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Technology and Skill Upgrading: Results from Linked Worker-Plant Data for Finnish Manufacturing

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Abstract

In this paper we use both the standard Census of Manufacturing data and new linked information on worker characteristics for the Finnish manufacturing plants to examine the skilled/unskilled relative demand and its correlation with technology and demand factors. The linked worker-plant data are produced by matching workers in the Employment Statistics database to the plants in the Census of Manufacturing. The employment statistics database is utilised to procure an alternative measure for the skill composition of plants' work force based on education and to obtain average wages for these educational skill groups. We are therefore able to analyse skill upgrading and relative wages using the standard non-production/production breakdown as well as a skill-grouping based on the workers' education. We apply decomposition techniques and regression analysis to study possible explanations for the changes in the share of skilled workers. In order to analyse the effects of technology on skill demand we introduce plant level technology indicators from the R&D Survey and a Manufacturing Technology Survey. Our main findings are that skill upgrading is mostly the results of increasing shares of more skilled workers within plants, but also that plant entry and exit effects have become more important. This within-plant skill upgrading correlates positively with the plant level R&D intensity which provides evidence for skill-biased technological change. We also find that the effect of increased demand for skilled workers has mainly increased their employment rather than their wages.

1. Introduction

In this paper we examine the sources of change towards the increased shares of more skilled workers in the skill mix of employment. Other studies observing the same phenomenon have suggested that this can be attributed to an increased demand for skill due to skill-biased technological change and increased trade. Related studies on changes in wage or earnings distribution usually rule out supply explanations because shifts in the demographic composition of the work force can explain only a small fraction of the changes observed in wage structure (see e.g. Bound and Johnson (1992), Katz, Loveman and Blanchflower (1993), Schmitt (1993) and Autor, Katz and Krueger (1997)). The purpose of this paper is to use a new linked worker-plant data set to examine this phenomenon by matching workers with their employer plants to obtain information on the skill structure of employment and wages as well as work force characteristics of plants. Although this linked worker-plant data enables the usage of education as a measure of work force skills at plant level, for comparability with earlier research we also use the non-production/production worker classification from Census of Manufacturing. Such data have rarely been available to examine the technology/skills issue.[1]

These data are particularly useful, since it is often argued that within-plant changes reflect skill-biased technical change and between-plant changes reflect trade and other demand explanations of skill upgrading. We therefore use decompositions of the skilled employment and wage bill share changes to employment shifts *between plants* and skill upgrading *within plants* to describe and discuss possible sources of the rising shares of skilled labour. Compared to the industry-level decompositions used in most studies following Berman et.al. (1994), we present more detailed plant-level decompositions, which provide a better distinction of between and within changes, and enable to obtain separate plant entry and exit effects (see Dunne, Haltiwanger and Troske (1996), Bernard and Jensen (1997) and Machin (1995) for plant-level decompositions using US and UK data). We find that skill upgrading is mostly due to within-plant increases in employment and wage bill shares for both non-

[1] The Worker Establishment Characteristics Database (WECD) for US manufacturing is perhaps the closest comparable to our data. The differences are that we have panel data at the skill group level (derived from individual data), whereas WECD is a cross-section for individuals. See e.g. Doms et. al. (1997) for the WECD data.

production workers and more educated workers, which suggests that skill-biased technology is the primary explanation for skill upgrading. We also find that plant entry and exit effects have become more important over time, and that this component is likely to reflect both technology and demand related effects. In general, between effects have not been important.

Another contribution of this paper is to calculate the impact of these relative demand changes on both relative employment and relative wages of skilled workers. Instead of the Bernard and Jensen (1997) *wage gap* measure we propose a decomposition of the *observed* skilled wage bill change in order to get the relative skilled wage and employment effects. We find that increased skilled demand has predominantly increased skilled employment rather than their wages relative to unskilled. In fact, relative skilled wages have declined during late 80's and early 90's, and we argue that the growing supply of more educated workers and a skill neutral aggregate shock from the recession in a non-competitive labour market are likely explanations for this development.

Finally, we use regression analysis to examine different explanations for skill upgrading at plant level, since decomposition analyses cannot fully resolve the issue. In order to test technology, trade and other explanations for skill upgrading more directly, we regress the within-plant changes of skilled shares on plant-level variables, including observable technology indicators (R&D intensity and new manufacturing technologies used) and a trade variable (export sales). We find that R&D intensity is positively correlated with changes in skilled shares for non-production and especially highly educated workers. We also find some evidence of trade related export effects, so both skill biased technological change and exporting provide some explanation for skill upgrading. However, in quantitative terms these and other plant-level variables (like capital growth and outsourcing) explain only a small share of the observed increase in skilled shares, and its acceleration/deceleration over time. Most skill upgrading remains unexplained by plant-level variables.

In the rest of the paper we first briefly review related earlier literature, and then describe our data sources and the development of skilled shares and wages in Finnish manufacturing. This is followed by the decomposition and regression analyses for skilled shares and our main conclusions.

2. Previous literature

In this paper we follow the method of Berman, Bound and Griliches (1994) in decomposing the change in skilled worker wage bill share into ‘within’ and ‘between’ components of the aggregate change. Berman et. al. (1994) suggested that within- and between-industry components are useful indicators for the sources of change in relative demand for skilled labour. Skill biased technological change is expected to change skill composition of labour demand within industries, while other explanations like increase in trade would primarily shift demand for labour between industries from unskilled intensive import industries to skilled intensive export industries. They found that the within industry component dominated the between component in all the periods studied from 1959 through 1987. A further decomposition to contributions of defence, import, export and domestic consumption sectors indicated that the consumption sector dominated, and particularly the trade related effects were small. Several studies have conducted similar analyses for other countries using industry data and have obtained similar results (e.g. Machin (1995), Machin et. al. (1996)), and Haskel (1996)). In these industry-level studies the within-industry shares have been approximately 70% to 90% depending on the time period, country and industry aggregation level. A problem of industry studies is however that the within-industry change could arise from demand induced *between-plant* shifts of employment towards plants with higher average skilled shares. The apparent skill upgrading within production units (industries), which favours technology explanations, could thereby disappear. Some recent studies have used plant-level decompositions which should help to resolve this issue, although they are limited too by the fact that the demand shift effects can operate across products within plants (see Machin (1995), Bernard and Jensen (1997) and Dunne, Haltiwanger and Troske (1996)). Bernard and Jensen (1997) compared industry-level and plant-level decompositions for US manufacturing and observed that the between-plants change increased from 70’s to 80’s and was more important than the between-industry change, especially for the wage bill share (which increased from 51% to 58% at plant level). They argued that the increasingly important shifts between plants are due to export-related product demand effects, and this explains the rising relative wage of non-production workers in the 1980’s. However, Dunne et.al. (1996) found both that the within-plants component dominates over the between-plants change (about 70% of joint within and between effect and 43% of total change for 1972-87), and that the plant net entry effect is important (over 30% of total change).[2] Machin (1995) reports results indicating that the within components for non-manuals and various occupations have been even more important in UK establishment level data (over 80%), but the sample used was quite small (402 establishments from WIRS 1984-90).

In order to examine the technology explanation proposed for the within-industry changes, Berman et.al. (1994) conducted cross-industry regressions for changes in non-production wage bill shares using computer investment (as share of total investment) and R&D intensity as indicators of technological change. They found significant positive effects for both, which is consistent with the argument that skill-biased technological change is an important contributor to skill upgrading. Earlier, Bartel and Lichtenberg (1987) used a similar approach to test their hypothesis that highly educated workers have a comparative advantage in adjusting to and implementing new technologies, which should increase their relative demand when more recent vintages of capital (and technology) are used. Their analysis using labour cost share of educated workers confirmed this bias of technology. This approach has been applied in many recent studies which have used both industry- and plant-level data and various measures for worker skills (non-production, occupational and educational groups) as well as different technology indicators (R&D intensity and R&D capital, computer investments, share of workers using computers in industry, share of establishments introducing microprocessor/computer technology in industry, and plant-level usage of new manufacturing technologies); see Autor et. al. (1997), Goldin and Katz (1996), Machin (1995), Machin et. al. (1996), Haskel (1996), Dunne et.al. (1996), Bernard and Jensen (1997) and Doms et.al. (1997). These studies report evidence for both capital-skill and technology-skill complementarity confirming the importance of skill-biased technology in explaining the move towards more skilled workers. However, with some exceptions plant level studies have mainly examined non-production shares. Machin (1995) found that the establishment level introduction of micro-computers had a positive effect on the change in the employment share of higher level non-manual occupations in UK. Doms et. al. (1997) report that the shares of skilled occupations and of better educated workers are higher in US manufacturing plants

[2] Bernard and Jensen (1997) use the BBG type decomposition. Dunne at al. (1996) use a related, but different decompositions which includes plant entry and exit effects. Dunne et. al. (1996) also point to other sources for the deviation in results, such as differences in (sub-)periods and treatment of ASM sampling weights. In reproducing the BBG type decomposition, they find the between share to be approximately 40% for the wage bill share for the 1979-87 period but less (about 1/3) for the 1972-88 period.

that use more new manufacturing technologies, but this is a cross-sectional correlation for one year. When examining changes in non-production share, they detected no correlation with usage or adoption of manufacturing technologies, but found a positive effect for plant-level computer investments (similar to US industry studies). Also Dunne et. al. (1996) report positive effects for changes in R&D capital stock to non-production share growth at plant level. As for other possible explanatory factors, using UK industry data Haskel (1996) found that contracting out or trade (import share or prices) did not significantly affect the skilled share. However, Bernard and Jensen (1997) discovered that plant-level exporting (in addition to R&D/Sales) had a significant positive effect on non-production share growth during 80's in US manufacturing plants.

