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Abstract:
In the Norwegian fabricated metal industry there has been a shift in demand from unskilled to skilled workers during the period 1972 to 1990, and relative demand for white collar employees has also increased. The paper analyses the factors behind the shift in the composition of these three kinds of labour. A translog cost function approach is applied, using an error-correction representation of the development in cost shares. The results indicate substitutability between unskilled and both skilled and white collar workers. Increased supplies of skilled workers and engineers seem to have been the most important factors for the change in the composition of employment, indicating lack of persons with these kinds of education. In addition, unskilled workers have been rationalized away as a result of technical progress.

Keywords: Labour market, employment composition, human capital, wage differentials, time series analysis.

JEL classification: J21, J23, J31.

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1. Introduction

When analysing the labour market and the links to the entire economy it is often too simple to assume labour to be homogeneous. In models of endogenous economic growth[1] the increasing amount of skilled labour is held to be of importance, and the growing rate of unemployment in most Western countries during the past two decades has contributed to an increased focus on the cyclical variability of employment, hours and real wages for skilled and unskilled workers[2]. The analyses by among others Kydland and Prescott (1988) and Juhn et al. (1991) indicate that demand for low-skilled workers is most severely hurt in a recession. In US unemployment has been highly concentrated among less skilled individuals, and this has also been the case in most European countries[3].

Knowledge of factors influencing demand for different kinds of labour is thus important when analysing the labour market. In their analyses for respectively US and UK, Berman, Bound and Griliches (1994) and Machin (1994) find that the major shifts towards skilled labour are due to changes within-industry or establishment changes. According to the analysis by Cappelen and Stølen (1994) the composition of labour differs a lot between Norwegian industries, indicating that a change in the relative importance of different industries may influence aggregate demand for different categories of skill levels. As production technology and behaviour also may differ between industries, we have found it most appropriate in the first hand to focus on one single Norwegian industry, namely the fabricated metal industry. This industry is one of the most important Norwegian manufacturing industries and data are also of higher quality than for most other industries[4].

In earlier empirical works analysing demand for different categories of labour, a particular interest has been devoted to the possibilities of substitution. As early as 1969 Griliches showed that the possibility of substitution between real capital and blue collar workers was larger than between real capital and white collars. The result, which is also confirmed among others by Berndt and Christensen (1974), indicates that it is not appropriate to treat labour as a separable group. Demand for different kinds of labour therefore ought to be analysed simultaneously with other factors of production. In this analysis the translog cost function introduced by Christensen, Jorgenson and Lau (1973) is chosen as a flexible functional form, and the theoretical foundation is further discussed in section 2.

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[1] See e.g. Romer (1990) and Grossman and Helpman (1991).

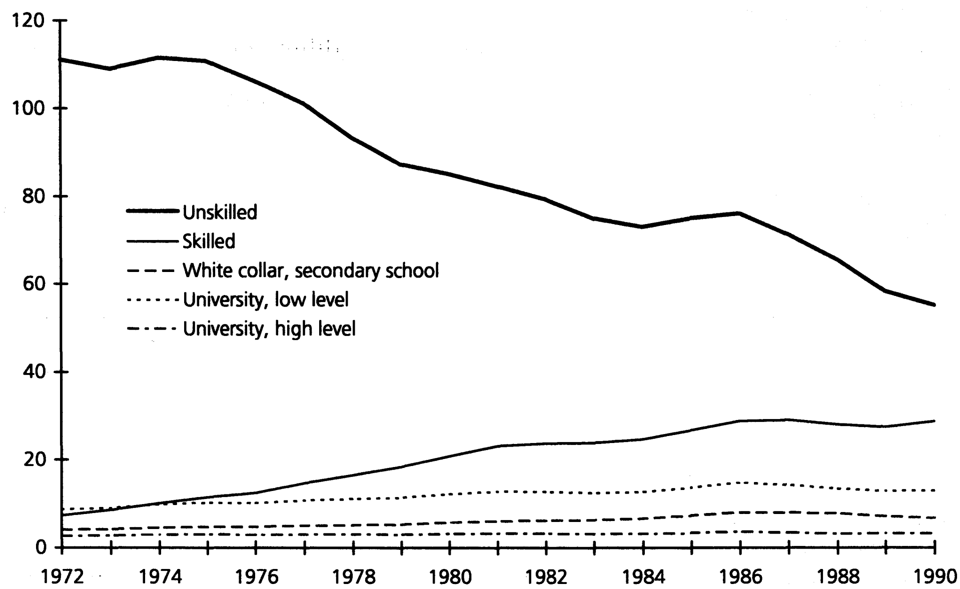
[2] See e.g. Juhn et al. (1991) and Keane and Prasad (1993).

[3] See e.g . Machin (1994) for an analysis of changes in relative demand for skills in the UK labour market, van Ours and Ridder (1995) for the Netherlands, Shadman-Mehta and Sneessens (1995) for France, Risager (1993) for Denmark and Cappelen and Stølen (1994) for Norway.

[4] To get an overall picture we should of course have analysed demand for different kinds of labour in all of the most important industries regarding employment, but we have not managed to do that yet.

Due to lack of consistent time series data for wages and employment by skill or education, analyses of factors determining relative demand for different kinds of labour are almost non-existent in Norway[5]. However, in the last years new time series for wages and man-hours by education and industry corresponding to the National Accounts (cf. Skotner (1994)) are established for the period 1972 to 1990[6]. For the fabricated metal industry labour is divided into five categories as presented in figure 1.

Figure 1. Manhours by education in the fabricated metal industry. Millions



The figure shows that the relative number of man-hours for unskilled workers has decreased during the period 1972 to 1990 while the shares of man-hours done by skilled workers and employees with secondary or higher education have increased.

From figure 2 relative wages, however, seem to have stayed almost constant, indicating that other factors have been important when explaining the shift in the composition of labour. One possibility is that non-neutral technological progress has caused unskilled workers to be rationalized away. Another explanation may be that small relative wage differentials in Norway may have caused lack of skilled workers, and the increasing number of man-hours done by this group may reflect growth in supply. The empirical results presented in section 4 support these explanations. Technological progress thus seems to have been important when explaining the decreasing share of man-hours done by unskilled workers, while increasing supply has increased actual employment for skilled workers.

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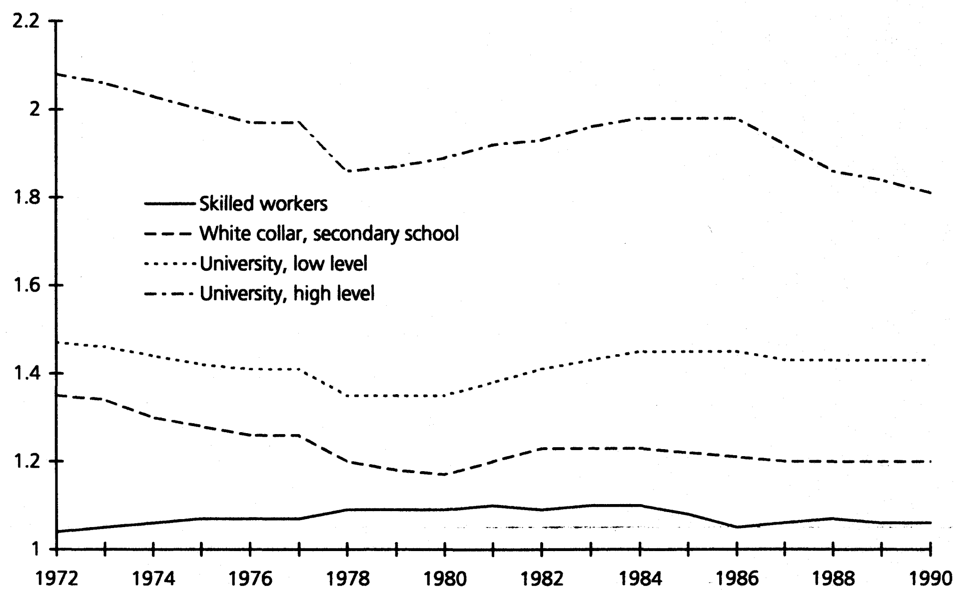
[5] One exception is Aamdal (1987) who divides labour into blue collar and white collar workers in an analysis of factor demand in the fabricated metal industry.

