Trade, Technology and Changes in Employment of Skilled Labour in Swedish Manufacturing*

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Abstract

The paper investigates the shift in demand towards more skilled labour in Swedish manufacturing during the last two decades. Two competing hypotheses to explain this shift are examined: skilled-biased technical change and increased international competition.

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1. Introduction

The composition of employment has undergone considerable changes during the last few decades. In particular, the skill level in the labour force has risen. The share of employees with higher education (tertiary) in Swedish manufacturing rose from 2.7 percent in 1970 to 15.7 percent in 1993 and a similar pattern can be observed in many other OECD countries.

The two most popular hypotheses put forward to explain this development are: increased international competition from the newly industrialized and the less-developed countries (NICs and LDCs) and technical progress which reduces the need for unskilled labour, i.e., unskilled-labour-saving biased technical progress. The former explanation is primarily expected to result in increased specialization in skill-intensive industries, and accordingly, to growing employment in these industries and contracting employment in industries using large shares of unskilled labour. The latter effect is mainly supposed to take place within industries and implies rising skill-intensities within industries and plants. Yet stronger exposure to trade may also raise the within-industry share of skilled labour. Wood (1994, 1995) argues that, above all, increased import competition from NICs and LDCs would raise the proportion of skilled labour within industries due to shifts from less-skill-intensive to more-skill-intensive activities and/or by search for new production methods that economize on unskilled labour ("defensive innovation").

The purpose of this paper is to examine the importance of these factors in Swedish manufacturing industries during the 1970s and the 1980s. One approach is to decompose the changes in the share of skilled labour into between- and within-industry changes. Previously, the method has been used by Berman, Bound & Griliches (1994) for the US and by Machin (1994) for the UK. An advantage with this study is that we have access to better data on skill and that we have data at the plant level. The latter means that we can decompose the changes in the share of skilled labour further, i.e., into within- and between-plant changes. We can also look at skill shares in plants entering into and exiting from the industry and make comparisons with plants that have been in operation the whole studied period.

Another way to investigate shifts in skill structure is to examine whether changes in the demand for skilled labour can be attributed to technical changes. There are many examples where the introduction of computers has shifted the composition of labour demand from manual production workers towards technicians and other types of skilled labour. To analyse this more systematically we follow a methodology developed by Berman, Bound & Griliches (1994), where we derive our estimated model from a translog cost function and regress changes in the share of skilled labour on various indicators of technical change. Within this framework we also test the idea set out by Wood that increased import competition would affect the within-industry share of skilled labour.

This paper is organized as follows: Section 2 documents some trends in Swedish manufacturing employment and trade; Section 3 gives a theoretical background; in Section 4 we present the decomposition; in Section 5, we attempt to explain the shift in the demand for skilled labour with observable measures of technical change; Section 6 provides a conclusion to this paper.

2. Trends in skill structure and internationalization

Both in the US and the UK one can observe a steady increase in the share of skilled labour in manufacturing during the post-war period. For the period 1970 to 1990 Berman, Machin & Bound (1994) discovered a shift towards increased use of skilled workers in almost all the studied countries (both developed and developing). In theirs and many other studies, skilled labour is defined as non-production workers and a growing share of non-production workers is interpreted as increased use of relatively skilled workers. Obviously, the distinction between production and non-production workers is a crude measure of skill and some economists, e.g., Leamer (1994), have asserted that it is inappropriate. A worker’s skill is probably related to education, on-the-job training and work experience, and obviously, there are misclassifications with the measure since not all non-production workers are skilled and not all production workers are unskilled. For instance, low-skilled office employees are classified as non-production workers. Generally, however, non-production workers appear to have higher education.[1]

Our classification of skilled labour is based entirely on educational attainment. Of course, educational attainment is an imperfect measure of skill.[2] The main weakness is that it does not capture experience and it partially understates participation in further education and training. Another problem is variations in quality of schooling, both over time and between areas. Educational attainment seems, however, to be strongly correlated with occupation and earnings, and initial attainment is a good predictor of whether a person will participate in further education and training. We thus think educational attainment is a better measure of skill than the share of non-production workers.

We define skilled labour as employees with tertiary education, i.e., most of them have at least 15 years of education. We can observe a continuous increase in the share with higher education in the whole economy from 8.6 percent in 1971 to 25.8 percent in 1994. The corresponding figures for the manufacturing industry (the tradables sector) is lower, but shows the same pattern of development over time. From **Table 1** it is evident that the non-manufacturing part of the economy (the nontradables sector) is dominated by the public sector, in which the skill share has grown considerably. A substantial increase in the share of skilled labour has also occurred in the financial sector. On the other hand, the rest of the nontradables sector is not as skill intensive, and has experienced less structural changes regarding employment and skill intensity, in comparison with manufacturing.

Table 1 Sector skill and sector employment shares in 1994 and changes in shares between 1971-94 in Sweden, in percentage terms.

