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Explaining the change in skill structure of labour demand in Norwegian manufacturing

Abstract:
In most OECD-countries, labour demand has shifted from unskilled to skilled over time. Many analyses of this phenomenon focus on either the effect of technical change, capital-skill complementarity or labour-labour substitution. We present a more general analysis of labour demand in Norwegian manufacturing, and estimate a multivariate error-correction model of the cost-shares of skilled and unskilled labour, materials and energy on industry-level panel data. The results show that skilled-biased technical change, primarily due to a positive effect on skilled labour and less due to a negative effect on unskilled labour, as well as labour-labour substitution and capital stock growth are important for explaining the shift in Norwegian labour demand. Of minor importance is also non-homotheticity.

Keywords: Heterogeneous labour; Dynamic factor demand; Panel data

JEL classification: C33; E23

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1. Introduction

In Norway, as in most OECD-countries, the skill structure of labour demand has shifted in favour of skilled workers over the last decades. In the literature, two main hypotheses have been put forward to explain this change in labour demand; (i) the skilled-biased technical change hypothesis, and (ii) the increased international competition hypothesis, see for example Hamermesh (1993), Wood (1994), Krugman (1995) and Berman et al. (1998).

According to the first hypothesis, the shift in relative labour demand is largely due to a disproportional change in productivity caused by non-neutral technical change; skilled labour has increased their productivity more than unskilled. Such skilled-biased technical change may reflect both skilled-labour using and unskilled-labour saving processes, which in general are assumed to be a result of changes in production techniques, organisation and capital structure. It is also argued that the introduction and utilisation of new technology is conditioned on the presence of skilled labour and at the same time makes unskilled labour redundant. This implies that skilled labour and new technology are complements, while unskilled labour and new technology are substitutes. Because of the wide diffusion and adoption of new technology, particularly new information technology, one expects labour demand to shift within a wide range of industries if the skilled-biased technical change hypothesis is important. This is referred to as *within industry* changes.

The alternative hypothesis asserts that the relative increase in skilled-labour demand within OECD-countries is due to changes in the domestic industry structure, which in turn is a result of increased international competition. Growth in manufactured exports from low-wage, newly and less industrialised countries has spurred a reallocation of resources away from industries that use relatively much unskilled labour, and gained growth in industries that use relatively much skilled labour. This hypothesis predicts that the observed shift in relative labour demand is largely due to these *between industry* changes.

During the last years, a large number of analyses have concluded that most of the observed change in relative labour demand in OECD-countries is due to within industry rather than between industry changes. Positive effects on the demand for skilled labour from increased computerisation or R&D intensity are also found. In general, this is assumed to support the skilled-biased technical change and capital-skill complementarity hypotheses, see Bound and Johnson (1992), Autor et al. (1998), Berman et al. (1998), Machin and Van Reenen (1998), Kahn (1998), Kahn and Lim (1998) and Salvanes and Førre (1999).

The share of skilled workers in Norwegian manufacturing, measured in number of man-hours relative to the total number of man-hours, has increased from below 10 per cent in 1972 to 42 per cent in 1995. A simple shift-share analysis[1] shows that as much as 98 per cent of this increase is due to within industry changes, and hence only 2 per cent of the increase is explained by changes in industry structure. Although the within industry effect is very high, the result is in line with what is found for other OECD-countries, see Autor et al. (1998) and Berman et al. (1998). However, even if this gives support to the skilled-biased technical change hypothesis, the observed within industry changes are probably due to several factors. To identify the effect of technical change on labour demand, it is in general necessary to take all factors of importance into account. One additional explanation to the observed shift in relative labour demand is probably labour-labour substitution due to changes in relative wages. The wage inequality in Norway has in fact been decreasing during the last decades, see Appendix 2 and also Aaberge et al. (2000) and Hægeland et al. (1999). By contrast, in United States and United Kingdom, wage inequality has increased, cf. Card et al. (1999) and Nickell and Bell (1995) among others.

Although there is a growing body of articles that study the demand for heterogeneous labour using both macro and micro data[2], this analysis is more general than most others and studies the influence of a number of factors on the demand for skilled and unskilled labour. Industry-level panel data from Norwegian manufacturing is applied, and labour is classified as skilled or unskilled according to their highest formal education. Our data do not include information on work experience, which may - to some degree - substitute for formal education. The important issue for this analysis is how employers consider education vis-à-vis experience, however, and arguments can be raised that support our education-based classification. Education signals that a person is ambitious and that he or she is capable of both acquiring new skills and functioning in a system with obligations. Hence, as a signal, education is more important than experience. Furthermore, if it takes longer time to achieve the same level of qualifications by work experience than by education, and age counts negatively on its own, this adds to the argument that education is more important than experience.

The translog cost function suggested by Christensen et al. (1971, 1973) is applied, and a multivariate error-correction model of the cost shares of two types of labour, materials and

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[1] The *shift* in the *share* of skilled man-hours of total man-hours is decomposed into two parts: one that shows the importance of shifts in the labour composition within industries, and one that shows the importance of changes in the composition of industries with different skilled-labour intensities. Our calculations rely on the framework used by Autor et al. (1998) and Berman et al. (1998) among others.

[2] For a survey of analyses using micro-data, see Chennells and Van Reenen (1999).

energy is estimated, cf. Anderson and Blundell (1982). Few analyses have treated the demand for heterogeneous labour, materials and energy within the context of a dynamic factor demand system with theory consistent cross-equation restrictions embedded, see, however, Falk and Koebel (1999) and Fitzenberger (1999).

The chosen framework enables us to consider both mutual labour substitution and labour substitution with other variable inputs. In addition, non-neutral technical change is specified in a general way, so that both skilled-labour using and unskilled-labour saving technical change are taken into account. Furthermore, the importance of growth in capital stock is studied, and homotheticity of the production function is tested rather than imposed à priori. The importance of industry structure for labour demand is also emphasised, and the general model includes both a fixed industry effect and heterogeneous coefficients, i.e. a fixed but heterogeneous coefficient specification on capital, output and technical change. Capital is assumed to be quasi-fixed, which implies that, in this analysis, the "long-run" has a partial-equilibrium interpretation.

Section 2 presents the econometric model, and the empirical results are presented in section 3. The main conclusions are summarised in section 4.

2. The cost-share equation system

The main objective of this analysis is to compare the substitution properties of skilled and unskilled labour, and to test if the technical progress is biased or neutral. We also focus on the importance of production function homotheticity, capital growth and industry structure for labour demand. The translog cost function suggested by Christensen et al. (1971, 1973) is well suited to our purpose, since it does not impose a priori restrictions on the elasticities of substitution, and the technological process can be specified in a general manner. In addition, the translog cost function is flexible and can be interpreted as a quadratic approximation to a general continuous twice-differentiable cost function. A disadvantage of this functional form is that the area where the regularity conditions are met can be narrow, cf. Salvanes and Tjøtta (1998) among others. We check, however, the "concavity in prices" condition, cf. Jorgenson (1986).

The static (and deterministic) translog cost function with two labour categories; skilled (S) and unskilled (U), materials (M) and energy (E) as variable inputs is given in equation (1). Employees with a university or higher technical degree or with a diploma from a vocational school are classified as skilled, while employees with only compulsory school or high school are classified as unskilled. Labour is measured in man-hours. Capital (K) is treated as a predetermined variable, and the four variable inputs are adjusted conditionally on the capital stock.[3] Subscript f denotes industry. (The industry codes are defined in Table A1 in Appendix 1.) The coefficients α_{if}, γ_{iXf}, γ_{iKf}, and $\gamma_{i\tau f}$ are industry-specific in our general model. The remaining coefficients are assumed to be constant across industries.[4] The symbol Σ_i implies the sum over all variable inputs.

$$
\begin{aligned}
(1)\ \ln C_f = {} & \gamma_0 + \Sigma_i\, \alpha_{if} \ln Q_{if} + 1/2\, \Sigma_i \Sigma_j\, \beta_{ij} \ln Q_{if} \ln Q_{jf} + \gamma_X \ln X_f + 1/2\, \gamma_{XX} (\ln X_f)^2 \\
& + \Sigma_i\, \gamma_{iXf} \ln Q_{if} \ln X_f + \gamma_K \ln K_f + 1/2\, \gamma_{KK} (\ln K_f)^2 + \Sigma_i\, \gamma_{iKf} \ln Q_{if} \ln K_f \\
& + \gamma_{XK} \ln X_f \ln K_f + \gamma_\tau\, \tau + 1/2\, \gamma_{\tau\tau}\, \tau^2 + \Sigma_i\, \gamma_{i\tau f} \ln Q_{if}\, \tau + \gamma_{X\tau} \ln X_f\, \tau + \gamma_{K\tau} \ln K_f\, \tau \\
& \qquad i,j = S,U,M,E; \quad f \in \{15,25,34,37,43,45\}
\end{aligned}
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[3] Initially, the model was specified with two capital categories: Buildings, structures and transport equipment as one category and Machinery as a second. Computers, which incorporate new technology, are included in Machinery. We wanted to test if Machinery and Buildings affected labour demand differently and to see if we could find support for the hypothesis that skilled labour is complementary to new technologies. This approach gave implausible results, probably because of strong multicollinearity between the two capital categories. The within industrial correlation coefficient is as high as 0.97-0.98 for most industries.

