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Exploring the Change in Skill Structure of Labour Demand in Norwegian Manufacturing

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Abstract

In most OECD-countries, labour demand has shifted from unskilled to skilled over time. Many analyses of this phenomenon focus either on technical change, capital-skill complementarity or mutual labour substitution. Applying a more general approach enables us to explore the relative importance of different factors behind the shift in labour demand in Norwegian manufacturing. A multivariate error-correction model of the cost-shares of skilled and unskilled labour, materials and energy is estimated. 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, explains much of the shift in labour demand. In addition, mutual labour substitution and capital stock growth are important.

Keywords: Skilled-biased technical change; Factor demand; Industry level panel data

JEL classification: C33; E23

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Preface

This is a substantially revised version of Discussion Paper 293 ("Explaining the Change in Skill Structure of Labour Demand in Norwegian Manufacturing") by the same authors. The empirical analysis are conducted on revised and longer time series. Free estimation of the cost-share functions produced (within sample) results which violated concavity of the implicit cost function. Based on this global concavity of the cost function was imposed. In Discussion Paper 293 we tested whether wages and output were weakly endogenous variables relative to the dynamic cost share equations. This inference is now based on improved marginal models for wages and output.

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, Bound and Machin (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, see the discussion in Bartel and Lichtenberg (1987). 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 exports of manufactured goods 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.

A 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, Katz and Krueger (1998), Berman et al. (1998), Machin and Van Reenen (1998), Kahn (1998), Kahn and Lim (1998) and Salvanes and Førre (2003).

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 nearly 44 per cent in 1997. A simple shift-share analysis[1] shows that as much as 99 per cent of this increase is due to within industry changes, and hence only 1 per cent of the increase is explained by changes in industry structure. (Similar calculations using data for the whole economy - where the 5-digit level NACE classification is aggregated to 28 industries - shows that 92 per cent of the increase in the skilled/unskilled man-hours ratio is due to within industry changes.) The within industry effect is very high, but this 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 the calculations above gives support to the skilled-biased technical change hypothesis, the observed within industry changes are probably due to a number of factors. To identify the effect of technical change on labour demand, one should ideally control for all other factors of importance. In countries with changes in relative wages, or relative input prices more generally, substitution should clearly be controlled for. In Norway, the wage inequality between skilled and unskilled labour has decreased during the last decades, see Appendix 2 and also Aaberge, Bjørklund, Jantti, Pedersen, Smith and Wennemo (2000), Hægeland, Klette and Salvanes (1999) and Kahn (1998). The expected isolated effect of this is a shift from unskilled to skilled labour. By contrast, in United States and United Kingdom, wage inequality has increased, cf. Card, Kramarz and Lemieux (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. In addition, we focus not only on whether skilled-biased technical change is present or not, but also on how important this is for explaining the observed shift in relative labour demand. Industry-level panel data from Norwegian manufacturing is applied, and labour is classified as skilled or unskilled according to their highest formal education. A multivariate error-correction model of the cost shares of two types of labour, materials and energy is estimated. 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, Paul and Siegel (2002), Falk and Koebel (1999, 2001) and Fitzenberger (1999).

The chosen framework enables us to study substitution between the two labour categories as well as substitution between labour and other variable inputs. In addition, non-neutral technical

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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 surveys of analyses using micro-data, see Chennells and Van Reenen (1999) and Siegel (1999).

change is specified in a general way, so that both skilled-labour using and unskilled-labour saving technical change can be explored. 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 fixed industry effects and heterogeneous slope coefficients, i.e. a heterogeneous coefficient specification on capital, output and technical change. Hence, calculated elasticities will in general vary across industries due to variation in both data and estimated coefficients. The common approach in previous industry studies of the shift in labour demand is pooling or assuming a fixed or random effect only. This is, in general, also true for existing studies on micro data. 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. The empirical results are presented in Section 3, and the main conclusions are summarised in Section 4.

2 The cost-share equation system

To analyse the importance of technical change, substitution, production function properties, capital growth and industry structure for the observed change in labour demand, we apply the translog cost-function suggested by Christensen, Jorgenson and Lau (1971, 1973). This is well suited to our purpose, since the technological development can be specified in a general manner. 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.

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). 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 $\gamma_{i\tau f}$, i=S,U,M,E, are industry-specific in our

[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. The results from this approach were difficult to interpret, however, probably because of strong multicollinearity between the two capital categories. The within industry correlation coefficient is as high as 0.97-0.98 for most industries.

general model. The remaining coefficients are assumed to be constant across industries.[4] The symbol Σ_i implies the sum over all variable inputs.

$$\ln C_f = \gamma_0 + \Sigma_i\, \alpha_{if} \ln P_{if} + 1/2\, \Sigma_i \Sigma_j\, \beta_{ij} \ln P_{if} \ln P_{jf} + \gamma_X \ln X_f + 1/2\, \gamma_{XX} (\ln X_f)^2$$
$$+ \Sigma_i\, \gamma_{iXf} \ln P_{if} \ln X_f + \gamma_K \ln K_f + 1/2\, \gamma_{KK} (\ln K_f)^2 + \Sigma_i\, \gamma_{iKf} \ln P_{if} \ln K_f$$
$$+ \gamma_{XK} \ln X_f \ln K_f + \gamma_\tau\, \tau + 1/2\, \gamma_{\tau\tau}\, \tau^2 + \Sigma_i\, \gamma_{i\tau f} \ln P_{if}\, \tau + \gamma_{X\tau} \ln X_f\, \tau + \gamma_{K\tau} \ln K_f\, \tau \qquad (1)$$
$$i,j=S,U,M,E;\quad f\in\{15,25,34,37,43,45\}$$

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

where C_f represents total variable costs of industry f; P_{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.