***F*igure 1** Foreign trade ratio in Swedish manufacturing 1969-92, in current prices.

To a large extent the growing skill level in manufacturing coincided with increased internationalization, which ***F*igure 1** demonstrates. Over the past 20 years international trade in Sweden has been boosted by international agreements, e.g., the free trade agreement between the EC and EFTA (which came into force in 1973) and the Tokyo Round (which was completed in 1979), market liberalization in the developing world, and falling costs of communication and transport. ***F*igure 1** shows the foreign trade ratio in manufacturing, i.e., exports plus imports as a share of the value of sales (production). The foreign trade ratio rose from 55 percent in 1969 to 90 percent in 1985, but has since then been almost constant (92 percent in 1992). Hence, it is inviting to believe that increased internationalization has, at least partially, affected the employment structure in manufacturing.

3. Theoretical background[3]

3.1 International trade

To see how international trade may influence the composition of employment, let us consider the simple 2×2×2 Heckscher-Ohlin-Samuelson (HOS) model.[4] There are two factors of production (skilled and unskilled labour) producing two goods (a skilled-labour-intensive and an unskilled-labor-intensive good) where one country has an abundance of skilled labour and therefore exports the skilled-labour-intensive good, whilst the other country exports the unskilled-labour-intensive good.[5]

Reciprocal reduction of tariffs and/or falling costs of communications and transport may lead to a situation where trade expands as a share of GDP without any change in the international prices of goods. The changes will, however, increase the domestic price in Sweden of the skilled-labour-intensive good and lower the domestic price of the unskilled-labour-intensive good. This will imply increased demand for skilled workers since overall production shifts towards the skill-intensive good and away from the less-skill-intensive good because of increased international specialization according to comparative advantage. In the simple Heckscher-Ohlin model, the endowments of skilled and unskilled labour are assumed to be fixed in each country as these trade and product market changes take place. To preserve the labour market equilibrium and in response to the change in relative factor prices (higher relative wages of skilled workers), there will be a substitution of unskilled labour for skilled labour within each subsector. Thus, as trade expands, there is both a **between**-industry shift in employment towards the skilled labour-intensive goods and a **within**-industry shift in both industries towards an increase in the proportion of unskilled workers.

3.2 Unskilled-labour-saving biased technical progress

The increased requirement of skilled labour **within** industries could, however, be explained by skilled-biased technical progress. Technical progress means that more output can be produced with given amounts of inputs, and unskilled-labour-saving technical progress increases the marginal productivity of skilled labour more than it raises the marginal productivity of unskilled labour at a constant ratio of skilled to unskilled labour. Unskilled-labour-saving technical progress is illustrated in ***F*igure 2**.

***F*igure 2** Unskilled-labour-saving technical progress

$1/\mathbf{p}_Y$ and $1/\mathbf{p}_X$ are unit-value isoquants of the two goods produced in industry *Y* and industry *X*, where $\mathbf{p}_X$ and $\mathbf{p}_Y$ are the initial equilibrium prices. The line *AB* is the unit-value isocost line. Perfect competition implies that prices equal unit costs so that *AB* is tangent to both unit-value isoquants. The slope of *AB* shows the relative wages of unskilled to skilled labour, $\mathbf{w}_u / \mathbf{w}_s$, and the rays from origin to the tangency points indicate the ratio of skilled to unskilled labour used in the production of each good. Hence, the production of the good in industry *Y* is more skill-intensive than the production of the good in industry *X*.

Unskilled-labour-saving technical progress in both industries means that the unit-value isoquants in ***F*igure 2** shift towards the origin and change the tangency point with the unit-value isocost line in a manner such that, for given relative factor prices, i.e., where the slope of the isocost **C***D* equals the slope of *AB*, the ratio of skilled to unskilled labour used in producing each good increases. The product prices $\mathbf{p}$ and $\mathbf{p}$ are unchanged so the same output value can be produced with less skilled and unskilled labour. This is a case where technical progress occurs to exactly the same extent in both industries. Let us now assume that the technical progress is faster in the skill intensive industry *Y*. We illustrate this by the dotted lines in ***F*igure 2.** The slope of the unit-value isocost line **E*F*** is then flatter, i.e., the relative wage $\mathbf{w}_u / \mathbf{w}_s$ decreases. The relative wage of skilled labour increases, since skilled labour is used intensively in the industry with the fastest rate of technical progress.[6] Because technical progress is unskilled-labour-saving, the **within**-industry proportion of skilled labour rises in both industries. The factor endowments are given in our simple 2×2×2 HOS-model, which means that there will also be a **between**-industry shift of employment, namely increased employment in the unskilled-labor-intensive industry *X*, in order to fully employ unskilled labour.

3.3 Increased relative endowments of skilled labour

Let us now relax the assumption of fixed factor endowments. Higher relative wages of skilled labour, as a result of faster technical progress in the skill-intensive industry and/or of intensified international competition in the unskilled-labour-intensive industry, may then lead to increased supply of skilled labour. Increased supply of skilled labour relative to unskilled labour would in turn boost production in the skill-intensive industry *Y* relative to the unskilled-intensive industry *X*.