It is of interest to determine also to what extent the observed and unobserved factors in these types of regressions can explain the average change in the skilled share, ie. are the effects of obsreved plant-level variables quantitatively important? Berman et. al. (1994) found that capital accumulation explained only little (15%) of skill upgrading. Once technology variables are added they report that computer investments and R&D-intensity explain about 40% of the change in non-production share when included separately or about 70% when both are included. In addition, plant and equipment intensities account for about 10% of the *acceleration* over time in the non-production share growth, but capital intensity and output together explain none of the acceleration. Dunne et. al. (1996) found that observables (plant-level variables except the common year effect) account for about 40 % of the average annual change in the nonproduction labour share change. This rises to 45% when change in R&D stock is included, and to 50% when dummies for technology adoption are used (the separate effect of technology is unclear because of differences in samples of plants). Doms et. al. (1997) report that computer investments explain 16% of the change in non-production labour share. It appears that the contribution of observables, and technology indicators in particular, is lower at the plant level than at the industry level. Indeed, the overall message of Dunne et.al. (1996) is that the *unobservable* factors both dominate the cyclical variation and account for most of the secular increase in the non-production labour share.

In this paper we attempt to provide further evidence on these issues. Our point of departure is twofold. First, in terms of data we have *plant* level *panel* data on the skill structure of employees according to *education* from the linked worker-plant data. We also have several different technology indicators and export and outsourcing variables for these plants. Second, most of the micro data evidence is for the US and UK where labour market developments have been different from many European countries over the 80's. Finland has remained strongly unionised with a tendency to centralised wage determination, which may shape the way labour markets react to demand and supply shocks for different skill groups.

3. Data and description of the development of skilled shares and wages

We have two main data sources to analyse skill upgrading. First, to gain a long term view for the period 1975-94 we use the standard non-production/production skill-grouping from Census of Manufacturing plant-level data that is deployed by Statistics Finland to produce manufacturing statistics. From this source we obtain the usual employment, hours and wage bill data for non-production and production workers, as well as other useful information on the plants, such as output, export sales, outsourcing, ownership, industry, region and real capital stock.[3] However, manufacturing statistics include no information on the characteristics of the plant's workers, so only the division to non-production and production employees can be used to measure worker skills. This breakdown has been generally acknowledged to have drawbacks, but also defended on the grounds that non-production share is highly correlated with other skill measures like occupation and education.[4]

Second, we created a linked worker-plant data set to obtain an alternative indicator for the skills of plant's workers. This linked data is based on the identification of each person's employer during the last week of each year in the Employment Statistics database of Statistics Finland. Using the plant identifiers in both databases as a key, we can match individual workers in Employment Statistics with their employer plant in Census of Manufacturing. The Employment Statistics database includes information on some important background characteristics of individual workers and their plant specific earnings, so it can

[3] Detailed information on data sets and variables used in this study is available in a longer working paper version; see Vainiomäki (1999).

[4] See e.g. Berman, Bound and Griliches (1994), Machin, Ryan and van Reenen (1996) and Berman, Bound and Machin (1997) for further discussion of this issue. The first two studies conduct checks of the robustness of the decompositions or regressions using alternative skill measures from other data sources at industry level. The last paper investigates the relationship between different skill measures at plant level, which is found strong based on the Worker Establishment Characteristics Database (WECD).

be utilised to create different skill classifications for the plants' work force and calculate average wages and employment for these skill groups. Here we use education to measure worker skills, since it is a primary candidate from human capital theory and because information on occupation is not available in the database. We define four educational groups: 1) Basic compulsory education only (comprehensive school); 2) Vocational education (senior secondary school and vocational programmes based on comprehensive school); 3) Lower university and equivalent non-university degrees (Bachelor's degrees, professional programmes at higher institutions, e.g. engineering, and equivalent professional programmes based on comprehensive school lasting at least four years), and 4) Higher university degrees (Master's level and postgraduate degrees at Universities and Technical Universities and equivalent). We then calculated the number of persons in each education group for each plant, the sum as well as the average of their monthly wages, and averages of economically relevant worker characteristics (such as years of education, age, experience, and seniority).[5]

This plant-level worker characteristics data can then be matched with other plant-level information from Census of Manufacturing to obtain our Linked Worker-Plant Data. This linked data is available only for the period 1988-94, but in the case of Finland it appears to be the best way to get representative linked data that is rich enough on both worker and employer characteristics. The six year period available should however be sufficiently long to witness important changes in the skill structure of workers and their relationships with the plant characteristics, so we believe this to be a valuable data source. Finally, in order to examine the skill-biased technology and trade-based explanations of skill upgrading and wages, we merge in plant-level technology measures from R&D Surveys (available every second year) and a Manufacturing Technology Survey (available only for 1990).

Our Census of Manufacturing data includes annually some 5400-7500 active production plants (headquarters, storage-, sales- and other service-units, and plants in the investment phase have been excluded). Total employment of these plants peaked in 1980 but the

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[5] Initially we define 56 worker (skill) groups based on the individual's education, age and gender. To concentrate on education these groups are aggregated into four education groups as well as totals for the plant. For details on the variables and the linking process see Vainiomäki (1999) and Ilmakunnas, Maliranta and Vainiomäki (1999).

number of jobs has decreased since then about 2.7% per year, resulting in a 38% loss of manufacturing jobs by 1994. Virtually all lost jobs have been production oriented, except during the early 90's recession when also non-production employment decreased to some extent. Therefore the non-production employment and wage bill shares have increased strongly since 1980. Over the entire 1975-94 period their employment share has increased from 22,5% to 30,1%, and wage bill share from 30,2% to 37,9%, both approximately at 0.4 percentage points per year. This long-term increase is similar to that in other industrialised countries.[6] The increase in non-production shares was strongest during early 80's, but slowed down during later years of the decade and again during early 90's, especially for the wage bill share. During late 70's non-production shares increased slowly (see Table 1, first panel).

(insert Table 1 here - Table1.xls)

The linked worker-plant data includes some 4800-5800 plants annually, covering about 90% of the active production plants in Census of Manufacturing each year. However, the number of linked persons for these plants is lower, accounting for about 65-79% of the Census of Manufacturing employment.[7] Our plant-level variables for employment and wage bill shares by educational groups are based on these linked workers. The share of the basic education group decreased annually by well over one percentage point both in employment (from 42% to 34%) and wage bill (from 38% to 31%) over the period 1988-94, whereas all groups with further education experienced significant increases. This change was quite steady over the years, but the increase in the share of vocational education group concentrated in the

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[6] Berman, Bound and Griliches (1994) report and increase of 0.38 percentage points per year in employment share in US manufacturing over the period 1979-89. Machin, Ryan and van Reenen (1996) report similar annualized changes of 0.47 for US, 0.57 for UK, 0.39 for Denmark and 0.23 for Sweden in wage bill shares over the period 1973-89.

[7] In the linking process we lose both plants and some of their workers compared to the number of employees according to Census of Manufacturing for various reasons. These include 1) the unavailability or unreliability of the the wage data in Employment Statistics, 2) different concepts of employment in Employment Statistics (end of year situation) and Census of Manufacturing (annual average), 3) the exclusion of short employment spells (less than one month), and 4) some differences in plant coding practices in Employment Statistics and Census of Manufacturing (even though the basic source for plant codes is the same). The linking process and possible problems related to it are explained in more detail in Vainiomäki (1999) and Ilmakunnas, Maliranta and Vainiomäki (1999).

recession period 1990-94 (see Table 2, first panel). Since the shares of the two highest educational groups are much smaller, Table 2 also presents *relative* annual changes in the shares to obtain a more comparable view. Although the absolute percentage point changes for the higher educational groups are lower than for the vocational group, the relative change is consistently increasing with the level of education. These numbers indicate a stronger shift in the skill mix of employees according to education than by the non-production/production breakdown, so the pace of skill upgrading may be underestimated by the change in non-production share.

