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Exporters, skill upgrading, and the wage gap[1]

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Abstract

This paper examines plant level evidence on the increase in demand for non-production workers in U.S. manufacturing during the 1980s. The major finding is that increases in employment at exporting plants contribute heavily to the observed increase in relative demand for skilled labor in manufacturing during the period. Exporters account for almost all of the increase in the wage gap between high- and low-skilled workers. Tests of the competing theories with plant level data show that demand changes associated with increased exports are strongly associated with the wage gap increases. Increases in plant technology are determinants of within plant skill-upgrading but not of the aggregate wage gap rise.

Key words: Wage inequality; Skill-biased technological change; International trade

JEL classification: F10; J21; E24

1. Introduction

The rise in wage inequality both between and within demographic groups was pronounced in the 1980s and has prompted a large literature by the way of potential explanations. This rise in inequality is a widely reported, established fact and has been the focus of attention by politicians, the popular press, and academics. Academic work has focused both on supply-side and demand-side

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explanations, with the latter garnering the majority of the attention. Since Katz and Murphy (1992) effectively argued that relative supply shifts could only account for some of the relative price and quantity movements, research has concentrated on locating factors affecting the relative demand for high-skilled workers.[2] The demand stories have fallen roughly into three categories: (i) increases in demand for goods produced intensively with high-skilled labor, (ii) increases in international trade and associated changes in relative prices or factor supplies, or (iii) skill-biased technical change. Almost all previous empirical work has failed to adequately explain the inequality rise with industry level demand stories, either domestic or trade-induced, and has been left to conclude that skill-biased technical change is the source of increased wage inequality.[3]

This paper looks at one aspect of the rising inequality story and evaluates product demand and technology deepening explanations with plant level data on the manufacturing sector. By necessity, as with many other studies, this project is limited to explaining employment and wage movements for two types of labor in a single sector of the economy. However, by looking at plant data, as opposed to industry data, we more carefully associate the movements in wages and employment for the two labor categories with plant level demand and technology variables. In contrast to previous research, we find that significant wage and employment changes for skilled workers are associated with shifts between plants, often within industries, rather than within plants. We find that the demand for skilled labor changed from the 1970s to the 1980s and we can associate this change over time to movements of workers between industries and especially between plants. In accord with previous research, we do find substantial skill upgrading within both industries and establishments. However, we find that the rise in wage differentials between production and non-production workers results primarily from shifts from production intensive establishments to non-production intensive establishments, often within the same industry. In attempting to pinpoint the sectors and plant characteristics associated with these movements, we find that the export status of the plant is a key variable both at the industry and plant level.

Since exporting is associated with other plant characteristics, such as size and technology usage, which are also potential sources of labor demand shifts, we present evidence on the relative importance of product demand, technology, and other plant characteristics in the change in demand for skilled labor. We find that demand variables, particularly export sales, are strongly correlated with increases in between plant movements of skilled labor while technology variables positively affect within plant changes in the composition of the workforce. Together, these results suggest that both phenomena of interest, product demand changes and

[2] See for example Berman, Bound and Griliches (1994), Lawrence and Slaughter (1993), Mishel and Bernstein (1994).

[3] Mishel and Bernstein (1994) point out many explanations can account for *only* 10–20% of the total movements and that the focus on a single explanation may be misguided.

skill-biased technical change, were taking place during the 1980s, but that demand changes were the dominant source of increased demand for skilled labor and thus the rise in wage inequality over the period. The results suggest that further work on wage inequality should recognize the substantial heterogeneity among firms and establishments, even within narrowly defined standard industrial classifications (SIC), and focus on the apparently special role of exporting plants during the period of rapid wage and employment growth for high-skilled workers.

The paper is organized as follows: in Section 2, we describe the data set of 50,000+ plants and examine the evidence on the growth in the relative employment and wages of non-production workers at both the industry and the plant level. We look at the role of plant characteristics, including export status and size, in the changes in employment and wages in Section 3. To address the question of wage inequality, we construct a measure of the wage gap between types of workers in Section 4. In Section 5 we estimate the contributions of competing "demand" and "skill-biased" technical change explanations to the increases in relative wages and employment. The final section concludes and discusses areas of further research.

2. Skill-upgrading and inequality

The main competing explanations for the rise in demand for skilled labor are the increase in skill-biased technical change and the shifts of demand to goods which use skilled labor more intensively. The former argues that changes in production practices, especially the widespread introduction of computers and related technologies, have increased the demand for more educated workers at the expense of less educated employees. While the specifics of the arrival of skill-biased technologies are usually not discussed, two likely mechanisms come to mind. First, managers realize the productive potential of computers and technology and introduce them into their plants. This internal path leads to increased demand for high-skilled workers within each plant that has upgraded its technology. A second possible pattern of technical change involves the closing of plants with outdated technologies and the opening of new plants with the latest, skill-biased capital. These two stories for the role of skill-biased technical change will have equivalent effects at an industry level (or perhaps even at a firm level). In each case, within industries, the relative composition of workers will shift to a more educated, higher-skill workforce. However, at the plant level the stories differ, the first implies that the workforce will shift within plants, while the latter suggests that the composition of plants within an industry is changing through births and deaths.

The product demand explanation for rising inequality also has at least two possible variations. In one, demand for broadly defined products is changing, e.g. from clothes to computers, so at an aggregated industry level there is a shift in the composition of manufacturing. Another possible change involves shifts within industries, typified by the decline of mainframes and the rise of personal computers and workstations.[4] These two product demand stories have comparable implications for industry versus plant level analysis. With the first, we should see shifts across industries, while in the second, we would expect to observe within industry changes. However, these product demand explanations do not involve changing the skill mix of the workforce within plants.

Research on wage differentials has attempted to provide evidence on these competing theories of product demand shifts versus skill-biased technical change. Due to data limitations, most authors have studied the movements of wages and workers within and between industries at fairly high levels of aggregation. Bound and Johnson (1992), Katz and Murphy (1992), and Mishel and Bernstein (1994) all use one- or two-digit industries. Lawrence and Slaughter (1993) consider two-, three-, and four-digit breakdowns while Berman, Bound and Griliches (1994) look at demand within and across four-digit industries.

The conclusions of previous work on increasing wage dispersion and the demand for skilled labor generally have been that skill-biased technological change must account for the observed skill upgrading within industries. This conclusion is usually reached because other potential candidates, especially trade, do not seem to contribute heavily.[5] In this paper we argue that industry classifications, even at the four-digit SIC level, hide important elements of the change in demand for skilled labor. We reconsider the roles of skill-biased technical change, product demand, and trade, by looking at the contribution of individual plants to the aggregate increase in relative demand for skilled labor. For both industries and plants, we examine whether employment and wage shares for non-production workers are increasing as a result of within plant changes or shifts of employment and wages across plants. Our measure of trade is the value of production shipped abroad by the manufacturing establishment. We contrast the plant results with the industry level findings presented here and elsewhere.

For this analysis, we take as given that changes in relative supply of high-skill and low-skill labor cannot account for the aggregate movements in the relative quantity and price of the two inputs. In particular, we make the strong assumption that all plant and industry movements can be associated with demand changes.[6] We conduct two types of analyses of the wage and employment data. First, in this and the subsequent section, to facilitate comparison of our results with those in

[4]It is obvious that, if appropriately defined, all product demand shifts would be across industry. We take industry to mean four-digit SIC classification which is the greatest level of disaggregation available in published data.

[5]Berman, Bound and Griliches (1994) and Krueger (1993) directly test for and find significant effects of technology on the wage gap.