[6] Work is in progress to update these series.

Figure 2. Wages for different educational groups relative to unskilled workers. Fabricated metal industry



2. Theoretical foundation

2.1. The neoclassical approach

We assume that the production process may be described by a production function, expressing the relation between the quantity produced and the different factors of production. In empirical analyses (see among others Christensen et al. (1971, 1973)), the factors of production have usually been divided into capital (K), labour (L), energy (E) and intermediate goods (M). These groups may further be divided into different subgroups. Especially the disaggregation of labour is interesting in our case, and a survey of the literature in this field is given by Hamermesh and Grant (1979) and Hamermesh (1985)[7]. A very common approach has been to divide labour in the manufacturing industries into blue collar and white collar workers[8]. Fixed capital may also be divided into the stock of buildings and construction and the stock of machineries and equipment. It may be reasonable to think that there exist complementarity between the stock of buildings and construction and certain types of labour and substitutability between labour and the stock of machineries and equipment. This division of capital is, however, not a common feature in the literature, probably as a consequence of lacking data.

[7] We have also benefitted from a survey made by Naug (1995) as a part of this project.

[8] See among others Griliches (1969), Berndt and Christensen (1974), Fallon and Layard (1975), Bresson et al. (1992) and Berman, Bound and Griliches (1994).

In the general analyses of factor demand[9], it is often assumed that capital, labour, energy and materials constitute separable subgroups, but the empirical results from analyses where labour is divided into different catagories indicate that this may not be appropriate. A very common result in the literature is «capital-skill complementarity» which means that the possibilities of substitution between blue collar workers and capital are greater than the possibilities of substitution between white collar workers and capital. This result is found by among others Griliches (1969), Fallon and Layard (1975) and Berman, Bound and Griliches (1994), and the results by Berndt and Christensen (1974) indicate that white collar workers and fixed capital even may be technical complementary factors of production.

In most countries a considerable decrease in the relative demand for unskilled workers is observed. The technological progress may have been an important factor behind this development, and in most of the earlier analyses it has been represented by a trend. Although a «look» at the data may indicate that technical progress is not neutral, this is taken into consideration in only a few of the earlier analyses reported in Hamermesh (1993). But after the analysis by Berman, Bound and Griliches (1994) technical progress represented by expenditures on R&D and computers has been held to be a main explanatory factor. An expanding international trade with higher import shares is also found to be of importance in some analyses.

In earlier analyses of producer behaviour on Norwegian data it has been difficult to construct relevant time series for the user cost of capital. Particularly, it may be troublesome to get good data for the enterprises' price expectations. As pointed out by Hamermesh (1986), this is a common problem in most countries, and some simplifications are made. An additional problem in Norway is the fact that a regulated credit market with low rates of interest until the middle of the 1980s contributed to very low user costs, and even negative ones for years with a strong increase in prices of fixed capital. To avoid the problems with the user cost of capital, we have chosen to regard the stock of capital as given to concentrate the analysis on the possibilities of substitution between the variable inputs. Our focus here is thus on the conditional demand functions.

Based on assumptions of cost minimizing behaviour for a given level of production, capital stock and input prices, demand for the different kinds of labour may be expressed like:

$$(1)\ L_i = g_i(W_i / W_1, \ldots, W_i / W_n, W_i / P_M, X, CB, CM, TIME) \qquad (i = 1, \ldots, n)$$

[9] Cf. Christensen et al. (1971, 1973) and Hesse and Tarkka (1986).

where L_i is the number of manhours for educational group i, W_i is wages per manhour for group i, P_M is the price of intermediate goods, X is gross output, CB is the stock of buildings and construction, CM is the stock of machineries and equipment, and TIME is a trend representing technological progress.

The equations for demand for labour ought to be estimated simultaneously together with intermediate goods. In the case with more than two factors of production, a functional form like CES will be too restrictive regarding substitution. In most of the empirical works with more than two factors of production, a common approach has been to use the dual cost function and from this derive the demand equations. The translog cost function introduced by Christensen, Jorgenson and Lau (1971, 1973) is a widely used functional form in this respect because of its flexibility, not imposing any a priori restrictions on the possibilities of substitution. This function may be interpreted as a quadratic approximation in the logarithms of a general, continous, twice differentiable cost function and may be expressed as:

$$(2)\ \ln C(W_i, P_M, X, CB, CM, TIME) = c + \sum_i c_i \ln W_i + \frac{1}{2}\sum_i \sum_j c_{ij} \ln W_i \ln W_j + c_{PM} \ln P_M +$$
$$\frac{1}{2} c_{PMPM} (\ln P_M)^2 + c_X \ln X + \frac{1}{2} c_{XX} (\ln X)^2 + c_{CB} \ln CB + \frac{1}{2} c_{CBCB} (\ln CB)^2 + c_{CM} \ln CM +$$
$$\frac{1}{2} c_{CMCM} (\ln CM)^2 + c_T \ln TIME + \frac{1}{2} c_{TT} (\ln TIME)^2 + \sum_i c_{iPM} \ln W_i \ln P_M + \sum_i c_{iX} \ln W_i \ln X +$$
$$\sum_i c_{iCB} \ln W_i \ln CB + \sum_i c_{iCM} \ln W_i \ln CM + \sum_i c_{iT} \ln W_i \ln TIME + c_{PMX} \ln P_M \ln X +$$
$$c_{PMCB} \ln P_M \ln CB + c_{PMCM} \ln P_M \ln CM + c_{PMT} \ln P_M \ln TIME + c_{XCB} \ln X \ln CB + c_{XCM} \ln X \ln CM$$
$$+ c_{XT} \ln X \ln TIME + c_{CBCM} \ln CB \ln CM + c_{CBT} \ln CB \ln TIME + c_{CMT} \ln CM \ln TIME$$

$i = 1, \ldots, n$

By partial differentiation of the translog cost function with respect to wages for group i, using Shephard's lemma and claiming symmetry, we find the following expression for the shares of total variable costs:

$$(3)\ S_i = \frac{\partial \ln C}{\partial \ln W_i} = \frac{L_i W_i}{C} = c_i + \sum_j c_{ij} \ln W_j + c_{iPM} \ln P_M + c_{ix} \ln X + c_{iCB} \ln CB +$$
$$c_{iCM} \ln CM + c_{iT} \ln TIME$$

i = 1,...,n

In addition, there will be a similar equation for the cost share of intermediate goods.

2.2. Rationing from the supply side

The existence of an extensive unemployment in many countries indicates that wages are not so flexible that they are able to clear the labour market in the short-run. This is the basis for the discussion of macroeconomic disequilibrium models by Sneessens (1983) and Drèze and Sneessens (1986). They also discuss a possible disequilibrium in the product market and distinguish between classical and keynesian unemployment. In order to simplify, we ignore the last aspect, but concentrate on the possibility for disequilibrium in the labour market.

In its simplest form the disequilibrium thought implies that the actual observed employment is the smallest of supply and demand and may be expressed as follows:

$$(4)\ L_i = \min(LD_i, LS_i)$$

where LD_i is the demand for labour of type i and LS_i is the supply of labour of type i.