(insert Table 2 here - Table2.xls)

In some countries (especially US and UK) it has been found that the relative wage of skilled workers has increased at the same time as their relative employment share has increased. In Finnish manufacturing, we find some increase in the relative non-production/production wage during early 80's, but a decreasing trend after mid or late 80's (Table 3, panel a). There have also been decreases in the relative wages of highly educated groups compared to the basic education group during 1988-94, and in particular after 1990 (Table 3, panel b). For the lower university group the relative wage decreased by 1.5% per annum (from 1.55 to 1.42), and for the higher university group by 1.9% (from 2.24 to 2.00). This development is based on unadjusted averages across plants without controlling for human capital effects, but estimates from earnings functions find no indication of substantial increase in returns to education in Finland since 1975.[8]

Simultaneous increases in the supply of skilled labour could restrain wage differentials when skilled demand increases. Table 3 presents changes in the supply structure of the labour force by education, and changes in demand with the wage bill share as an indicator for demand. These indicate strong increases in the relative share of educated groups compared to the least educated group – potentially explaining the lack of increase in returns to education. A demand-supply explanation seems consistent with the observed development of

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[8] Asplund and Vuori (1996) found some decrease in returns to education years and degrees over the period 1980-92 for non-manual workers in the Finnish manufacturing (but some increase in 1992-94). Asplund (1997) reports that computer wage premiums have also decreased during recent years. The estimates in Vainiomäki and Laaksonen (1995) for 1975-85, which included individuals from all sectors and worker groups, also indicated

relative non-production wages (panel a). During the early 80's demand for non-production workers increased strongly, while the supply growth of higher educated workers was slow, which would explain the increase in relative non-production wage. During the late 80's and early 90's in turn, the supply of higher educated increased much faster than previously, whereas the demand growth slowed down, both shifts contributing to the fall in relative non-production wages during these two later periods.

The educational supply shares however are not fully comparable with the non-production wage bill share and relative wage. Table 3 (panel b) therefore also presents the demand and supply changes from the Employment Statistics database over the period 1988-94 using exactly the same educational classification for both sides. The table also presents average annual changes in the demand-to-supply ratio for each educational group, based on the ratio of wage bill share to labour force share. They indicate that for the two highest (university level) educational groups the demand shifts have been stronger than supply shifts, which is not consistent with the observed decrease in relative wages for the higher educated groups. However, a non-competitive model could explain the decreasing relative skilled wage as a reaction to the skill-neutral aggregate shock the Finnish economy obviously faced during the recession of early 1990's, over and above the skill-biased demand and supply changes. With a stable non-linear wage setting curve, an equal proportionate drop in demand for skilled and unskilled workers would decrease skilled wages more along a steeper part of the wage curve than unskilled wages, producing a reduction in relative skilled wages.

(insert Table 3 here - Table3.xls)

4. Decompositions for skilled employment and wage bill shares

Basic decomposition

We first decompose the aggregate increase in skilled employment and wage bill share into between- and within-plants effects. The *between-plants* effect captures shifts of employment between units with different average proportions of skilled workers, and the *within-plants*

some decrease in returns to educational degrees compared to basic education especially over the 1975-80 period.

effect captures changes in skilled worker share within each plant, weighted by the plant's average share of total employment. The purpose of these decompositions is to identify where skill upgrading occurs; is it a pervasive change occurring within all plants (reflecting skill-biased technical change), or is it due to employment shifts between plants (related to demand changes).

The Berman-Bound-Griliches (BBG) type decomposition can be applied straightforwardly to industry data or data for plants that operate continuously through the period studied. However, *plant entry and exit* potentially creates a difference across industry- and plant-level results, since industry aggregates include the entry and exit of plants, but at plant level, the within and between changes can be calculated only for surviving (continuing) plants. Plant entry and exit can therefore change the balance of between and within effects at industry level compared to plant level, depending on whether entry and exit occurs within or between industries. The aggregate change in skilled share can also be different for all plants and surviving plants, so it is important to include plant entry and exit effects in plant level analyses. It can be shown that the BBG type decomposition can be augmented to include them as follows (superscript A for all, S for continuing, N for new, and D for exiting plants) [9]

(1) $$\Delta P^A = \sum_i \Delta S_i^S \overline{P}_i^S + \sum_i \Delta P_i^S \overline{S}_i^S + w_t^N \left(P_t^N - P_t^S\right) + w_{t-s}^D \left(P_{t-s}^S - P_{t-s}^D\right),$$

where $P_i = \dfrac{E_i^{skilled}}{E_i}$, $S_i = \dfrac{E_i}{E}$, $w_t^N = \dfrac{E_t^N}{E_t^A}$, $w_{t-s}^D = \dfrac{E_{t-s}^D}{E_{t-s}^A}$.

P is the aggregate share of the skilled group of total employment or wage bill (denoted by E), P_i is the corresponding share in plant *i*, S_i is the share of plant *i* in aggregate employment or wage bill, Δ indicates change and bar an average over the period. The first two terms are the *between* and *within* effects. The *entry* effect (third term) is the greater the higher the share of the skilled is in new plants, and the *exit* effect (last term) is the greater the smaller the share of the skilled workers is in exiting plants compared to continuing plants. These differences are weighted by employment (or wage bill) shares of entering and exiting

[9] Further details of this and other decomposition results in this paper are available in the working paper version, Vainiomäki (1999). We have omitted time subscripts from the first two terms and definitions of *P* and *S* to avoid further complicating the notation. Time subscripts *t* and *t-s* denote the ending and starting years of the period.

plants.[10] The *aggregate change* in the skilled share for *all plants* is therefore decomposed into within and between effects for *continuing* plants plus *entry and exit* effects.

Another factor potentially creating differences across industry and plant level decompositions is that the *within-industry* effect may capture *between-plant* changes within industries. Applying the decomposition *directly* to plant data gives the between-plants (BP) and within-plants (WP) components of aggregate change. An *indirect* decomposition gives three components, the *between- industry* effect (BI), *within-industry-between-plants* effect (WIBP) and *within-industry-within-plants* effect (WIWP).[11] It can be shown that the plant-level decomposition essentially moves the effect of between plants employment shifts within industries from the within (industries) effect to the between (plants) effect, but there is an additional interaction term affecting this comparison, which is however likely to be small. Perhaps the main benefit of conducting an indirect decomposition is that one gets the between-industry and within-industry-between-plants effects separately, which may be of some interest.

These decompositions for the non-production and educational *wage bill shares* are presented in Tables 1 and 2 (panels 2 and 3). Results in Table 1 indicate that the bulk of *non-production* skill upgrading in the Finnish manufacturing has occurred *within plants* (over 70% of the combined within and between change).[12] Also the acceleration-deceleration pattern over time is mostly related to changes in the within-plants component over time. The between

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[10] These effects differ somewhat from those in the decomposition of Dunne et.al. (1996). In their entry effect the entering plants' skilled share is compared to the aggregate share for all plants in the initial period, wheras our term uses the aggregate share for continuing plants in the end period. In the exit effect both studies use the initial period average, but the term in Dunne et. al. is again for all plants while ours is for continuing plants. Our entry-exit effects show that also Berman et. al (1994) type decompositions can incorporate plant entry and exit effects.

[11] The indirect decomposition is obtained by performing first an industry-level decomposition, and then a plant-level decomposition for the within component of each industry. See Vainiomäki (1999) for more details.

[12] All decomposition results for the *employment shares* were very similar and therefore not included here. However, one notable difference between wage bill and employment share results is observed during the early 90's recession period. The change of wage bill share for continuing plants dips to almost zero due to the drop in the *within-plants* component. Also the employment share growth drops, but it remains at 0.37 for all plants and at 0.22 for continuing plants. The within-plants change is 0.18 (a share of 81% of total change for continuing plants), so in terms of employment, the non-production share continues to grow within plants.

plants component has been in general small, but explains some of the change for the 1980-85 period. Finally, the *net entry* effect has become relatively more important after the mid 80's (accounting for over 30% of aggregate change for all plants), which mostly arises from the *exit* effect. In the early 90's the exit effect could be considered to be a 'cleansing' effect related to the severe recession, but the exit effect, although smaller in relative terms, was almost as large during the 80's.