***F*igure 3** Increased relative endowments of skilled labour

***F*igure 3** exemplifies this. *A* is the initial endowment of skilled and unskilled labour in the economy. $0X_{1A}$ and $0Y_{1A}$ are the employment levels in industry *X* and *Y* respectively. The slopes of these rays from the origin indicate the ratio of skilled to unskilled labor in each industry (cf. ***F*igure 2**). Technical progress which leads to a saving of unskilled labour raises the skill intensity in both industries and leads to new employment levels $0X_{2A}$ and $0Y_{2A}$. Let us now assume that the level of education in the economy rises; the number of skilled grow at the expense of the number of unskilled. Point *B* shows the new factor endowments and $0X_B$ and $0Y_B$ are the new employment levels.

We conclude that unskilled-labour-saving technical progress gives rise to raised **within**-industry proportions of skilled labor. A simultaneous **between**-industry shift in employment towards skill-intensive industries requires, in turn, an increased relative supply of skilled labour.

4. Decomposition of changes in labor skills

We can decompose the increase in skilled labour in Swedish manufacturing into a **between**- and a **within**-industry component. The share of the employed with higher education can be expressed as:

$$P^E = \sum_{i=1}^{n} \frac{\mathbf{E}_i^s}{\mathbf{E}} = \sum_{i=1}^{n} \frac{\mathbf{E}_i^s}{\mathbf{E}_i} \frac{\mathbf{E}_i}{\mathbf{E}} = \sum_{i=1}^{n} P_i^E \mathbf{S}_i \qquad (1)$$

where P_i^E is the share of the employees in industry **i** with tertiary education and $\mathbf{S}_i$ is industry **i**'s share of total employment in manufacturing.

The change in the share of skilled workers can be decomposed into two parts

$$\Delta P^E = \sum_{i=1}^{n} \Delta \mathbf{S}_i \overline{P}_i^E + \sum_{i=1}^{n} \Delta P_i^E \overline{\mathbf{S}}_i \qquad (2)$$

where $\overline{P}_i^E$ and $\overline{\mathbf{S}}_i$ are period averages. The first part captures reallocations of employment between industries, e.g., from low-skill to high-skill industries. Changes in international specialization at the industry level and other factors that invoke changes in product demand between industries imply shifts in this component. Growth in relative endowments of skilled labour would, as we have shown in Section 3, be reflected as shifts in production towards skill-intensive industries. The second part measures increased skill intensities within industries. Technical changes in the production process are, among other things, expected to affect that component.

Table 2 Changes in the employment structure in Swedish manufacturing 1970-90. Between- and within-industry decomposition.

We have studied the changes in skill structure in 36 Swedish manufacturing industries during the periods 1970-85 and 1985-90. It is evident from **Table 2** that the annual total change is about the same in both periods (roughly 0.4 percentage points per year). The within industry component is by far the most important. The **between**-industry component is even negative during the 1985-90 period. This means that most of the shift away from relatively unskilled labour occurred **within** given industries. A result which is in line with similar US and UK work on this issue.

To examine whether changes in international specialization have been related to shifts in the employment structure between industries of different skill-intensities, we correlate cross section changes in the specialization index,[7] $\Delta \mathbf{r}_i$, with the between-industry component, $\Delta \mathbf{S}_i P_i^E$. An increase in the specialization index implies, given unchanged consumption, larger net exports, so a positive relationship indicates the occurrence of a shift in employment from low-skilled to high-skilled industries due to increased net exports of skill-intensive products. According to **Table 2**, the correlation coefficient is positive and clearly significant for the period 1970-85, whereas it is insignificant for the period 1985-90. Our interpretation is that the growing internationalization during the first period (see ***F*****igure 2**) involved a shift in employment between industries towards more skill-intensive industries. During the second period, changes in international specialization seem to have been unrelated to the average skill upgrading of workers. The results are consistent with the findings in Hansson & Lundberg (1995), which indicate that the tendency towards increased specialization in skill-intensive industries may have declined in the late 1980s. The explanation we put forward is insufficient accumulation of human capital during the 1980s in Sweden relative to other countries, in particular to the NICs, but also relative to other OECD countries.

The industry data we use for the period 1970-90 are highly aggregated. For the years 1986 and 1993 we have access to plant level data in 146 manufacturing industries. We start utilizing this data by carry out the same analysis as above. **Table 2** shows that the total annual change is larger in this period (0.9 percentage points) than in the periods 1970-85 and 1985-90. The reason may be the sharp increase in the share of skilled labour between 1990 and 1993.[8] **Table 2** demonstrates that the **within**-industry component is by far the largest. The **between**-industry component is positive, but uncorrelated with changes in international specialization.