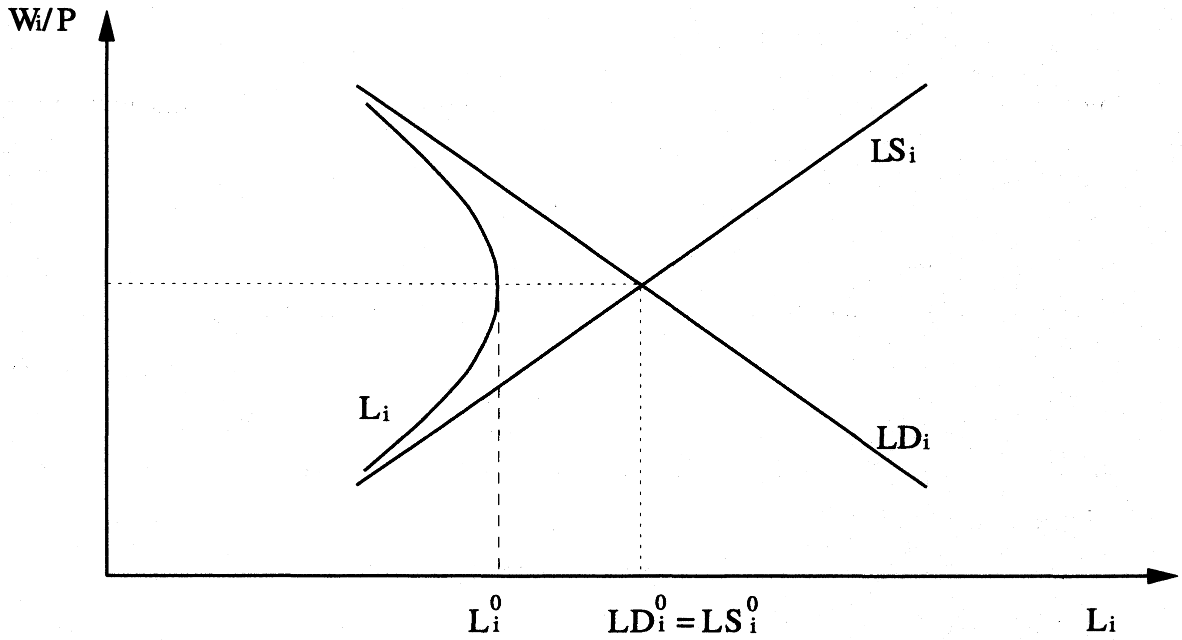
Even if labour is divided into different categories, there may be a large heterogeneity within these groups. Therefore, it is relevant to assume that a relation like (4) applies to each enterprise. Further, the enterprises may face different situations in such a way that some are rationed from the supply side while the actual employment is determined from the demand side for others.

Assuming a log-normal distribution among the micro units regarding this aspect, Lambert (1988) has shown that aggregate employment may be expressed as a simple CES-aggregate of demand and supply.

$$(5)\ L_i = (LD_i^{-\rho} + LS_i^{-\rho})^{-1/\rho}$$

Here $1/\rho$ is proportional to the mismatch between supply and demand at the micro level. The situation may be illustrated as in figure 3. Actual employment can never be as large as supply or demand, but will approach the smallest of them asymptotically when the discrepancy becomes large. The distance between actual employment L_i^0 and the point of intersection between supply and demand $LD_i^0 = LS_i^0$ measures the mismatch for this category of labour.

Figure 3. The relation between observed employment, supply and demand

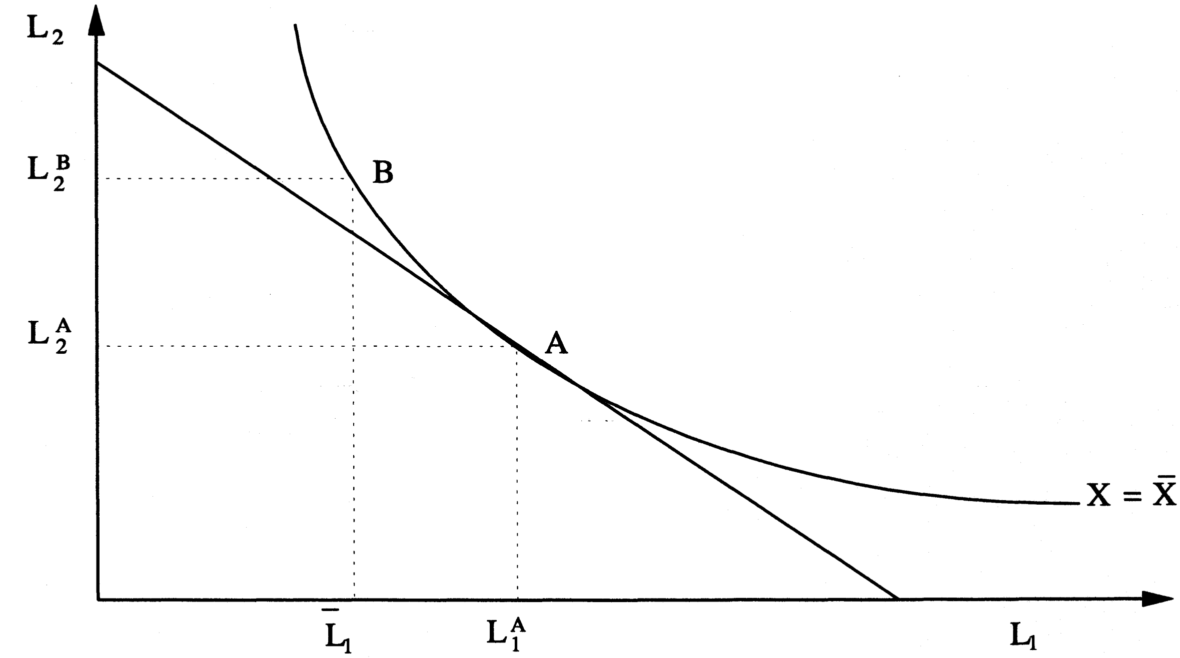


A simplification in the works by Sneessens (1983) and Drèze and Sneessens (1986) is that they only specify one kind of labour (even though inhomogeneity implicitly is the basis for the structural problems). Our aim is to analyse demand for several kinds of labour simultaneously. In such a situation, limitations from the supply side concerning one kind of labour may also be of importance for the actual employment of other groups. Lack of labour with one kind of education may therefore lead to higher employment for labour with a related education (especially if the latter level of education is higher than what is needed, but also to a certain extent if it is lower).

The situation with two categories of labour may be illustrated as in figure 4. Assuming cost minimisation for a given output, the situation with unrestricted demand is given by A. We then assume that there is a limitation on the supply of labour of type 1. The limited supply, denoted $\overline{L}_1$, is smaller than the unrestricted demand, L_1^A. In order to produce the quantity $X = \overline{X}$, the use of labour of category 2 has to increase to L_2^B which is larger than the use of this category without rationing. We notice from the figure that if the supply of category 1 increases, the demand for category 2 will decrease.

The situation also raises some other questions. With rationing, the produced quantity may be influenced by the supply of the specific category of labour. Relative wages may also be influenced if a disequilibrium situation lasts. A rather comprehensive analysis is needed in order to analyse these questions. The econometric methodology for estimating disequilibrium models is described in among

Figure 4. The situation with rationing of one kind of labour



others Quandt (1982). However, it may be rather irrelevant to talk about a specific supply of labour directed towards a single industry[10]. In order to simplify, this analysis is limited to include supply of different categories of labour as additional factors of importance for the actual composition of employment.

3. Actual development - Choice of aggregation

In Statistics Norway, time series for wages and employment in the fabricated metal industry consistent with the National Accounts are established for the following 5 educational groups (cf. Skotner (1994)) (length of education in parentheses):

Compulsory education / upper secondary school, first year (-10 years): Unskilled
Upper secondary school, second and third year, vocational training (11 - 12 years): Skilled
Upper secondary school, second and third year, general education (11 - 12 years): White collar, secondary school
Tertiary education, one to four years (13 - 16 years): University low level
Tertiary education, more than 4 years (17 years -): University high level

As presented in figure 1, unskilled workers constitute the largest group, and the number of man-hours for this group has fallen dramatically during the depicted period. Approximately half as many man-hours were executed by the unskilled in 1990 compared to the situation in 1972. The number of man-

[10] Cf. the discussion of supply variables in section 3.

hours for skilled workers has, however, increased strongly and was nearly four times as high in 1990 as in 1972. The growth has, with some exceptions, been uniformly strong over the whole period.