[6]Relative supply shifts at the aggregate cannot produce the increase in relative quantity and price we observe in the data. However, assuming that plant and industry changes are entirely demand driven also presumes that local relative supply changes are not the source of the relative price and quantity movements at the plant level.

Berman, Bound and Griliches (1994) and Machin (1994), we construct the ratio of non-production workers to total employment in manufacturing and the ratio of the wage bill for non-production workers to the total wage bill and then calculate the decomposition of changes in the ratios into between industry/plant movements and within industry/plant movements. This type of decomposition allows us to see where the changes are occurring and whether the aggregate movements are occurring within industries and plants or across industries and plants. We can further group industries and plants by their characteristics to see which sectors or what types of plants are generating the aggregate movements.

We examine changes in measures of wage inequality in Section 4. In Section 5 we estimate the effect of plant level changes in technology, domestic demand, and exports on the rise in employment and wages for skilled workers.

For the decomposition analysis, the basic formulation is

$$\Delta P_n = \sum_i \Delta S_i \bar{P}_{n_i} + \sum_i \Delta P_{n_i} \bar{S}_i \qquad (1)$$

for $i = 1,...,I$ industries (or plants) where ΔP_n is the change in the ratio of interest, either the share of non-production workers in the manufacturing workforce or the percentage of total wages paid to non-production workers. $P_{n_i} = E_{n_i}/E_i$ is the employment or wage ratio in industry i. $S_i = E_i/E$ is the share of total employment or total wages in industry or plant i. $\bar{P}_{n_i}$ and $\bar{S}_i$ are time averages of P_{n_i} and S_i. The *between* effect is given by the first term on the right-hand side which shows the change in the aggregate ratio due to movements of workers between industries or plants. Net positive between movements result from an increasing share of total employment at plants with higher than average non-production worker ratios. The second term on the right gives the contribution of changes in the proportion of non-production employment or wages within the industry or plant, the *within* effect. Net positive movements result from increases in non-production worker ratios at plants with higher than average employment shares. For analysis at the industry level, the *within* effect can be either due to changes across plants in the same industry or changes within the plant itself. Note that if all plants have the same non-production/production worker ratios then the between contribution will be zero. The within component will be positive if, on average, plants are increasing their share of non-production workers in total employment.

The between and within changes can be associated with different factors affecting the relative demand of inputs. Because the between component is related to changes of employment share across industries or plants, it is primarily associated with changes in product demand. However, to the extent that technology is driving the reallocation of employment between plants, the between measure may also be capturing technical change. The within component is generally attributed to changes in technology or demand for skilled labor within the industry or plant rather than changes in product demand. Due to the high level of aggregation even at the four-digit SIC level, within changes at the industry level may still be due to shifts in demand for goods within an industry; for example, the change from mainframe computers to microcomputers all occurred within a four-digit SIC industry. Even at the plant level, within changes may represent switches from the production of one good to another due to changes in taste. In Section 2, Section 3, and Section 4, we report the between and within components for wages and employment and a measure of the wage gap and refrain from making the link to product demand and technology explanations. Instead, by using additional plant level data in Section 5, we test directly whether these assumptions are appropriate.

2.1. Data

We make use of plant level data for the manufacturing sector in our study of the determinants of employment and wage changes. We use newly available, detailed plant level data from the Census Bureau's Annual Survey of Manufactures (ASM) for the period 1976 to 1987 to investigate the relationship between exporting and labor market structure. The ASM surveys U.S. manufacturing establishments and collects information on production and non-production employment; production hours; salaries and wages; shipments; value-added, capital measures; ownership structure; and direct exports.

Excepting exports, a detailed description of the variables we employ is given in Appendix A. For exports, the ASM asks establishments to "Report the value of products shipped for export. Include direct exports and products shipped to exporters or other wholesalers for export. Also include the value of products sold to the United States Government to be shipped to foreign governments. Do not include products shipped for further manufacture, assembly, or fabrication in the United States." To the extent that plants do not know the ultimate destination of products they ship, these directly reported exports understate the true value of exports from establishments. Direct exports reported in the ASM account for about 70–75% of total exports (reported to the Census Bureau's Foreign Trade Division from ports of export) for all years but 1987, where direct exports account for about 66% of total exports. The coverage also varies by industry, typically where small firms are more important in production, direct exports account for a smaller percentage of total exports. The ASM was conducted in every year over the period 1976–1987; however, in 1978, 1979, and 1982 the direct export question was not asked. This limits our analysis of the impact of exports on wage inequality and skill upgrading to the period 1980–1987.

Ideally, we would prefer to use information on detailed demographic components of the labor force at the plant to conduct our analysis of the change in wage inequality. Unfortunately, in the ASM and the Census of Manufactures, total employment at the plant is broken into only two components: production workers and non-production workers. For the purposes of this paper, these two categories of employment will be thought of as representing low-skilled or blue collar (production) and high-skilled or white collar (non-production) workers.[7]

While we are able to link plants' detailed information across time, the ASM is not designed as a long-term panel. Instead, the ASM is a series of five-year panels of U.S. manufacturing establishments. Each five years the sample is partially redrawn. Questionnaires are sent to about 56,000 of the 220,000 establishments that are surveyed in the Census of Manufactures (which occurs every five years). Some of the 56,000 establishments are included in the sample with certainty. These "certainty" cases include establishments with large total employment (greater than 250 employees), establishments with large value of shipments, and establishments owned by large enterprises. (While the criteria for inclusion in the panels has changed over time, particularly between the 1974–1978 ASM panel and subsequent panels, the general principle of sampling based on size and importance has held during the period we study.) Other establishments are sampled with probabilities ranging from 0.99 to 0.005, based on the size and industry of the establishment. The sample is designed to be representative of the population of manufacturing establishments in terms of industry and plant size. Establishments are assigned weights which are inversely proportional to their sampling probabilities. The weights are used to produce aggregate industry totals.

2.2. Within/between industries and plants

In this and the following two sections, we begin by conducting the analysis at the industry level and then proceed to the plant level analysis. In this way, we highlight the similarities and differences of the movements of workers and wages across plants and industries. We study the two classes of workers reported in the ASM, non-production and production, and associate them with high-skilled and low-skilled workers respectively. While this categorization hides much of the change in the wage and employment structure during the period in question, it does not prevent us from learning about the sources of these changes.

Table 1 reports the changes in the employment and wage shares for non-production workers during the periods 1973–1979 and 1979–1987 for four-digit industries. From 1973–1979, the share of non-production workers rose at a rate of 0.320% per year, while from 1979–1987, this ratio increased at an annual rate of 0.546% per year. The share of the wage bill paid to non-production workers rose at 0.331% per year during 1973–1979, but the growth rate more than doubled to

[7] For discussions of the appropriateness of this categorization, see Berman, Bound and Griliches (1994) and Davis and Haltiwanger (1991). Other studies that use the ASM and thus employ this breakdown of the labor force include Lawrence and Slaughter (1993) and Berman, Bound and Griliches (1994).

Table 1
Changing labor market share of non-production workers. Decomposition of employment and wages

	Employment			Wages		
	Between	Within	Total	Between	Within	Total
All manufacturing by industry[a]						
1973–1979	0.121	0.199	0.320	0.119	0.212	0.381
1979–1987	0.184	0.362	0.546	0.309	0.410	0.719
Continuous plants[b]						
1973–1979	0.101	0.170	0.271	0.140	0.134	0.274
1979–1987	0.177	0.215	0.392	0.315	0.022	0.536

Notes: Numbers are % changes per year. Between numbers represent shifts across cells; within numbers represent changes within cells. All calculations have been annualized.
[a] Plants are placed into cells according to four-digit SIC industry (449 cells).
[b] Each plant is a cell.