Comparing the industry- and plant-level decompositions for the non-production share, we find usually *smaller within-industry* shares (for all plants) than *within-plants* shares for continuing plants, especially after the mid 80's.[13] Bernard and Jensen (1997) found larger within-industry shares in US and they argued that this is due to export related between-plants changes which have become increasingly more important during the 80's. However, in Finland we find *small within-industry between-plants effects* (WIBP from indirect decompositions), so that within-industry change is not substantially overestimated by inclusion of this effect. The difference is mainly due to the *net entry* effect on industry-level components. Net entry of plants may influence both between- and within-*industry* effects (for all plants) depending on industry distribution of net entry, and on how the skill mix of entering and exiting plants deviates from continuing plants. Therefore comparisons of between and within effects at industry and plant levels (for continuing plants) should also indicate the underlying source of plant entry and exit effects. As discussed in Dunne et. al. (1996) net entry can be driven by skill-biased technological change or by product demand shifts towards more skill intensive products. If new skill intensive technologies are introduced through new plants, and outdated less skilled technologies are abandoned via exits, we would expect this to increase the within-industry component compared to within-plants component (as long as this way of technology adoption operates in all industries). On the other hand, if entry concentrates in high skilled industries and exit in low skilled industries, producing larger employment shifts between industries via entry-exit than between plants, the change would more likely originate from product demand shifts (across industries). Given our results in Table 1, the net entry effect seems mainly due to skill-biased

[13] This is more prevalent for employment shares. The within-industry shares for the 1985-90 and 1990-94 periods were 71% and 60%, while within-plants shares were 92% and 81%.

technology during 1980-85 period (WI>WP), but also due to product demand shifts during last two periods (BI>BP).[14]

The decomposition results for wage bill shares by *educational groups* in Table 2 show that the large increases of higher educated shares are also essentially the outcome of a large *within effect* among continuing plants and an important *net entry* effect. The within change dominates in all education groups with about 80% or larger shares from the combined between and within effect. The net entry effect is usually larger than the between-plants effect, but also substantial compared to the within effect for the two highest (university level) education groups, with 26% and 45% shares of total change for all plants. Net entry effects arise mainly from exit effects, but for the basic group the negative entry effect is more important. The pattern of entry and exit effects implies that exiting plants have been intensive in the vocational and basic groups labour, whereas entering plants have used more workers with lower university and vocational education. For the higher (university level) educated groups, the positive exit effects and small entry effects imply that plants using highly educated workers intensively have been more likely to survive, but new plants have not been using these highly educated groups to any greater extent than the continuing plants.

Although the overall picture of skill upgrading applying educational shares is much the same as using the non-production share, there are also some interesting differences. First, contrary to non-production results, we find no indication of slowdown in skill upgrading by education during the recession period 1990-94.[15] Second, there is a substantial rise in the growth of vocational education share, and a correspondingly faster decline in basic education group for this period. Also the growth of the higher university share is somewhat faster or remains high (for continuing plants), but the increase of the lower university group is slower during this period. This development suggest that skill upgrading may have become more of a *within group* nature during early 90's. Among the lower educated groups (production workers) there is a faster shift from basic education to vocational group, and similarly within the higher

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[14] Dunne et. al. (1996) divided their net entry effect to within- and between-industry components, finding 55% within share (technology related) and 35% between share (product demand related).

[15] Our first sub-period for educational decompositions is admittedly short for strong conclusions, but we chose to use this periodization in order to have educational and non-production results for exactly the same period of 1990-94.

educated groups (non-production workers) a faster shift from lower to higher university group. This pattern may also explain the slowdown in the growth of non-production wage share in the 1990-94 period, since the slower growth of lower university share slackens non-production share growth and the faster growth of vocational group boosts production share growth.

Relative Wage and Employment Effects on Wage Bill Share

It is of considerable interest to examine whether increasing wage bill shares of skilled workers are due to increasing relative skilled employment or wages. An increase in skilled wage bill share indicates that relative demand for skilled workers rises, but depending on simultaneous supply changes and the wage determination mechanism, greater demand for skilled may cause an increase in skilled employment, their wages or both. In order to examine the change in relative skilled wages, a possible measure might seem to be the difference between the change in skilled wage bill share and the change in employment share. However, this does not indicate directly changes in the relative skilled to unskilled wage ratio.[16] To analyse the sources of change in the relative skilled (non-production) wage ratio Bernard and Jensen (1997) proposed a measure called *wage gap*, and its decomposition into within and between effects.[17] We derive a related but different decomposition for the *observed* change in skilled wage bill share, which includes changes in both relative wages and employment, as follows (0 and 1 indicate years, variables subscripted by *i* indicate plants and unsubscripted aggregates, e.g. W_0E_1 denotes aggregate wage bill calculated using year 0 wages and year 1 employment for each plant, and superscripts *s* and *u* indicate skill groups)

(2) $$\Delta P = \sum_i \Delta SW_i \overline{P_i} + \sum_i \Delta SE_i \overline{P_i} + \sum_i \Delta WG_i \overline{S_i} + \sum_i \Delta EG_i \overline{S_i}$$

[16] The difference between *percentage changes* in wage bill share and employment share gives the *percentage change* in the ratio of non-production wage to *average wage for all workers.* Denoting the non-production wage bill share by $S=W^nE^n/WE$ and employment share by $N=E^n/E$, then $S/N=W^n/W$ and dln(S)-dln(N)=dln(W^n/W), where W is the aggregate average wage of all workers.

[17] The aggregate wage gap is defined to capture the increase in non-production wage bill in excess of the increase in their share of employment, holding aggregate relative wages constant. This measure can be positive either because the relative wage within plants rises or because employment shifts towards plants with high relative wages. See Bernard and Jensen (1997) for more details.

where $\Delta SW_i = \left(\frac{W_{i,1}E_{i,1}}{W_1 E_1} - \frac{W_{i,0}E_{i,1}}{W_0 E_1} \right)$, $\Delta SE_i = \left(\frac{W_{i,0}E_{i,1}}{W_0 E_1} - \frac{W_{i,0}E_{i,0}}{W_0 E_0} \right)$,

$$\Delta WG_i = \left(\frac{W_{i,1}^s E_{i,1}^s}{W_{i,1}^s E_{i,1}^s + W_{i,1}^u E_{i,1}^u} - \frac{W_{i,0}^s E_{i,1}^s}{W_{i,0}^s E_{i,1}^s + W_{i,0}^u E_{i,1}^u} \right), \text{ and}$$

$$\Delta EG_i = \left(\frac{W_{i,0}^s E_{i,1}^s}{W_{i,0}^s E_{i,1}^s + W_{i,0}^u E_{i,1}^u} - \frac{W_{i,0}^s E_{i,0}^s}{W_{i,0}^s E_{i,0}^s + W_{i,0}^u E_{i,0}^u} \right).$$

ΔSW and *ΔSE* divide the change in a plant's share of total wage bill into wage and employment changes, and *ΔWG* and *ΔEG* do the same for the within-plant change in skilled share of wage bill. *ΔWG* is Bernard and Jensen's wage gap for an individual plant, which is positive only if relative skilled wage increases in the plant. The third term therefore reflects the effect of within-plants changes in relative skilled wage on the aggregate change in the skilled wage share, and although similar to the within component of the Bernard and Jensen (1997) wage gap decomposition, it is not exactly the same.[18] We define *ΔEG* similarly as an 'employment gap' which is positive only if relative skilled employment increases, so the last term reflects changes only in relative skilled employment within plants. The first two between effects on the other hand reflect changes in wage structure across plants, and shifts in employment across plants towards plants with higher skilled wage bill shares. It seems that this more detailed decomposition is valuable in identifying both the sources of increasing skilled wage share (between and within components) and whether the effects of such changes are channelled into relative skilled wages or employment.

Table 4 presents these decompositions of wage bill shares for non-production workers and for educational skill groups. For the non-production share and all educational shares we find that *the within-plant increase in relative skilled employment dominates* in all periods (decrease for basic education group). The within-plant *changes in relative skilled wage* have in general been *negative*, and particularly strong in the 1990-94 period for non-production workers and the two university level education groups (but positive for basic education group indicating increase in their wages against other groups). The *between-plants* effects have generally been

[18] In Bernard and Jensen (1997) wage gap decomposition unit i wage bill shares in period 0 are 'weighted' by $W_o^n / W_{i,o}^n$ (aggregate non-production wage divided by unit i's wage). This term seems to make their components hard to interpret. Our decomposition does not include such weights.

quite small and they also occurred mainly through employment shifts across plants rather than through changes in relative plant wages. However, in the case of the higher education groups the demand shifts between plants towards higher skilled plants had some importance for skill upgrading during the late 80's, and also early 90's for the higher university group, different from the results for non-production workers.