The growth in employment for white collar workers (the three remaining groups) has been more moderate. Persons with tertiary education for about 3 years, dominated by engineers (short programmes), but also some economists, constitute the largest group. For this group, man-hours have increased by almost 50 percent from 1972 to 1990. Influenced by the general economic development, the growth was especially strong in the years 1985 and 1986, while the number of man-hours for this group declined from 1986 to 1990.

The share of man-hours done by the group with more than 4 years of tertiary education, basically engineers (long programmes), is relatively small, and the number of man-hours for this group has only increased by 22 percent from 1972 to 1990. This is clearly weaker than the growth for engineers (short programmes). The growth in employment for the group with more than 4 years of tertiary education was also most evident in the years 1985 and 1986, while man-hours declined in 1987 and 1988.

White collar workers with secondary school constitute a relatively small share of the manhours in the fabricated metal industry. For this group, the number of manhours has increased by 68 percent during the period 1972 to 1990. As was the case for the other two groups of white collar workers, the growth was particularly strong in 1985 and 1986, while the number of man-hours has declined from 1986 to 1990.

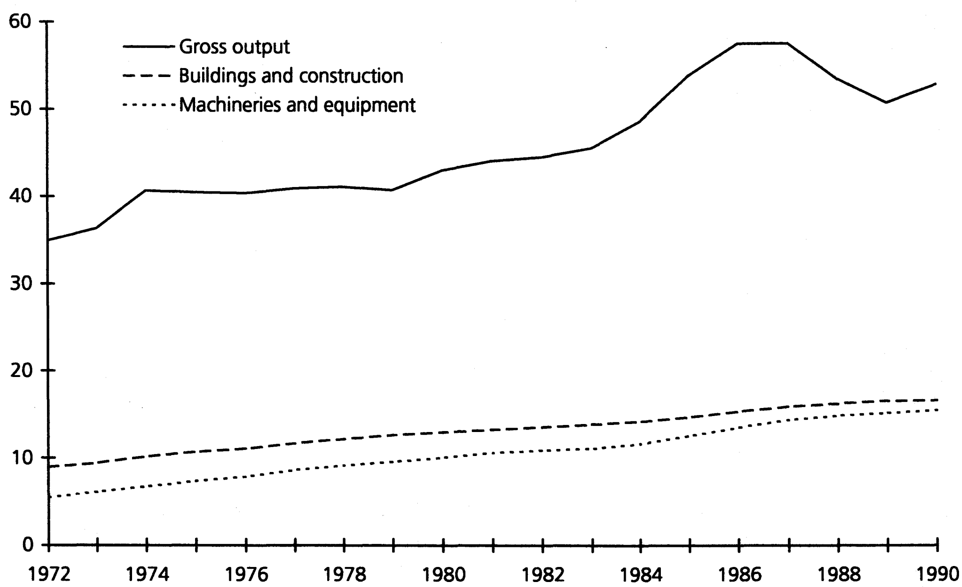
It would have been of interest to analyse the possibilities of substitution between all of these five groups. Since we for the moment only have access to annual data for the period 1972 to 1990 and few degrees of freedom as a result of this, it is not possible to carry through a general estimation procedure, and it is necessary to simplify. From figure 1, a possible simplification is to aggregate the three groups of white collar workers. This aggregation seems appropriate since these groups are relatively small and because their development has been fairly parallel. This fact may indicate that the possibilities of substitution are small. Since the shares of employment for the unskilled and skilled workers are relatively large compared to the other groups and show a totally different development, it is not appropriate to aggregate them with any of the other groups.

According to the theoretical discussion in section 2, relative wages may be an important explanatory variable when analysing the possibilities of substitution between different kinds of labour. Wages for the different groups relative to the unskilled were presented in figure 2.

We notice that these wage ratios have not changed much, indicating that changes in relative wages probably have not been very important when explaining the changes in the composition of employment over the depicted period.

Changes in production and the stock of capital may have influenced the composition of employment, and the development in gross output, the stock of buildings and construction and the stock of machineries and equipment in the fabricated metal industry is shown in figure 5.

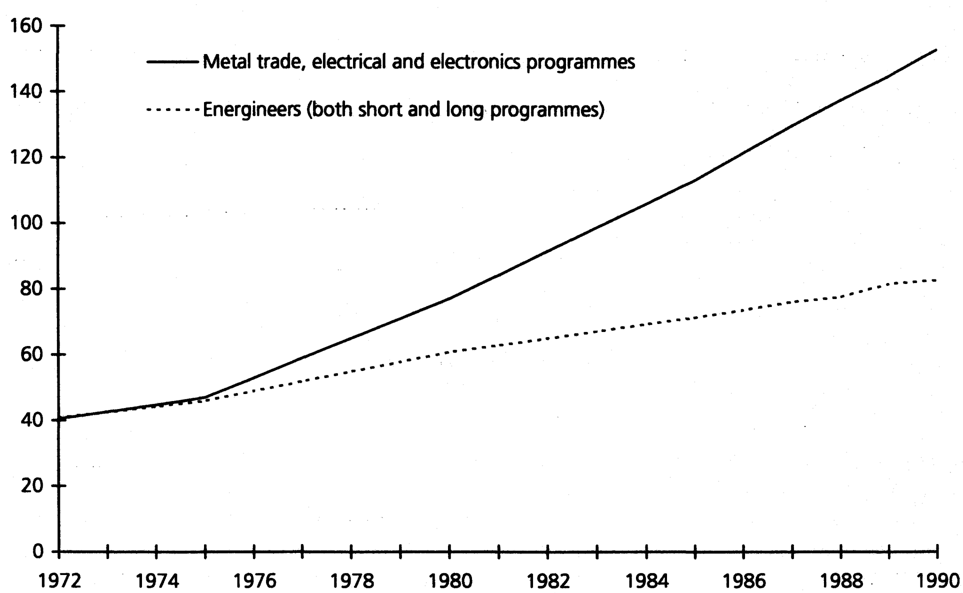
Figure 5. Gross output, stock of buildings and construction and stock of machineries and equipment in the fabricated metal industry. Billion kroner. Fixed 1991 prices.



We notice that the stock of buildings and construction and the stock of machineries and equipment have increased steadily over the period. The importance for the composition of employment will depend on whether there are complementarity or alternativity between the different educational groups and the two kinds of capital. The graph for gross output reflects the business cycles; a clear growth in 1972 - 1974, thereafter a weak development until 1983, a strong growth over the period 1984 - 1986 and then stagnation and decline until 1989. This development may have been of some importance when explaining the changes in the composition of labour, especially in the short-run as demand for unskilled labour may be more sensitive to changes in production than demand for skilled.

Since there has been a large shift in the composition of labour although relative wages have been almost constant, this may indicate that supply has been a limiting factor. This may especially be the case for skilled workers and white collar employees with higher education. A complicating element is that a specific kind of labour is used by several sectors. Apart from some kinds of education, mainly directed towards certain sectors, it makes no sence to talk about sector specific supply of labour. If there is lack of one category of labour, this may affect several sectors, and the analyses of actual employment in these sectors ought to be dealt with simultaneously. This may turn out to become a rather complex analysis, and it has been necessary to simplify in order to grasp the most important elements. The number of persons 16-66 years old with their highest completed education in the group metal trade, electrical and electronics programmes and the group of engineers (both short and long programmes) may be used as indicators for the supply of skilled workers and white collar employees with education relevant for the fabricated metal industry. These variables are included as additional explanatory factors in the empirical analysis according to the discussion in section 2.2. Figure 6 shows that these variables have increased substantially during the period 1972 to 1990.

Figure 6. Number of persons 16-66 years by education. 1000 persons



4. Empirical analysis

According to equation (3), demand for different kinds of labour constitutes a system of equations. In such a demand system, economic theory imposes restrictions across equations, and these restrictions ought to be taken into account. The full information maximum likelihood method (FIML) is therefore used.