0.719% per year in the latter period.[8] As a rough measure of the increase in wage inequality between the two labor types, we can look at the difference between the wage share and the employment share increases. For the early period, this difference was essentially unchanged; while for the later period, the wage share of non-production workers increased 0.173% per year faster than the employment share.[9]

To understand the sources of these changes, we consider the movements of the between and within components of the employment share for non-production workers and the wage share for the same workers. Over time, we find that for the employment share, the largest increase was due to a rise in within industry shares of non-production workers, with the annual growth rates jumping from 0.199 to 0.362 while the growth rate of the between component rose from 0.121 to 0.184. The wage bill shows a different story; as with the employment ratio, the within component contributes most heavily to overall changes in both periods, however, both the between and the within components rose substantially in the 1980s compared with the 1970s. The difference between the wage and employment shares is driven mostly by the between industry shifts of workers and wages. These results, also noted by Berman, Bound and Griliches (1994), present a puzzle: while the bulk of employment shifts towards increased shares of non-production workers and wages was occurring within industries, wages were shifting across industries faster than workers, suggesting that factors driving between industry movements may play a large role in the rise in wage inequality.

To determine the origins of the industry changes in employment and wage

[8]These numbers are slightly higher than those reported in Berman, Bound and Griliches (1994) for the early period and slightly lower for the later period.

[9]The difference between the wage share increase and the employment share increase does not correspond precisely to a measure of wage inequality. This is discussed in detail in Section 4 and in Appendix B.

shares, we make use of plant level data. Because the ASM sample changes substantially every fifth year we do not attempt the within/between decomposition at the plant level using the entire panel. Instead, we consider only those plants that have data throughout each sub-period. This introduces several potential problems when comparing the results with the industry analysis. First, the sub-samples of plants are biased towards large plants, since they are more likely to be sampled in each panel of the ASM. The problem is that small and medium size firms are more likely to enter and leave the panel over time even though they are still producing. Larger firms are more likely to be sampled with certainty. Second, it biases the results towards those plants that survived. This second problem means that we are missing the change in worker composition occurring due to the death of older, potentially production worker-intensive plants and the birth of new, potentially non-production worker-intensive plants in the same industry. In other words, if technology plays a role through the changing composition of plant types within industries, then we will mistakenly underestimate the role of technology in the changes in the workforce. We find, in other work, that the panel of continuing plants is largely representative of the manufacturing sector and that plant births and deaths do not contribute heavily to the changing composition of employment.[10] In addition, this sub-sample comprises roughly two thirds of employment and output in the manufacturing sector, making it an interesting sample to study in its own right.

The second panel of Table 1 reports the plant level decomposition for the two periods.[11] The total numbers show similar patterns to those at the industry level, with both employment and wage ratios rising faster in the 1980s than in the 1970s. In particular, these samples account for over 83% of the aggregate increases in the employment and wage ratios in the early years and over 72% of the aggregate increases in the 1980s.

The plant level decomposition yields different results for the contributions of the between and within components. Whereas at the industry level the within component dominated both employment and wage bill changes, now the between component is much stronger. For employment, within changes account for over 54% of the total, while for the wage bill, the between contribution is dominant with over 58% of the total movements.

These results suggest that the industry level analysis is hiding substantial, important heterogeneity across plants. While within plant skill upgrading is still responsible for the majority of employment changes in the samples, the differences between the 1970s and 1980s are driven mostly by large rises in between plant

[10] See Bernard and Jensen (1994) for results on this issue.

[11] All the decomposition results are directly comparable to the aggregate share increases. In other words, the aggregate increase in the employment share was 0.320% per year from 1973–1979, and the continuous plant sample showed a 0.271% per year increase over the same period. This means that the plants not in the sub-sample accounted for only 0.049% per year (or 15%) of the aggregate increase.

employment and wage composition. While these results do not bear directly on the technology versus demand alternatives so prominent in the literature, they suggest that within plant increases in skill-biased technical change are unlikely to be the prime source of wage inequality increases, although the rise in within plant employment ratios suggest that indeed the transformation of the production process within plants increased during the 1980s.

3. Exporters, size, and skill-upgrading

To help discriminate between competing explanations for the observed industry versus plant demand increases, we perform the decompositions using plant characteristics as additional categories. To keep the analysis manageable, we focus on only two characteristics: export status and total employment (size). Size has consistently been found to be highly correlated with a large number of plant characteristics including capital intensity and technology adoption, while export status is the only available measure of international trade available for the plant. In Section 5, we perform a multivariate analysis using other plant variables including product specialization and capital intensity.

For the analysis at the industry level, we divide each of the 449 four-digit level industries into four sub-industries based on export status and size of the plant in the initial year of the period. We use two export categories, one containing exporting plants and the other non-exporting plants, and two size categories, one containing plants with fewer than 250 employees in the initial year and the other with larger plants. The exports sub-division lets us see directly whether exporters have increased their non-production workers and wages faster than non-exporters. The size classification lets us discriminate between exporting and other plant level characteristics.[12]

Berman, Bound and Griliches (1994) use data from the NBER–Trade Data Base to impute share of workers to exports, imports, defense, and other domestic consumption for four-digit industries to evaluate the effect of trade on the aggregate ratio changes. We use data on exports at the plant level and consider all the employees at an exporting plant to be in an exporting industry. In doing this we are almost certainly overstating the importance of exports in the decomposition. However, the share of shipments exported is usually between 0–10% for exporting plants and thus we consider export status as more of a plant, or product,

[12]We considered two size classes to limit the number of cells. Results based on a cutoff of 500 employees did not change the results nor did decompositions with larger numbers of size categories. Plants in the 1987 ASM that were not sampled in 1980 are located according to their 1987 size. Ideally, we would also consider categories based on technology variables to discriminate between the competing stories for the rise in skilled labor demand. However, the plant level technology variables are available only for a sub-sample of the plants. We perform regressions with plant data on technology in Section 5.

Table 2
Changing labor market share of non-production workers.1980–1987 employment and wage decomposition by export status, size, industry

Export status	Size class	Employment Between	Employment Within	Wages Between	Wages Within
All plants	All plants	0.174	0.223	0.267	0.278
Non-exporters	All plants	−0.061	0.122	−0.093	0.123
Exporters	All plants	0.235	0.101	0.360	0.155
All plants	0–250	0.112	0.117	0.147	0.110
All plants	>250	0.062	0.106	0.121	0.167
Non-exporters	0–250	−0.059	0.095	−0.076	0.073
Exporters	0–250	0.172	0.022	0.223	0.037
Non-exporters	>250	−0.001	0.027	−0.017	0.050
Exporters	>250	0.063	0.079	0.138	0.117

Notes: Numbers are % changes per year. Between numbers represent shifts across cells; within numbers represent changes within cells. All calculations have been annualized. Plants are placed in cells according to export status, size class and four-digit SIC industry (1796 cells). Size class is determined by 1980 total employment.

characteristic and less as a pure indicator of the role of trade. The results are shown in Table 2 and Table 3 for 1980–1987.[13]

Table 2 decomposes the changes in the employment and wage ratios from 1980–1987 into between and within effects by industry and by export and size classes. The first line of Table 2 reports the breakdown of this aggregate annual increase into between and within components and shows results very similar to those reported in Table 1 for the 1979–1987 period.[14] The between component contributed 0.174% per year to the employment total, representing the increase in the employment share of industries with higher than average non-production ratios over the period. The within component increased 28% more quickly, at a rate of 0.223% per year. The results for the ratio of non-production wages change from those reported above. The aggregate wage ratio increased at 0.545% per year with the between and the within effects contributing 0.267% and 0.278% respectively. These results show a smaller role for within industry changes than are reported in previous work at the industry level, partly because we put firms in industry-export cells and partly because we must start our sample in 1980 to consider exporters.