Since we have access to data on plants for 1986 and 1993, we can decompose the within-industry component further, i.e., into a within- and a between-plant component. We can express the share of the employees with higher education as:

$$P^E = \sum_{i=1}^{n}\sum_{j=1}^{m}\frac{\mathbf{E}_{ij}^{s}}{\mathbf{E}_{ij}}\frac{\mathbf{E}_{ij}}{\mathbf{E}_{i}}\frac{\mathbf{E}_{i}}{\mathbf{E}} = \sum_{i}\sum_{j} P_{ij}^{E}\mathbf{S}_{ij}\mathbf{S}_{i} \qquad (3)$$

where P_{ij}^E is the share of the employees in plant *j* in industry **i** with tertiary education, $\mathbf{S}_{ij}$ is plant *j*'s share of employment in industry **i**, and $\mathbf{S}_i$ is industry **i**'s share of total employment in manufacturing.

Decomposition of the change in the share of skilled labour gives

$$\Delta P^E = \sum_{i=1}^{n}\sum_{j=1}^{m}\Delta P_{ij}^{E}\overline{\mathbf{S}}_{ij}\overline{\mathbf{S}}_{i} + \sum_{i=1}^{n}\sum_{j=1}^{m}\overline{P}_{ij}^{E}\Delta\mathbf{S}_{ij}\overline{\mathbf{S}}_{i} + \sum_{i=1}^{n}\sum_{j=1}^{m}\overline{P}_{ij}^{E}\overline{\mathbf{S}}_{ij}\Delta\mathbf{S}_{i} \qquad (4)$$

The first component measures the effect of changes in the share of skilled labour within plants. The second captures reallocations of employment between plants within industries and the third is the between-industry component (cf. equation (2)).[9] **Table 3** reports the results of such a decomposition.

Table 3 Changes in the structure of employment of skilled labour within and between plants and between industries.

The changes in employment composition are totally dominated by the within-plant component. The bulk of the increase in the share of skilled labour has occurred within plants, while shifts in employment between plants within industries and between industries have played a minor role.

The data set in **Table 3** consists of all plants with more than five employees that appeared in 1986 and 1993 and in both years were classified to the same industry; altogether this amounts to 7765 plants. This means that plants entering and exiting the industry are excluded. To compare the share of skilled labour in exiting and entering plants[10] with plants that have been in operation the whole period, we estimate two probit regressions:

$$\Pr\mathbf{ob}(\mathbf{Entry}) = \mathbf{f}(\mathbf{Skill\ share},\ \mathbf{Industry})$$

$$\Pr\mathbf{ob}(\mathbf{Exit}) = \mathbf{g}(\mathbf{Skill\ share},\ \mathbf{Size},\ \mathbf{Industry})$$

The variable entry (exit) is a discrete variable, which takes the value one if the plant has entered (exited) between 1986-93 and the value zero if it was in operation in 1986 and in 1993. In both regressions we include the plants' skill share and dummies to control for industry effects. The exit equation also contains a size variable (employment), since virtually all empirical studies of exit have found that smaller plants fail more frequently.[11] The probit estimates are presented in **Table 4**.

Table 4 Probit estimates of entry and exit

We find that the skill share in 1993 was significantly higher in plants established between 1986-93. In exiting plants, the skill share at the begining of the period was almost the same as in surviving plants. Finally, we observe that smaller plants have a significantly larger tendency to fail. We thus conclude that entry has contributed to a higher skill share.

5. Explaining shifts in the demand for skilled labour

To explore factors that might explain within-industry changes in skill structure, we start out from a cost function. We assume that the cost function is a non-homothetic[12] translog where skilled and unskilled labour are variable factors and capital is treated as a quasi-fixed factor, i.e., producers cannot adjust freely in response to relative price changes. This means that we can write the restricted variable or total labour cost function as

$$\ln(\mathbf{C}V) = \mathbf{a}_0 + \mathbf{a}_1 \ln \mathbf{w} + \mathbf{a}_2 \ln \mathbf{w}_u + 0.5[\mathbf{b}_{11} (\ln \mathbf{w})^2 + \mathbf{b}_{12} (\ln \mathbf{w})(\ln \mathbf{w}_u) +$$

$$\mathbf{b}_{21} (\ln \mathbf{w}_u)(\ln \mathbf{w}_s) + \mathbf{b}_{22} (\ln \mathbf{w}_u)^2] + \sum_{h=1}^{3} [\mathbf{c}_{0h} \mathbf{z}_h + \mathbf{c}_{1h} (\ln \mathbf{w}_s)(\mathbf{z}_h) + \mathbf{c}_{2h} (\ln \mathbf{w}_u)(\mathbf{z}_h)] \qquad (5)$$

$\mathbf{C}V$ is variable or total labour cost and $\mathbf{w}_s$ and $\mathbf{w}_u$ are wage rates of skilled and unskilled workers, respectively. $\mathbf{z}_1 = \ln K$ and $\mathbf{z}_2 = \ln Y$, where K is quasi-fixed capital and Y is real output. $\mathbf{z}_3 = \mathbf{T}$, where $\mathbf{T}$ is an index of the state of technology.[13]
Homogenity of degree one in prices requires that $\sum_{j=1}^{2} \mathbf{a}_j = 1$, $\mathbf{b}_{jk} = \mathbf{b}_{kj}$ and $\sum_{k=1}^{2} \mathbf{b}_{jk} = 0$.