[4] For simplicity, coefficients that do not enter the estimated cost-share equation system (presented later), i.e. coefficients that do not include *i* in its subscript, are specified as identical across industries in eq. (1).

$$(2)\ C_f = \Sigma_i\, Q_{if} \cdot V_{if} \qquad i=S,U,M,E; \quad f \in \{15,25,34,37,43,45\}$$

where C_f represents total variable costs of industry f; Q_{if} is the industry specific price of input i; V_{if} is the quantity of input i used by industry f; X_f is real gross output of industry f; K_f is the real capital stock in industry f; τ is a deterministic time trend intended to proxy the general level of technology.

By assuming price taking behaviour in factor markets and applying Shephard's lemma, we obtain the cost-share (S_{if}) equations in (3).

$$(3)\ S_{if} = \partial \ln C_f / \partial \ln Q_{if} = (Q_{if} \cdot V_{if})/C_f = \alpha_{if} + \Sigma_j\, \beta_{ij} \ln Q_{jf} + \gamma_{iXf} \ln X_f + \gamma_{iKf} \ln K_f + \gamma_{i\tau f}\, \tau$$
$$i,j=S,U,M,E; \quad f \in \{15,25,34,37,43,45\}$$

The cost-share equations include fixed effects, i.e. industry-specific intercepts, which capture permanent differences in technology across industries. In Norwegian manufacturing, growth in aggregate output is largely due to growth in the average output per plant at the micro level and less due to growth in the number of plants. In fact, in several industries the number of plants declines over time. Since growth in aggregate output is not a result of replications of a "standard" plant, we test rather than impose the restriction that the production functions are homothetic. Furthermore, because the growth process varies across industries, the output coefficient is industry specific in the general model.

The motivation for the industry specific capital coefficient is that the capital intensity and structure vary in important ways across industries, largely do to differences in composition of buildings, structures, machinery and transport equipment. This might influence the cost shares of variable inputs. The trend variable is assumed to capture technical change, and the industry specific trend coefficient is included to test if the effect of technical progress varies. Furthermore, if skilled-biased technical change - at least to some degree - is a response to increased international competition from less and newly developed countries, this is an additional argument for including industry specific trend coefficients, since the degree of competition varies.

The price coefficients are specified as identical across industries in our general model. Due to a degree of freedom problem, it is imprudent to increase the number of coefficients to be estimated substantially, and we are forced to put some restrictions on the coefficients across industries. Calculated price elasticities, formulas will be shown later, depend on both estimated coefficients and cost shares, and the latter element introduces variation in these elasticities both across industries and over time. A second argument for choosing common price coefficients, is that restrictions to avoid a violation of the "concavity in prices" condition may be easier to impose.

The static model presented above assumes that each industry produces any output level in a cost-efficient manner, and that costs are minimised with respect to the input mix given factor prices, output, the capital stock and technology. However, due to adjustment costs and incomplete information, for example, factor adjustment is not necessarily instantaneous, and economic agents will not always be on these cost-share schedules. To introduce short-run disequilibrium factor adjustment, we apply the multivariate error-correction model suggested by Anderson and Blundell (1982).[5]

The multivariate error-correction representation of (3) is given in (4). For convenience, we present the model in vector form. Our most general model includes all variables, with the exception of the trend, at t and t-1.

(4) $\Delta S_{ft} = B\Delta Z^{*}_{ft} - D[S_{f,t-1} - \Pi(\theta_f)Z_{f,t-1}] + u_{ft}$,

where Δ is the first difference operator, S_{ft} is a vector of industry-specific cost shares, and Z_{ft} is a vector of regressors that includes the logarithm of input prices, output, the capital stock (at the beginning of the period), the trend variable and an intercept. Z_{ft}^{*} represents Z_{ft} with the trend variable and intercept excluded. B is the short-run coefficient matrix and D is the speed of adjustment matrix, both of suitable dimensions. $\Pi(\theta_f)$ is a matrix function of the long-run coefficients, θ_f, i.e. the coefficients in (3). u_{ft} is a vector of genuine errors of industry f in year t.

Because the cost shares always sum to unity, that is $\Sigma_i S_{ift} = 1$ and hence $\Sigma_i \Delta S_{ift} = 0$, any cost-share equation can be expressed in terms of the other equations by using the adding up restrictions (given in Table 2.1). For each industry, the errors in the four cost-share equations must add to zero in each year, which implies a singular error-covariance matrix. Estimation may proceed with the deletion of one equation, cf. Anderson and Blundell (1982), who generalise the invariance proposition of Berndt and Savin (1975) as far as the long-run coefficients are concerned. The general system that is estimated is given in (5), and a typical equation is given in

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[5] An alternative way to introduce dynamic factor demands in the literature is to specify and include costs of adjustment from changes in quasi-fixed inputs as explicit processes. For a survey of this field, see Jorgenson (1986), see also Mahmud et al. (1987) and Gordon (1992).

(6). Let S_f^n, u_f^n and $\Pi^n(\theta_f)$ denote the vectors S_f and u_f and the matrix $\Pi(\theta_f)$ with the last row deleted, respectively. I.e., we exclude the cost-share equation for energy.

$$(5)\ \Delta S^n_{ft} = B^n \Delta Z^*_{ft} - D^n[S^n_{f,t-1} - \Pi^n(\theta_f) Z_{f,t-1}] + u^n_{ft}$$

$$\begin{aligned}(6)\ \Delta S_{ift} = {} & b_{iS}\,\Delta \ln Q_{Sft} + b_{iU}\,\Delta \ln Q_{Uft} + b_{iM}\,\Delta \ln Q_{Mft} + b_{iE}\,\Delta \ln Q_{Eft} + b_{iX}\,\Delta \ln X_{ft} + b_{iK}\,\Delta \ln K_{ft} \\ & - d_{iS}\,(S_{Sf,t-1} - \alpha_{Sf} - \beta_{SS} \ln Q_{Sf,t-1} - \beta_{SU} \ln Q_{Uf,t-1} - \beta_{SM} \ln Q_{Mf,t-1} - \beta_{SE} \ln Q_{Ef,t-1} \\ & - \gamma_{SXf} \ln X_{f,t-1} - \gamma_{SKf} \ln K_{f,t-1} - \gamma_{S\tau f}\,\tau_{t-1}) \\ & - d_{iU}\,(S_{Uf,t-1} - \alpha_{Uf} - \beta_{US} \ln Q_{Sf,t-1} - \beta_{UU} \ln Q_{Uf,t-1} - \beta_{UM} \ln Q_{Mf,t-1} - \beta_{UE} \ln Q_{Ef,t-1} \\ & - \gamma_{UXf} \ln X_{f,t-1} - \gamma_{UKf} \ln K_{f,t-1} - \gamma_{U\tau f}\,\tau_{t-1}) \\ & - d_{iM}\,(S_{Mf,t-1} - \alpha_{Mf} - \beta_{MS} \ln Q_{Sf,t-1} - \beta_{MU} \ln Q_{Uf,t-1} - \beta_{MM} \ln Q_{Mf,t-1} - \beta_{ME} \ln Q_{Ef,t-1} \\ & - \gamma_{MXf} \ln X_{f,t-1} - \gamma_{MKf} \ln K_{f,t-1} - \gamma_{M\tau f}\,\tau_{t-1}) + u_{ift} \\ & \qquad\qquad\qquad\qquad i=S,U,M, \quad f \in \{15,25,34,37,43,45\}\end{aligned}$$

Theory requires the cost-share equations in (6) to be homogeneous of degree zero in input prices and the cross-price effects to be symmetric in the long-run. These theoretical restrictions, in addition to the adding up conditions, see Table 2.1, are imposed on the general model that we estimate. We make the following assumptions about the (3×1)-vector u^n_{ft}

$$u^n_{ft} = [u_{Sft}, u_{Uft}, u_{Mft}]^{/} \sim \text{NIID}\,[0, \Omega], \qquad \text{for all } t \text{ and } f.$$

Beyond symmetry, there are no restrictions imposed on the covariance matrix, Ω. The genuine errors are assumed to be homoskedastic across industries and not autocorrelated within industries. At the outset we assume that all prices, output and the capital stock are weakly exogenous. However, we test the weak exogeneity assumption on wages and output at a later stage.

The long-run own- and cross-price elasticities of factor demand are given below. These elasticities are defined as the Slutsky analogues, i.e. as output-constrained price elasticities of input quantities. Grant (1993) shows that the elasticities of substitution in the translog function case may be evaluated at any expansion point, including points of sample means, as long as the restrictions of Slutsky-symmetry and homogeneity hold, cf. Table 2.1. The cross-price elasticities are in general not symmetric.

$$\varepsilon_{ijf} = \beta_{ij} / S_{if} + S_{jf} \qquad \text{for } i \neq j$$

$$\varepsilon_{iif} = \beta_{ii} / S_{if} + S_{if} - 1 \qquad \text{for all } i.$$

There are a number of hypotheses concerning the properties of the production function that can be tested on the general model. There is no natural order in which to test these hypotheses, and we are forced to design a sequence a priori that may influence the specification of the maintained model. We check the robustness of the results by testing various restrictions at different steps in the chosen route, however. In Table 2.1, coefficient restrictions are sorted in three categories. Restrictions due to the adding up condition and theory predictions, which are imposed on the model a priori, are given in the upper part of the table. Testable restrictions on the short-run part of the model, inclusive the adjustment process, are given in the second part of the table, while restrictions on the long-run part of the model are given in the third part of the table. With respect to the last category, not all possible and tested restrictions are outlined.