With several explanatory variables and a general demand system for three kinds of labour, there are no degrees of freedom left with annual data from 1972 to 1990. Partial estimation of the three demand equations has thus been necessary to eliminate the less important variables and so increasing the degrees of freedom in the system of equations.

4.1. Partial estimations

It is reasonable to assume that the possibility for substitution with other categories of labour and other factors of production is largest for unskilled employees, and therefore a rather general demand equation has been estimated for this group. Both the wage level relative to the other two groups and the price of intermediate goods, gross output, the stock of buildings and construction, the stock of machinery and equipment and a term indicating technological progress (a linear trend) have been included. If supply of skilled workers has been scarce at the actual wages, unskilled workers may have been employed instead. In order to take this into consideration, the number of persons in working age with their highest completed education in metal trade, electrical and electronics programmes was included as an explanatory variable. For skilled workers and white collar employees, possibilities of substitution against each other and against intermediate goods were assumed away a priori in the partial estimations.

The three equations for the different kinds of labour were estimated separately as an error-correction model, using Ordinary least squares (OLS). The estimation results presented in appendix A indicate that gross output may be of importance both in the short- and the long-run for all groups, except for skilled workers, where no effect was found in the long-run. Further, a hypothesis claiming that the elasticity for the impact of gross output is equal to 1 in the long-run could not be rejected, indicating that employment and production, partially considered, may change equivalently in the long-run.

A negative trend was significant for all the three groups. The results also indicated that supply of persons with education in metal trade, electrical and electronics programmes is of importance for the observed man-hours done by skilled workers and that the supply of engineers is of importance for the observed man-hours done by white collars. In general, the stock of buildings and construction and the stock of machineries and equipment were of no importance, the only exception is the demand for skilled workers, where the stock of buildings and construction was significant. The elasticity was relatively large, and together with a large negative trend this may indicate some problems of multicollinearity.

For the unskilled workers, their wage level relative to the skilled workers was not significant, neither in the short-run nor in the long-run, while the coefficient of their wage level relative to white collar employees was significant in the short-run, but not in the long-run. For skilled workers, however, their wage level relative to the unskilled workers level was significant, both in the short- and long-run, while the wage level between white collars and unskilled was of no significance for the white collars. Since most of the wage coefficients were insignificant, this may be an indication of small possibilities of substitution. However, as the wage ratios have been fairly constant over the estimation period, this may have caused problems in getting precise estimates.

For the unskilled workers the price on intermediate goods relative to the unskilled's wage level was not significant neither in the short-run nor in the long-run. This variable was assumed away apriori for the skilled workers and the white collars.

4.2. Simultaneous estimation

Based on the results from the partial estimations, the demand system (3) is simplified as we have omitted the stock of machineries and equipment and the price on intermediate goods both in the short- and long-run. As intermediate goods are excluded from the analysis, each educational group's share of total labour costs is used as dependent variables. Production is omitted because of the assumption of constant returns to scale in the long-run, a restriction which was not rejected by the partial estimations. From the discussion in section 2.2, supply variables are included as additional explanatory variables. More specifically, the supply of skilled and white collars is included since a hypothesis claiming that there have been too few skilled persons and white collars may seem realistic. Finally, we have imposed the restriction $c_{UPS} = -c_{SPS}$ since an effect on demand for white collar employees as a result of a change in supply of skilled workers may seem unrealistic. By limiting the analysis to the three kinds of labour: unskilled (U), skilled workers (S) and white collar employees (W), the symmetry and homogeneity restrictions mean that c_{SU} is equal to c_{US} (symmetry), and c_{UW} and c_{SW} are, respectively, equal to $-(c_{UU} + c_{US})$ and $-(c_{US} + c_{SS})$ (homogeneity).

The adjustment to the long-run solution (which is conditional on the capital stock) may take time, and we have therefore used a general error-correction representation. Since the cost shares for the different educational groups always sum to 1, $\Sigma_i \Delta S_i$ will equal 0, and any of the three cost share equations may be expressed in terms of the other two by using adding-up conditions. This also means that the sum of the residuals for the three educational groups in the econometric specification equals zero, implying a singular and non-diagonal error covariance matrix. When estimating, one of the cost shares must therefore be omitted (see Anderson and Blundell (1982)), and we have chosen to leave out the white collar employees.

Because of the few degrees of freedom, we only include the current changes in the explanatory variables in the short-run part of the model. The following two simplified error-correction equations are the point of departure for the simultaneous estimation. Lower case indicate the natural logarithm of the variables (t = ln(TIME)).

$$(6)\ \Delta S_{i,t} = a_{iX}\Delta x_t + a_{iU}\Delta w_{U,t} + a_{iS}\Delta w_{S,t} + a_{iW}\Delta w_{W,t} + a_{iPS}\Delta PS_t + a_{iPW}\Delta PW_t -$$
$$b_{iU}(S_{U,t-1} - c_U - c_{UU}w_{U,t-1} - c_{US}w_{S,t-1} + (c_{UU} + c_{US})w_{W,t-1} - c_{UT}t_{t-1} -$$
$$c_{UPS}PS_{t-1} - c_{UPW}PW_{t-1} - c_{UCB}cb_{t-1}) - b_{iS}(S_{S,t-1} - c_S - c_{US}w_{U,t-1} - c_{SS}w_{S,t-1} + (c_{US} + c_{SS})w_{W,t-1}$$
$$-c_{ST}t_{t-1} - c_{SPS}PS_{t-1} - c_{SPW}PW_{t-1} - c_{SCB}cb_{t-1}) + u_{it}$$

i = U, S

Here, PS is the ratio between the number of persons educated in metal trade, electrical and electronics programmes and the total population in the group 16 - 66 years, PW is the ratio between the number of persons educated as engineers (both short and long programmes) and the total population in the group 16-66 years, CB is the stock of buildings and construction and u_{it} is the error-term. We assume that the explanatory variables are weakly exogenous in the cost share equations, and that the errors are normally distributed with mean zero, in addition to the following assumption:

$$E(u_t, u_s^{'}) = \begin{cases} \Sigma & for\ t = s \\ 0 & otherwise \end{cases}$$

where u_t is a vector at time t, containing the two errors u_{Gt} and u_{VFt}.

In order to estimate the two equations in (6), the one-stage procedure is generally recognised. The one-stage procedure means that both long-run and short-run coefficients are estimated simultaneously. Because of few degrees of freedom and almost constant relative wages, the one-stage approach turned out to be troublesome. There were severe problems with stability and convergence when simulating the two cost share equations from 1991 onwards, holding all the exogenous variables constant at their 1990 level. The elasticities of substitution, in addition to some of the trend and supply coefficients, were unreasonably large. We therefore chose a two-stage procedure, that is first estimating the two static, long-run equations and then using the lagged residuals as input when estimating the dynamic model, that is getting estimates for the short-run coefficients and the adjustment parameters. Draper and Manders (1996) have used such a two-stage procedure, but in addition re-estimated the long-run parameters in another round given the dynamic structure and repeating this procedure until convergence is obtained.

The estimation results from the two-stage procedure are presented in the first column of table B1 in appendix B. We first estimated the two static, long-run equations using FIML. As we could not use t-values or the likelihood ratio test since the variables probably are non-stationary and the estimators therefore had a non-standard distribution, see for instance Banerjee, Dolado, Galbraith and Hendry (1993), we looked at the values of the estimated coefficients in order to determine the omission of variables (variables with coefficients with wrong sign were omitted).

In the second stage we estimated the short-run coefficients and the adjustment parameters, using the lagged residuals from the first stage as variables. The calculated eigenvalues of the coefficient matrix of the two cost share variables now became 0.64 and 0.28, indicating a stable system. According to the estimation results, the stock of buildings and construction has no effect on any of the cost shares and wages for skilled and supply of engineers have no effect on the cost share for skilled in the long-run. Concerning the adjustment parameters and the other short-run effects, the deviation from the long-run relation for unskilled was omitted in the equation for skilled, in addition to wages for white collars and supply of engineers. In the final estimation result we also imposed the restriction $a_{UPS} = -a_{SPS}$ which was not rejected.