Labour is measured in man-hours, and 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. The data do not include information on work experience, which may - to some degree - substitute for formal education. The important issue for this analysis is, however, how employers consider education vis-à-vis experience, and arguments can be raised that support an education-based classification. Education signals that a person is ambitious and that he or she is capable of both acquiring new skills and accomplish duties. Hence, as a signal, education is probably very important. Furthermore, if it takes more time to achieve the same level of qualification by work experience than by education, and age counts negatively on its own, this adds to the argument that education is important – also compared to experience.

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

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

The cost-share equations include fixed effects, i.e. industry-specific intercepts, which capture permanent differences in technology across industries. In Norwegian manufacturing, growth

[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).

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 due to differences in the composition of buildings, structures, machinery and transport equipment. This may influence the cost shares of variable inputs. The main reason for including industry specific trend coefficients is that the effect of technical change on input demand and hence cost shares may differ systematically across industries. This may be due to variation in the diffusion processes. In addition, the common deterministic trend variable is a proxy for the true level of technology, which may well vary across industries.

The price coefficients are specified as identical across industries in our general model. Due to a degree of freedom problem, it is difficult 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.

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 the level of the technology. However, due to adjustment costs and incomplete information, 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.

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

[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, Robb and Scarth (1987) and Gordon (1992).

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 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 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 (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.

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

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

$$i = S,U,M, \quad f \in \{15,25,34,37,43,45\}$$

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 1, are imposed on the general model that we estimate. We make the following assumptions about the (3×1)-vector u^n_{ft},

$$u^n_{ft} = [u_{Sft}, u_{Uft}, u_{Mft}]' \sim \text{NIID}\,[0, \Omega], \quad \text{for all t and f.}$$

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 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 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 the possible and tested restrictions are outlined.

We are primarily concerned with 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}).

We now focus on restrictions on the long-run part of the model. 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.

Table 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*

$\Sigma_i\alpha_{if} = 1$	$\forall$ 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	Simplified adjustment process
$\gamma_{ilf} = \gamma_{il}$	$\forall$ f	Industry invariant coefficient on variable l
$\gamma_{ilf} = 0$		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

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

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. Sufficient conditions for skilled-biased technical change are $\gamma_{S\tau f} > 0$ and $\gamma_{U\tau f} < 0$, or $\gamma_{S\tau f} > \gamma_{U\tau f} > 0$ and $S_{Sf} < S_{Uf}$. Furthermore, the technology is defined as input i using or saving dependent on whether $\gamma_{i\tau f} > 0$ or $\gamma_{i\tau f} < 0$.

The same framework can be used to study the effect on relative labour demand from changes in the capital stock or the output level in the case of non-homotheticity, i.e. we can evaluate

$$\partial(S_{Sf}/S_{Uf})/\partial K_f \text{ and } \partial(S_{Sf}/S_{Uf})/\partial X_f.$$

3 Empirical results

We now present the results from estimating the dynamic system (6). We use industry-level panel data from Norwegian National Accounts. Statistics Norway has calculated industry-level data on man-hours and wages by education for the years 1972-1997. Our panel includes six industries. 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. See Appendix 2 for graphs of variables.

Maximum likelihood estimation of the dynamic cost-share equation system is implemented by using the LSQ-procedure in TSP 4.5 [cf. Hall and Cummins (1999)]. 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 update the estimated covariance matrix of the genuine errors until convergence, cf. Berndt, Hall, Hall and Hausman (1974). The likelihood ratio test (LR-test) is applied to test coefficient restrictions.

Table 2 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 0.039 for skilled and 0.223 for unskilled labour in 1972, by 1997 these shares had increased to 0.109 and decreased to 0.106, respectively.

Table 2. *Cost shares for variable inputs in Norwegian manufacturing, 1972-1997*

	Mean	St. dev.	Minimum	Maximum
Skilled labour	0.074	0.039	0.014	0.176
Unskilled labour	0.160	0.061	0.059	0.314
Materials	0.721	0.063	0.587	0.829
Energy	0.045	0.031	0.009	0.111

The variation across industries in cost shares and some other selected variables is illustrated in Table 3. The table shows important variation across industries. (The NACE-classification of the industries is given in Appendix 1.)

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 largely produce 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.

Table 3. *Empirical mean of selected variables and share of manufacturing employment over 1972-1997*

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	0.074	0.031	0.084	0.049	0.091	0.059	0.126
S_U	0.160	0.137	0.224	0.141	0.101	0.132	0.223
S_M	0.721	0.816	0.669	0.752	0.740	0.718	0.633
S_E	0.045	0.016	0.023	0.059	0.068	0.091	0.014
$\ln P_S$	4.616	4.472	4.554	4.604	4.754	4.675	4.636
$\ln P_U$	4.412	4.256	4.360	4.404	4.557	4.470	4.427
$\ln P_M$	-0.389	-0.363	-0.441	-0.437	-0.392	-0.340	-0.361
$\ln P_E$	-0.519	-0.436	-0.439	-0.616	-0.612	-0.621	-0.388
lnX	10.473	11.253	11.276	9.658	9.599	10.106	10.947
lnK	10.116	10.351	10.613	9.722	9.766	10.092	10.150
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, P_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.

As already explained, a disadvantage of the translog function is that the regularity conditions, i.e. the "concavity in prices" condition in our case, may be violated, cf. Jorgenson (1986). We therefore check this condition on the general model and various reductions of this. In general, we find that global concavity is not satisfied, and we therefore impose the necessary restrictions to achieve this.

Let the (symmetric) matrix β be defined by $\beta = \begin{bmatrix} \beta_{SS} & \beta_{US} & \beta_{MS} \\ \beta_{US} & \beta_{UU} & \beta_{UM} \\ \beta_{MS} & \beta_{UM} & \beta_{MM} \end{bmatrix}$. To impose global concavity we follow Diewert and Wales (1987) and parameterize β as $\beta = -\zeta\zeta'$,

where ζ is a lower triangular matrix given by $\zeta = \begin{bmatrix} \zeta_{SS} & 0 & 0 \\ \zeta_{US} & \zeta_{UU} & 0 \\ \zeta_{MS} & \zeta_{UM} & \zeta_{MM} \end{bmatrix}$. In addition, in order to avoid problems with convergence, $\zeta_{SS} = \zeta_{MM} = 0$.