Table 2.1. Coefficient restrictions due to the adding up condition, theoretical predictions, simplifications of the dynamic process and hypotheses with respect to the long-run part of the model[a]

$\Sigma_i \alpha_{if} = 1$	$\forall$ f	Adding up condition
$\Sigma_i \beta_{ij} = 0$	$\forall$ j	Adding up condition
$\Sigma_i \gamma_{ilf} = 0$		Adding up condition
$\Sigma_j \beta_{ij} = 0$	$\forall$ i	Price homogeneity
$\beta_{ij} = \beta_{ji}$	$\forall$i,j; i$\neq$j	Symmetry
$b_{ij} = 0$; $b_{il} = 0$		Zero restrictions on short-run effects
$d_{ii} = d$	$\forall$i	Simplified adjustment process
$d_{ij} = 0$	$\forall$i,j; i$\neq$j	
$\gamma_{ilf} = \gamma_{il}$	$\forall$ f	Industry invariant coefficient on variable l
$\gamma_{ilf} = 0$		The cost share of input i is independent of the level of variable l
$\gamma_{iXf} = 0$	$\forall$ i	Homotheticity
$\gamma_{i\tau f} = 0$	$\forall$ i	Hicks neutrality
$\beta_{ij} = 0$	$\forall$ i,j	Zero price effects

[a] i,j = S,U,M,E; l = X,τ,K; f = 15,25,34,37,43,45.

We are primarily concerned about the long-run features of the model, and we start by reducing the model with respect to short-run effects, i.e. insignificant short-run coefficients (b_{ij}) are restricted to zero. Then we continue by testing various restrictions on the output, trend and capital coefficients, both zero restrictions and the restriction that the coefficients are common to all or some industries. Finally we see if we can simplify the adjustment process (d_{ij}).

If all cost shares are independent of the output level, we conclude that the production technology is homothetic, and factor ratios remain constant when the level of output changes. Homotheticity in addition to the absence of price effects imply a Cobb-Douglas production technology. As in Jorgenson (1986), we define a positive (negative) effect of output growth on a cost share as a positive (negative) scale bias.

We are particularly interested in testing whether technical progress is Hicks neutral or biased in favour of skilled labour. Technical change is neutral if it leaves cost shares, and hence input-ratios, unchanged when relative factor prices, the output level and the capital stock are constant. If technical change increases the relative cost-shares between skilled and unskilled, i.e. if

$$\partial(S_{Sf}/S_{Uf})/\partial\tau = (\gamma_{S\tau f} \cdot S_{Uf} - \gamma_{U\tau f} \cdot S_{Sf})/(S_{Uf})^2 > 0,$$

we define this as skilled-biased technical change. Hence, if $\gamma_{S\tau f} > 0$ and $\gamma_{U\tau f} < 0$, or if $\gamma_{S\tau f} > \gamma_{U\tau f} > 0$ and $S_{Sf} < S_{Uf}$, these are sufficient conditions for skilled-biased technical change. We also denote the technology as input i using or saving dependent on whether $\gamma_{i\tau f} > 0$ or $\gamma_{i\tau f} < 0$. This is consistent with the terminology in Fitzenberger (1999).

Within the chosen framework, we can also study the effect on relative labour demand from changes in the capital stock. If $\gamma_{SKf} > 0$ and $\gamma_{UKf} < 0$, or if $\gamma_{SKf} > \gamma_{UKf} > 0$ and $S_{Sf} < S_{Uf}$, the skilled-unskilled labour ratio increases with capital stock. If $\gamma_{SKf} = \gamma_{UKf} = 0$, the two labour cost-shares are independent of the capacity.

3. Empirical results

We now present the results from estimating the dynamic system (6). The cost-share equation for energy is omitted. We use industry-level panel data from Norwegian national accounts in addition to data on man-hours, wages and education provided by Statistics Norway. Our panel includes six industries with annual observations over the period 1972-1995. For estimation purposes we construct synthetic time series by stacking time series of the different industries. If Y_f denotes a column-vector containing all the data on variable Y in industry f, the stacked vector is simply obtained by $Y^* = vec(Y_{15},Y_{25},Y_{34},Y_{37},Y_{43},Y_{45})$, where *vec* denotes the column-stacking operator. Since the model specification includes fixed heterogeneity across industries, we need to introduce industry specific dummy variables due to the stacking of the data. The variables are defined in Appendix 1, while Appendix 2 gives graphs of some important variables.

Maximum likelihood estimation of the dynamic cost-share equation system is implemented by using the LSQ-procedure in TSP 4.3 [cf. Hall (1996)]. This routine is convenient in our situation with non-linearity in coefficients as well as cross-equation coefficient restrictions. To obtain maximum likelihood estimates of the coefficients in the systematic part of the model, we have to update the estimated covariance matrix of the genuine errors until convergence, cf. Berndt et al. (1974). The likelihood ratio test (LR-test) is applied to test coefficient restrictions.

Table 3.1 gives overall statistics of the cost shares of the variable inputs in Norwegian manufacturing. According to the empirical means, the input share of materials is well above the other variable inputs, and the cost share of skilled labour is only half of that of unskilled labour. However, while the average cost share was 0.040 for skilled and 0.224 for unskilled labour in 1972, by 1995 these shares had increased to 0.102 and decreased to 0.106, respectively.

Table 3.1. Cost shares in the four variable input case in Norwegian manufacturing

	Mean	St. dev.	Minimum	Maximum
Skilled labour	0.071	0.038	0.014	0.171
Unskilled labour	0.163	0.061	0.064	0.311
Materials	0.721	0.068	0.587	0.845
Energy	0.045	0.031	0.010	0.111

The variation across industries in cost shares and some other selected variables is illustrated in Table 3.2. The table shows important variation across industries. (The NASE-classification of the industries is given in Appendix 1.)

Table 3.2. Empirical mean of selected variables and share of manufacturing employment over 1972-1995

Variable	All industries	Food, beverages & textiles	Miscellaneous manufacturing	Paper & pulp	Industrial chemicals	Basic metals	Machinery
	f=15,.,45	f=15	f=25	f=34	f=37	f=43	f=45
S_S	0.071	0.026	0.081	0.046	0.089	0.057	0.126
S_U	0.163	0.129	0.228	0.143	0.105	0.139	0.230
S_M	0.721	0.828	0.668	0.754	0.734	0.714	0.630
S_E	0.045	0.016	0.024	0.057	0.072	0.089	0.014
$\ln Q_S$	4.539	4.313	4.492	4.545	4.690	4.621	4.575
$\ln Q_U$	4.334	4.108	4.296	4.341	4.488	4.411	4.360
$\ln Q_M$	-0.421	-0.374	-0.469	-0.501	-0.422	-0.365	-0.397
$\ln Q_E$	-0.397	-0.350	-0.345	-0.459	-0.464	-0.446	-0.316
lnX	10.470	11.203	11.215	9.792	9.589	10.141	10.883
lnK	10.074	10.299	10.567	9.683	9.735	10.056	10.104
SV_S	1.00	0.14	0.31	0.04	0.06	0.08	0.37
SV_U	1.00	0.26	0.34	0.05	0.03	0.07	0.25

S_i is the cost share of input i, Q_i is the price of input i, i = S,U,M,E; X is real gross output; K is real capital stock; SV_i is the industry's share of total manufacturing employment (measured in man-hours) of category i = S,U.

The industries Paper & pulp, Industrial chemicals and Basic metals have important features in common. They are highly export oriented, employ only a minor share of total manufacturing manpower, and they produce largely industrial raw materials. With respect to the remaining three industries, which employ most of the manufacturing manpower, Food, beverages & textiles and Miscellaneous manufacturing produce mainly consumer goods, while Machinery produces more investment goods. We test if these two sub-groups of industries have common coefficients on X, K and τ before testing if these coefficients are common across all industries. The "common across all industries" hypotheses are clearly rejected by the LR-test, however.