To determine the role of exporters in these increases, we look at the contributions of exporting plants to the between and within increases. The second and third lines of Table 2 report the changes for non-exporters and exporters respectively. Looking at employment, we find that non-exporters have within

[13]These years are mandated by the availability of the export question in the surveys.

[14]By grouping firms into cells based on their four-digit SIC industry code and export and size status (1796 cells) we reduce the contribution of the within component. By definition, as the analysis uses more cells, the between component will rise, or at least not fall.

Table 3
Changing labor market share of non-production workers. 1980–1987 employment and wage decomposition by export status, size, plant

		Employment		Wages	
Export status	Size class	Between	Within	Between	Within
All plants	All plants	0.114	0.151	0.215	0.155
Non-exporters	All plants	0.024	0.060	0.031	0.058
Exporters	All plants	0.090	0.091	0.184	0.098
All plants	0–250	0.037	0.028	0.045	0.023
All plants	>250	0.077	0.123	0.170	0.132
Neither	0–250	0.015	0.017	0.011	0.010
Neither	>250	0.044	0.029	0.054	0.034
Stop	0–250	−0.001	0.003	−0.001	0.002
Stop	>250	−0.034	0.011	−0.034	0.012
Thru	0–250	0.008	0.005	−0.013	0.006
Thru	>250	0.032	0.069	0.087	0.077
Start	0–250	0.015	0.004	0.022	0.005
Start	>250	0.035	0.013	0.063	0.009

Notes: Numbers are % changes per year. Between numbers represent shifts across cells; within numbers represent changes within cells. All calculations have been annualized. Each plants is a cell. Size class is determined by 1980 total employment. Neither contains plants that did not export in 1980 or 1987. Stop contains plants that stopped exporting after 1980. Thru contains plants that exported in 1980 and 1987. Start contains plants that began exporting after 1987. Exporters combines Start and Thru. Non-exporters combines Stop and Neither.

effects 21% larger than exporters, 0.122% and 0.101% respectively. The between effects on employment are negative for non-exporters, −0.061%, and strongly positive for exporters, 0.235%. For wages the role of exporters is even more pronounced. Unlike employment, exporters have within wage changes 26% larger than non-exporters. As in the employment results, the between effects are strongly positive for exporters, 0.360%, and more than offset the negative between effects for non-exporters, −0.093%. These differences between the employment and wage ratio movements suggest that the rise in wage inequality is occurring due to employment gains at exporting establishments even though skill-upgrading is taking place at both exporters and non-exporters.

Unlike Berman, Bound and Griliches (1994) who attribute only 6% of the increase in the aggregate employment and wage ratios to exports, we find that exporting industries account for a substantial fraction of the movements. Within industry changes for exporters represent more than a quarter of the total upgrading for employment and 28% for wages. Between industry effects contribute more to the aggregate movements; shifts of employment to exporting industries account for more than 59% of the aggregate change (offset by employment losses for non-exporters). The results for the wage ratio are even stronger, providing more evidence that exporting industries contributed strongly to the increase in the wage gap.

Looking at the interaction of export and size class of the plant, the results are somewhat surprising. Plants with fewer than 250 employees account for the bulk of both the within industry and cross-industry movements for employment. However, larger plants seem to account for a greater fraction of the wage bill changes. Especially prominent are the employment and wage bill gains for small exporters, while large exporters and small non-exporters dominate the within industry skill upgrading.

3.1. Within/between plants

These results at the industry level provide new evidence that exporting plants are a significant force behind the aggregate increase in skill upgrading and the associated increase in wage differentials during the 1980s. In particular, the shifts of workers and wages to exporting plants is the primary source of skill-upgrading at the industry level. We now return to the plant level decompositions to determine if the export effect is primarily cross-industry or if it is also a within industry phenomenon.

In reporting the plant level decompositions, we classify firms into four export categories and two size categories. Table 3 contains the between and within results for employment and wages for all plants and for the export and size categories. The four export categories are Neither, Stop, Thru, and Start. Neither contains plants that did not export during the period; Thru contains plants that exported throughout. Stop holds plants that were exporters but ceased, while Start contains those plants that starting exporting after 1980.[15]

The plant level analysis by category reinforces the industry results given in the previous section and the plant level decomposition in Section 2. While we see substantial within plant employment shifts in plants that did not export, the largest contribution comes from exporting establishments, especially those that exported through the period. Perhaps more important is the fact that exporters throughout increased their wage share for non-production workers faster than their employment share. Both Starters and Stoppers show less evidence of within plant upgrading.

The major finding from this decomposition at the plant level is the importance of shifts across plants. Employment share gains by exporters are large and account for a third of the total upgrading in employment, while fully 50% of the wage bill shifts results from increased shares at exporting plants. These increases for exporters are split roughly equally between plants that start exporting and those that export throughout.

Again the interaction with size class is revealing. Large plants are more important in this sub-sample than in the aggregate and they contribute more

[15]The tables report changes using the ASM weights so the percentages represent contributions to the aggregate. Using the unweighted numbers did not change the results.

heavily to the share increases here as well. The large exporters throughout show the largest contributions to both within and between plant employment and wage rises for non-production workers. Plants that start exporting during the period in both size classes also show employment and especially wage share rises. Large non-exporters throughout also gain employment and contribute to between plant movements.

Combining the between and within components, we find that exporters contribute 68% of the employment share changes and 76% of the wage bill changes within the sample. Even as a fraction of the entire manufacturing sector, exporters in this group of continuously sampled plants accounted for 46% of the total employment upgrading and 52% of the wage bill gains by non-production workers.

Remembering that this panel accounts for almost two thirds of total manufacturing employment and shipments in 1980 and 1987, we cannot conclude that the results are an artifact of the sample. Rather, these results suggest that a fresh look at the characteristics of exporting plants should shed light on the sources of the increased demand for skilled labor in U.S. manufacturing. While these decompositions help us understand the sources of demand growth for high-skill labor, as yet we have not considered the issue of the wage gap between types of labor. The next section develops a measure of wage inequality and asks whether within plant or between plant changes have been the source of inequality movements.

4. Wage inequality

The results of the previous sections show that while within industry and within plant shifts have been ongoing, and even increasing in the 1980s, a substantial fraction of the increased demand for non-production labor is due to between plant and between industry shifts. These movements of workers and wages do not directly address the question of the wage gap between high-skilled and low-skilled workers. In this section, we survey the evidence on the wage gap between non-production and production workers in the manufacturing sector. To determine the sources of relative wage changes we construct a measure of the increase in the wage gap and examine the contributions of sectors, plants, and exporters.