Cost minimization implies that we obtain the cost share equation of skilled labour if we differentiate (5) with respect to $\mathbf{w}$ and employ Shephard’s lemma. The cost share of skilled labour $\mathbf{CS}$ is

$$\mathbf{CS}_s \equiv \frac{\mathbf{w}_s \mathbf{L}_s}{\mathbf{C}V} = \frac{\mathbf{w}_s}{\mathbf{C}V} \frac{\partial \mathbf{C}V}{\partial \mathbf{w}_s} = \frac{\partial \ln \mathbf{C}V}{\partial \ln \mathbf{w}_s} = \mathbf{a}_1 + \mathbf{b}_{11} \ln(\mathbf{w}_s / \mathbf{w}_u) + \sum_{h=1}^{3} \mathbf{c}_{1h} \mathbf{z}_h \qquad (6)$$

Differentiating (6) yields

$$\mathbf{dCS}_s = \mathbf{b}_{11} \mathbf{d} \ln(\mathbf{w}_s / \mathbf{w}_u) + \mathbf{c}_{11} \mathbf{d} \ln K + \mathbf{c}_{12} \mathbf{d} \ln Y + \mathbf{c}_{13} \mathbf{dT} \qquad (7)$$

If we assume that neither $\mathbf{c}_{11}$ nor $\mathbf{c}_{12}$ vary across industries we obtain the following equation

$$\mathbf{dCS}_{si} = \beta_0 + \beta_1 \mathbf{d} \ln(\mathbf{w}_{si} / \mathbf{w}_{ui}) + \beta_2 \mathbf{d} \ln K_i + \beta_3 \mathbf{d} \ln Y_i + \varepsilon_i \qquad (8)$$

where **i** is the industry. The sign of β_1 depends on whether the elasticity of substitution between skilled and unskilled labour is greater than or less than one.[14] Estimates of β_2 indicate whether skilled labour and capital are complementary inputs ($\beta_2 > 0$) or substitutes $(\beta_2 < 0)$ in the production process. Estimates of β_3 show whether growth in output is related to changes in the wage bill of skilled labour. Finally, we can interpret $\beta_0 + \varepsilon_i$ as bias in technical change at the industry level, which means that estimates of β_0 represent the average bias across industries.

We obtain direct evidence of the impact of technical change on the demand for skilled labour by including an observable measure of technical change in the regression equation in (8). Similar to Berman, Bound & Griliches (1994) and Machin (1994), we use the industry level research and development (R&D) intensity defined as R&D expenditure divided by value added (average for the studied period).

As an alternative indicator we employ the share of technicians **TEC***H*. Presumably, technical growth is faster in industries where the share of technicians is high; the ability to develop, adopt and implement new technologies is superior for industries with a large amount of technicians. Our prior belief is strengthened by the very strong correlation between the R&D intensity and the share of technicians at the industry level (0.91). The measure **TEC***H* has some advantages compared to the R&D intensity. First, R&D expenditures are only reported on a fairly high level of aggregation.[15] Second, the amount of R&D in small- and medium-sized firms is underestimated since the figures only include firms with more than 50 employees.

Wood (1994, 1995) asserts that increased import competition, especially from the LDCs and NICs, has contributed to skill-biased technical progress in the developed countries. By this he means that the emergence of low-wage competitors caused drastic changes in market conditions. In order to survive, firms in the developed countries have had to search for new production technologies, which generally use less unskilled labour. A theoretical underpinning for his arguments can be found in the literature on X-efficiency.[16] The basic idea here is that managers, in particular in oligopolistic industries, do not maximize profits. One reason may be that they prefer leisure before profit; another is that they appreciate the power and satisfaction an excess number of employees can afford. A rent-threatening disturbance, such as increased import competition implies, however, that managers take action, e.g., by eliminating excess labour or by introducing labour-saving techniques. To capture this effect we add the annual change in the import share of consumption $\Delta(\mathbf{M}/\mathbf{C})$ to the regression in equation (8).

In a careful study of skill upgrading in US manufacturing during the 1970s and 1980s Bernard & Jensen (1995) found that higher employment at exporting plants contributed heavily to the observed increases in relative demand for skilled labour. One reason could be that in a skill-abundant country, like the U.S., exports expand the more skill-intensive activities. In order to examine whether we could trace a similar development in Sweden we include the annual growth in the export share of sales $\Delta(X/Q)$ in our model.