The estimated maintained model

Table 3.3. Coefficient estimates of the maintained cost-share equations model

Long-run coefficients	Estimates	Constant terms	Estimates	Short-run coeff.	Estimates
β_{SS}	0[a]	α_{S15}	-0.182 (.029)	b_{SS}	0.054 (.017)
β_{SM}	-0.035 (.008)	α_{S25}	-0.054 (.163)	b_{SU}	-0.034 (.017)
β_{UU}	-0.097 (.013)	α_{S34}	0.475 (.137)	b_{SM}	-0.032 (.005)
β_{UM}	0.035[b]	α_{S37}	0.217 (.076)	b_{SE}	0[a]
β_{US}	0.048[c]	α_{S43}	0.514 (.143)	b_{UU}	0.091 (.013)
β_{MM}	0[a]	α_{S45}	-0.005 (.157)	b_{US}	0[a]
γ_{SXf} f=15	0[a]	α_{U15}	2.026 (.205)	b_{UM}	-0.091 (.008)
γ_{SXf} f=25,34,37,43,45	-0.039 (.008)	α_{U25}	1.393 (.285)	b_{UE}	0[a]
γ_{UXf} f=15	0[a]	α_{U34}	1.611 (.185)	b_{MS}	0[a]
γ_{UXf} f=25,45	0.073 (.030)	α_{U37}	1.188 (.113)	b_{MU}	-0.124 (.018)
γ_{UXf} f=34,37,43	-0.092 (.014)	α_{U43}	2.534 (.173)	b_{MM}	0.149 (.011)
γ_{MXf} f=15,25,45	0[a]	α_{U45}	0.496 (.322)	b_{ME}	-0.018 (.004)
γ_{MXf} f=34,37,43	0.136 (.014)	α_{M15}	0.517 (.149)	b_{SX}	-0.037 (.005)
γ_{SKf} f=15,37	0[a]	α_{M25}	0.348 (.153)	b_{SK}	0[a]
γ_{SKf} f=25,45	0.032 (.011)	α_{M34}	-0.848 (.206)	b_{UX}	-0.079 (.007)
γ_{SKf} f=34,43	-0.030 (.010)	α_{M37}	-0.840 (.205)	b_{UK}	0[a]
γ_{UKf} f=15,25	-0.169 (.021)	α_{M43}	-0.654 (.143)	b_{MX}	0.110 (.010)
γ_{UKf} f=34	-0.038 (.016)	α_{M45}	0.607 (.011)	b_{MK}	0[a]
γ_{UKf} f=37	0[a]			d[d]	0.320 (.028)
γ_{UKf} f=43	-0.125 (.019)				
γ_{UKf} f=45	-0.079 (.022)				
γ_{MKf} f=15,25,34,37	0.032 (.014)				
γ_{MKf} f=43,45	0[a]				
$\gamma_{S\tau f}$ f=15	0[a]				
$\gamma_{S\tau f}$ f=25,34,37,43,45	0.002 (.0003)				
$\gamma_{U\tau f}$ f=15	0.003 (.0004)				
$\gamma_{U\tau f}$ f=25,34,43	0[a]				
$\gamma_{U\tau f}$ f=37	0.001 (.0005)				
$\gamma_{U\tau f}$ f=45	-0.005 (.0007)				
$\gamma_{M\tau f}$ f=15,25,43	0[a]				
$\gamma_{M\tau f}$ f=34,37	-0.002 (.0005)				
$\gamma_{M\tau f}$ f=45	0.003 (.0006)				
Est. period = 1973-95	S: R^2 = 0.624 SER = 0.003		U: R^2 = 0.820 SER = 0.004		M: R^2 = 0.802 SER = 0.006

Maximum likelihood estimation. Standard errors in parentheses. The multiple correlation coefficient (R^2) and the equation standard error (SER) are given for the estimated cost-share equations; S=skilled labour, U=unskilled labour, M=materials; f denotes industry, see Table 3.2.

[a] The coefficient is restricted to zero a priori.

[b] A priori restriction: $\beta_{UM} = -\beta_{SM}$.

[c] A priori restriction: $\beta_{US} = -0.5\cdot\beta_{UU}$.

[d] A priori restrictions: $d_{ij} = 0$, i,j = S,U,M, $i\neq j$; $d_{ii} = d$, i = S,U,M.

The cost-share equation of energy is not included in Table 3.3, but the long-run part of this equation can easily be found by using the adding up conditions in Table 2.1. In the following discussion, we concentrate on the long-run results. The restrictions on the price coefficients in Table 3.3 will be discussed in connection with the price elasticities.

Except for Food, beverages & textiles (f=15), homotheticity is rejected, and in general input ratios vary with the output level. The output coefficients are common across Paper & pulp (f=34), Industrial chemicals (f=37) and Basic metals (f=43), i.e. the raw-materials producing industries, and also across the two remaining industries Miscellaneous manufacturing (f=25) and Machinery (f=45). In all these five industries, the scale bias is negative for skilled labour, i.e. the cost-share decreases as output grows. Within the raw-materials producing industries, the scale bias is negative also for unskilled labour, but positive for materials input. The cost share of energy is basically unaffected by an increase in the output level. With respect to the remaining two industries, Miscellaneous manufacturing and Machinery, which are more labour intensive than the raw-materials producing industries, the scale bias is positive for unskilled labour and slightly negative for energy. The cost share of materials input is unaffected by output changes.

We now turn to the effect on cost shares and hence input ratios of an increase in the capital stock. According to the results, an increase in the capital stock increases the relative cost shares between skilled and unskilled in all three labour intensive industries, i.e. in Food, beverages & textiles, Miscellaneous manufacturing and Machinery, and also in Metals. The skilled-unskilled labour ratio remains unchanged as capital grows in Chemicals, and declines in Paper & pulp.

Hicks neutral technical change is rejected, and so is also the (sub) hypothesis that the cost shares of the two labour categories are unaffected by technical change. With the exception of Food, beverages & textiles, we find clear evidence of skilled-biased technical change in Norwegian manufacturing, i.e. $\gamma_{S\tau f} > \gamma_{U\tau f}$ at the same time as $S_{Sf} < S_{Uf}$. And furthermore, again with the exception of Food, beverages & textiles, we find skilled-using technical change in all industries, i.e. $\gamma_{S\tau f} > 0$. The results imply unskilled-saving technical change in one industry only, which is the relative labour intensive Machinery industry. In two industries we find, in fact, evidence for unskilled using technical change.

The estimated trend effect should be interpreted with some care, however, since the trend may pick up other effects than technical change. For example a “supply creates its own demand” type of argument has been put forward, and Acemoglu (1999) presents a theory that predicts that demand for skilled workers may well increase as a result of increased supply of skilled workers. If important, this may influence our estimated trend effects, since the number of skilled persons in Norway has increased rapidly during the last decades. On the other hand, a relatively small and even declining share of all skilled workers in Norway is employed by the manufacturing industries, the share has decreased from 15 per cent in 1978 to 12 per cent in 1995. Due to this, we assume the argument above to be less important for our analysis than if we had modelled labour demand of the whole economy.

We test the weak exogeneity assumption on wages, as well as on output, later in this paper, however. We also test the validity of the coefficient restrictions of the maintained model.

Price elasticities

In Table 3.4 we present the long-run own-price and cross-price elasticities predicted by the model in Table 3.3 at the overall empirical sample means for the cost shares. The standard errors are calculated at the predicted sample means, cf. Toevs (1982).

Table 3.4. Own- and cross-price elasticities in the maintained model calculated at the overall empirical mean of the cost shares[a]

Own-price elasticities	Estimate	Cross-price elasticities	Estimate
ε_{SS}	-0.929 (.003)	ε_{SU}	0.844 (.096)
ε_{UU}	-1.431 (.129)	ε_{US}	0.368 (.064)
ε_{MM}	-0.279 (.006)	ε_{SM}	0.233 (.114)
ε_{EE}	-0.955 (.006)	ε_{MS}	0.023 (.011)
		ε_{SE}	-0.148 (.073)
		ε_{ES}	-0.230 (.172)
		ε_{UM}	0.934 (.074)
		ε_{MU}	0.211 (.012)
		ε_{UE}	0.129 (.051)
		ε_{EU}	0.464 (.174)
		ε_{ME}	0.045 (.006)
		ε_{EM}	0.721 (.006)

[a] Standard errors in parentheses. Evaluated at the predicted cost shares (where the observed variables are represented by their overall empirical means) by utilising the "ANALYZ"-routine in TSP 4.3.

Table 3.4 shows that all own-price elasticities evaluated at sample means have the correct sign. This is true for all sample points, and our maintained model satisfy the "concavity in prices" condition. Without the restrictions on the price coefficients, β_{UM} and β_{US}, we have some problems with the own-price elasticity of energy, however, and the "concavity in prices" condition is violated. As shown later, these restrictions are not rejected by the LR-test.