(insert Table 4 here - Table4.xls)

It is possible to interpret the observed pattern of within-plants relative wage effects in terms of changes in the relative skilled demand and supply ratios, together with an additional effect from a skill-neutral aggregate shock during the recession period 1990-94. The relative supply changes in Table 3 indicate an increasing supply of higher educated (and non-production) workers since 1985, which has created pressure for their relative wages to decrease. A skill-neutral aggregate demand shock from the recession would explain the larger decreases in relative skilled wages during the early 90's, skilled wages being more elastic to rises in unemployment than unskilled wages along the wage setting curve. The decrease in the demand over supply ratio for basic education group was small, so a dominating aggregate shock effect would explain increasing relative wages for this group during the recession period.

Our decomposition results in this sub-section highlight three important features of skill upgrading in Finnish manufacturing. First, the increase in skilled demand has predominantly increased relative skilled employment rather than wages. Second, since the mid 80's relative skilled wages within plants have actually decreased, so increasing skilled employment shares are likely to be partly a substitution effect due to lower relative skilled wages during later periods. Third, increasing skilled supply and a skill neutral aggregate shock from the recession are likely explanations for decreasing skilled wages.

5. Explaining skill upgrading

The decomposition framework above shows that skill upgrading occurs mostly within plants. We next attempt to explain the changes in skilled worker shares *within plants* by *plant characteristics* that are related to the different explanations proposed for skill upgrading;

skill-biased technology, trade effects, contracting out and capital-skill complementarity. The effects of skill-biased technology on skilled worker shares within plants arise from its effect on labour demand for each worker group. A common approach to estimate labour demand effects of technology is to use a specification that can be derived from the translog cost function treating capital as a quasi-fixed factor, and including technology effects in the cost function (see e.g. Berman et. al. (1994), Goldin and Katz (1996), Machin et. al. (1996) and Haskel (1996))

(3) $$\Delta S_{si} = \beta_0 \Delta T_i + \beta_1 \Delta \ln(W_s / W_u)_i + \beta_2 \Delta \ln(K_i) + \beta_3 \Delta \ln(Y_i) + \varepsilon_i$$

where S_s is the skilled workers share in total wage bill, W_s and W_u are wage rates for skilled and unskilled workers, K represents capital, Y is output (value added), T represents technology, and i indexes observations (industries or plants). This is a first dífferenced form of the skilled share equation imposing linear homogeneity of costs and adding an error term (the unskilled share equation is redundant via cross-equation restrictions). The coefficient of relative wage reflects the elasticity of substitution, positive coefficient on capital indicates capital-skill complementarity, and output coefficient the effects of scale on factor demands at given factor prices (non-homotheticity of production). Note also that the (wage bill) weighted average of the dependent variable gives the within plants component of wage bill decompositions.

If there are no observable indicators for change in technology (ΔT_i), a common time trend can be used to proxy (average) technological change. Then an intercept term ($\beta_0 \Delta T = \beta_0$) would capture the cross-unit average skill bias of technological change. Inclusion of observable plant level technology indicators for ΔT_i would however pick up the plant specific skill bias (otherwise included in the error term). A significant positive coefficient for a technology variable implies that *within-plants* skill upgrading is related to skill-biased technological change. Other possible explanations for skill upgrading from the above equation are capital growth (capital-skill complementarity) and output growth (changes in demand).

Another explanation is the possibility of demand shifts towards products which use skilled labour more intensively. If plants specialise in different products, such demand changes would shift output and total employment across plants, implying larger contributions for the *between*-plant component in the decompositions. However, demand shifts can also affect the *within*-plant changes because the plant level within upgrading could be a 'between' effect induced by output shifts from low- to high-skilled goods produced by the plant. Such demand shifts can originate e.g. from *trade* effects (globalization), when a skill-abundant country opens (or increases openness) to international trade with unskilled-abundant countries. A prediction from trade theory is that employment would shift towards skill-intensive goods and plants whose production for exports increases.[19]

We test these explanations by estimating equation (3) above for plant-level changes in skilled employment and wage bill shares using plant-level indicators for technology and exporting as explanatory variables, and including other plant-level variables and characteristics as further controls. We use the R&D/Sales ratio from R&D Surveys as the primary technology indicator and export share of plant's total output to capture the effects of cross-plant differences in technological change and exporting on skill demand. If the skill intensity of export production differs from domestic production the skill 'adjusted' output is $Y^a = DOM + cEXP$, where c>1 indicates higher skill intensity of exports. Substituting skill adjusted output for unadjusted output ($Y = DOM + EXP$) in the share equation introduces change in export share as a regressor since $\Delta\ln(Y^a) \approx \Delta\ln(Y) + (c-1)\Delta(EXP/Y)$. The other plant-level variables included are capital-output ratio, output, two measures for outsourcing (contracting out), industry, region and ownership dummies. Outsourcing may affect skilled share if activities which were previously performed by the plant's workers, but are now bought from outside suppliers, involved different skill intensity compared to plant's remaining production activities. We divide the total purchased services into industrial and non-industrial services to allow for different skill intensities and effects. Industry, region and ownership dummies are included as control variables for possible variations in skilled share changes across these plant characteristics, but which are not directly measured, e.g. technological opportunities across industries, industrial and regional variation of the omitted relative wage, and differential changes in organisation structures related to ownership. The

[19] For an exposition of the effects of trade and different types of technological change on relative skilled demand and wages see e.g. Berman, Bound and Machin (1997).

constant and time dummies capture the cross-plant unexplained average change in the skilled share, and its changes across time periods.

There are a number of econometric issues that arise in relation to these regressions. First it should be noted that the equations are estimated using differences so that possible biases from plant specific fixed effects correlated with other explanatory variables are controlled. Second, the skilled share equations should include the relative skilled wage as a regressor, but this is usually omitted for a number of reasons. Plant wages reflect unobserved labour quality differences, so cross-sectional variations in relative wage changes could be more related to variations in labour quality than exogenous changes in the price of labour. In the case of wage bill share, there is also a direct definitional relationship between the dependent variable and relative wage (division bias). Finally, any changes in relative wages that are common to all plants in an industry, which can constitute a large proportion in the case of Finland due to strong centralised wage setting effects, are captured by the constant and industry dummies. Third, it should be noted that estimations may suffer from various endogeneity and measurement error biases, but in using simple Weighted Least Squares we follow much of the existing literature.[20]

We estimated this regression equation for the *non-production* employment and wage bill shares from Census of Manufacturing data using all plants for the period 1975-94 (pooling changes over periods 1975-80, 1980-85, 1985-90 and 1990-94), and also using smaller sub-samples of plants for which we have technology indicators. The purpose of regressions for all plants without technology indicators is not only to provide a background for the technology results, but also to examine the contributions of other plant-level variables in explaining skill upgrading across the sample of all plants and over time. We use R&D expenditures/Sales as our primary technology indicator because it is available for a larger sub-sample of plants than alternative technology variables. The information on R&D expenditures is available from R&D Surveys every second year between 1985 and 1993, and we use the change in the R&D/Sales ratio to indicate the change in a plant’s technological

[20] See e.g. Dunne et.al. (1996) for a discussion of measurement error and endogeneity questions and instrumental variable methods to correct for them. Our regressions are conducted using five year differences and their instumentation using lags is likely to fail, e.g. instrumental variable results using longer than three year differences were less succesful in Dunne et.al. (1996).

status (changes for the 1985-89 and 1989-93 periods are matched with periods 1985-90 and 1990-94 respectively). In addition we use a dummy variable which indicates the usage of new manufacturing technologies in the plant (AMT) and computer share (share of computer related capital from total equipment and machinery) as alternative technology indicators. These are available from a Survey of Capital Stock and Technology for a cross-section in 1990.[21]

(insert Table 5 here - Table5.xls)

Table 5 shows the results for non-production wage bill shares (results based on employment shares were similar and therefore not reported here). Columns (1)-(3) present estimates for all plants and columns (4)-(5) those based on R&D sub-sample. Columns (2) and (5) add industry-period interactions to the basic regressions in columns (1) and (4). The lower panel reports results using alternative technology indicators from separate regressions similar to that in column (4). Starting with our main interest, we find that the R&D effect is positive and significant at 5% level, which is consistent with skill biased technological change explaining the move towards non-production workers. In employment share regressions this effect was somewhat weaker, being just (in)significant at 10% level. With respect to export share there is a statistically strong positive effect for all plants, but insignificant in the R&D sample. This is consistent with skill upgrading reflecting within-plant shifts in demand towards more skill intensive products related to exporting, but this effect is less important for the more technologically oriented plants in the R&D sample. In further regressions we allowed the R&D and export share effects to vary over time periods. For R&D intensity we find a stronger effect for the 1990-94 period (the coefficient and t-value were 0.25 (2.90)), but insignificant for the 1985-90 period. This could indicate a change in skill bias, or reflect the concentration of skilled share increases in more technologically intensive plants (adoption of new technologies) to recession periods. The export share effect was significant

[21] The R&D Surveys of Statistics Finland are carried out (primarily) at firm level. We use a longitudinal data set for firms in Census of Manufacturing created from original annual surveys; see Husso, Leppälahti and Niininen (1996). This firm level data is matched to plants using common firm codes in both data sources, so all plants of the same firm have the same R&D data (like in US studies). The Survey of Manufacturing Capital and Technology (SMCT) by Statistics Finland includes primarily large plants and all plants of largest firms. The survey asked current usage in production of the following specific technologies: Numerically controlled machines, Computer aided design, Computer aided manufacturing, Computer controlled processes, Flexible Manufacturing systems, Robots, and other application.

only for the 1980-85 and 1985-90 periods (coefficients and t-values for these periods were 0.016 (2.25) and 0.018 (2.27)). In decompositions we found the largest between-plants changes for these periods, which supports interpreting the export share effect on within-plant skill upgrading as a demand shifts effect. These patterns were similar for the employment share.