We begin by estimating our model in (8) for 16 manufacturing industries (2- and 3-digit ISIC), where we pool observations from two periods 1970-85 and 1985-90. Data on capital stocks K and R&D-intensity determines the level of aggregation.[17] Y is real output. Unfortunately, we do not have data on wage costs for skilled and unskilled labour at the industry level so we replace the cost share of skilled labour $\mathbf{CS}_s$ with the skill share in employment. If labour is perfectly mobile across industries, the wages of the skilled and unskilled are equalized and thus $\mathbf{d}\ln(\mathbf{w}_{si}/\mathbf{w}_{ui})$ is a constant. The exclusion of the relative wages will then only affect the constant β_0. According to ***F*igure 2,** the growth rate of the foreign trade ratio differs between the two periods -- positive for 1970-85 and zero for 1985-90. One could therefore expect that the factors that led to changes in trade exposure vary between the two periods. Reduced trade barriers and increased competition from the LDCs and the NICs have probably had its largest impact during the first period and consequently we allow for shifts in the coefficients of $\Delta(X/Q)$ and $\Delta(\mathbf{M}/\mathbf{C})$ between the two periods.

We estimate the same model for 107 manufacturing industries (5-digit SNI) during the period 1986-93. For this period we have access to data on wage costs so our dependent variable here is the cost share of skilled labour. Yet we follow Berman, Bound & Griliches (1994) and Machin (1994) and exclude the relative wage variable, since one could expect that some of the relative wage changes depend on cross-sectional differences in skill-upgrading, i.e., price changes are confounded with quality changes. In other words this means that it is not reasonable to consider the relative wage changes to be exogenous. But, as we noticed above, if both types of labor are mobile across industries then there will be no variation in the price of quality-adjusted skilled and unskilled labour across industries and an exclusion of $\mathbf{d}\ln(\mathbf{w}_{si} / \mathbf{w}_{ui})$ will only influence the constant β_0.

In **Table 5,** we report the results of the estimation of various specifications of (8). In specifications (i)-(iv) we combine data from the two periods 1970-85 and 1985-90 and include a dummy variable for the second period. The annual growth in the share of skilled labour is measured in terms of employment. In specifications (v)-(vii) we have estimated corresponding regressions for the period 1986-93 where we explain the annual growth in skilled labours' share of the wage bill.

Table 5 Effects of increased internationalization and technical change on the demand for skilled labour in Swedish manufacturing.

The coefficient on the capital stock is positive and significant in all specifications. Capital-skill complementarity seems to prevail in Swedish manufacturing.[18] However, capital accumulation explains only a fraction of the observed skill upgrading. The positive and significant coefficients on output in almost all specifications are signs of higher demand for skilled labour in growing industries.[19] Yet the effect of output is not as robust as the effect of capital; it tends to disappear when we include our indicators of technical change.

We consider the unexplained shift from unskilled towards skilled labour in equation (8) as biased technical change in addition to the average bias across industries β_0. Hence, the positive and highly significant coefficients on average R&D intensity in specifications (i) and on the share of technicians in specifications (ii) and (v) indicate that the technical change is skill-biased.

The growth in the foreign-trade ratio between 1970 and 1985 seems to have influenced the within-industry share of skilled labour. It applies in particular to increased import penetration, for which the coefficient is strongly significant. During the period after 1985 changes in trade are unrelated to changes in skill shares. Our results thus give some support to the hypothesis that increased import competition caused producers to invest in labour-saving techniques and thus increasing the proportion of skilled labour within industries.

6. Concluding remarks

During the last 20 years we have observed an uninterupted increase in the share of skilled labour in Swedish manufacturing. To scrutinize that development we have decomposed the increase into a within-industry and a between-industry component. Until 1985 the between-industry component, which captured the shift in employment from low-skill industries to high-skill industries, coincided with increased international specialization in skill-intensive industries. After 1985, however, no relationship between changes in international specialization and between-industry shifts could be established. One reason may be that the continuous shift towards increased international specialization in human-capital-intensive industries in the 1970s and the beginning of the 1980s was interupted because of a relatively slow accumulation of human capital in Sweden during the 1980s.

The bulk of the observed shifts towards skilled labour has taken place within industries, or rather within plants. Capital-skill complementarity is one explanation to that development. Another is biased technical change. R&D intensive industries and industries with high shares of technicians have been more likely to increase their shares of skilled labour. We regard this as direct evidence of the presence of skill-biased technical change in Swedish manufacturing industries during the 1970s and 1980s. Our findings conform with similar studies for the US and the UK. The tendency that industries characterized by high rates of innovation, adoption and implementation of new technologies create the most opportunities for highly educated workers is thus an international phenomenon. We also find that increased import competition contributed to higher skill shares within industries during the period when competition from abroad intensified the most.

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Table 1 Sector skill and sector employment shares 1994 and changes in shares between 1971-94 in Sweden, in percentage terms.