An alternative and less restrictive approach is to apply local rather than global concavity as in Ryan and Wales (2000). Imposing local concavity at a single point may result in concavity at many points. Local concavity in our setting with industry-level panel data is less neat to achieve than in their setting, and we have not followed that line.

The estimated maintained model

The estimated coefficients of the maintained model are given in Table 4. The cost-share equation of energy is not included in Table 4, but the long-run part of this equation can easily be found by using the adding up conditions in Table 1. The results show that there are no short-run effects on the cost-shares of changes in the level of capital. Furthermore, we find no short-run effect on the cost share of skilled labour of changes in unskilled wages and visa-versa. In the following discussion, we concentrate on the long-run results.

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-material producing industries, and also across the two remaining industries Miscellaneous manufacturing (f=25) and Machinery (f=45). In these five industries, the scale bias is negative for skilled labour, i.e. the cost-share decreases as output grows. With respect to unskilled labour, we find a negative scale bias in the three raw-material producing industries, while the scale bias is zero, i.e. the cost share is not affected by output growth, in the more labour intensive industries Miscellaneous manufacturing and Machinery. For materials the scale bias is positive in the five non-homothetic industries, while the scale bias is close to zero for energy in these industries. Concentrating on the effect of output growth on the skilled-unskilled labour ratio, we find that this ratio declines in the labour intensive industries Miscellaneous manufacturing and Machinery, while the ratio increases in all three raw-material producing industries. Hence, an expansion in output in these two labour intensive industries is done by employing relatively less skilled labour, while this is not the case in the raw-materials producing industries.

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 labour in the labour intensive industries Food, beverages & textiles and Machinery, the same is true in Metals. The skilled-unskilled labour ratio remains unchanged as capital grows in Chemicals, but declines in Miscellaneous manufacturing and Paper & pulp. Miscellaneous manufacturing is a relatively broad aggregate, however, covering wood, chemical and metal products. Changes over time in the composition of the various products included in this industry may influence the results to some extent. In general, the estimated capital stock effects may capture a technical change effect, because the capital measures applied probably include embodied technical change. Since capital stock has followed a positive trend, at least most of the sample period for most of the industries, one may expect a positive correlation between the capital stock measure and embodied technical change to be present and affect the results.

Table 4. *Coefficient estimates of the maintained cost-share equations model*

Long-run coefficients	Esti-mates	Std. error	Constant terms	Esti-mates	Std. error	Short-run coeff.	Esti-mates	Std. error
β_{SS}	-0.059[a]	.021	α_{S15}	0.143	.076	b_{SS}	0.037	.009
β_{SM}	-0.025[a]	.008	α_{S25}	0.775	.219	b_{SU}	0[b]	
β_{UU}	-0.139[a]	.020	α_{S34}	0.304	.189	b_{SM}	-0.035	.005
β_{US}	0.090[a]	.021	α_{S37}	0.209	.078	b_{SE}	0[b]	
β_{UM}	0.039[a]	.015	α_{S43}	0.330	.196	b_{UU}	0.100	.013
β_{MM}	-0.017[a]	.012	α_{S45}	0.561	.179	b_{US}	0[b]	
γ_{SXf} f=15	0[b]		α_{U15}	1.570	.291	b_{UM}	-0.094	.007
γ_{SXf} f=25,45	-0.054	.016	α_{U25}	0.461	.062	b_{UE}	-0.015	.005
γ_{SXf} f=34,37,43	-0.012	.008	α_{U34}	1.674	.277	b_{MS}	0[b]	
γ_{UXf} f=15,25,45	0[b]		α_{U37}	0.972	.119	b_{MU}	-0.118	.018
γ_{UXf} f=34,37,43	-0.068	.014	α_{U43}	2.642	.280	b_{MM}	0.170	.011
γ_{MXf} f=15	0[b]		α_{U45}	1.698	.292	b_{ME}	-0.022	.006
γ_{MXf} f=25,45	0.059	.022	α_{M15}	-0.347	.319	b_{SX}	-0.035	.005
γ_{MXf} f=34,37,43	0.081	.019	α_{M25}	-0.143	.248	b_{SK}	0[b]	
γ_{SKf} f=15,25	-0.023	.007	α_{M34}	-1.875	.803	b_{UX}	-0.081	.007
γ_{SKf} f=34,43	-0.031	.017	α_{M37}	-0.436	.177	b_{UK}	0[b]	
γ_{SKf} f=37,45	0[b]		α_{M43}	-1.246	.427	b_{MX}	0.116	.010
γ_{UKf} f=15,45	-0.122	.028	α_{M45}	-1.182	.388	b_{MK}	0[b]	
γ_{UKf} f=25,37	0[b]					d_{SS}	0.442	.085
γ_{UKf} f=34	-0.069	.028				d_{SU}	0.116	.064
γ_{UKf} f=43	-0.160	.027				d_{SM}	0.121	.061
γ_{MKf} f=15,45	0.101	.031				d_{UU}	0.392	.090
γ_{MKf} f=25,37	0[b]					d_{US}	0.058	.119
γ_{MKf} f=34,43	0.101	.040				d_{UM}	0.142	.086
$\gamma_{S\tau f}$ f=15	0[b]					d_{MM}	0.406	.134
$\gamma_{S\tau f}$ f=25,45	0.003	.0003				d_{MS}	0.253	.187
$\gamma_{S\tau f}$ f=34,43	0.002	.0004				d_{MU}	0.179	.140
$\gamma_{S\tau f}$ f=37	0.001	.0003						
$\gamma_{U\tau f}$ f=15	0.002	.0008						
$\gamma_{U\tau f}$ f=25,45	-0.003	.0004						
$\gamma_{U\tau f}$ f=34	0.004	.0007						
$\gamma_{U\tau f}$ f=37,43	0[b]							
$\gamma_{M\tau f}$ f=15	-0.001	.0009						
$\gamma_{M\tau f}$ f=25,37,45	0[b]							
$\gamma_{M\tau f}$ f=34	-0.003	.0009						
$\gamma_{M\tau f}$ f=43	-0.001	.0005						

Est. period = 1973-97 S: R^2 = 0.640, SER = 0.003 U: R^2 = 0.846, SER = 0.004 M: R^2 = 0.821, SER = 0.006

Maximum likelihood estimation. 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.

