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IMPLICATIONS OF SKILL-BIASED TECHNOLOGICAL CHANGE: INTERNATIONAL EVIDENCE

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ABSTRACT

Demand for less skilled workers decreased dramatically in the US and in other developed countries over the past two decades. We argue that pervasive skill-biased technological change, rather than increased trade with the developing world, is the principal culprit. The pervasiveness of this technological change is important for two reasons. Firstly, it is an immediate and testable implication of technological change. Secondly, under standard assumptions, the more pervasive the skill-biased technological change, the greater the increase in the embodied supply of less skilled workers and the greater the depressing effect on their relative wages through world goods prices. In contrast, in the Heckscher-Ohlin model with small open economies the skill-bias of *local* technological changes does not affect wages. Thus, pervasiveness deals with a major criticism of skill-biased technological as a cause. Testing the implications of pervasive, skill-biased technological change, we find strong supporting evidence. Firstly, *across* the OECD, most industries have *increased* the proportion of skilled workers employed, *despite* rising or stable relative wages. Secondly, increases in demand for skills were concentrated in the *same* manufacturing industries in *different* developed countries.

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1. INTRODUCTION

Less skilled workers have suffered declines in relative wages, increased unemployment and sometimes both in the OECD economies over the 1980s. In the United States the real wages of young men with twelve or fewer years of education *fell* by 26 per cent between 1979 and 1993, and have not recovered since.[1] Between 1979 and 1992 the average unemployment rate in European OECD countries increased from 5.4 per cent to 9.9 per cent[2] and has remained high, with most of the unemployment concentrated among unskilled workers. In the same period, relative wages of less skilled workers declined slightly in several OECD countries and sharply in others. Over the last few years several authors have documented the decline in the relative wages of less skilled workers in the US and the concurrent decline in their employment in manufacturing (e.g., Murphy and Welch, 1992, 1993; Bound and Johnson, 1992; Katz and Murphy, 1992; Blackburn, Bloom and Freeman, 1990), and a number have documented similar trends in wages, employment or unemployment in other OECD countries (e.g., Freeman, 1988; Freeman and Katz, 1994; Katz and Revenga, 1989; Katz, Loveman and Blanchflower, 1995; Davis, 1992; Machin, 1996a; Nickell and Bell, 1995). Over the past two decades, despite the fact that rapid increases in the supply of skilled labour in the OECD have made the less skilled increasingly scarce, their labour market outcomes have clearly worsened.

The literature has proposed several reasons for this decline in the demand for unskilled labour, including both Stolper-Samuelson effects of increased exposure to trade from developing countries and skill-biased (or unskilled labour saving) technological change (SBTC). While there is no consensus, labour economists generally believe that skill-biased technological change is the principal culprit. That belief is based on a combination of three factors: a) employment shifts to skill-intensive sectors seem to be too small to be consistent with explanations based on product demand shifts, such as those induced by trade, or Hicks-neutral, sector biased technological change (Bound and Johnson, 1992; Katz and Murphy, 1992; Berman, Bound and Griliches, 1994 (BBG); Freeman and Katz, 1994); b) despite the increase in the relative cost of skilled labour, the majority of US industries have had within-sector shifts in the composition of employment towards skilled labour (Bound and Johnson, 1992; Katz and Murphy, 1992; BBG); and c) there appear to be strong, within-sector correlations between indicators of technological change and increased demand for skills (Berndt, Morrison and Rosenblum, 1994; BBG; Autor, Katz and Krueger, 1997; Machin, 1996b; Machin, Ryan and Van Reenen, 1996).

In this paper we make the stronger claim that skill-biased technological change was pervasive in the OECD over the past two decades, occurring simultaneously in most, if not all, developed countries. Pervasiveness is important for two reasons: firstly, at the current level of international communication and trade it is hard to imagine major productive technological changes occurring in one country without rapid adoption by the same industries in countries at the same technological level. Thus pervasive SBTC is an immediate implication of SBTC, which invites testing. If we did not observe evidence of SBTC throughout the OECD, we would be forced to doubt it occurred in any OECD country.

Secondly, the more pervasive the SBTC, the greater its potential to affect relative wages. To illustrate this point consider a Heckscher-Ohlin (H-O) model with small open economies and two factors of production. In that context skill-biased technological change cannot change the wage structure in an H-O model unless it is also sector-biased. On those grounds, Leamer (1994, 1995, 1996) has objected to the notion that SBTC is the dominant factor explaining the decline in the demand for skilled labour. This critique is powerful, as the long run H-O model is widely considered to be the relevant model for analyzing the effect on wages of the increased exposure of developed economies to LDC manufacturing over the past few decades. (The long run is long enough for factors to detach themselves from industries, allowing wages to be set by perfectly elastic demand curves.[3]) However, as Krugman (1995) has pointed out, *pervasive* skill-biased technological change will affect relative wages, since an integrated world economy will respond to such technological change as a closed economy would. Under standard assumptions, including homothetic preferences, a sector-neutral skill-biased technological change would release less skilled workers from industries, depressing their relative wages. Pervasive skill-biased technological change in the developed world provides an explanation consistent with both increased wage premiums for skilled workers and within-industry substitution towards skilled workers. That conclusion generalizes to the large open economy H-O model as well.