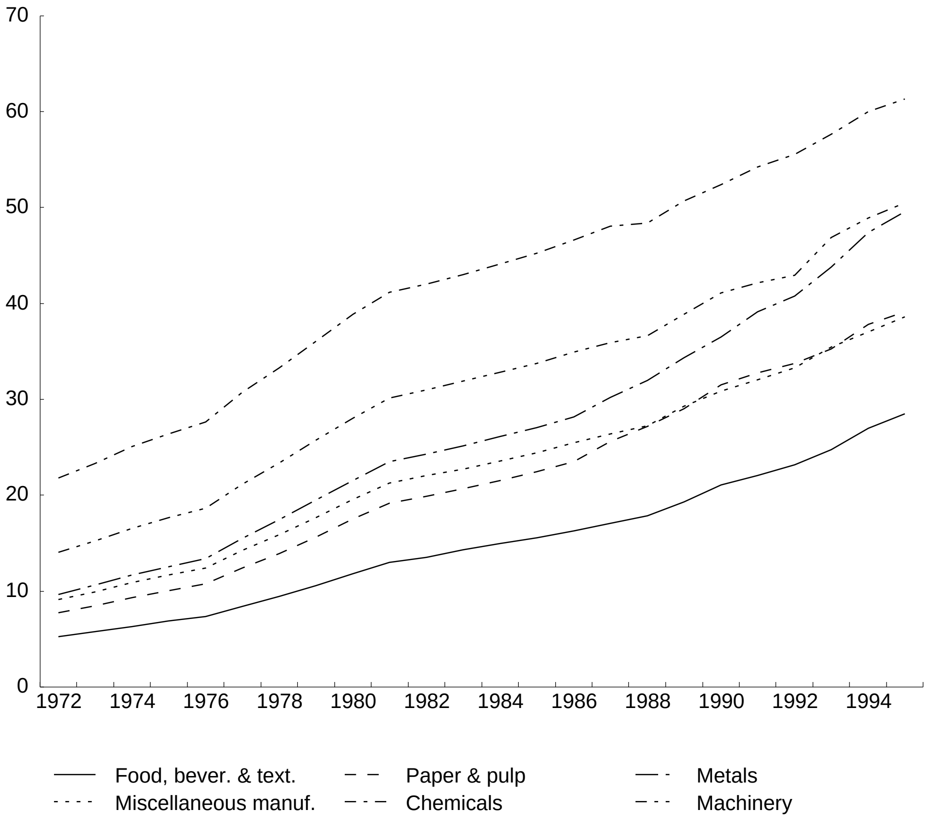
According to our results, the demand for unskilled labour is clearly elastic, while the demand for materials input is inelastic. The own-price elasticities for skilled labour and energy are close to minus one. The cross-price elasticities between skilled labour and both materials and energy are not significantly different from zero, which means that the demand for skilled labour and these two other inputs are on average independent. The demand for unskilled labour is approximately independent of changes in the energy price. The positive and significant cross-price elasticities between unskilled labour and materials, which implies that these inputs are substitutes, deserve some comments. Materials include services and subcontracting, and the degree of labour-materials substitution can therefore provide information on outsourcing or out-contracting. Interpreted within this context, the results suggest that unskilled labour may well have been outsourced, while skilled labour has not.

With the exception of the insignificant cross-price elasticities between skilled labour and energy, all variable inputs are substitutes in demand. Furthermore, the cross price elasticities imply that the substitution effect on skilled labour from an increase in unskilled wages is larger than the substitution effect on unskilled labour from an increase in skilled wages.

A decomposition of the shift in relative labour demand

We will now focus on the development in the *skilled-labour share* measured as skilled man-hours in per cent of total man-hours, i.e. as $100 \cdot V_S/(V_S+V_U)$, which reflects the shift in relative labour demand. According to Figure 3.1, all industries have increased their demand for skilled labour relative to unskilled over time. While the skilled-labour share in Industrial chemicals is higher than in the other industries over the whole sample period, Food, beverages & textiles is permanently at the bottom.

Figure 3.1. Skilled man-hours in per cent of total man-hours in different industries



To get a better understanding of how the various explanatory variables have contributed to the change in the skilled-labour share, and hence to the change in relative labour demand, a number of simulations have been conducted on our maintained cost-share equations model in Table 3.3. Starting the simulations in 1973, we let a sub-set of explanatory variables follow their historical path, while all the other explanatory variables are kept constant at their 1972-values.[6] The results from these dynamic simulations are summarised in Table 3.5.

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[6] To avoid the effect of initial error terms on the simulations, the model is intercept-corrected such that it fits perfectly in the initial simulation year, 1973.

Table 3.5. Model predicted effects on the skilled-labour share (in per cent) from changes in different explanatory variables. Simulated skilled-labour shares in 1995[a]

Non-constant variable		All industries[b]	Food, beverages & textiles	Miscel. manufacturing	Paper & pulp	Industrial chemicals	Basic metals	Machinery
True	1973	10.7	5.8	9.9	8.5	23.3	10.6	15.2
Share	1995	42.2	28.6	38.6	39.2	61.3	49.6	50.5
Q_S and Q_U		46.9	55.6	39.2	58.3	48.1	54.4	42.4
Q_i i=S,U,M,E		26.3	24.0	22.4	28.3	34.1	29.3	29.3
τ		24.2	7.2	22.2	26.9	37.3	26.6	35.9
K		20.1	15.4	21.6	11.2	25.7	16.2	24.9
X		12.6	8.3	12.3	13.2	13.7	12.6	16.0
All variables		41.1	26.6	37.2	43.0	30.5	54.2	50.3

[a] The simulations are dynamic over 1973-1995. A sub-set of explanatory variables follow their historical path while the remaining are kept constant at their 1972-values. The model is adjusted according to the error-terms in 1973. The simulated skilled-labour share is found by using the identity $100 \cdot V_S / [V_S + V_U] \equiv 100 \cdot S_S / [S_S + (Q_S / Q_U) \cdot S_U]$.

[b] Each industry is weighted according to its actual share of total manufacturing employment (man-hours).

According to Table 3.5, wages (Q_S and Q_U) have contributed heavily to the increase in the skilled-labour share in Norwegian manufacturing (compare row 1 and 3). This reflects substitution effects due to a general increase in relative wages between unskilled and skilled most of the sample period, see Figure A5 in Appendix 2. Comparing actual skilled-labour shares with the predicted in 1995 (row 2 and 3), one sees that the isolated effect of wage changes in most industries have increased the skilled-labour share more than the observed increase over 1973-1995. The development in prices of materials and energy (Q_M and Q_E) have to some degree neutralised the effect of wage changes on relative labour demand. This is seen by comparing the results from the "wage-change" simulation (row 3) with the results from the simulation where all prices are allowed to follow their historical path (row 4). In the latter case, the increases in the skilled-labour shares are much smaller than in the "wage-change" simulations. Still, the total price effect on relative skilled-unskilled labour demand is positive and important in all industries (compare row 1 and 4).

With the exception of Food, beverages & textiles, technical change (row 5) has clearly contributed to the increase in the skilled-labour share. Looking at the aggregated effect across all industries, the skilled-labour share, which is 10.7 per cent in 1973, increases to 24.2 per cent due to technical change. Hence, the effect of technical change is close to the total effect of price changes.

Capital stock (row 6) has contributed positively to the skilled-labour share. The impact is relatively big in all the labour intensive industries, i.e. Food, beverages & textiles, Miscellaneous manufacturing and Machinery, while the impact is relatively small in the less labour intensive raw-materials producing industries. For total manufacturing, the isolated effect of the observed growth in capital stock is an almost doubling of the skilled-labour share.

The effect of output growth is, in general, not very strong (row 7). Hence, non-homotheticity is not very important for relative labour demand according to these results. The exception is Industrial chemicals, for which the isolated effect of the output growth is a significant decline in the skilled-labour share. However, with respect to this industry, the dynamic specification is problematic. When conducting simulations on the long-run part of the model only, we get results that differs from those reported in Table 3.5. In this case, output is of little importance, and the "All variables" simulation gives a predicted skilled-labour share of almost 50 per cent, which is much closer to the actual share in 1995. This may suggest that the dynamic effects, at least to some degree, should have been industry specific and not common. However, a generalisation of the model with respect to the short-run effects would escalate our degrees of freedom problem, since the model already contains relatively many coefficients. Therefore, as explained earlier, our focus or primary interest is more on the long-run than on the short-run elasticities.

Validity of coefficient restrictions

Compared to our most general model, the maintained model in Table 3.3 includes 56 coefficient restrictions of which 29 are zero-restrictions. Since the validity of restrictions is tested at different stages in the reduction process, as explained in the previous section, this process is complicated to summarise. However, as a final stage in our model search, we accomplish a "specific to general" testing procedure. The restrictions are organised in seven subsets, and the robustness of each subset and some combinations of subsets is checked by testing the restricted maintained model in Table 3.3 (H_M) versus the alternative and (more) general model ($H_{A,r\text{-}s}$, r,s=1,..,7, s≥r). The alternative model $H_{A,r\text{-}s}$ is defined as the maintained model without the restrictions classified in subsets r-s. The subsets of restrictions are given in Table 3.6.