In all equations capital-output ratio is strongly significant supporting capital-skill complementarity in Finnish manufacturing, similar to results obtained for other countries. The output effect varies depending on sample, specification and dependent variable, so the evidence on non-homotheticity is not clear-cut. For all plants the pattern of capital and output effects is however similar to that in other studies, i.e., output growth increases non-production share holding K/Y constant, but decreases it holding K constant. Also both outsourcing variables are usually significant for all plants with a stronger effect from industrial services, but turn insignificant in R&D sample (the non-industrial services effect was significant at 5% level for employment share and remains so in R&D sample). This provides some evidence that sub-contracting of activities increases skilled share, and both industrial and non-industrial services contracted out have been unskilled intensive.

Column (3) presents estimates without the R&D variable for *all* plants but only for the period 1985-94, in order to check for any changes in parameters due to the change in estimation period. The only notable difference compared to column (1) is that outsourcing effects of non-industrial services are stronger. Columns (2) and (5) report results which include industry-period interaction effects to check that plant-level variables are not picking up industry effects that are changing over time. This does not affect the results; if anything, the R&D, export, output and capital effects become stronger. On the other hand, when dropping industry and region dummies (results not shown) we find also minor changes in magnitude and significance of other variables, so the relevant variation in plant level variables seems to be across plants rather than across industries (or regions).

Table 6 presents the results from similar estimations for *educational skill groups* from the Linked Worker Plant data. The variables are average annual changes over the period 1988-

94.[22] Columns (1) present estimates based on all plants without technology variables, and columns (2) add R&D/Sales using the R&D sample. These results for educational shares provide stronger evidence for skill-biased technological change than non-production shares, and reveal an interesting pattern of effects. The R&D intensity is positive for the higher university and vocational groups, but negative for the lower university and basic groups. These effects are strongly significant for the two university level education groups. This pattern is consistent with the 'within-group' skill upgrading from lower to higher university education and from basic to vocational education, similar to the results we found above using decompositions. The regression results show that this within-group skill upgrading is related to technology, i.e. the skill bias of technology seems to increase the demand for more educated employees within both the higher and lower educated segments of workers. These results also indicate that using non-production shares may hide important changes in demands for skills.

On the other hand, our results based on educational shares provide less support for export-related skill upgrading than our non-production results. In regressions for all plants the pattern of coefficients is consistent with exports increasing demand for skills (positive effects for two highest educated groups and negative effects for two lowest educated groups), but only the lower university group's effect is significant. In the R&D sample export share is never significant, as in non-production results. Regarding other variables we find significant educational skill upgrading related to outsourcing of non-industrial services, but the effect of industrial services is mostly insignificant. There is also evidence of capital-skill complementarity for all plants, the coefficient being significantly positive for the higher university group and negative for the basic group, but again these effects are not significant in the R&D sample.

(insert Table 6 here - Table6.xls)

[22] It should be noted that instead of estimating a share equation system to impose cross-equation restrictions implied by the translog specification, we estimate the share equations individually for each educational group. However, since wages are omitted as explanatory variables there is no need to apply system methods in estimation as there are no symmetry conditions for factor prices to impose. The remaining adding-up constraints implied by linear homogeneity in prices are fulfilled by equation-by-equation OLS 'column sum adding up constraints', i.e. capital, output and technology coefficients across educational groups add up to zero in all our results. See e.g. Berndt (1991), Ch 9, for equation-by-equation OLS in relation to translog systems.

The lower panels of Tables 5 and 6 report results using Advanced Manufacturing Technology dummy (AMT) or computer share of capital as alternative technology indicators instead of R&D intensity. We find no significant effects on non-production skill upgrading for these technology measures (Table 5). For the educational skill groups (Table 6) the AMT dummy attracts a negative (and almost significant) coefficient for the highest educational group and a fairly large positive point estimate for the vocational share (but not significant). Computer share tends to be positive (and almost significant) for the basic education group, but for other groups coefficients are insignificant. This highlights the possibility that different technology indicators reflect different aspects of technological change, and have different implications for skill demand as measured by education (see Doms et. al. (1997) for a similar conclusion for non-production share in US using manufacturing technology and computer investment variables). For example, it is feasible that some new manufacturing technologies and computer-controlled machinery and equipment (computer share) are saving higher educated labour by reducing supervisory, management and designing tasks. On the other hand the operation and maintenance of these technologies at the factory floor may require more skilled workers with some specific vocational education.

Contributions to skill upgrading

How much do observable plant-level variables explain of the skill upgrading and what share remains unexplained? In order to answer this we calculate for *each period* the contributions of different variables in our model to the non-production employment share growth as follows. 1) The *period effect* (coefficient for period dummy), which describes how much the cross-plant average change of non-production share during the period in question deviates from the change during the base period (1990-94), and is not explained by other variables in the model. 2) The contribution of *plant-level characteristics* is the employment weigted average of coefficients for industy, region and ownership dummies plus the constant. Each dummy coefficient describes how much the average change in skilled share for the plants in this cell deviates from the base group, and is not explained by other variables in the model. The contribution is a weigted average of these effects and essentially describes what is the predicted average change in non-production share from these dummy variables given the employment structure for the period. This contribution changes across time periods because of changes in employment structure. 3) The contribution of *plant level variables* (capital-output ratio, output, outsourcing, export share, and R&D) gives the average predicted value of non-production share growth by these variables, calculated as the product of regression coefficient and period specific mean of each variable.

These contributions for each period are given in columns (1) of Table 7 separately for all plants and for the R&D sample. The sum of these three contributions is the weigted mean of the dependent variable in regression for each period, ie. the within-plants change in non-production share for the plants used in estimation. These are given in the row headed as total change and they are similar to the within-plants change for all plants in Table 1. The contribution of plant-level characteristics is substantial (about 0.15 percentage points) and very stable over time using the results for all plants. We characterise this effect as 'unexplained', though plant characteristics are 'observable', because it is not clear what exactly causes the differential average growth across classes of plant characteristics.[23] The contribution of plant-level variables is small, dropping from 0.05 percentage points for the 1975-80 period (about 30 % of total change) to zero in the 1990-94 period. Over the 80's plant-level variables explained about 9% of total change. The contribution of plant-level variables comes mostly from the growth of capital output ratio (capital-skill complementarity). Finally, the period effects are changing considerably over time, so most of the change over time in non-production share growth (acceleration/deceleration) cannot be explained by the plant-level variables in our model. Since the contribution of plant-level variables is decreasing over time, these variables explain about 13-17% of the *deceleration* in non-production share growth from 80's to the 1990-94 period.

(insert Table 7 here - Table7.xls)

The results for the R&D sample for the last two periods are somewhat different. First of all, there is no unexplained deceleration for this sample of plants (the period effect is small), and the decrease in total change is mostly (about 80%) explained by the decrease in the effect of plant-level variables. This change over time is driven by capital-skill complementarity and the huge decrease in capital growth from the late 80's to the recession of the 90's (about 10

[23] The constant term is included in this contribution because its value depends on the base group for plant characteristics dummies, so this contribution is essentially similar to a constant (without characteristics). Although characteristics dummies do not 'explain' the growth in the share of skilled workers, it is important to include them in estimations as controls.

percentage points in the R&D sample). The contribution of R&D on skill upgrading is very small, about 0.01 percentage points (3%) of the total change for the 1985-90 period, and an approximately equal decrease over 1990-94. In the R&D sample also the contribution of plant level characteristics declines somewhat during the 90's, so for these plants there have also been changes in the employment distribution towards characteristics associated with lower growth of non-production share.