[a] The parameter estimate is derived from the estimates of the parameters involved when imposing global price concavity. The standard error is obtained by the delta-method.

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

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 evidence of skilled-biased technical change in Norwegian manufacturing, i.e. $\partial(S_{Sf}/S_{Uf})/\partial\tau > 0$. And furthermore, with the exception of Food, beverages & textiles only, we find skilled-using technical change in all industries, i.e. $\gamma_{S\tau f} > 0$. The results imply unskilled-saving technical change in the two labour intensive industries Miscellaneous manufacturing and Machinery, while we find unskilled-using technical change in Food, beverages & textiles and Paper & pulp. Based on these findings, we conclude, however, that the skilled-biased technical change effect is more due to skilled-using than unskilled-saving technical change.

As already explained, however, the trend effect should be interpreted with some care, since we may face a measurement error problem and the trend may pick up other effects than technical change. In addition, in the literature, 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 share of all skilled workers in Norway is employed in the manufacturing industries that we analyse. This share was 15 per cent in 1978 and declined to 14 per cent in 1997. Due to this, we expect the argument above to be less important for our analysis than if we had modelled labour demand of the whole economy.

Later in this paper we test the weak exogeneity assumption on wages and output. We also test the validity of the coefficient restrictions of the maintained model.

Price elasticities

In Table 5 we present the long-run own-price and cross-price elasticities as predicted by the maintained model in Table 4. Empirical sample means of the cost shares are used in the calculations. The standard errors are calculated at the predicted sample means, cf. Toevs (1982). Table 5 shows that all own-price elasticities evaluated at sample means have the correct sign. This is true for all sample points. By restriction, our maintained model satisfies the "concavity in prices" condition. Without the necessary coefficient-restrictions, this regularity condition is violated. The price elasticities are in general relatively large, implying that input demand in Norwegian manufacturing is rather sensitive to changes in relative input prices.

Table 5. *Own- and cross-price elasticities in the maintained model calculated at the overall empirical mean of the cost shares*

Own-price elasticities	Estimate	Cross-price elasticities	Estimate
ε_{SS}	-1.718 (.213)	ε_{SU}	1.381 (.213)
ε_{UU}	-1.712 (.168)	ε_{US}	0.639 (.182)
ε_{MM}	-0.302 (.024)	ε_{SM}	0.381 (.087)
ε_{EE}	-1.097 (.083)	ε_{MS}	0.039 (.012)
		ε_{SE}	-0.043 (.065)
		ε_{ES}	-0.070 (.112)
		ε_{UM}	0.965 (.114)
		ε_{MU}	0.213 (.026)
		ε_{UE}	0.108 (.084)
		ε_{EU}	0.383 (.172)
		ε_{ME}	0.049 (.010)
		ε_{EM}	0.785 (.119)

Standard errors in parentheses are obtained by the delta-method. The standard errors are evaluated at the predicted cost shares (where the observed variables are represented by their overall empirical means).

According to the results, the demand for labour, both skilled and unskilled, is clearly elastic, while the demand for materials input is inelastic. The cross-price elasticities between skilled labour and energy are not significantly different from zero, which means that the demand for these two inputs on average are independent. The demand for unskilled labour is independent of changes in the energy price. The positive and significant cross-price elasticities between labour and materials, which implies that these inputs are substitutes, are interesting. Materials include services and subcontracting, and the high degree of labour-materials substitution, particularly for unskilled labour, probably captures an outsourcing or out-contracting effect.

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 $100 \cdot V_S/(V_S+V_U)$. According to Figure 1, the use of skilled labour relative to unskilled labour has increased over time in all industries. 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.

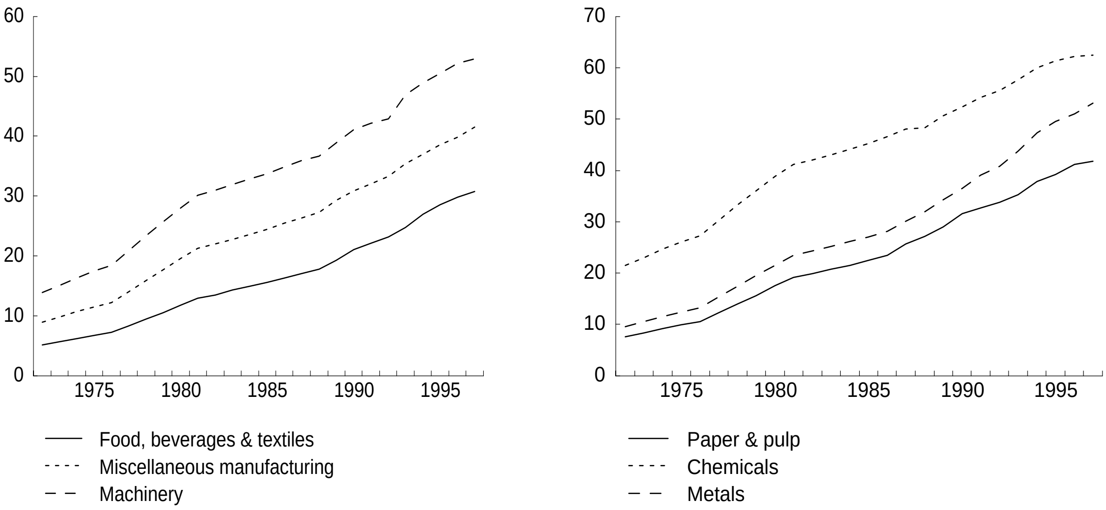

Fig. 1. Skilled man-hours in per cent of total man-hours in different industries

To get a better understanding of how the various explanatory variables included in our maintained model in Table 4 have contributed to the increase in the skilled-labour share, a number of simulations have been conducted on the model. These simulations should be interpreted with care, since the supply side of the labour market, or the wage formation, is not modelled. 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. The simulated change in the skilled-labour share is interpreted as the isolated effect of the variable in question on labour demand. The "All variables" alternative is a standard within sample dynamic simulation of the estimated model, where all the explanatory variables follow their historical path. The results from these simulations are summarised in Table 6.