While the evidence on the rise of wage inequality is compelling and widespread, due to the limited demographic breakout of the ASM data we are forced to examine only the returns to non-production and production workers. Table 4 contains the wages for non-production and production workers for selected years from 1973–1987 for all of manufacturing and by two-digit SIC industry. As found in other studies, the relative wage of non-production workers to that of production workers in all of manufacturing was falling from 1.53 to 1.51 during the 1970s, and then rising during the 1980s to 1.56 in 1987. Much more striking is the variance across industries. Industries with consistently high wage ratios include

Table 4
Average industry wages for 1973, 1979, and 1987

Industry	1973		1979		1987	
	Non-production	Production	Non-production	Production	Non-production	Production
All	29007	18912	28026	18513	29363	18785
Food	24224	17776	24361	17578	24544	16691
Tobacco	28504	17184	30554	19724	35770	27428
Textiles	25579	13785	23585	13099	24941	13580
Apparel	23981	10707	20713	9780	22119	9858
Wood	27670	16004	25425	15728	24848	15136
Furniture	26335	14425	25137	13376	25900	13930
Paper	29416	20822	29437	20749	31170	22687
Printing	23985	20418	21873	17836	23254	18052
Chemicals	30434	21724	30892	22333	32558	24061
Petroleum	33947	26612	33396	28636	35886	29454
Rubber	27909	17551	27424	16274	29043	16558
Leather	25355	11632	23884	10392	22965	9729
Stone, glass	27408	20010	26778	19307	27750	19667
Primary metals	32435	24625	33694	26493	31666	23417
Fabricated metals	29468	20184	28718	19063	29329	19177
Machinery	30619	21816	29354	20630	31478	21027
Electronics	30305	18037	28222	17159	31005	18801
Transportation equipment	35639	25285	34081	25304	35149	25702
Instruments	30034	17547	28684	16952	30683	18317
Miscellaneous manufacturing	27114	13864	24993	12962	25147	13549

Note: Numbers are real $ per worker (1982–1984 base).

apparel (2.24 in 1987) and leather products (2.36 in 1987) while printing and petroleum show low wage gaps, 1.23 and 1.17 respectively in 1979. There is also considerable heterogeneity in sectoral performance over time. More than half the 20 sectors show declines in wage inequality during the 1970s while only six have falling wage ratios in the 1980s.

Over time, the variation within industries is much smaller than that across industries in any year. Tobacco shows the greatest movement during the 1979–1987 period, with the relative wage falling from 1.66 to 1.30. However, this is substantially less than the cross-industry spread in each year, whose standard deviation is around 0.28 and rising slowly. This pattern of wide cross-section variance and substantially lower within industry variance reinforces the decomposition results from the preceding sections in that the source of rising wage inequality during the 1980s is located primarily in the between industry and between plant movements of workers and wages, not in the relative wage movements of individual sectors or plants.

To analyze the sources of change in wage inequality, we form a measure of the "excess" increase in the fraction of the wage bill paid to non-production workers. Since non-production workers are paid more than production workers and their share in manufacturing employment is rising, we would expect their share of total wages to be rising as well. In fact, the non-production wage share would most likely be increasing more quickly than the employment share due to the relative wage premium enjoyed by non-production workers. Our measure of the wage gap calculates the share of total wages non-production workers would have received had the aggregate relative wage remained constant while their employment share changed.[16] Of course, increased employment of the relatively expensive factor input, in this case non-production workers, could be associated with a decline in their relative price, absent any demand changes. Our statistic is calibrated to a zero change in relative wages.

$$\Delta\ \text{WageGap} = \Delta\ \text{ObservedWageShare} - \Delta\ \text{ExpectedWageShare} \tag{2}$$

The wage gap measure captures the increase in non-production wages in excess of the increase in their share of employment, holding aggregate relative wages constant. Formally, the construction of the statistic is given as

$$\Delta WG = \frac{W_1^n E_1^n}{W_1^n E_1^n + W_1^p E_1^p} - \frac{W_0^n E_1^n}{W_0^n E_1^n + W_0^p E_1^p} \tag{3}$$

where W_m^j and E_m^j are the average wage and total employment for group j in period m. If the manufacturing sector were comprised of one firm, then this

[16] This measure allows a separate identification of aggregate wage increases due both to shifts of employment to high wage plants and to within plant relative wage increases. See Appendix B for more details.

measure would reduce to a measure of the increase in relative wages for non-production workers at the firm.

There are two main reasons that this measure might be different from zero. First, the relative wage at the plant/industry may rise even as the percentage of non-production workers increases; this is the within plant effect typically associated with skill-biased technical change within the plant. Second, the composition of employment within manufacturing might shift towards plants with high relative wages for non-production workers. These two factors correspond to the within and between components described above and can be calculated for each plant/industry from the change in the wage gap statistic.

Since the sign of this measure for the entire manufacturing sector is driven by the change in the aggregate relative wage, it is unsurprising that our wage gap measure is negative for 1973–1979 and positive for 1980–1987. Results are reported in the first panel of Table 5. Constructing the between and within breakdown, we find that in both periods the between industry movements are much larger than the within sector changes. In particular, the change across the periods from a decline in the wage gap measure to an increase is almost entirely accounted for by the large swings in the between industry movements.

We can also calculate the wage gap measure for our sample of manufacturing plants continuously operating in the periods. Here, we find that the sub-sample of plants behaves differently from the manufacturing sector as a whole. From 1973–1979, the wage inequality measure for this sub-sample was increasing, and the rate of increase doubled during the 1980s to twice the rate of the overall manufacturing sector. The same breakdown of within plant and between plant movements is evident. During both periods the between plant inequality was dominant, accounting for 93% of the rise in the sample from 1973–1979 and 82% in the 1980–1987 period. Within plant relative wage changes account for a minor part of overall rises in wage inequality in this sample of plants. Breaking out the

Table 5
Change in the wage gap

	Export Status	Between	Within	Total
Industry decomposition[a]				
1973–1979	All plants	−0.038	−0.015	−0.053
1980–1987	All plants	0.054	0.038	0.092
Plant decomposition[b]				
1973–1979	All plants	0.120	0.008	0.128
1980–1987	All plants	0.198	0.044	0.242
1980–1987	Exporters	0.282	0.022	
1980–1987	Non-exporters	−0.084	0.022	

Notes: Numbers are % changes per year. Between numbers represent shifts across cells; within numbers represent changes within cells. All calculations have been annualized.

[a]Plants are placed into cells according to 4-digit SIC industry (449 cells).

[b]Each plant is a cell.

increases by export status, the pattern continues. Non-exporters actually show a negative contribution to aggregate inequality due to between movements, while exporting plants account for all the increase in inequality in the sample.

The results of this and the preceding two sections shed substantial light on the source of the rise in demand for skilled labor and wage inequality during the 1980s. While there is evidence that plants and industries were increasing the share of non-production workers in their labor mix, the bulk of the evidence suggests that between industry and especially between plant movements contributed to the rise in relative wages for non-production workers. The striking facts are that while employment share increases occurred within plants, wage share increases occurred because of shifts across plants.

However, the decomposition analyses do not indicate whether skill-biased technical change, or product demand shifts were the underlying source of these between plant movements. In the next section we estimate the relationship between product demand and technology factors and increases in employment and wages for non-production workers in the manufacturing sector.

5. Technology, product demand, and exporters – empirical evidence

In this section, we present evidence on differences in technology for exporters and non-exporters and test the assumptions that between plant movements are related to demand shifts while within plant changes are technology driven. To discriminate between technology and export/demand-related hypotheses concerning the rise in wage inequality, we would ideally regress plant level changes in employment and wage ratios on measures of changes in product demand, exports, and technology deepening for the 1973–1979 and 1979–1987 periods. We could then test for significant differences in the coefficients across the time periods to determine the source of the increase in inequality. Due to data limitations and changing samples of plants, we can perform only parts of this exercise and thus proceed in several stages. To identify the differences between the 1970s and 1980s, we regress plant level wage and employment share increases on demand and technology indicators for the periods 1973–1979 and 1979–1987. Next, we consider the relationship between technology and exports at the plant. Finally, we regress wage and employment share changes during 1980–1987 on export, demand, and technology variables to examine the influences of these factors on the large wage inequality increase in the 1980s.