6. Conclusions

In this paper we have made use of two data sources to analyse skill upgrading in Finnish manufacturing plants. First, we have employed plant-level data from the Census of Manufacturing for the period 1975-94 to examine longer term changes in non-production employment and wages. Our second data source is a new linked worker-plant data for a shorter period of 1988-94, which is used to obtain an alternative and more detailed view on the skill composition of the plants' work force based on education. We decompose the changes in skilled shares to within- and between-plant components, and perform regression analyses of the within-plant changes to examine how skill upgrading is related to the proposed explanations of technology and trade inducing greater skilled demand.

The non-production labour share increased in Finnish manufacturing during the 1980's with a speed comparable to other industrialised countries, but there was a slowdown in this development during late 80's and early 90's. The more detailed educational worker grouping indicates an even more pronounced change in the skill structure of workers. The employment and wage share of workers having only basic (compulsory) education declined at a rate of over one percentage point per year, and there appears to be no slowdown during 90's. The relative non-production wages increased until mid- or late 80's, but contrary to many other countries have decreased thereafter. Also relative wages for the higher education groups showed notable decreases during 90's.

The decomposition analyses for both non-production and educational employment and wage shares imply that skill upgrading is dominated by increasing skilled shares within plants, and the between-plant shifts in employment towards more skill intensive plants have been modest. We also find an increasing importance over time of plant entry and exit effects in explaining the aggregate change in skilled shares. These results are similar to findings for other countries, especially by Dunne et.al. (1996) for US. We also derive and present a decomposition of the skilled wage share change into separate employment and wage change components both within and between plants, as an alternative to the wage gap analysis by Bernard and Jensen (1997). Our results for both non-production and educational shares indicate that increases in skilled shares are predominantly driven by increases in relative skilled employment within plants, rather than increases in relative skilled wages within plants. Therefore, in the case of Finland the effects of higher demand for skilled workers seem to have been channelled into higher skilled employment, but not to increases in their wages. This decomposition in fact shows that there have been within-plant decreases in relative skilled wages after the mid 80's. We argue that the observed relative wage developments can be explained as the combined outcome of an increased supply of more skilled (educated) workers and an aggregate neutral demand shock related to the 90's recession.

Our regression analyses of within-plant changes for skilled shares, using the change in R&D intensity as technology indicator, provide evidence for skill-biased technological change as an explanation of within-plant skill upgrading towards both non-production and more educated workers. This evidence is stronger for educational shares from the linked worker-plant data, especially for the highest educational group (Master's level and above). Furthermore, we find a pattern of effects that is consistent with an interpretation of 'within-group' educational upgrading from lower to higher university level and from basic to vocational education. The technology effects are however different when the presence of specific manufacturing technologies or computer share of capital are used as the technology indicator. These results indicate that different technology measures may capture different types of technological change that have different effects on demands for skill groups. Also the share of exports gains some support (when using all plants samples) in explaining within-plant skill upgrading, which is consistent with export related demand shifts towards more skill intensive products. This effect is stronger for the non-production share than for the educational shares. As for other possible explanations, we also find support for capital-skill complementarity and outsourcing effects. However, in terms of explaining the observed average change in non-production share and its changes over time, we find that the 'unexplained' components related to plant characteristics dummies and period effects constitute the major part of skilled share growth. This is consistent with the plant-level results for US manufacturing by Dunne et.al. (1996) on the importance of unobservables. The contributions for plant-level variables also indicate that in explaining the average growth of skilled share capital-skill complementarity and capital growth have been more important factors in Finnish manufacturing than skill-bias of technology. The slowdown in capital growth also explains a large share of the slowdown in non-production share growth in the R&D sample.

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Table 1.
Change in Wage Bill Share of Non-Production Workers.
Plant and Industry level Decompositions, 1975-94.

	1975-80	**1980-85**	**1985-90**	**1990-94**
(1) Industry decomposition:				
Aaggregate change (all plants)	0.053	0.859	0.449	0.221
Between Industry (BI)	-0.009	0.127	0.107	0.109
Within Industry (WI)	0.062	0.732	0.343	0.112
(WI share)	(117)	(85)	(76)	(51)
(2) Plant decomposition:				
Aggregate change (continuous plants)	0.077	0.741	0.280	0.051
Between Plants (BP)	-0.038	0.222	0.022	0.047
Within Plants (WP)	0.115	0.519	0.259	0.003
(WP share)	(149)	(70)	(93)	(6)
Within Industry Between Plants (WIBP)	0.010	0.084	-0.003	0.053
(3) Entry/Exit effects:				
Net entry	-0.024	0.118	0.169	0.170
Entry	-0.066	-0.030	0.035	0.015
Exit	0.042	0.148	0.134	0.155
(Net entry share of total)	-(45)	(14)	(38)	(77)
Number of plants:				
All Plants (first/last year)	6 080/ 7 065	7 065/ 7 119	7 119/ 6 087	6 087/ 5 363
Continuous Plants	4 707	5 516	4 959	4135

Notes: Numbers in Table are annualized percentage-point changes. *All Plants* uses all plants operating in a particular year when calculating the aggregate change and industry decompositions. *Continuous plants* uses only plants operating in both years of the period when calculating the aggregate change and decompositions. *Entry-exit* is the difference between All Plants and Continuous Plants, and separate entry and exit effects are calculated as given in text. *Entry-exit share* is from aggregate change for All plants. Industry decomposition (29 3-digit industries) calculated using industry aggregates, where plant's industry is according to the first year in each period. Allowing plant industry changes in calculating aggregate industry figures did not significantly affect these results.
Data source: Census of Manufacturing Plant level data.

Table 2.
Change in Wage Bill Share by Educational Worker Groups.
Plant level decompositions, 1988-94.

	1988-90		**1990-94**	
(1) All Plants:	**Change**	**Change,%**	**Change**	**Change,%**
Higher University	0.270	5.3	0.335	6.0
Lower/Non-university	0.475	3.6	0.322	2.3
Vocational	0.289	0.7	0.706	1.6
Basic	-1.034	-2.7	-1.363	-3.8
(2) Continuous Plants:	**Change**	**Change,%**	**Change**	**Change,%**
Higher University	0.299	5.9	0.248	4.2
Lower/Non-university	0.402	3.0	0.178	1.2
Vocational	0.398	0.9	0.743	1.7
Basic	-1.099	-2.7	-1.168	-3.2
Within plants:	**Change**	**WP share**	**Change**	**WP share**
Higher University	0.239	79.9	0.207	83.5
Lower/Non-university	0.255	63.4	0.141	79.2
Vocational	0.420	105.5	0.792	106.7
Basic	-0.914	83.2	-1.140	97.6
(3) Entry/Exit (1990-94):	**Entry**	**Exit**	**Net entry**	**NE share**
Higher University	-0.004	0.091	0.087	26.0
Lower/Non-university	0.040	0.103	0.144	44.7
Vocational	0.092	-0.128	-0.037	-5.2
Basic	-0.128	-0.067	-0.195	14.3
Number of Plants				
All plants	1988: 5528	1990: 5563	1990: 5563	1994: 4820
Continuous plants	4641		3633	

Notes: As in Table 1. *WP share* is *Within plats* share from total change for *continuous* plants. *NE share* is *Net Entry* share from total change for *all* plants. Entry/Exit effects presented for the 1990-94 period only.
Data source: Linked Worker-Plant data.

Table 3.
Changes in Demand, Supply and Relative wage.

(a) Non-Production Workers, 1975-95.

Period	Labour Force Shares by Education			Non-Production	
	Basic	Inter-mediate	Higher	Wage Bill Share	Relative Wage
		Percentage points per annum			
1975-80	-1.53	1.11	0.40	0.05	
1980-85	-1.70	1.80	-0.10	0.86	
1985-90	-1.47	1.04	0.44	0.45	
1990-95	-1.33	0.44	0.89	0.22	
		Percent per annum			
1975-80	-2.6	3.5	4.3	0.2	-0.2
1980-85	-3.2	5.0	-0.9	2.6	0.9
1985-90	-3.3	2.3	4.2	1.3	-0.9
1990-95	-3.6	0.9	7.1	0.6	-1.1

Sources: Labour force shares for total labour force from Statistics Finland Labour Force Survey. Wage bill share and relative wage from Census of Manufacturing plant data.
Notes: The Labour Force Survey changed data collection methods in 1983 due to large non-response, which was skewed by education. The labour force shares of highly educated were overestimated prior to 1983, so the change over 1980-85 is underestimated for highly educated. However, Census of Population gives a similar pattern over the periods: for the higher education group the relative change of labour force share from Census of Population was 75-80: 4.7%, 80-85: 1.6% and 85-90: 3.4% (percent per annum).