Sector code	Sector	1994		1994–1971	
		Skill share*	Employ-ment**	ΔSkill share	ΔEmploy-ment
1	Agriculture, forestry and fishing	10.24	3.49	9.34	–4.18
2,3,4	Mining and quarrying, manufacturing, and electricity gas and water	15.39	19.51	12.62	–8.70
38	Engineering	17.44	8.76	14.76	–2.60
5	Construction	7.33	6.14	5.97	–3.63
6	Wholesale and retail trade, hotels and restaurants	14.40	14.72	10.61	0.06
7	Transport, storage and communication	12.61	6.85	8.19	0.37
8	Financing, insurance, real estate and business services	36.69	9.46	24.48	4.12
9	Other personal services	38.98	39.83	17.15	11.95
91,931-934	Public administration, education and medical service	42.41	33.02	15.89	12.20
	All sectors	25.79	100	17.23	

Note: * Share of skilled labour in sector employment ** Share of employment in all sectors

Source: SCB Labour Force Survey (AKU)

Table 2 Changes in the employment structure in Swedish manufacturing 1970-93. Between- and within-industry decomposition. Percentage points.

Number of industries and sample period	Total change (annualized)	Between-industry component	Within-industry component	Correlation between $\Delta \mathbf{S}_i \overline{P}_i^E$ and $\Delta \mathbf{r}_i$
36 1970-85	0.435	0.040	0.395	0.41 (0.01)
36 1985-90	0.418	–0.018	0.436	–0.16 (0.37)
146 1986-93	0.905	0.095	0.810	0.10 (0.28)

Note: Parentheses give significance levels of the correlation coefficients

Table 3 Changes in the structure of skilled labour within and between plants and within industries. Percentage points.

1986-93 Annulized changes in percentage points	Within-plant component	Between-plant-within-industry component	Between-industry component
0.696	0.672	0.011	0.013

Table 4 Probit estimates of entry and exit

	Skill share	Size	Obs
Entry = 1	0.726 (9.43)		13283
Exit = 1	0.151 (1.63)	–0.001 (–10.36)	14601

***Note**:* Figures in parentheses show t-values.

Table 5 Effects of increased internationalization and technical change on the demand for skilled labour in Swedish manufacturing.

Variable	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
$\Delta \ln K$	0.039 [2.69]	0.028 [2.68]	0.050 [2.32]	0.056 [2.42]	0.011 [2.16]	0.013 [2.41]	0.012 [2.14]
$\Delta \ln Y$	0.014 [1.56]	–0.001 [–0.12]	0.036 [2.19]	0.039 [2.48]	0.028 [1.99]	0.033 [2.25]	0.033 [2.23]
R& D	0.028 [4.60]						
TEC*H*		0.026 [6.92]			4.436 [3.63]		
$\Delta(X/Q)$ 1970-85			0.083 [1.59]				
$\Delta(X/Q)$ 1985-90			–0.093 [–1.60]				
$\Delta(M/C)$ 1970-85				0.111 [3.15]			
$\Delta(M/C)$ 1985-90				0.022 [0.54]			
$\Delta(X/Q)$ 1986-93						0.004 [0.28]	
$\Delta(M/C)$ 1986-93							–0.026 [–0.87]
1985-90	–0.084 [–1.56]	–0.036 [–0.83]	0.036 [0.42]	0.013 [0.19]			
Constant	0.150 [3.61]	0.023 [0.46]	0.086 [1.06]	0.079 [1.23]	0.609 [10.05]	0.795 [13.29]	0.818 [12.71]
$\bar{R}^2$	0.652	0.736	0.405	0.442	0.221	0.129	0.136
n	32	32	32	32	107	107	107

Note: The dependent variable in specification (i) - (iv) is changes in the share of skilled labour in employment 1970-90. The dependent variable in specification (v) - (vii) is the skilled labours' share of the wage bill 1986-93. Square brackets give White's (1980) heteroscedasticity consistent t-statistics.

*A*ppendi*x: D*efinitions and sources of data

16 industries

Employment *(***E***)*: Number of employees. **Source**: SCB (1991) and SCB Regional Labour Statistics.

Skilled labor ($\mathbf{E}^S$): Employees with tertiary education. Source: SCB (1991) and SCB Regional Labour Statistics.

Skilled labors′ share of employment (P^E): $P^E = \frac{\mathbf{E}^S}{\mathbf{E}}$

Capital stock *(K)*: Capital stock estimates are derived by the Perpetual Inventory Method (PIM). This implies that capital formations are added to and capital assets withdrawn are subtracted from an initial estimate of the capital stock. We assume linear depreciation, which means that the gross capital stock at time **t** is:

$$K_t = K_{t-i}[1-(\mathbf{i}/2\mathbf{a})] + \sum_{m=1}^{i} \mathbf{I}_{t-m}[1-(\mathbf{m}/2\mathbf{a})]$$

where K_{t-i} is the capital stock in the beginning of year $\mathbf{t}-\mathbf{i}$. $\mathbf{I}_i$ is gross fixed capital formation year $\mathbf{t}-\mathbf{m}$ in 1980 constant prices and **a** is the average service life in manufactures. We assume the average service life to be 27 years (Meyer-zu-Schlochtern 1994). **Source**: SCB, Statistiska meddelanden. National Accounts: Expenditure of GDP, SM N 1984:5.5 appendix 2 and SM N 1981:2.5 appendix 2.