Table 3.6. The restrictions on the maintained model in Table 3.3 sorted in subsets

Subset	Restrictions
1	$b_{SE} = 0$; $b_{US} = 0$; $b_{UE} = 0$; $b_{MS} = 0$; $b_{iK} = 0$, i=S,U,M
2	$\gamma_{SX15} = 0$; $\gamma_{SXf} = \gamma_{SX25}$, f=34,37,43,45; $\gamma_{UX15} = 0$; $\gamma_{UX45} = \gamma_{UX25}$; $\gamma_{UXf} = \gamma_{UX34}$, f=37,43 $\gamma_{MXf} = 0$, f=15,25,45; $\gamma_{MXf} = \gamma_{MX34}$, f=37,43
3	$\gamma_{S\tau15} = 0$; $\gamma_{S\tau f} = \gamma_{SX25}$, f=34,37,43,45; $\gamma_{U\tau f} = \gamma_{U\tau f}$, f=25,34,43; $\gamma_{M\tau f} = 0$, f=15,25,43 $\gamma_{M\tau37} = \gamma_{M\tau34}$
4	$\gamma_{SKf} = 0$, f=15,37; $\gamma_{SX45} = \gamma_{SK25}$; $\gamma_{SX43} = \gamma_{SK34}$; $\gamma_{UK25} = \gamma_{UK15}$; $\gamma_{UK37} = 0$ $\gamma_{MKf} = \gamma_{MK15}$, f=25,34,37; $\gamma_{MXf} = 0$, f=43,45
5	$\beta_{ii} = 0$, i=U,M
6	$\beta_{UM} = -\beta_{SM}$; $\beta_{US} = -0.5 \cdot \beta_{UU}$
7	$d_{ij} = 0$, i,j = S,U,M, $i \neq j$; $d_{ii} = d$, i = S,U,M

Table 3.7 contains the uncorrected and corrected LR-statistics and associated significance probabilities from testing the maintained model versus more general alternative models defined by the subsets of restrictions in Table 3.6.

Table 3.7. Likelihood ratio-tests of the maintained model in Table 3.3 against more flexible specifications[a]

Test	Alternative model ($H_{A,r\text{-}s}$)[b]	LR (n_R)	Significance Probability	LR_{SI} (n_R)	Significance probability
1	$H_{A,1\text{-}7}$	87.94 (56)	0.0041	70.31 (56)	0.0945
2	H_{A1}	8.82 (7)	0.2658	7.57 (7)	0.3720
3	H_{A2}	11.18 (14)	0.6718	9.51 (14)	0.7971
4	H_{A3}	12.04 (12)	0.4425	10.25 (12)	0.5940
5	$H_{A,2\text{-}3}$	29.28 (37)	0.8132	24.08 (37)	0.9499
6	H_{A4}	4.84 (11)	0.9387	4.13 (11)	0.9660
7	H_{A5}	0.48 (2)	0.7866	0.42 (2)	0.8106
8	H_{A6}	1.42 (2)	0.4916	1.23 (2)	0.5406
9	$H_{A,5\text{-}6}$	3.28 (4)	0.5121	2.83 (4)	0.5867
10	H_{A7}	14.14 (8)	0.0782	12.12 (8)	0.1459

[a] LR is the standard likelihood-ratio test statistic. n_R is the number of restrictions. LR_{SI} denotes the small-sample corrected LR-value following the suggestion by Italianer (1985) and is given by $LR_{SI} = m_I LR$. $m_I = [pT-0.5(n_A+n_M)-0.5p(p+1)]$, where p is the number of equations, T is the total number of observations, n_A is the number of coefficients under the alternative hypothesis and n_M is the number of coefficients under the maintained hypothesis.

[b] Confer Table 3.6.

The first row of Table 3.7 shows the results from confronting the maintained model with our most general model. According to the usual LR-statistic, the maintained model is rejected at the 1 per cent significance level. However, since the general model contains a rather high number of estimated coefficients, it is important to conduct a small-sample correction. Using the small sample correction suggested by Italianer (1985), the maintained model, i.e. the null hypothesis, cannot be rejected at the 5 per cent level and barely at the 10 per cent level. In the other rows of Table 3.7, the alternative specification is more flexible than the maintained model but less flexible than the general model. We find that most of the restrictions outlined in Table 3.6 are rather innocent. This is the case for the homogeneity (across industries) and zero restrictions imposed on the long-run effects of changes in output, capital and the trend, and for the restrictions on the short-run effects (consider row 2 of Table 3.7). This is also the case for the long-run price restrictions, which was introduced inter alia to ensure "concavity in prices". In the last row of Table 3.7, the maintained model is confronted with an alternative model which has a full adjustment matrix, but which is equal to the maintained model in all other respects. Even when not conducting a small sample adjustment, the maintained model cannot be rejected at the 5 per cent significance level. Hence, our conclusion is that the maintained model is a reasonable simplification of the general model given at the outset.

Testing for weak exogeneity

To test for weak exogeneity of output and wages, we conduct Hausman-Wu misspecification tests [cf. Godfrey (1988)]. Marginal models are constructed for the variables $\Delta\ln(X_{ft})$, $\Delta\ln(Q_{Sft})$ and $\Delta\ln(Q_{Uft})$. In the marginal model for $\Delta\ln(X_{ft})$ we use current relative changes and lagged levels (in logs) of input variables together with a trend and industry specific dummy variables. With respect to wages, we use a wage-curve modelling framework, where changes in nominal wages are a function of unemployment, consumer and producer prices and productivity growth. In addition, dummy variables are included to capture the effects of wage and price stops.[6]

Based on the three estimated marginal equations we derive three vectors of residuals that we include in our maintained model in Table 3.3. We test whether these additional variables are significant in the dynamic factor demand system by using a standard LR-test. The value of the LR-statistic corresponds to a significance probability of about 0.03. However, a more thorough investigation reveals that the low significance probability stems from the contribution of the residuals of the marginal output equation. Including only the residuals

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[6] We thank Roger Bjørnstad for providing us with the estimation results for the wage equations.

from the wage-equations, we obtain a LR-value equal to 1.7, and according to the $\chi^2(6)$-distribution, the hypothesis of weak exogeneity of wages is clearly supported. However, when we only include the residuals from the marginal output equation we get a LR-value of 16.7, which gives a significance probability of 0.0008 using the $\chi^2(3)$-distribution. Thus, the assumption that the output variable is weakly exogeneous is problematic. In light of this, we estimate our maintained model with an iterated 3SLS procedure, taking care of the potential lack of weak exogeneity of the output variable. The detailed results are given in Appendix 3, and Tables A2, A3 and A4 correspond to Tables 3.3, 3.4 and 3.5 respectively. Our general conclusion is that estimating under the assumption that output is weakly exogeneous does not affect our conclusions seriously. The price elasticities are very similar, and a comparison of the model predicted effects on the skilled-labour share of different explanatory variables shows that the conclusions change qualitatively in only one case. In Pulp & paper, the growth in capital stock has decreased and not increased the skilled-labour share according to the 3SLS-results. In both the 3SLS-case and ML-case the effect is not very strong, however.

4. Conclusions

Using a multivariate error-correction model of the cost shares of skilled and unskilled labour, materials and energy, the increase in demand for skilled relative to unskilled labour is analysed. Panel data from Norwegian manufacturing is applied. Focus is on the importance of non-neutral technical change, substitution due to changes in wages and prices, the effect of capital stock growth, homotheticity in the production function and industry structure.

The skilled-biased technical change hypothesis is supported by the results. First, we find, as in shift-share analyses of other OECD-countries, that most of the increase in the relative demand for skilled labour is due to within industry changes. The between industry effect is only marginal. Second, the econometric analysis supports the assumption that skilled-biased technical change is present, and furthermore, the results show that this non-neutrality is due to skilled-labour using rather than unskilled-labour saving technical change.

Dynamic simulations on the estimated cost-share equation model over 1973-1995 reveal that particularly three factors have contributed significantly to the shift in relative labour demand. In addition to skilled-biased technical change, we find that labour-labour substitution due to a decline in relative wages between skilled and unskilled labour and the growth in capital stocks explain most of the shift. Although homotheticity is rejected for all but one industry, the scale bias has in general not affected relative labour demand much.

Appendix 1

The data and definition of variables

The industry data are from the annual Norwegian national account. Data on man-hours and labour costs for different levels of education are recently calculated. In this analysis, skilled labour is defined as labour with a university or higher technical degree or with a diploma from a vocational school. Labour with compulsory school or high school is defined as unskilled.

V_{Sf}	Skilled labour, measured in man-hours, in industry f
V_{Uf}	Unskilled labour, measured in man-hours, in industry f
Q_{Sf}	Skilled labour costs per man-hour in industry f
Q_{Uf}	Unskilled labour costs per man-hour in industry f
M_f	Materials input in industry f, constant 1995-kroner
Q_{Mf}	Price of materials in industry f, 1995=1
E_f	Energy consumption, defined as the sum of electricity and fuels, by industry f, constant 1995-kroner. In general, electricity dominates the aggregate
Q_{Ef}	Price of energy consumption in industry f, 1995=1
X_f	Real gross output in industry f, constant 1995-kroner
K_f	Real capital stock of industry f measured at the beginning of the year, constant 1995-kroner

The definition of industries follows the Norwegian national accounts, which is based on the 2-digit NASE-classification system. Norwegian manufacturing is divided into eight different industries, and we include six of these in our analysis; Petroleum refining and Shipbuilding are excluded.