Because the cost shares must stay in the interval 0 to 1 also when the equations are used for projections outside the sample, we have found it more appropriate with a log-linear than a linear trend. In other words, the effect of the trend on the cost shares decreases over time. According to the simultaneous two-stage estimation, the partial effects of the trend from 1990 to 1991 implies a 0.15 percentage point decrease in the cost share for unskilled workers, a 0.11 percentage point increase in the cost share for skilled workers and a partial increase of 0.05 percentage point in the cost share for the white collars.

There are indications that there has been a structural break in the technological development, particularly in the US, over the 1980s, see OECD (1994). This technical change has been biased in favour of more highly educated persons. In order to investigate if this is the case in Norway, we introduced a dummy variable in the final estimation result for the two static, long-run equations. This dummy variable is 0 before 1984 and 1 from 1984 onwards (the chosen break point is a bit arbitrary), and is multiplied with the additional variable log(TIME). We can not rely on an ordinary Chow-test with the two-stage estimation method. Instead, large changes in the estimated elasticities and in the adjustment parameters when introducing the mentioned dummy variable may be an indication of a structural break in the technological development. The sign of the trend coefficients alters after the break point for all the three groups, but apparently in the wrong direction. The price elasticities are also somewhat altered, but the changes are, however, not very large (see table 1). From this exercise there are thus no indications of a shift in the technological progress in favour of more skilled and white collar workers relative to unskilled. However, the results are rather inconclusive as the change in the trend coefficients also may be influenced by other factors than the technological development.

The long-run Hicks-Allen partial elasticities of substitution and the wage elasticities are defined in equation (7)-(10), see Berndt and Wood (1975). The elasticities of substitution are given by:

$$(7)\ \sigma_{ij} = \frac{c_{ij}}{S_i \cdot S_j} + 1 \quad for\ i \neq j$$

and

$$(8)\ \sigma_{ii} = \frac{c_{ii} + S_i^2 - S_i}{S_i^2} \quad for\ all\ i.$$

The wage elasticities are given by:

(9) $\varepsilon_{ij} = S_j \sigma_{ij} \quad for\ i \neq j$

and

(10) $\varepsilon_{ii} = S_i \sigma_{ii} \quad for\ all\ i.$

The presented elasticities in table 1 are based on the cost share from the last year of observation, 1990, because this gives the most up-to-date figures. We also present the wage elasticities from the partial estimation in order to compare the results.

Table 1. Long-run Hicks-Allen partial elasticities of substitution and long-run own and cross price elasticities. Partial, two-stage and two-stage with break in the trend

Elasticities of substitution	Partial estimation	Two-stage	Two-stage with break in the trend
σ_{US}		2.99	2.09
σ_{UW}		1.65	0.47
σ_{SW}		-2.37	-0.84
Wage elasticities			
e_{UU}	0	-1.22	-0.67
e_{US}	0	0.77	0.54
e_{UW}	0	0.46	0.13
e_{SU}	3.07	1.40	0.98
e_{SS}	-3.07	-0.74	-0.74
e_{SW}	0[11]	-0.65	-0.23
e_{WU}	0	0.77	0.22
e_{WS}	0[11]	-0.61	-0.22
e_{WW}	0	-0.16	-0.004

[11] Assumed apriori.

We notice that the results from the simultaneous estimations indicate substitutability between unskilled and both skilled and white collar employees and complementarity between white collars and skilled. The elasticities of substitution from the two-stage estimation with break in the trend all have the same sign as those without break. The elasticities are, however, a bit smaller. The direct elasticities of wages have the correct sign (negative) in both the simultaneous estimations.

The results from table B1 further indicate that supply of skilled persons has an effect on the cost share for the unskilled and the skilled while the effect on the white collar's cost share is assumed away apriori. The supply of engineers is also found to have an effect on the cost share for unskilled and white collars, but no effect on the cost share for skilled. The estimated long-run coefficients from the simultaneous two-stage estimation without break in the trend indicate that when the number of persons with education in metal trade, electrical and electronics programmes increases with 1 percent, the cost share for the unskilled decreases with 0.42 percent and the cost share for the skilled increases with 0.76 percent. The values of the cost shares and the supply variables from the last year of observation, 1990, are used.

When the number of persons educated as engineers (both short and long programmes) increases with 1 percent, the cost share for white collars increases with 0.88 percent while the cost share for the unskilled decreases with 0.52 percent.

In order to investigate whether the size of the coefficients of the supply variables is appropriate or not, the shifts and the effects are converted into number of persons. A one percent increase in the number of persons educated in metal trade, electrical and electronics programmes means an increase of about 1500 persons with this education. We then take into account that only a fraction of these persons will get employed, about 1100 when using the labour force participation rate and the unemployment rate. These persons will then be spread over the different sectors using skilled persons with this type of education.

The cost share for the skilled increases with 0.76 percent. We look upon this as if the demand for man-hours from skilled persons increases with the same amount. Assuming that an employed person works 1600 man-hours a year, the increase in the cost share for the skilled is equivalent to an increase of about 140 persons or about 12 percent of the total employment increase of skilled persons. This corresponds quite well with the actual share of employed persons educated in metal trade, electrical and electronics programmes working in the fabricated metal industry which approximately is 14 percent.

An increase of about 1100 employed persons educated in metal trade, electrical and electronics programmes leads to a reduction of about 150 unskilled persons in the fabricated metal industry.

When the number of persons educated as engineers (both short and long programmes) increases with 1 percent, this is equivalent to an increase of about 600 employed persons with such an education. This leads to an increase in the employment of white collars with 130 persons in the fabricated metal industry, and a decrease in employment of unskilled persons with 180. This sector's share of the employment increase of white collars is 21 percent, while its share of the total employment of engineers is about 11 percent.

In figure C1, C2 and C3 in appendix C, the simulated (dynamic simulation of the whole model) developments of the two cost shares from the partial and simultaneous two-stage estimation without break in the trend are compared to the actual. The white collar employees' cost share is calculated using the adding-up conditions, while the simulated man-hours from the partial estimation are transformed into simulated cost shares.

From the figures we notice that the simulated cost shares from both the partial and the simultaneous estimation correspond quite well to the actual development although the simulated cost share from the simultaneous estimation procedure deviates a bit more than the simulated cost share from the partial one.

4.3. Decomposition of the actual development in the contribution from the different explanatory factors

In order to evaluate how important the different variables have been in explaining the development in the cost shares during the estimation period, we have decomposed the total change in the cost shares over the period 1973 to 1990 into effects from each of the explanatory variables. The results from the simultaneous two-stage estimation without break in the trend form the basis for this decomposition. First, we have simulated the cost shares over the period 1973 to 1990 using the historical data and the entire estimated model. Further, we have undertaken the same simulation, but this time holding a specific variable constant, letting all the other variables vary according to their historical development. The difference between these two simulations gives the impact of the specific variable being held constant.