Table 6 shows that, according to the maintained model presented in Table 4, the increase in the skilled-labour share in Norwegian manufacturing is very much due to price effects and technical change (compare row 3 "Observed change" with row 5 "P_i" and row 6 "τ" respectively). Concentrating on the All industries column, the isolated effect of price changes and the trend is an increase in the skilled-labour share of 18.5 and 15.4 percentage points respectively from 1973 to 1997. These effects can be compared with the observed change of 33.3 percentage points in this share. The observed capital stock growth and output growth affect the All industries skilled-labour share relatively little.

Table 6. *Observed and simulated changes in the skilled-labour share (in man-hours) from 1973 to 1997 in percentage points*[a]

		All industries[b]	Food, beverages & textiles	Miscel. manufacturing	Paper & pulp	Industrial chemicals	Basic metals	Machinery
True share	1973	10.5	5.7	9.8	8.4	22.9	10.5	15.0
in per cent	1997	43.8	30.7	41.5	41.7	62.4	53.1	52.9
Observed change		33.3	25.0	31.7	33.3	39.5	42.6	37.9
Simulated change								
P_i i=S,U,M,E		18.5	25.5	14.8	18.2	19.4	16.7	16.7
τ		15.4	1.6	21.9	14.3	10.3	13.1	18.6
K		3.8	1.9	2.1	0.5	4.7	3.7	6.6
X		1.2	2.5	-0.1	3.8	13.6	2.7	-1.3
All variables		32.9	23.7	31.7	32.5	40.1	43.7	37.2

[a] The simulations are dynamic over 1973-1997. The model in Table 4 is used. Sub-sets of the explanatory variables follow their historical path, while the remaining are kept constant at their 1972-values. The "All variables" alternative is a standard dynamic simulation on the estimated model. The simulated change in the skilled-labour share is found by subtracting the observed share in 1973 from the predicted share in 1997. The latter is found by using the identity $100 \cdot V_S / [V_S + V_U] \equiv 100 \cdot S_S / [S_S + (P_S / P_U) \cdot S_U]$.

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

The main conclusions are relatively robust across industries, but there is some variation. While the trend effect is relatively large in the two labour intensive industries Miscellaneous manufacturing and Machinery compared with the three raw materials producing industries, the trend effect in the third labour intensive industry Food, beverages & textiles is only minor. For this last industry we find the largest price effects, however. In all industries the price effects are dominated by a skilled-unskilled labour substitution effect due to changes in relative wages. There has been a general increase in relative wages between unskilled and skilled most of the sample period, see Figure A5 in Appendix 2. Output growth, and hence non-homotheticity, is not very important for relative labour demand according to our results. The exception is Chemicals, for which the isolated effect of output growth is important. A comparison of the "All variables" row with the "Observed change" row shows that the model predicts very well the increase in the skilled-labour share in all industries over the design period.

Validity of coefficient restrictions

Compared to our most general model, the maintained model in Table 4 includes 40 coefficient restrictions of which 24 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 four subsets, and the robustness of each subset is checked by testing the restricted maintained model in Table 4 (H_M) versus the alternative and (more) general model ($H_{A,r\text{-}s}$, r,s=1,..,4, 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 7.

Table 7. *The restrictions on the maintained model in Table 4 sorted in subsets*

Subset	Restrictions
1	$b_{SU}= 0$; $b_{SE} = 0$; $b_{US} = 0$; $b_{MS} = 0$; $b_{iK} = 0$, i=S,U,M
2	$\gamma_{iX15} = 0$, i=S,U,M; $\gamma_{iX45} = \gamma_{iX25}$, i=S,M; $\gamma_{UX45} = \gamma_{UX25} = 0$;
	$\gamma_{iX43} = \gamma_{iX37} = \gamma_{iX34}$, i=S,U,M
3	$\gamma_{iK43} = \gamma_{iK34}$, i=S,M; $\gamma_{iK37} = 0$, i=S,U,M; $\gamma_{iK45} = \gamma_{iK15}$, i=U,M; $\gamma_{iK25} = 0$, i=U,M;
	$\gamma_{SK25} = \gamma_{SK15}$; $\gamma_{SK45} = 0$
4	$\gamma_{S\tau15} = 0$; $\gamma_{i\tau45} = \gamma_{i\tau25}$, i=S,U; $\gamma_{M\tau45} = \gamma_{M\tau25} = 0$; $\gamma_{S\tau43} = \gamma_{S\tau34}$;
	$\gamma_{U\tau37} = \gamma_{M\tau37} = \gamma_{U\tau43} = 0$

Table 8 reports the LR-statistics and associated significance probabilities from testing the maintained model versus more general alternative models defined by the subsets of restrictions in Table 7. The last row of Table 8 confronts the maintained model with our most general model. According to the LR-statistic, all coefficient restrictions on the maintained model are accepted, and we conclude that the maintained model is a reasonable simplification of the general model given at the outset.