*R***eal output** *(Y)*: Value added in 1985 constant prices. **Source***:* OECD (1994).

Technicians*:* Employees with technical upper secondary education of more than two years or technical tertiary education. **Source**: SCB (1991).

R&D **intensity** ($R\&D$): The ratio of R&D expenditure to value added. The first-period average R&D intensity 1970-83 and the second-period average R&D intensity 1976-89. **Source**: SCB, Statistiska meddelanden, Research statistics R&D in Sweden (R&D expenditure current prices) and OECD (1994) (value-added current prices).

E*x***port and import** (*X* and **M**): Values of export and import in current prices. **Source**: Time Series Database (TSDB).

*P***roduction** *(Q)*: Sales value in current prices. **Source**: SOS Industri.

1*07* industries

*W***age incomes** *(W):* Wage incomes for all employees. **Source***:* SCB Regional Labour Statistics.

*W***age incomes skilled labor** (W^S): Wage incomes for employees with tertiary education. **Source***:* SCB Regional Labour Statistics.

Skilled labors*'* **share of the wage bill** (P^W): $P^W = \frac{W^S}{W}$

Capital stock *(K)*: Capital stocks are available in SCB (1995) at a fairly high level of aggregation (mostly SNI 3-digit level). To obtain capital stocks at the SNI 5-digit level we allocate the capital stocks constructed by SCB on the 5-digit industries by means of unpublished book values of buildings and machinery from SCB Financial Accounts.

Real output *(Y)*: Calculated from volume indices and value added in SOS Industri. We assume the same deflator in sub-industries on the SNI 5-digit level as in the corresponding 4-digit industry

Technicians*:* Employees with technical tertiary education. **Source**: SCB Regional Labour Statistics.

Export and import (*X* and **M**): Values of export and import in current prices. **Source**: Time Series Database (TSDB).

Production *(Q)*: Sales value in current prices. **Source**: SOS Industri.

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Endnotes

[1] See, e.g., Berman, Machin & Bound (1994).

[2] Howell & Wolff (1991) use many different indicators of skills to examine skill changes in the US workplace.

[3] For a more thorough exposition see Baldwin (1994) and Deardorff & Hakura (1994).

[4] One may question the relevance of using a HOS framework for the analysis since most of the increased trade during the last few decades has been intra-industry trade. On the other hand, it is unclear how the models developed to explain intra-industry trade -- where product differentiation and economies of scale are the driving forces behind trade -- will affect the composition of employment.

[5] Sweden's relative endowments of skilled labour, measured in terms of educational attainment in the labour force, is about the same as in other OECD countries. In comparison with less-developed and newly industrialized countries, i.e., the LDCs and the NICs, Sweden is relatively abundant with skilled labor (Hansson & Lundberg 1995 Table 2.5). Sweden also seems to have a comparative advantage, particularly in trade with LDCs, in human-capital-intensive industries, i.e., in industries where the employees' average years of schooling is high (Hansson & Lundberg op.cit. Table 3.2).

[6] The firms in the unskilled-labour-intensive industry have to offset their growing technical disadvantage by holding back the wages of the majority of their workers.

[7] We define the specialization index as:

$$\mathbf{r}_i = \frac{Q_i}{\mathbf{C}_i} = \frac{\mathbf{C}_i - \mathbf{M}_i + X_i}{\mathbf{C}_i} = 1 + \frac{X_i - \mathbf{M}_i}{\mathbf{C}_i}$$

where Q_i, $\mathbf{C}_i$, $\mathbf{M}_i$ and X_i are production, consumption, import and export in industry **i**.

[8] The share of skilled labour was 9.1 percent in 1985 and increased to 11.2 percent in 1990 and jumped to 15.7 percent in 1993. At this time employment in Swedish manufacturing dropped substantially. The employment was 0.93 million in 1990 and decreased to 0.74 million in 1993. This implies that most of the employees that were laid off from manufacturing were unskilled.

[9] $$\sum_{i=1}^{n}\sum_{j=1}^{m} \overline{P}_{ij}^{E}\, \overline{\mathbf{S}}_{ij}\, \Delta\mathbf{S}_i = \sum_{i=1}^{n} P_i^{E}\, \Delta\mathbf{S}_i$$

[10] Plants entering after 1986 and which have exited before 1993 are not included.

[11] See e.g. Doms et. al. (1995) and Evans (1987).

[12] We allow the ratios of cost-minimizing input demand to depend on the level of output.

[13] Quadratic and interaction terms among the $\mathbf{z}_h$ are suppressed since they disappear in the first-order conditions.

[14] See e.g. Hamermesh (1993) p.41.

[15] In Swedish manufacturing for 18 industries.

[16] See e.g. Leibenstein (1966), Corden (1974) and Caves & Krepps (1993).

[17] A complete description of the data is given in Appendix.

[18] Bergström & Panas (1992) gain a similar result.

[19] Our result differs in that respect from Berman, Bound & Griliches (1994) and Machin (1994) who gain a negative coefficient on output growth.