Table 2. Explanation of the development in the cost share for the unskilled. Change in percentage points

Explanatory variables	1973-1980	1980-1985	1985-1990
Wages	0.8	0.6	-0.5
Production	-0.2	-0.8	1.3
Supply of skilled persons	-5.0	-4.5	-4.7
Supply of engineers	-5.1	-2.5	-2.7
Trend	-5.2	-1.9	-1.2
Cross-effects/dynamics	0.9	0	-0.1
Simulated development	-13.8	-9.1	-7.9
Unexplained	-0.6	0.9	0.7
Actual development	-14.4	-8.2	-7.2

Table 3. Explanation of the development in the cost share for the skilled. Change in percentage points

Explanatory variables	1973-1980	1980-1985	1985-1990
Wages	2.1	-1.7	0.7
Production	0.1	0.6	-0.9
Supply of skilled persons	4.9	4.5	4.7
Supply of engineers	0	0	0
Trend	3.6	1.3	0.8
Cross-effects/dynamics	-0.6	-0.1	0
Simulated development	10.1	4.6	5.3
Unexplained	0.2	-0.5	-0.3
Actual development	10.3	4.1	5.0

We notice that especially the supply variables have been important in explaining the development in the cost shares. The increase in supply of skilled persons has reduced the cost share of unskilled by approximately 5 percentage points each period and increased the cost share of skilled by approximately the same amount. Relative to the total simulated development the effect on the cost share for unskilled has become stronger for each period, while the effect on the cost share for skilled is especially strong in the second period (but also very important in the third). The increase in supply

Table 4. Explanation of the development in the cost share for the white collars. Change in percentage points

Explanatory variables	1973-1980	1980-1985	1985-1990
Wages	-2.8	1.1	-0.2
Production	0.1	0.2	-0.4
Supply of skilled persons	0.2	0	0
Supply of engineers	5.1	2.5	2.7
Trend	1.6	0.6	0.4
Cross-effects/dynamics	-0.5	0.1	0.1
Simulated development	3.7	4.5	2.6
Unexplained	0.4	-0.4	-0.3
Actual development	4.1	4.1	2.3

of engineers has especially reduced the cost share of unskilled in the first and third period (relatively speaking) and a bit less in the second one. This factor has also influenced the cost share of white collars, especially in the first and third period. It is assumed apriori that supply of engineers has no effect on the cost share of skilled. The effect of the trend variable is decrasing over time (absolutely speaking) due to the log-linear formulation. This holds for the relative development, too, with the exception of the effect on the white collars' cost share, where the trend variable explains a bit more in the third than in the second period. Wages only explain a minor part of the development in the cost share for unskilled, while they are of some importance in explaining the development in the other two cost shares in the first and second period. Production only affects cost shares in the short-run and is thus of minor importance.

Concluding remarks

Although the estimation results are quite sensitive to the chosen approach, the analysis indicates that supplies of skilled and engineers have been important variables in explaining the shift in the composition of the three kinds of labour in the Norwegian fabricated metal industry. Persons from these groups have been hired instead of unskilled when supply has increased, indicating that the wage and productivity differentials may not correspond. In addition, unskilled workers have been rationalized away as a result of technical progress. Relative wages have been almost constant and have been of minor importance. The results indicate substitutability between unskilled and both skilled and white collars and complementarity between white collars and skilled.

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Results from the partial estimations

The following three error-correction equations are the point of departure for the partial estimations. Lower case indicate the natural logarithm of the variables, and CM is the stock of machineries and equipment.

$$\Delta l_{U,t} = d_0 + d_1 \Delta x_t + d_2 \Delta (w_U / w_S)_t + d_3 \Delta (w_U / w_W)_t + d_4 \Delta (w_U / p_M)_t + d_5 \Delta ps_t$$
$$+ d_6 l_{U,t-1} + d_7 x_{t-1} + d_8 (w_U / w_S)_{t-1} + d_9 (w_U / w_W)_{t-1} + d_{10} (w_U / p_M) + d_{11} cb_{t-1}$$
$$+ d_{12} cm_{t-1} + d_{13} TIME + d_{14} ps_{t-1}$$

$$\Delta l_{S,t} = e_0 + e_1 \Delta x_t + e_2 \Delta (w_S / w_U)_t + e_5 \Delta ps_t + e_6 l_{S,t-1} + e_7 x_{t-1} + e_8 (w_S / w_U)_{t-1}$$
$$e_{11} cb_{t-1} + e_{12} cm_{t-1} + e_{13} TIME + e_{14} ps_{t-1}$$

$$\Delta l_{W,t} = f_0 + f_1 \Delta x_t + f_3 \Delta (w_W / w_U)_t + f_5 \Delta pw_t + f_6 l_{W,t-1} + f_7 x_{t-1} + f_9 (w_W / w_U)_{t-1}$$
$$+ f_{11} cb_{t-1} + f_{12} cm_{t-1} + f_{13} TIME + f_{14} pw_{t-1}$$

Table A1. Results from the partial estimations (t-values in parentheses)

Coefficients	Unskilled	Skilled	White collars
Long-run coefficients			
Constant	-4.66 (-5.80)	-35.17 (-4.19)	-24.03 (-5.30)
Output	0.64 (5.78)	0	0.89 (5.05)
Relative wages			
d_8, e_8, f_8	0	-1.41 (-2.04)	0[12]
d_9, e_9, f_9	0	0[12]	0
Own wage/price intermed.	0	0[12]	0[12]
Buildings	0	2.51 (4.69)	0
Machineries	0	0	0
Trend	-0.04 (-5.98)	-0.12 (-3.70)	-0.06 (-5.40)
Supply, resp. skilled, white collars	0	0.74 (2.40)	1.49 (5.22)
Adjustment parameters			
d_6, e_6, f_6	-0.64 (-5.78)	-0.46 (-3.62)	-0.89 (-5.05)
Short-run coefficients			
Output	0.57 (9.18)	0.70 (4.16)	0.61 (7.38)
Relative wages			
d_2, e_2, f_2	0	-2.02 (-2.26)	0[12]
d_3, e_3, f_3	-0.32 (-1.66)	0[12]	0
Own wage/price intermed.	0	0[12]	0[12]
Supply	0	0	0
Statistics			
R^2	0.93	0.94	0.91
CR^2	0.91	0.89	0.88
SER	0.012	0.021	0.015

[12] Assumed apriori.

Results from the simultaneous estimations

Table B1. Results from the simultaneous two-stage and two-stage with break in the trend estimation (t-values in parentheses)

Coefficient	Two-stage	Two-stage with break in the trend
Long-run coefficients		
c_U	0.87	1.05
c_S	0.14	0.02
c_W	-1.01	-1.07
c_{UU}	-0.32	-0.06
$c_{SU} = c_{US}$	0.24	0.13
$c_{WU} = c_{UW}$	0.08	-0.07
c_{SS}	0	0
$c_{WS} = c_{SW}$	-0.24	-0.13
c_{WW}	0.15	0.20
c_{UPS} ($-c_{SPS}$)	-3.53	-6.20
c_{WPS}	0[13]	0[13]
c_{UPW}	-8.15	-9.85
c_{SPW}	0	0
c_{WPW}	8.15	9.85
c_{UT}	-0.03	
c_{UT} (1972-1983)		-0.01
c_{UT} (1984-1990)		0.10
c_{ST}	0.02	
c_{ST} (1972-1983)		0.01
c_{ST} (1984-1990)		-0.09
c_{WT}	0.01	
c_{WT} (1972-1983)		0.003
c_{WT} (1984-1990)		-0.01
$c_{UCB} = c_{SCB} = c_{WCB}$	0	0
Adjustment parameters		
b_{UU}	0.72 (2.66)	0.61 (2.17)
b_{US}	0.58 (1.53)	0.58 (1.04)
b_{SU}	0	0
b_{SS}	0.36 (4.29)	0.20 (0.60)
b_{WU}	-0.72 (-2.66)	-0.61 (-2.17)
b_{WS}	-0.95 (-2.58)	-0.78 (-1.87)

[13] Assumed apriori.

