (x1000)	−0.14	(4.0)	−0.12	(3.1)
			dynamic parameters	
γ_{pl}	0.74	(15.5)	0.90	(6.7)
γ_{ph}	0.78	(1.3)	1.12	(3.3)
γ_{pk}	0.89	(3.1)	1.32	(21.8)
γ_{yl}	0.31	(3.1)	1.19	(9.6)
γ_{yh}	0.82	(5.7)	0.14	(0.9)
γ_{yk}	0.78	(9.0)	0.28	(10.3)
λ_{ll}	0.25	(1.4)	0.46	(4.9)
λ_{lh}	0.22	(1.4)	−0.13	(1.1)
λ_{lk}	0.03	(0.3)	0.37	(5.5)
λ_{hl}	−0.33	(1.5)	−0.32	(3.9)
λ_{hh}	0.29	(1.3)	0.44	(4.0)
λ_{hk}	0.27	(2.5)	0.12	(1.7)
λ_{kl}	−1.38	(1.6)	−0.19	(6.9)
λ_{kh}	−0.13	(0.2)	0.15	(4.7)
λ_{kh}	1.38	(3.4)	0.11	(6.9)
			statistics	
DW_l		1.9	2.4	
DW_h		1.7	1.8	
DW_k		2.3	1.9	
R^2_l		0.99	0..99	
R^2_h		0.60	0..99	
R^2_k		0.93	0..99	

[a] Estimation period 1973-1993; t-values between brackets

C Decomposition in between and within components

Which part of the shift in employment toward high-skilled workers can be explained by shifts in the demand between industries from those intensive in low-skilled workers to those intensive in high-skilled workers? In order to address this question a decomposition of the change in educational structure of employment is useful. A standard way (*e.g.* Bound, Johnson and Grilliches, 1993) of decomposing a change in an aggregate proportion into a term reflecting reallocation of employment between industries and another reflecting changes of proportions within industries is as follows:

$$\Delta P_i = \sum_j \Delta S_j \overline{P_{ij}} + \sum_j \Delta P_{ij} \overline{S_j} \qquad \text{(C.1)}$$

for $i = 1, \ldots, N$ skill levels and $j = 1, \ldots, M$ industries, $P_i = x_i/x$ is the employment share of skill level i, $P_{ij} = x_{ij}/x_j$ is the proportion of i-skilled labor in industry j, $S_j = x_j/x$ is the share of employment in industry j. A bar denotes a mean over time. The first term on the right reports the change in the aggregate proportion of workers with educational level i attributable to shifts in employment *between* industries. The second term reports the change in the aggregate proportion of workers with educational level i which can be attributed to shifts in employment *within* industries.

Table C.1 Employment share and decomposition in between and within industry shifts[a]

	employment share		decomposition	
	1979	1989	between	within
low-skilled	73.9	61.4	−1.8	−10.7
primary	21.8	11.8	−0.7	−9.3
extended primary	52.1	49.6	−1.1	−1.4
high-skilled	26.1	38.6	1.8	10.7
secondary	20.3	31.1	1.1	9.7
higher vocational	4.5	5.6	0.4	0.7
university	1.3	1.9	0.3	0.3

[a] Percentage values

Table C.1 reports the employment share by skill in 1979 and 1989 and the between and within decomposition of the change in these shares. The decomposition is based on employment data from the Wage Strucure Inquiries in the years 1979 and 1989. We distinguish five educational levels: primary, extended primary, secondary, higher vocational and university. Low-skilled consists of the first two categories, high-skilled consists of the upper three levels. The decomposition is based on a two-digit classification of industries.

The within-industry component dominates the between-industry component for each educational level. The within component explains 86 percent of the shift in employment from low-skilled toward high-skilled. The decomposition suggests that shifts in product demand, *e.g.* the shift from industrial towards service-oriented sectors, did not play a large role in explaining the increased share of high-skilled workers.

It should be noted that aggregation over industries decreases the importance of the between component. Bound, Johnson and Grilliches (1993) show for US data that the between component decreases from 30 percent to 13 percent when, instead of a four-digit-classification, a two-digit classification is used. Unfortunately, our data did not allow us to make a decomposition based on a three-digit or four-digit classification of industries.