Table A1. Industry

Code	Definition	NASE-Rev. 1	Output share 1995
15	Food, beverages & textiles	14, 15, 16, 17, 18	24.7
25	Miscellaneous manufacturing	10, 20, 22, 25, 37	22.1
34	Paper & pulp	21	6.3
37	Industrial chemicals	24	5.6
43	Basic metals	27	9.9
45	Machinery	30	19.2
40	Petroleum refining	23	3.6
50	Shipbuilding	35, 36	8.5

Appendix 2

Figure A1. Cost shares of unskilled labour in Norwegian manufacturing

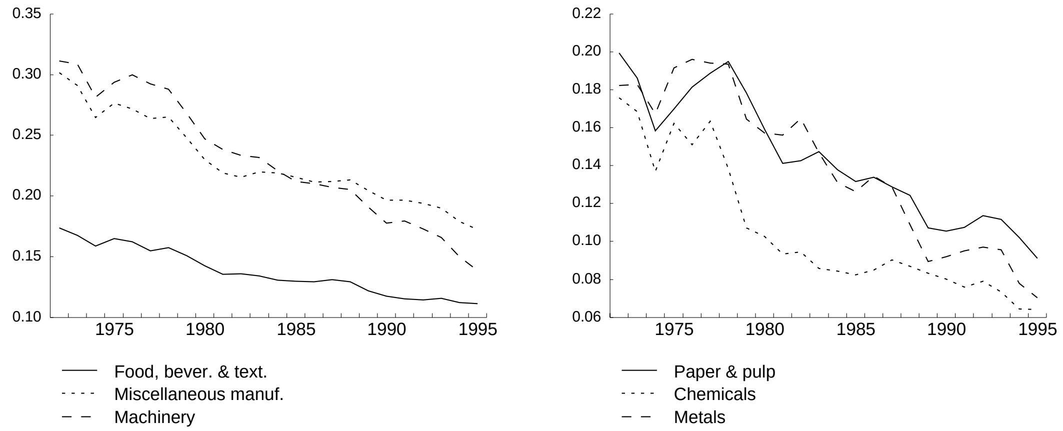


Figure A2. Cost shares of skilled labour in Norwegian manufacturing

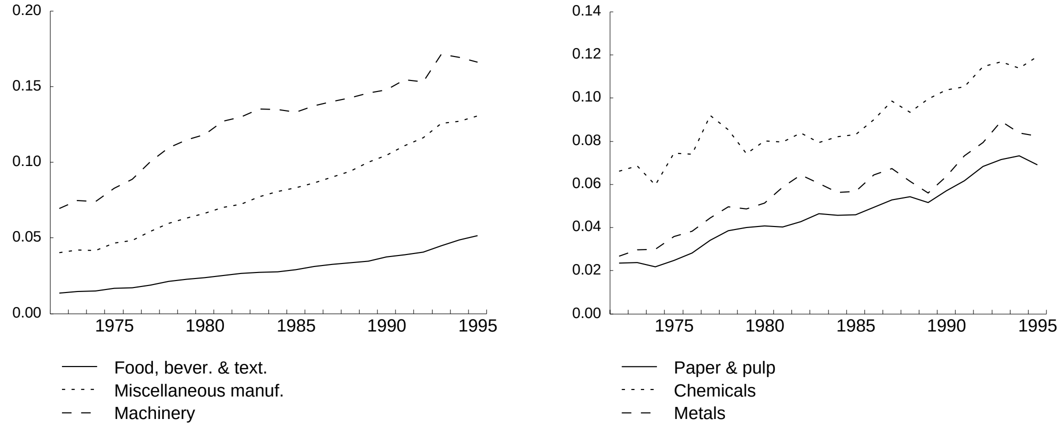


Figure A3. Cost shares of materials in Norwegian manufacturing

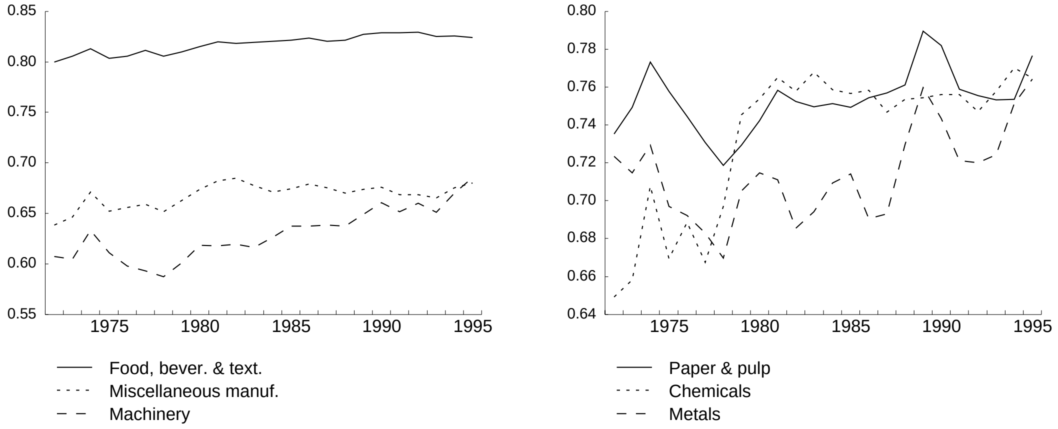


Figure A4. Cost shares of energy in Norwegian manufacturing

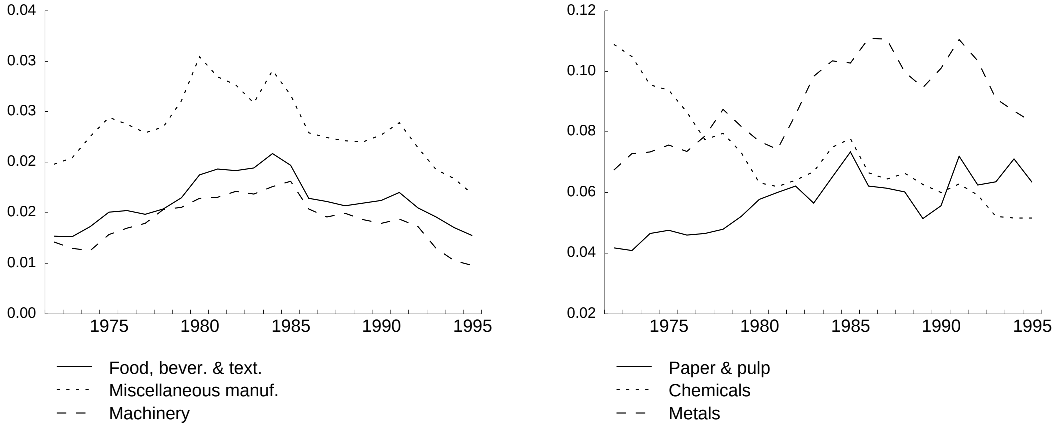


Figure A5. Labour costs per man-hour of unskilled relative to skilled in Norwegian manufacturing