Short-run coefficients		
a_{UU}	0.53 (3.34)	0.59 (2.26)
a_{SU}	-0.47 (-4.50)	-0.45 (-2.05)
a_{WU}	-0.06 (0.63)	-0.14 (-1.21)
a_{US}	-0.38 (-2.78)	-0.43 (-1.81)
a_{SS}	0.46 (4.85)	0.45 (2.27)
a_{WS}	-0.08 (1.06)	-0.02 (-0.20)
a_{UW}	-0.14 (-3.41)	-0.16 (-3.98)
a_{SW}	0	0
a_{WW}	0.14 (3.41)	0.16 (3.98)
a_{UX}	-0.07 (-2.46)	-0.04 (-1.32)
a_{SX}	0.06 (2.94)	0.02 (0.88)
a_{WX}	0.02 (1.16)	0.02 (1.25)
a_{UPS}	-4.59 (-7.56)	-4.56 (-4.45)
a_{SPS}	4.59 (7.56)	4.56 (4.45)
a_{WPS}	0[14]	0[14]
a_{UPW}	-7.89 (-5.40)	-8.07 (-4.98)
a_{SPW}	0	0
a_{WPW}	7.89 (5.40)	8.07 (4.98)
Statistics		
R^2	0.64 (U) 0.71 (S)	0.50 (U) 0.40 (S)
CR^2	0.38 (U) 0.62 (S)	0.16 (U) 0.22 (S)
SER	0.006 (U) 0.003 (S)	0.006 (U) 0.005 (S)

The coefficients in the equation for the cost share of white collar employees are found using the adding-up conditions mentioned earlier.

All of the adding-up conditions are linear, and we have therefore calculated these coefficients' standard deviations by utilizing the variance formula for a linear combination of coefficients[15].

[14] This was imposed as a restriction in the final estimation result and was not rejected.

[15] For example: $a_{WU} = -a_{UU} - a_{SU}$, the variance of a_{WU} is then equal to $var(a_{UU}) + var(a_{SU}) + 2cov(a_{UU}, a_{SU})$.

Actual and simulated development in cost shares

Figure C1. Actual and simulated development in the cost share for unskilled workers. Partial and simultaneous two-stage estimation without break in the trend

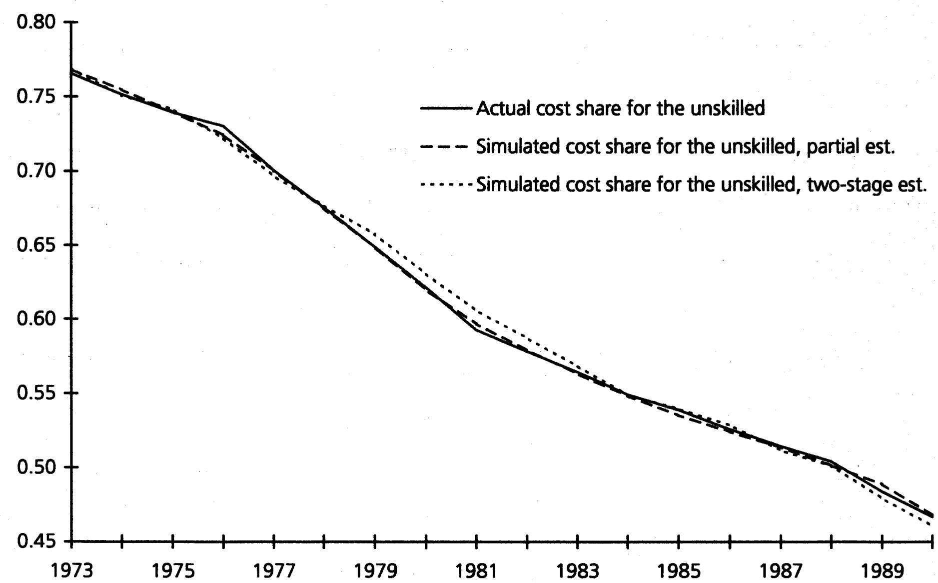


Figure C2. Actual and simulated development in the cost share for skilled workers. Partial and simultaneous two-stage estimation without break in the trend

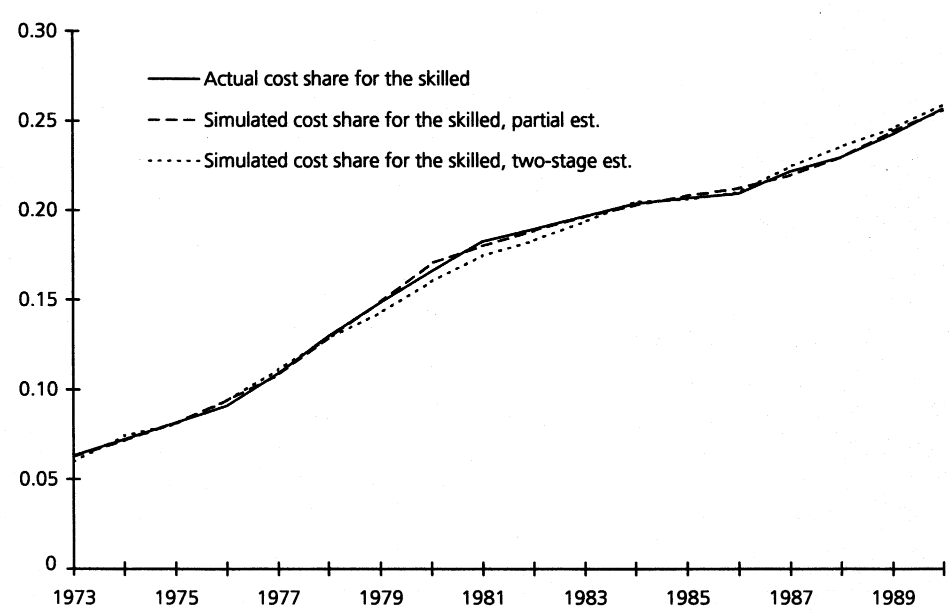
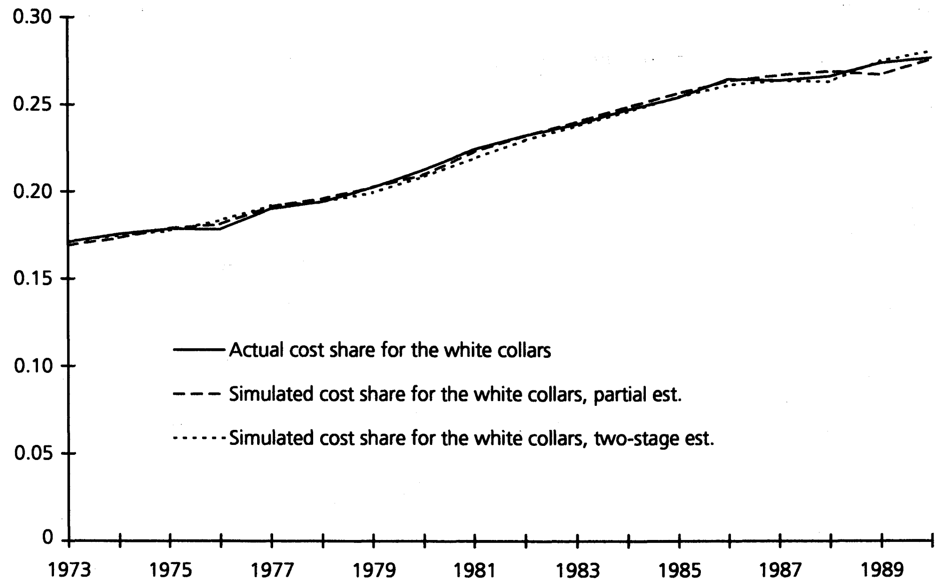


Figure C3. Actual and simulated development in the cost share for white collar employees. Partial and simultaneous two-stage estimation without break in the trend



Definition of variables

- L_i is the number of man-hours for educational group i consistent with the Norwegian National Accounts (NA)
- W_i is wages per man-hour for group i (consistent with NA)
- P_M is the price of intermediate goods (NA)
- X is gross output (NA)
- CB is the stock of buildings and construction (NA)
- CM is the stock of machineries and equipment (NA)
- TIME is a trend representing technological progress
- PS is the ratio between the number of persons educated in metal trade, electrical and electronics programmes and the total population in the group 16 - 66 years from the Norwegian population statistics (P)
- PW is the ratio between the number of persons educated as engineers (both short and long programmes) and the total population in the group 16-66 years (P)

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