We draw on three data sources to investigate technology at the plant level. The broadest coverage comes from the Census of Manufactures which contains information on computer investment at the plant level in 1977, 1982, and 1987. While we would prefer to work with stocks of computers or a continuous investment series, the plant level investment numbers give an indication of computer intensity. The second source is an ongoing annual survey of Industrial

Research and Development conducted for the NSF by the Census. The survey is at the firm level covering about 10,000 firms in 1987 and gives data both on R&D expenditures and on scientists and engineers employed in R&D. Finally we consider evidence from the Survey of Manufacturing Technology (SMT) in 1988 which asks about the plant level adoption of 17 technologies in five technology groups. The sampling frame consisted of 10,526 establishments with 20 or more employees in two-digit SIC industries 34–38. None of these three sources is an exact match for technology intensity at the plant level. The computer numbers, while covering all plants in the sample, are single year flows rather than stocks of computer equipment. A serious problem in using the computer data is the large percentage of imputed numbers.[17] The R&D data are total R&D expenditures by the firm, thus confounding capital expenditures and payments to workers in R&D. Additionally, the issue of sample selection is potentially important as the firms covered are larger than the typical firm and are not selected to be representative of industry mix. The SMT numbers give only a "yes" or "no" indication of whether a technology is in place at the plant, thus larger plants are likely to have more technologies, but could still have lower levels of technology per worker. Since the SMT data is available only for 1988, we cannot use these measures in our analysis of changes over time.

As outlined in the introduction and emphasized by Mishel and Bernstein (1994), an important aspect of the increase in wage inequality is the difference between the 1980s and earlier periods. In Section 2 and Section 4, we showed that the major change from 1973–1979 to 1979–1987 was the rise in the movements of workers and wages between plants. To distinguish among the competing explanations for this increase, we regress the between and within components of the wage and employment shares at the plant level on demand and technology variables as well as on other plant and industry characteristics. Because of the smaller sample for the R&D survey, we are limited to working with 9000–11,500 plants with records for all variables depending on the years covered. This sample contains roughly half of the plants used in the decomposition analysis for the comparable periods. The basic formulation is

$$\Delta\text{Share}_{i,C} = \alpha_j + \beta_1 \Delta\text{Tech}_i + \beta_2 \Delta\text{Sales}_i + \beta_3 \text{Plant Characteristics}_i + \varepsilon_{i,C} \tag{4}$$

where i indicates the plant, j the five-digit SIC industry, and C the between or

[17] Computer investment has been used by other researchers as a measure of technology, e.g. Berman, Bound and Griliches (1994) or Mishel and Bernstein (1994), however it is not obvious that computers differ in their skill complementarity from other forms of capital. Roughly two thirds of the ASM responses on computer investment are imputed. Generally this results from a missing response on the questionnaire which is then imputed to zero. All the results relating to computers should be regarded with extreme caution. The effect of this problem on computer investment reported at the industry level from ASM data is unclear.

within component. The dependent variables, $\Delta\text{Share}_{i,C}$, represent the annual percent contribution of the plant's between and within components to the change in the aggregate wage and employment ratios. Changes in the firm's R&D–sales ratio are used as the technology variable and changes in total value of shipments (ΔTVS) as the demand variable. Due to data limitations for the earlier years, the R&D variable is the only available technology measure and TVS cannot be broken into domestic and export components. Additional controls include five-digit industry dummies, the change in the capital–labor ratio, total employment in the initial year, and the age of the plant.

The results are presented in Table 6. For 1973–1979, changes in R&D are positive but not significant for both the between and within components. On the other hand, the demand variable, ΔTVS, is positive and strongly significant for the between components of both employment and wages, with the coefficient on wages twice that on employment. ΔTVS shows mixed results for the within plant upgrading, is negative and significant for the within plant employment change and positive and significant for the within wage change. Interestingly, the $\bar{R}^2$ is surprisingly high for all specifications, 0.29 and 0.17 respectively for the between and within employment share regressions, and 0.30 and 0.14 for the between and within wage share estimations.

Looking at the 1979–1987 regressions, we find interesting differences from the 1973–1979 period. Now ΔR&D is positively and significantly related to the within plant component, although it is still not significant in the between regression. ΔTVS is still positive in the between regressions but the magnitude of the coefficient is much greater. ΔTVS now is negative and significant in both within regressions. The $\bar{R}^2$ is even higher for four components.

These results provide some insight into the possible explanations for the wage gap increase in the 1980s. Technology, while significantly related to changes in within plant wage inequality in the 1980s, does not contribute to the between movements (although the point estimates are consistently positive). Changes in total values of shipments, on the other hand, are positively correlated with between plant movements in both periods but especially so in the later period. The results, combined with those from the earlier sections on the importance of the between movements, suggest that cross-plant demand changes are the dominant source of manufacturing wage inequality increases in the 1980s. We next investigate whether exports or domestic sales are the source of the demand movements.

Before considering the role of exports in plant level wage and employment share increases, we examine the level of technology intensity at the plant for exporters and non-exporters. The results from Section 3 strongly indicate that exporters are contributing to the bulk of the changes in the wage gap at the industry and at the plant level and that these increases are due to employment and wage shifts across plants. However, the decomposition analysis did not clarify the issue of whether export status is associated with product demand or plant characteristics such as technology. It is possible that export status is merely a

Table 6
Determinants of wage and employment changes, 1973–1987

	Dependent variable							
	1973-1987				1979-1987			
	Δ in Employment share		Δ in Wage share		Δ in Employment share		Δ in Wage share	
	Between	Within	Between	Within	Between	Within	Between	Within
Δ R&D/Sales	0.321	0.135	0.455	0.407	1.66	4.91	2.52	5.95
	(0.58)	(0.40)	(0.51)	(0.79)	(0.40)	(2.32)	(0.41)	(2.03)
Δ Shipments	0.481	−0.037	0.929	0.066	0.751	−0.022	1.21	−0.077
	(41.60)	(5.31)	(49.82)	(6.13)	(44.82)	(2.55)	(48.11)	(6.47)
Δ K/L	−3.11	1.18	3.36	1.58	−7.60	−0.52	−9.90	0.33
	(2.62)	(1.64)	(1.75)	(1.42)	(2.81)	(0.37)	(2.44)	(0.17)
Employment 1980	−3.82	1.43	−4.66	0.28	4.26	3.42	5.70	3.73
	(31.20)	(19.25)	(23.61)	(2.50)	(19.00)	(29.79)	(17.00)	(23.42)
R^2	0.29	0.17	0.30	0.14	0.45	0.21	0.50	0.17

Notes: *t*-statistics are in parentheses. Age dummies are included in all specifications and are significant in none. Units of the independent variables have been scaled, coefficients are comparable across specifications for a given variable and are comparable with those in Table 8. There are 11,509 observations for 1973–1979 and 8920 for 1979–1987.

proxy for technology intensity. Table 7 reports mean levels of the technology variables for exporters and non-exporters in 1987. For all three variables, exporters are more technology intensive than non-exporters. Computer investment per plant is more than four times higher at exporting establishments and computer investment per employee is 4% higher than that for non-exporters.[18] R&D expenditures at exporting establishments are 4.45% of sales while at non-exporters they are only 2.34% of total sales. Exporters report higher numbers of technologies employed, 3.91 per plant, while the non-exporters use 2.20 technologies on average. These numbers taken together suggest that export status and technology status are correlated and caution that the attribution of the wage inequality changes to export demand alone is premature.

To more completely identify the relative importance of exports and technology on the plant level contributions to the aggregate wage and employment increases, we regress the between and within components on exports, domestic sales, and technology variables as well as other plant characteristics. Again due to the smaller sample for the R&D survey, we are limited to working with approximately 9000 plants with records for all variables from 1980–1987. Table 8 contains the results with technology represented by computer investment per employee and R&D/ sales. Demand changes are broken into domestic and foreign contributions.