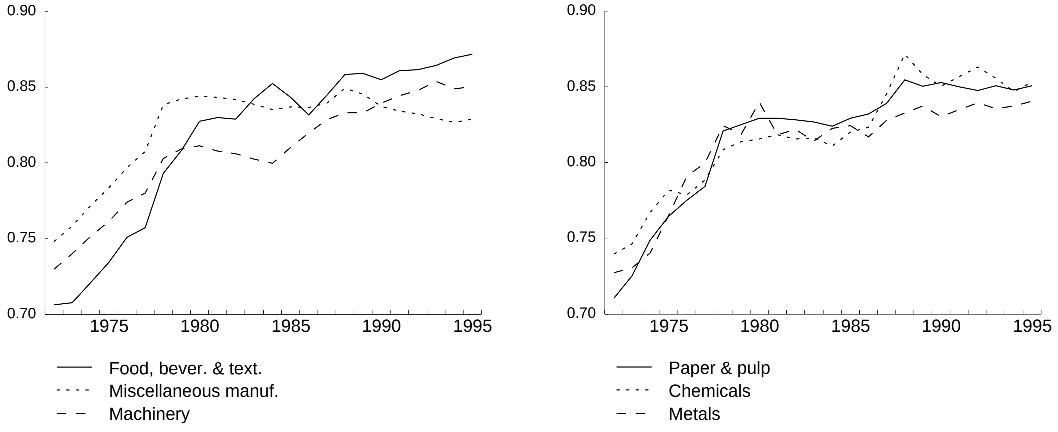


Figure A6. Output in Norwegian manufacturing, 1995-kroner

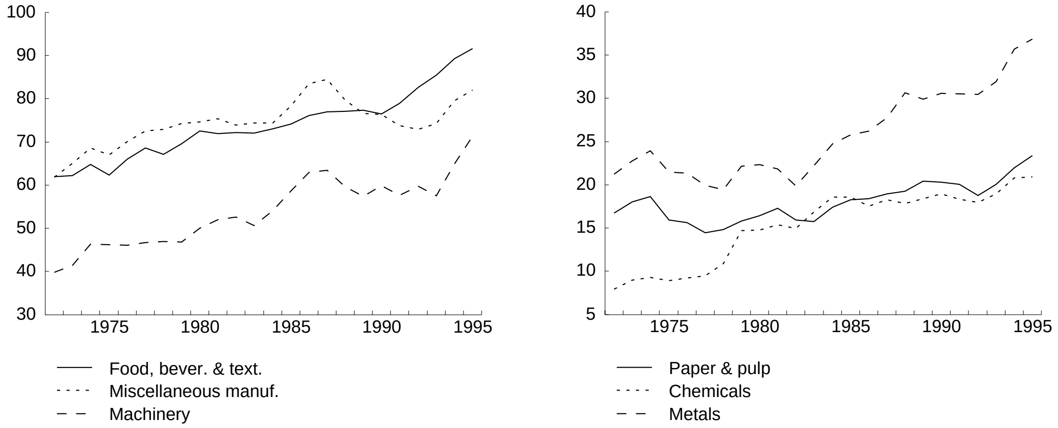
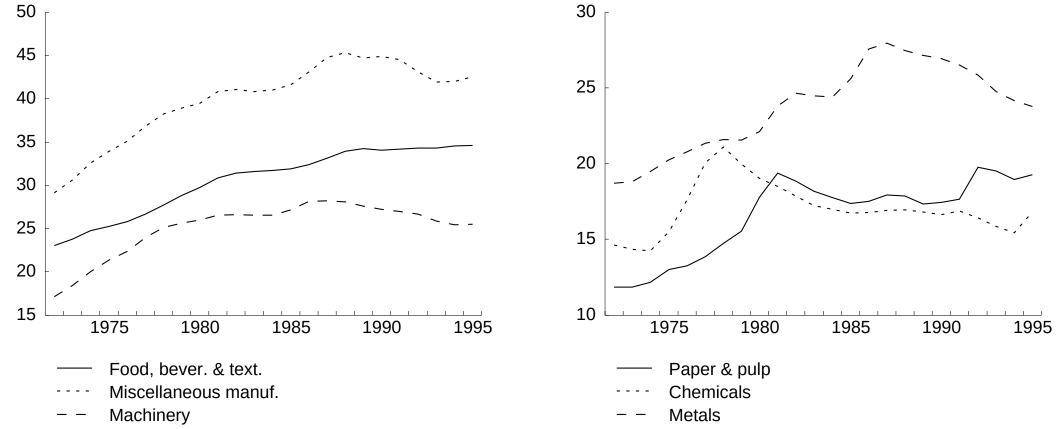


Figure A7. Real capital stock in Norwegian manufacturing, 1995-kroner



Appendix 3

The maintained model estimated by iterated three stage least squares (3SLS).

Table A2. Alternative coefficient estimates of the preferred cost-share equations model

Long-run coefficients	Estimates	Constant terms	Estimates	Short-run coeff.	Estimates
β_{SS}	0^a	α_{S15}	-0.165 (.045)	b_{SS}	0.056 (.019)
β_{SM}	-0.028 (.012)	α_{S25}	-0.204 (.264)	b_{SU}	-0.023 (.021)
β_{UU}	-0.087 (.020)	α_{S34}	0.349 (.207)	b_{SM}	-0.040 (.006)
β_{UM}	0.028^b	α_{S37}	0.088 (.113)	b_{SE}	0^a
β_{US}	0.044^c	α_{S43}	0.382 (.214)	b_{UU}	0.088 (.018)
β_{MM}	0^a	α_{S45}	-0.151 (.254)	b_{US}	0^a
γ_{SXf} f=15	0^a	α_{U15}	2.896 (.504)	b_{UM}	-0.086 (.011)
γ_{SXf} f=25,34,37,43,45	-0.024 (.011)	α_{U25}	2.161 (.924)	b_{UE}	0^a
γ_{UXf} f=15	0^a	α_{U34}	0.996 (.532)	b_{MS}	0^a
γ_{UXf} f=25,45	0.085 (.090)	α_{U37}	1.318 (.206)	b_{MU}	-0.145 (.024)
γ_{UXf} f=34,37,43	-0.108 (.023)	α_{U43}	2.747 (.402)	b_{MM}	0.158 (.013)
γ_{MXf} f=15,25,45	0^a	α_{U45}	0.402 (.794)	b_{ME}	-0.021 (.005)
γ_{MXf} f=34,37,43	0.109 (.023)	α_{M15}	0.547 (.242)	b_{SX}	-0.005 (.012)
γ_{SKf} f=15,37	0^a	α_{M25}	0.378 (.248)	b_{SK}	0^a
γ_{SKf} f=25,45	0.032 (.017)	α_{M34}	-0.556 (.314)	b_{UX}	-0.091 (.019)
γ_{SKf} f=34,43	-0.031 (.014)	α_{M37}	-0.548 (.312)	b_{UK}	0^a
γ_{UKf} f=15,25	-0.256 (.050)	α_{M43}	-0.369 (.229)	b_{MX}	0.071 (.026)
γ_{UKf} f=34	0.040 (.057)	α_{M45}	0.615 (.016)	b_{MK}	0^a
γ_{UKf} f=37	0^a			d^d	0.332 (.054)
γ_{UKf} f=43	-0.132 (.047)				
γ_{UKf} f=45	-0.085 (.065)				
γ_{MKf} f=15,25,34,37	0.029 (.023)				
γ_{MKf} f=43,45	0^a				
$\gamma_{S\tau f}$ f=15	0^a				
$\gamma_{S\tau f}$ f=25,34,37,43,45	0.002 (.0005)				
$\gamma_{U\tau f}$ f=15	0.003 (.0011)				
$\gamma_{U\tau f}$ f=25,34,43	0^a				
$\gamma_{U\tau f}$ f=37	0.002 (.0012)				
$\gamma_{U\tau f}$ f=45	-0.005 (.0016)				
$\gamma_{M\tau f}$ f=15,25,43	0^a				
$\gamma_{M\tau f}$ f=34,37	-0.002 (.0011)				
$\gamma_{M\tau f}$ f=45	0.003 (.0008)				

Est. period = 1974-95 S: $R^2 = 0.506$ U: $R^2 = 0.765$ M: $R^2 = 0.784$

SER = 0.003 SER = 0.005 SER = 0.007

Iterated three stage least squares. The stacked series of $\Delta\ln Q_{Sf,t-1}$, $\Delta\ln Q_{Uf,t-1}$, $\Delta\ln Q_{Mf,t-1}$, $\Delta\ln Q_{Ef,t-1}$, $\Delta\ln K_{f,t-1}$ and $\Delta\ln X_{f,t-1}$ are used as identifying instruments. Standard errors in parentheses. The multiple correlation coefficient (R^2) and the equation standard error (SER) are given for the estimated cost-share equations; S=skilled labour, U=unskilled labour, M=materials; f denotes industry, see Table 3.2.

[a] The coefficient is restricted to zero a priori.

[b] A priori restriction: $\beta_{UM} = -\beta_{SM}$.

[c] A priori restriction: $\beta_{US} = -0.5 \cdot \beta_{UU}$.

[d] A priori restrictions: $d_{ij} = 0$, i,j = S,U,M, $i \neq j$; $d_{ii} = d$, i = S,U,M.

Table A3. Own- and cross-price elasticities in the maintained model estimated by 3SLS calculated at the overall empirical mean of the cost shares[a]

Own-price elasticities	Estimate	Cross-price elasticities	Estimate
ε_{SS}	-0.929 (0.004)	ε_{SU}	0.779 (.143)
ε_{UU}	-1.375 (0.219)	ε_{US}	0.340 (.106)
ε_{MM}	-0.279 (0.011)	ε_{SM}	0.333 (.166)
ε_{EE}	-0.955 (0.013)	ε_{MS}	0.033 (.016)
		ε_{SE}	-0.183 (.095)
		ε_{ES}	-0.285 (.291)
		ε_{UM}	0.891 (.113)
		ε_{MU}	0.201 (.019)
		ε_{UE}	0.145 (.070)
		ε_{EU}	0.519 (.299)
		ε_{ME}	0.045 (.013)
		ε_{EM}	0.721 (.011)

[a] Standard errors in parentheses. Evaluated at the predicted cost shares (where the observed variables are represented by their overall empirical means) by utilising the "ANALYZ"-routine in TSP 4.3.

Table A4. Model predicted effects on the skilled-labour share (in per cent) from changes in different explanatory variables. Simulated skilled-labour shares in 1995[a]

		All industries[b]	Food, beverages & textiles	Miscel. manufacturing	Paper & pulp	Industrial chemicals	Basic metals	Machinery
True	1973	10.7	5.8	9.9	8.5	23.3	10.6	15.2
Share	1995	42.2	28.6	38.6	39.2	61.3	49.6	50.5
Q_S and Q_U		42.4	51.3	34.5	51.5	43.1	48.6	39.2
Q_i i=S,U,M,E		23.3	22.0	19.3	23.1	29.5	25.2	27.0
τ		21.6	5.8	19.9	23.8	31.3	23.8	33.0
K		17.9	21.3	14.9	5.6	21.3	12.0	23.4
X		12.3	8.4	11.1	12.0	14.3	13.0	16.2
All variables		37.9	29.5	27.7	31.9	30.3	55.5	47.5

[a] The simulations are dynamic over 1973-1995. A sub-set of explanatory variables follow their historical path while the remaining are kept constant at their 1972-values. The model is adjusted according to the error-terms in 1973. The simulated skilled-labour share is found by using the identity $100 \cdot V_S / [V_S + V_U] \equiv 100 \cdot S_S / [S_S + (Q_S / Q_U) \cdot S_U]$.

[b] Each industry is weighted according to its actual share of total manufacturing employment (man-hours).

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