Table 8. *Likelihood ratio-tests of the maintained model in Table 4 against more flexible specifications*[a]

Test	Alternative model ($H_{A,r\text{-}s}$)[b]	LR (n_R)	Significance probability
1	H_{A1}	9.40 (7)	0.2253
2	H_{A2}	10.09 (13)	0.6862
3	H_{A3}	3.34 (11)	0.9853
4	H_{A4}	12.40 (9)	0.1919
5	$H_{A,1\text{-}4}$	47.57 (40)	0.1916

[a] LR is the standard likelihood-ratio test statistic. n_R is the number of restrictions.
[b] Confer Table 7.

We also test if we can restrict our maintained model to include a scalar adjustment matrix, i.e. if $d_{ij} = 0$, i,j = S,U,M, $i \neq j$ and $d_{ii} = d$, i = S,U,M. The LR-statistic equals 29.62 in this case. The number of restrictions is 8, and this gives a significance probability of 0.00025. We clearly reject this hypothesis. However, since our maintained model contains a rather high number of estimated coefficients, it may be important to correct for our relatively small sample. Using the small sample correction suggested by Italianer (1985)[6], we get a corrected LR-statistic of 25.34, which gives a significance probability of 0.00136, and again we reject the scalar adjustment-matrix hypothesis.

Testing for weak exogeneity

To test for weak exogeneity of output and wages, we conduct Hausman-Wu misspecification tests [cf. Godfrey (1988), pp. 148-149]. Marginal models are constructed for the variables $\Delta\ln(X_{ft})$, $\Delta\ln(P_{Sft})$ and $\Delta\ln(P_{Uft})$. In the marginal model for $\Delta\ln(X_{ft})$ we use current changes of the product price relative to variable unit costs (incl. taxes), lagged changes of the capital stock, lagged levels of output, the levels of the price/cost variable and the capital stock. All variables are in logarithms. We also include a deterministic trend variable. As the product price we use the export price for the three export oriented raw-materials producing industries, while we use the price on domestic deliveries for the remaining three industries. With respect to wages, we use a wage-curve modelling framework, where changes in the nominal wages are a function of unemployment, consumer and producer prices and labour productivity growth. In addition, dummy variables are included to capture the effects of wage and price stops.[7] With respect to both output and wages, industry specific equations are estimated.

Based on the three estimated marginal equations, we derive three vectors of residuals that we include in our maintained model in Table 4. We test whether these additional variables are significant in the dynamic factor demand system by using a standard LR-test. Testing the assumption that all three variables are weakly exogenous simultaneously gives a LR-value equal to 9.8481, and according to the $\chi^2(9)$-distribution this gives a significance probability of 0.3629. We have also tested the assumption of weak exogeneity on output and wages separately. Including only the residuals from the marginal output equation gives a LR-value of 3.0452, which gives a significance probability of 0.3847 using the $\chi^2(3)$-distribution. Testing weak exogeneity of the two wages gives a LR-value of 7.2545, which gives a

[6] The small-sample corrected LR-statistic suggested by Italianer (1985) is defined by $LR_{SI} = m_I LR$. $m_I = [pT-0.5(n_A+n_M)-0.5p(p+1)]/pT$, 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.

[7] We thank Roger Bjørnstad and Jørgen Ouren for providing us with the estimation results for the wage equations.

significance probability of 0.2980 according to the $\chi^2(6)$-distribution. These LR-tests clearly support the weak exogeneity assumptions on output and wages.

4 Conclusions

Using a multivariate error-correction model of the cost shares of skilled and unskilled labour, materials and energy, the increase in skilled-labour use relative to unskilled-labour use is analysed. Industry-level panel data from Norwegian manufacturing over 1972-1997 is applied. Norwegian manufacturing, excluding Petroleum refining and Shipbuilding, is divided in three labour intensive and three less labour intensive raw-materials producing industries. The three latter industries are also highly export oriented. Focus is on the importance of non-neutral technical change, substitution due to changes in relative wages and other input 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 relative demand for skilled labour is due to within industry changes. In Norwegian manufacturing, the between industry effect is marginal. Second, the econometric analysis shows that skilled-biased technical change is present in all but one industry. And furthermore, this non-neutrality is more due to skilled-using than unskilled-saving technical change. Hence, the results support the assumption that introduction and utilisation of new technology is conditioned on the presence of skilled labour and that skilled labour and new technology are complements.

Homotheticity is rejected in all but one of the labour intensive industries, and an increase in output will, in general, affect the skilled-unskilled labour ratio. In the two remaining labour intensive industries, the skilled-unskilled labour ratio declines as output increases, while the skilled-unskilled labour ratio increases in all the three raw-materials producing industries. Hence, output growth in these two labour intensive industries is accomplished by employing relatively less skilled and relatively more unskilled labour, while the opposite is the case in the raw-materials producing industries. Our interpretation of these results is that the raw-materials producing industries, which are also relatively capital intensive, need to employ more skilled labour to be able to increase the capital utilisation or take into use new capacity. The labour intensive industries can achieve output growth by employing more unskilled labour while keeping the use of skilled labour more stable.

The effect of increased capital stock on the skilled-unskilled labour ratio is mixed across the industries. Increased capital stock increases the skilled-unskilled labour ratio in two of the labour intensive industries and decreases this ratio in the third. With respect to the raw-materials producing industries we find evidence for an increase in the skilled-unskilled labour ratio in one industry, a decline in this ratio in a second industry and a constant skilled-unskilled labour ratio in the third.

Dynamic simulations on the estimated cost-share equation model over 1973-1997 reveal that particularly two factors have contributed significantly to the shift in skilled-unskilled labour demand. In addition to skilled-biased technical change, we find that substitution, due to changes in relative input prices, explain most of the shift. Furthermore, these substitution effects largely reflect mutual labour substitution due to a decline in relative wages between skilled and unskilled labour. Although homotheticity is rejected for all but one industry, the scale bias has in general not affected relative labour demand much.