Table 7
Exporters and technology. Plant means – 1987

	Non-exporters	Exporters
Computer investment		
% of all plants	66.32%	33.68%
Total employment	107	319
Computer investment	34039	144346
Computer investment per worker	342	356
Research and development		
% of all plants	6.62%	6.37%
Total employment	205	502
R&D (% of sales)	2.34%	4.45%
Technology in use		
% of all plants	16.45%	8.01%
Total employment	93	343
Technologies employed	2.20	3.91

Notes: Total employment comes from the Annual Survey of Manufactures. Computer investment comes from the 1987 Census of Manufactures – non-imputed responses only. R&D comes from the 1987 R&D survey. Technologies in use comes from the 1988 Survey of Manufacturing Technology.

[18] These figures are for only those establishments whose responses were not imputed. If, as we believe, non-responses are more likely to be zero or close to zero, the reported numbers probably underestimate the gap between exporters and non-exporters, since 73% of non-exporters were imputes while only 37% of exporters had imputed responses.

Table 8
Determinants of wage and employment changes, 1980–1987

	Dependent Variable			
	Δ in Employment share		Δ in Wage share	
	Between	Within	Between	Within
Δ R&D/Sales	1.00	0.75	1.56	1.73
	(2.46)	(7.38)	(2.37)	(6.44)
Δ Computer investment	−5.65	3.79	−4.76	3.38
	(2.82)	(3.57)	(1.47)	(2.57)
Δ Domestic shipments	5.66	−0.70	9.27	−0.80
	(31.53)	(7.38)	(31.90)	(6.65)
Δ Foreign shipments	15.94	2.83	25.16	1.70
	(18.51)	(6.22)	(18.07)	(3.02)
Δ Specialization	−4.92	−0.14	−5.99	0.12
	(3.53)	(0.19)	(2.66)	(0.13)
Δ K/L	−6.69	−0.32	−8.61	1.04
	(2.69)	(0.24)	(2.14)	(0.63)
Employment 1980	3.92	2.45	4.06	2.82
	(16.49)	(19.43)	(10.56)	(18.01)
R^2	0.38	0.17	0.38	0.19

Notes: *t*-statistics are in parentheses. All specifications include age dummies, an export dummy, and five-digit industry dummies. Units of the independent variables have been scaled, coefficients are comparable across specifications for a given variable and are comparable with those in Table 7. There are 8981 observations in each specification.

Additional variables include initial employment, change in the degree of primary product specialization, change in the capital–labor ratio, dummies for five-digit SIC industry, for plant age and for the export status of the establishment. We report results for the between and within components of employment and wage share changes.

The results are striking. The between plant shift of both wages and employment towards high-skilled workers is strongly positively related to increases in both domestic and foreign demand. The technology variables show mixed results; changes in computer investment per employee have a negative and significant coefficient while increases in R&D/sales are significant and positive. Perhaps the most striking result is that the coefficient on changes in export sales is substantially larger than the coefficient on changes in domestic sales; a dollar increase in exports is almost three times as important as a dollar increase in domestic sales.

Among the other variables in the regressions for the between plant movements, significant variables are plant size and the change in the capital–labor ratio which surprisingly enters with a negative coefficient. Plant age and export status dummies are not significant, nor is the degree of product specialization given by the primary product specialization ratio.

These results suggest that the between plant movements of workers and wages, which are especially important in the increases in the aggregate wage gap, are largely determined by demand shifts across plants and in particular by export related demand movements. Technology plays an ambiguous role. Increases in the R&D/sales ratio at the firm are related positively to between plant increases of white collar workers and wages. However, changes in measures of changes in capital intensity, computer investment per employee, and the capital–labor ratio are significantly negatively related to the between plant movements. While not conclusive, these results suggest that changes in product demand, especially export-related sales, play a primary role in accounting for much of the observed labor market shifts in this sample of plants.

As we observed in Section 2, while the between component accounted for the bulk of observed increases in wage inequality, within plant changes in employment were substantial in the 1980s. Accordingly we regress the within plant employment and wage changes at the plant level on the same set of variables to determine if both types of transformation were driven by similar processes. The results, also presented in Table 8, show a somewhat different story for the within plant components of the employment and wage share increases.

While domestic and foreign demand variables were the primary source of between plant shifts, within plant skill-upgrading is related much more strongly to technology and investment factors. Both technology variables enter significantly and positively, while the demand variables show mixed results. Export increases still show a positive and significant relation to within plant skill upgrading, however, increases in domestic sales are now negative and significant, although the coefficient is quite small. Changes in capital intensity, negative and significant for the between movements, are now positive although not significant. Other variables remain largely unchanged, plant size is still strongly positive, and export status and plant age dummies are again insignificant.

These results yield information on two related issues, the source of the increase in non-production employment during the 1980s and the factors contributing to the rise in wage inequality between groups during the same period. Relative employment shifts for this sample were roughly split between within plant changes and between plant changes. Regressions on the plant level factors leading to these changes show that between plant shifts were largely demand driven, although a role for technology in the form of R&D intensity is present in the data. Within plant changes were much more closely linked to technology and investment factors, although export sales still show a positive association with skill-upgrading.

The determinants of increased wage inequality at the plant level are almost entirely driven by between plant shifts, as shown in Table 1 and Table 3. These increases are much more strongly linked to the demand variables, especially foreign sales, than the technology or investment variables.

Overall, the regressions speak to two related sources for the rise in non-production employment and faster wage growth in the manufacturing sector. Within plants, technology investment is associated with a change in the skill mix of the workforce, although not with a rise in wage inequality. However, changing demand across plants, often within industries, towards establishments intensive in non-production employment led to rises in relative employment and even faster rises in relative wages for non-production workers at those plants. At this point it should be emphasized that the results we have presented are in the context of declining aggregate employment in the manufacturing sector. Non-production employment was falling, but production worker employment was falling faster.

6. Conclusions and future research

In this paper we have examined the sources of the increased demand for skilled labor and rising wage inequality in the 1980s in the U.S. manufacturing sector. Focusing on the primary competing explanations of skill-biased technical change and product demand shifts, we make use of an exhaustive microeconomic data set on individual establishments from 1973–1987 to focus on plant level movements in the skill composition of labor. The main results are dramatic and revealing. The major shifts from the 1970s to the 1980s are associated with between plant movements. In particular, the increase in the relative employment of non-production workers and the associated increase in the wage gap between high-skilled and low-skilled workers can be attributed substantially to changes at exporting establishments. While previous researchers have found little role for trade, we examine plant level data and find the export status of the plant is fundamental to these changes in the labor market over this period. Our results show that even at the industry level, where a large fraction of the increased demand for skilled labor, or skill-upgrading, is occurring within industries, exporting plants in a few sectors contribute the bulk of the changes.

We focus on two aspects of the rise in wage inequality and the demand for skilled labor. First we identify differences in labor demand from the 1970s to the 1980s. At the industry level, most of the changes in employment composition are occurring within industries. The pattern is different for wages, suggesting that the wage gap may be driven by between industry movements. Using data on establishments, we find that most of the change from the 1970s to the 1980s occurred between plants rather than within plants. Second, making use of a panel of plants from 1980–1987 which accounts for almost two thirds of total manufacturing employment and output, we consider the role of plant characteristics in the changing demand for skilled labor. We find that the increase in the demand for skilled labor stems from employment movements across plants and firms both within and across industries, largely to exporting establishments. This result raises anew the possibility that product demand changes are responsible for a larger portion of the relative demand increase for high-skilled employees than previously thought.