(b) Education groups from Linked Data, 1988-94.
(Percent per annum)

Education group	Labour Force share	Wage bill share	Demand/ Supply	Relative Wage
Basic	-3.3	-3.6	-0.3	
Vocational	1.2	1.1	-0.1	0.0
Lower/Non-Univ.	2.3	2.7	0.4	-1.5
Higher University	4.6	5.5	0.8	-1.9

Data Sources: Wage bill share from linked worker-plant data for manufacturing plants. Labour force shares from full Employment Statistics database for Total Labour Force (aged 15-65) using the same educational classification as in linked data.
Notes: Numbers in the table are estimated trend growth rates (%) for each education group and each variable separately from the following model $\ln y_t = \alpha + \beta Trend + u_t$, where y_t is the variable indicated by column heading. For relative Demand/Supply the dependent variable is wage bill share divided by labour force share. For relative wage the dependent variable is average annual growth rate (%) of education group's relative wage ratio vs. the basic education group.

Table 4.
Relative Wage and Employment effects on Change in Wage Bill Share.

(a) Non-production share, 1975-94.

	1975-80	1980-85	1985-90	1990-94
Between plants:	-0.048	0.192	0.017	0.049
Wage shifts	-0.069	0.048	-0.007	-0.006
Employment shifts	0.021	0.144	0.024	0.055
Within plants:	0.090	0.510	0.255	0.001
Relative wages	-0.042	0.020	-0.115	-0.175
Relative employment	0.132	0.490	0.370	0.176
Total change	0.042	0.701	0.271	0.050
Number of plants	3968	4643	4233	3643

(b) Educational Worker groups, 1988-90 and 1990-94.

	1988-90				1990-94			
	Basic	Vocational	Lower/ Non-Univ.	Higher Univ.	Basic	Vocational	Lower/ Non-Univ.	Higher Univ.
Between Plants:	-0.158	-0.016	0.204	0.122	-0.019	-0.012	0.017	0.084
Wage shifts	0.016	0.028	-0.014	-0.005	0.002	-0.013	0.001	-0.003
Employment shifts	-0.174	-0.044	0.218	0.127	-0.021	0.001	0.016	0.087
Within Plants:	-0.958	0.419	0.107	0.164	-1.164	0.763	0.128	0.176
Relative wages	-0.083	-0.002	-0.085	-0.049	0.117	-0.071	-0.216	-0.122
Relative employment	-0.875	0.421	0.192	0.213	-1.281	0.834	0.344	0.298
Total Change	-1.116	0.404	0.312	0.287	-1.183	0.751	0.145	0.260
Number of plants	4380	4436	2756	1128	3472	3519	2395	1123

Notes: Calculations include only continuous plants that employed in the first period (a) both production and non-production workers or (b) workers in the particular educational group and in some other worker groups. Otherwise it is impossible to calculate the wage bill shares with constant wages, since the average wage rate is not defined in the first period. The within plants and between plants total effects in this table are however similar to those for all continuous plants, so this restriction does not significantly affect these results.
Data source: (a) Census of Manufacturing Plant level data and (b) Linked Worker-Plant data.

Table 5.
Regressions for Change in Non-Production Wage Bill Share.
All Plants and R&D sample, periods pooled, Weighted LS

Variable	All plants			R&D sample	
	(1)	(2)	(3)	(4)	(5)
ΔR&D/Sales				0.1330	0.1379
				(2.00)	(2.07)
ΔExport share	0.0130	0.0153	0.0135	-0.0086	-0.0117
	(3.58)	(4.15)	(2.29)	(0.70)	(0.93)
Δln(Y)	0.0011	0.0026	0.0009	0.0167	0.0194
	(0.94)	(2.09)	(0.43)	(3.88)	(4.43)
Δln(K/Y)	0.0056	0.0058	0.0044	0.0129	0.0141
	(5.80)	(5.96)	(2.67)	(3.62)	(3.92)
ΔOutsourcing					
Industrial	0.0149	0.0149	0.0149	0.0059	0.0033
	(9.78)	(9.78)	(6.59)	(1.34)	(0.75)
Non-industrial	0.0010	0.0010	0.0174	0.0100	0.0081
	(1.83)	(1.72)	(6.42)	(1.92)	(1.53)
Period					
1975-80	0.133	0.231			
	(3.11)	(0.52)			
1980-85	0.540	0.052			
	(12.70)	(0.12)			
1985-90	0.277	0.573	0.295	0.077	0.262
	(6.51)	(1.29)	(5.79)	(0.72)	(0.22)
Constant	-0.110	-0.120	0.063	-0.906	-0.999
	(0.27)	(0.25)	(0.10)	(0.43)	(0.46)
Industry*period	No	Yes	No	No	Yes
N	16850	16850	7950	1343	1343
R-Square	0.034	0.062	0.047	0.094	0.126
Alternative Technology indicators:					
AMT				-0.056	
				(0.58)	
Computer share				-0.0001	
				(0.07)	

Notes: t-ratios in parenthesis. Weighted by plant average share of total wage bill each period. All equations include also ownership, region and industry dummies. Dependent variable is the change in non-production share as percentage points per annum. 1990-94 is the base period. R&D sample includes plants for which change in R&D/Sales is available for at least one of the periods 1985-90 and 1990-94. The lower panel presents coefficients for alternative technology indicators in equations similar to column (4) in top panel. These include plants for which the AMT dummy or computer share is available from the SMCT90 survey (about 600 plants per period for AMT and 350 plants for computer share). AMT and Computer share regressions use all four periods over 1975-94.
Data source: Census of Manufacturing plants and R&D and SMCT90 Surveys.

Table 6.
Regressions for Changes in Wage Bill Shares by Education.
All Plants and R&D sample, 1988-94 change, Weighted LS

Variable	**Higher University**		**Lower University**		**Vocational**		**Basic**	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
ΔR&D/Sales		0.226		-0.343		0.180		-0.064
		(4.37)		(3.84)		(1.85)		(0.61)
ΔExport share	0.009	0.011	0.021	0.020	-0.015	-0.011	-0.015	-0.020
	(1.79)	(0.74)	(2.28)	(0.78)	(1.42)	(0.39)	(1.36)	(0.67)
Δln(Y)	0.001	0.000	-0.011	-0.027	0.015	0.026	-0.005	0.001
	(0.34)	(0.01)	(3.74)	(3.61)	(4.64)	(3.18)	(1.46)	(0.12)
Δln(K/Y)	0.005	0.001	0.002	-0.007	0.001	0.002	-0.008	0.004
	(3.68)	(0.24)	(0.87)	(1.12)	(0.21)	(0.34)	(2.61)	(0.53)
ΔOutsourcing								
Industrial	-0.007	-0.014	0.001	0.001	0.003	0.000	0.004	0.013
	(3.77)	(3.55)	(0.16)	(0.14)	(0.71)	(0.05)	(0.94)	(1.59)
Non-industrial	0.011	0.016	0.006	0.001	-0.007	-0.004	-0.009	-0.013
	(4.91)	(3.64)	(1.57)	(0.17)	(1.66)	(0.51)	(2.00)	(1.47)
N	2842	547	2842	547	2842	547	2842	547
R-Square	0.087	0.213	0.079	0.235	0.067	0.181	0.064	0.169
Alternative Technology Indicators:								
AMT		-0.229		0.025		0.230		-0.026
		(1.92)		(0.13)		(1.17)		(0.12)
Computer share		0.002		-0.005		-0.003		0.006
		(1.15)		(1.61)		(1.10)		(1.93)

Notes: t-ratios in parenthesis. Weighted by plant average share of total wage bill. All equations include also ownership, region and industry dummies. Dependent variable is the change in group's share over the period 1988-94 as percentage points per annum. R&D sample includes plants for which change in R&D/Sales ratio is available. The lower panel presents coefficients for alternative technology indicators in equations similar to those in top panel. These include plants for which AMT dummy or Computer share is available from SMCT90 Survey (457 plants for AMT and 286 for Computer share).
Data Source: Linked Worker-Plant data and R&D and SMCT90 Surveys.

Table 7.
Contributions to skill upgrading.
Non-production Employment share, 1975-94

	1975-80		**1980-85**		**1985-90**		**1990-94**	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
All plants								
Period Effect	-0.040	-(25)	0.276	(61)	0.166	(48)	omitted	
Plant level variables	0.053	(33)	0.040	(9)	0.032	(9)	0.0003	(0.2)
Plant level characteristics	0.149	(92)	0.140	(31)	0.146	(43)	0.1564	(99.8)
Total change	0.162		0.456		0.343		0.1567	
R&D plants								
Period Effect					-0.026	-(7)	omitted	
Plant level variables					0.156	(44)	-0.028	-(22)
Plant level characteristics					0.227	(64)	0.156	(122)
Total change					0.357		0.128	

Notes: Column (1) presents contributions to average change of non-production share for the period (given as total change) and column (2) shares from total change. Based on employment share regressions similar to columns (1) and (4) in Table 5.