Although this analysis has contributed to our understanding of the shift in the skilled-unskilled labour ratio, more work needs to be done. Due to data availability, we have focused on the development in manufacturing industries. However, a large share of the labour force is employed in private service industries and the public sector, and an important extension of this analysis would be to do similar analyses for these industries. Furthermore, to conduct policy analyses, with, for instance, the purpose to improve the labour market conditions for unskilled workers, a more complete model of the labour market is required. In that case, we would also need to model labour supply or the wage formation. A third interesting extension would be to estimate scale properties and evaluate the time dependency of these.

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. 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
P_{Sf} Skilled labour costs per man-hour in industry f, NOK
P_{Uf} Unskilled labour costs per man-hour in industry f, NOK
M_f Materials input in industry f, constant 1997-NOK
P_{Mf} Price of materials in industry f, the price index is 1 in 1997
E_f Energy consumption, defined as the sum of electricity and fuels, by industry f, constant 1997-NOK. In general, electricity dominates the aggregate
P_{Ef} Price of energy consumption in industry f, the price index is one in 1997
X_f Real gross output in industry f, constant 1997-NOK
K_f Real capital stock of industry f measured at the beginning of the year, constant 1997-NOK

The definition of industries follows the Norwegian national accounts, which is based on the 2-digit NACE-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 because they differ from the other industries in important ways at the same time as they employ a small share of total employment.

Table A1. *Manufacturing industry*

Code	Definition	NACE-Rev. 1	Output share 1997
15	Food, beverages & textiles	14, 15, 16, 17, 18	23.1
25	Miscellaneous manufacturing	10, 20, 22, 25, 37	23.0
34	Paper & pulp	21	4.3
37	Industrial chemicals	24	5.1
43	Basic metals	27	8.9
45	Machinery	30	19.7
40	Petroleum refining	23	4.5
50	Shipbuilding	35, 36	11.4