To test the demand and skill-biased technical change explanations directly, we employ plant level data on technology adoption and exports in a regression framework. The results are strongly in favor of the explanation that demand changes across plants associated with exports are a major source of the wage gap. Technology variables are positively associated with skill-upgrading at the plant level, but do not contribute to employment shifts across plants.

We caution, however, that our analysis of the changes in the relative demand for skilled labor is not a complete view of the relationship between trade and the labor market because we do not have data on imports. In spite of this drawback, our results suggest that any future work on these issues must take the export status of the plant into consideration. In particular, this research shows that the role of product demand for exported goods is larger than previously realized and should not be ignored when examining the returns to skill in the U.S. labor market.

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Appendix A

Data description

Descriptions of variables are from U.S. Bureau of the Census (1987). Total employment (TE) represents the total number of employees at the plant, which is broken into two components: production workers and non-production workers. Production workers are employees (up through the working foreman level) engaged in fabricating, processing, assembling, inspecting, receiving, packing, warehousing, shipping (but not delivering), maintenance, repair, janitorial and watchman services, product development, auxiliary production for plant's own use (e.g. powerplant), record-keeping, and other services closely related with these production activities at the establishment. Non-production workers include those employees of the manufacturing establishment engaged in factory supervision above the level of line supervisor, including sales, sales delivery, advertising, credit, collection, installation, service, clerical, executive, purchasing, financial, legal, personnel (including cafeteria, medical, etc.), professional, and technical employees.

Salaries and wages (SW) represent the total gross earnings paid in the calendar year to employees at the establishment. Benefits are supplemental labor costs (SLC), both those required by State and Federal laws and those incurred voluntarily or as part of collective bargaining agreements. Salaries and wages and benefits are deflated by the Bureau of Labor Statistics (BLS) regional consumer price index (CPI, 1982 − 1984 = 100). Total value of shipments (TVS) represents the output of the plant. We use the machinery assets at the end of the year as our capital measure (K). It represents the original cost of all production machinery, transportation equipment, and office equipment and any costs incurred in making the assets usable. Value-added (VA) is derived by subtracting the cost of materials, containers, fuel, purchased electricity, and contract work from the value of shipments. The result of this calculation is adjusted by the net change in finished goods and work-in-process between the beginning and end-of-year inventories. Shipments, capital, and value-added are deflated by the BLS national CPI (1982 − 1984 = 100).[19] Primary product specialization (PPS) is the percentage of a plant's output in its primary five-digit SIC industry.

The plant level data, while limited by the nature of the panel and sampling issues, gives us the ability to identify and control for differences between plants in the same industry. This is important because of the considerable heterogeneity that exists within industries, even at the four-digit SIC level. Size, production techniques, output, and propensity to export all vary considerably across plants within the same four-digit SIC category.

The ASM is not designed to collect complete information at the firm level. While the data are collected at the establishment level, we can use information on plant ownership to link establishments owned by the same corporate entity to create firm level information. The combined or linked data represent the manufacturing activities of commonly owned establishments. The firm level information does not include activities conducted outside of the manufacturing facilities, thus, the firm level information may omit a significant portion of the firm's activities. While this is a serious shortcoming, the data do allow us to examine similarities and differences across manufacturing establishments within firms.

Appendix B

Wage gap measure

The measure of the change in the wage gap employed in this paper is defined as the increase in the share of the wage bill paid to non-production workers in excess

[19] Ideally we would want to deflate these variables with an appropriate industry deflator, however, the ASM does not collect price data.

of what they would have received had the relative wage remained constant. It is given by

$$\Delta WG = \left(\frac{W_1^n E_1^n}{W_1^n E_1^n + W_1^p E_1^p} - \frac{W_0^n E_0^n}{W_0^n E_0^n + W_0^p E_0^p} \right) - \left(\frac{W_0^n E_1^n}{W_0^n E_1^n + W_0^p E_1^p} - \frac{W_0^n E_0^n}{W_0^n E_0^n + W_0^p E_0^p} \right) \tag{A.1}$$

where the terms in the first set of parentheses are the change in the wage share actually observed, and the terms in the second set of parentheses equal the expected change in the wage share if the wage had remained constant at period 0 levels. W_m^j and E_m^j are the average wage and total employment for labor type j in period m. After simplifying,

$$\Delta WG = \frac{W_1^n E_1^n}{W_1^n E_1^n + W_1^p E_1^p} - \frac{W_0^n E_1^n}{W_0^n E_1^n + W_0^p E_1^p} \tag{A.2}$$

For a single firm, this measure will be positive if the relative wage increases, i.e.

$$\frac{W_1^n}{W_1^p} > \frac{W_0^n}{W_0^p} \tag{A.3}$$

However, with heterogeneous plants and industries this measure could be positive because plant level relative wages increased or because employment shifted to plants with higher relative wages. To capture this we decompose the aggregate measure into the contributions of individual plants or industries by

$$\Delta WG = \sum_i \frac{W_{i,1}^n E_{i,1}^n + W_{i,1}^p E_{i,1}^p}{W_1^n E_1^n + W_1^p E_1^p} \cdot \frac{W_{i,1}^n E_{i,1}^n}{W_{i,1}^n E_{i,1}^n + W_{i,1}^p E_{i,1}^p} - \sum_i \frac{W_{i,0}^n E_{i,1}^n + W_{i,0}^p E_{i,1}^p}{W_0^n E_1^n + W_0^p E_1^p} \cdot \frac{W_0^n}{W_{i,0}^n} \cdot \frac{W_{i,0}^n E_{i,1}^n}{W_{i,0}^n E_{i,1}^n + W_{i,0}^p E_{i,1}^p} \tag{A.4}$$

As with the change in the employment share or the wage share we can decompose the increase into components related to changes in plant level relative wages and plant level employment gains.

$$\Delta WG = \sum_i \left[\left(\frac{Wi_{i,1}^n E_{i,1}^n + W_{i,1}^p E_{i,1}^p}{W_1^n E_1^n + W_1^p E_1^p} - \frac{W_{i,0}^n E_{i,0}^n + W_{i,0}^p E_{i,1}^p}{W_0^n E_1^n + W_0^p E_1^p} \cdot \frac{W_0^n}{W_{i,0}^n} \right) \cdot \sum_t \left(\frac{1}{2} \cdot \frac{W_{i,t}^n E_{i,1}^n}{W_{i,t}^n E_{i,1}^n + W_{i,t}^p E_{i,1}^p} \right) \right] + \sum_i \left[\Delta_t \left(\frac{W_{i,t}^n E_{i,1}^n}{W_{i,t}^n E_{i,1}^n + W_{i,t}^p E_{i,1}^p} \right) \cdot \frac{1}{2} \left(\frac{W_{i,0}^n E_{i,1}^n + W_{i,0}^p E_{i,1}^p}{W_0^n E_1^n + W_0^p E_1^p} \cdot \frac{W_0^n}{W_{i,0}^n} + \frac{W_{i,1}^n E_{i,1}^n + W_{i,1}^p E_{i,1}^p}{W_1^n E_1^n + W_1^p E_1^p} \right) \right] \tag{A.5}$$

The first term corresponds to the between measure, capturing the change in weighted wage bill share for the firm. It is comprised of the product of the weighted change in the wage bill share for the plant and of the average non-production wage share for the plant. The weight is the ratio of the non-production wage of the plant to the average non-production wage in the economy. The second summation corresponds to the within plant change in relative wages. This term is the product of the excess change in the wage share at the plant and the plant's average share of wages in the economy again weighted by the ratio of the non-production wage at the plant to that of the entire economy.

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