Appendix 2

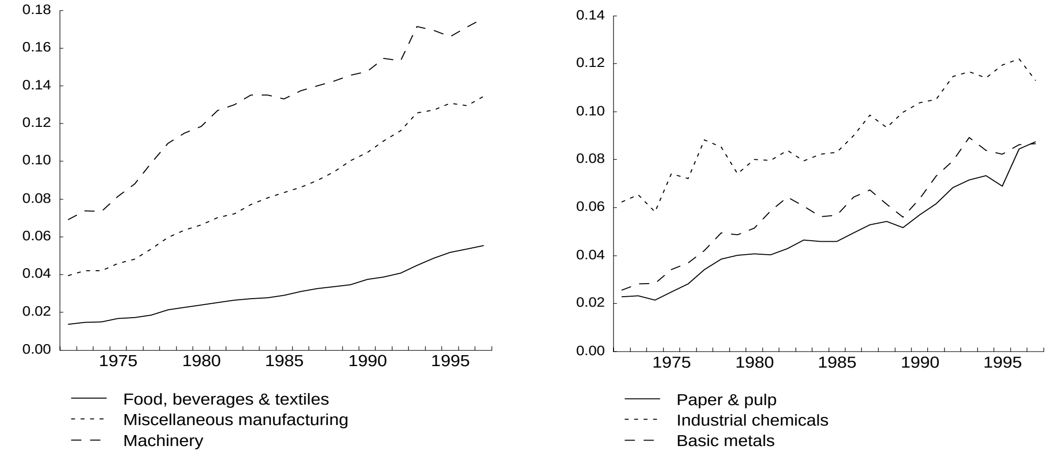

Fig. A1. Cost shares of skilled labour in Norwegian manufacturing

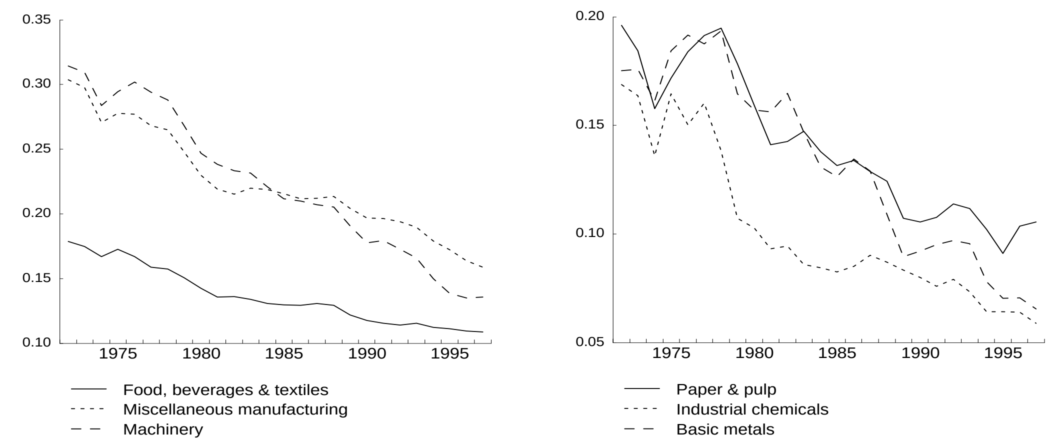

Fig. A2. Cost shares of unskilled labour in Norwegian manufacturing

Fig. A3. Cost shares of materials in Norwegian manufacturing

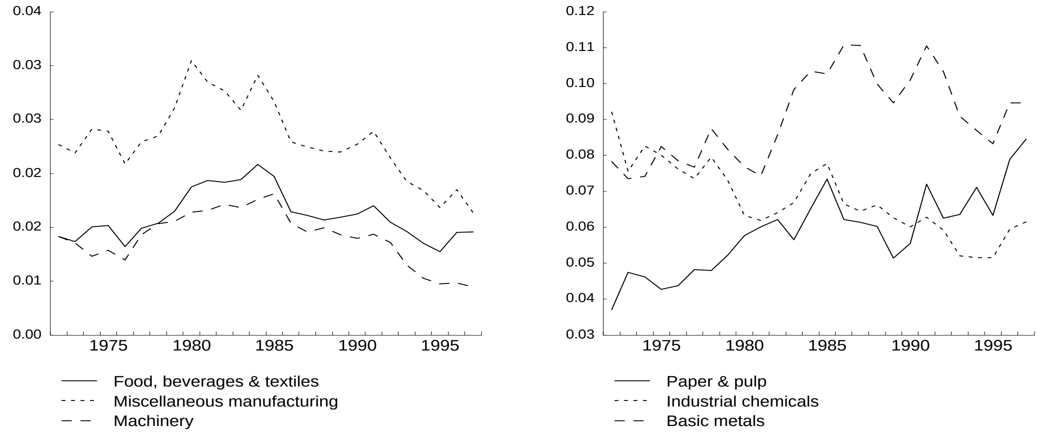

Fig. A4. Cost shares of energy in Norwegian manufacturing

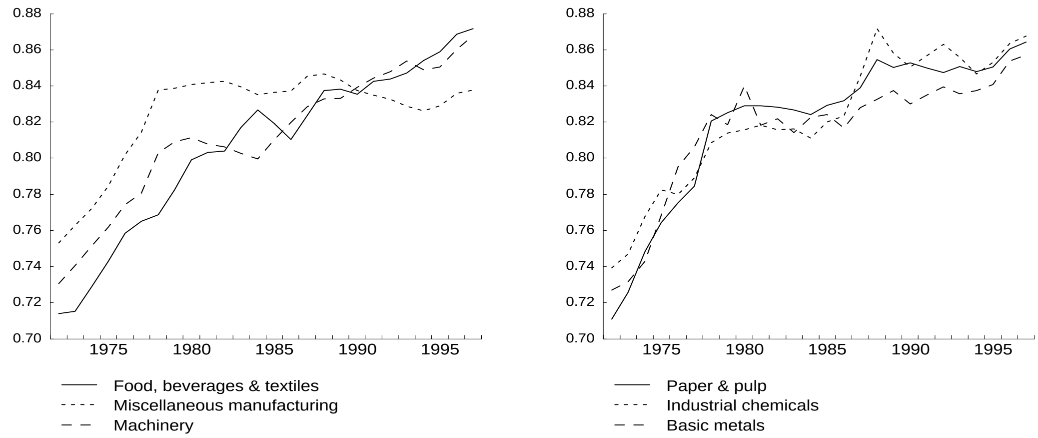

Fig. A5. Labour cost per man-hour of unskilled relative to skilled in Norwegian manufacturing

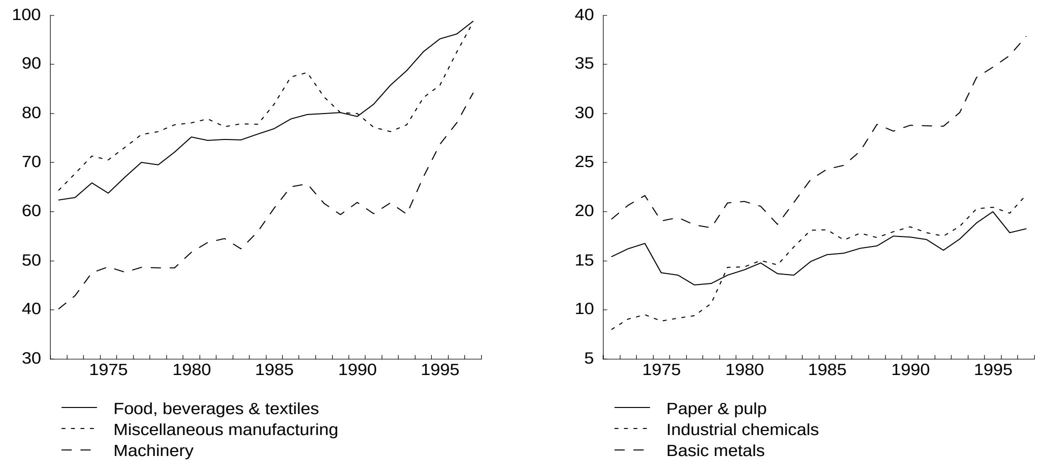

Fig. A6. Output in Norwegian manufacturing. Million 1997-NOK

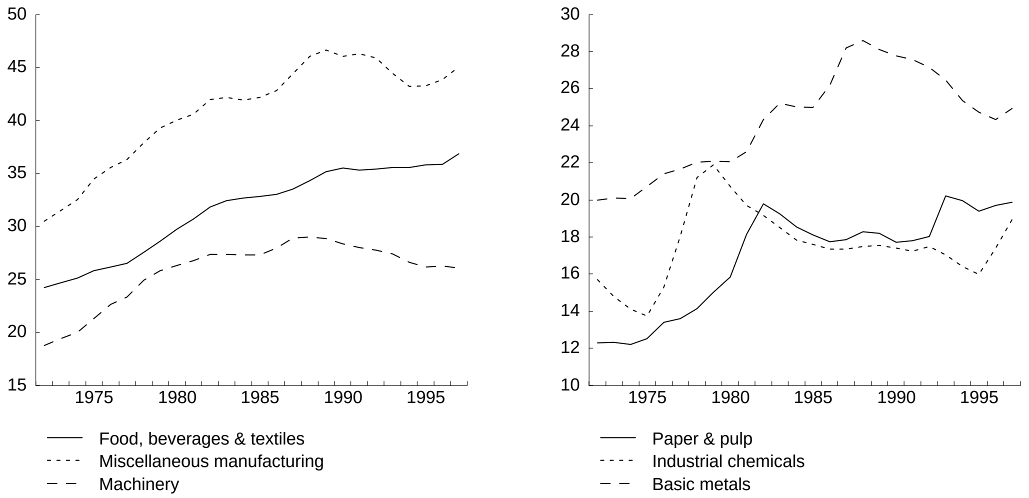

Fig. A7. Real capital stock in Norwegian manufacturing. Million 1997-NOK

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