Pervasive SBTC has two testable implications:

1) the within-sector shifts away from unskilled labour observed in the US should occur throughout the developed world.
2) These shifts should have been concentrated in the same industries in different countries.

Using data on the employment of production and non-production workers in manufacturing for 10 OECD countries, we find evidence consistent with both predictions. In all countries in our OECD sample we find large-scale within-industry substitution away from unskilled labour, despite rising or stable relative wages. Moreover, the cross country correlations of within-industry increases in employment of skilled workers are generally positive and often quite large.

The manufacturing industries which experience the greatest skill upgrading across our OECD sample are those we commonly associate with the spread of microprocessor technology. They are electrical machinery, machinery (including computers), and printing and publishing. Together, these three account for 40 per cent of the within-industry increase in the relative demand for skills. Case study evidence reveals that all three of these industries underwent significant technological changes associated largely with the assimilation of microprocessors.[4] Casual empiricism suggests that the spread of microprocessors within these and other manufacturing industries was pervasive in the 1980s. This pattern, combined with the correlation of skill upgrading with measures of technological change cited above, provides further evidence that technological change is the driving force behind increased demand for skill.

The little evidence we have from the developing world is also consistent with the SBTC hypothesis. Several studies have found *increased* relative wages of skilled labour in LDCs undergoing trade liberalization, despite the Stolper-Samuelson prediction (Feliciano, 1995; Hanson and Harrison, 1995; Robbins, 1995). We examine a larger sample of developing countries and check for evidence that increased trade in the 1980s depressed the wages of skilled workers. We find, on average, constant relative wages, despite the fact that the proportion of skilled workers increased as fast in the rapidly growing manufacturing sectors of the LDCs as in the shrinking manufacturing sectors of developed countries.

The paper proceeds as follows. In section 2 we embed skill-biased technological change in a H-O framework, examine possible explanations for the decrease in skill demand and derive their implications. In section 3 we test the implications of the model, presenting evidence on within-industry changes in the employment of skills in OECD countries. We also examine how well the non-production/production worker classification to education and occupation based measures of skill. Section 4 presents further evidence of pervasive technological change, describing common technological changes across countries. In section 5 we discuss possible extensions to developing countries. Section 6 concludes.

2. THE HECKSCHER-OHLIN FRAMEWORK

In this section we discuss a framework that allows both Stopler-Samuelson effects and skill-biased technological change to influence wages. Our purpose is to examine the roles of pervasiveness, factor bias and 'smallness' in those mechanisms and to develop empirical implications that will allow us to distinguish between causes. We start with the two factor, small open economy version of Heckscher-Ohlin trade theory with local technological change and then move on to pervasive technological change and the model in which countries are large enough to affect goods prices.

Consider a version of the standard theory (Helpman and Krugman, 1985) based on the following assumptions:

1) There are two factors, skilled and unskilled labour, $l = S,U$.
2) N goods are produced by constant returns to scale, quasi-concave production functions with associated cost functions $c_i(w)$, where w is a vector of wages $[w_s, w_u]$ and $i = 1,2,......,N$.
3) Perfect competition.
4) All goods are produced in equilibrium.
5) There are $J \geq 2$ countries.
6) Factor endowments and technology allow factor price equalization.
7) Homothetic preferences.

Define the demand for factor l per unit of good i as $a_{li}(w)$. Under cost minimization, it can be expressed as the derivative of a unit cost function with respect to the wage of factor l

$$a_{li}(w) = \frac{\partial c_i(w)}{\partial w_l} \qquad for \;\; i = 1,2,...N; \quad l = S,U.$$

Now consider the 'integrated equilibrium' for all countries. Using X^W_i to denote the world output level of good i and $V^W = [S^W, U^W]$ the world endowments of factors, the equilibrium conditions are:

1. $$p_i = c_i(w) \quad \text{for all } i,$$

2. $$\sum_i a_{li}(w) X_i^W = V_i^W \quad \text{for all } l,$$

3. $$\alpha_i(p) = \frac{p_i X_i^W}{\sum_i p_i(w) X_i^W} \quad \text{for all } i.$$

The conditions state that 1) goods are priced according to marginal cost as free entry of firms in any country and constant returns to scale dictate zero profits, 2) factor markets clear and 3) commodity markets clear.

The concept of an integrated equilibrium allows a convenient comparison of labour demand under trade and autarky. Consider the skill-abundant country with ($S/U > S^W/U^W$). In trade, the Heckscher-Ohlin-Vanek theorem states that it will export services of its abundant factor and import services of its scarce factor, thus the world price of the skill abundant good must exceed the price under autarky.

Implication for within-industry demand for skills

The Stolper Samuelson Theorem states that an increase in the price of the exported good will increase the return to the abundant factor (w_S) and decrease the return to the scarce factor (w_U).[5] So an opening up to trade will increase w_S/w_U for a skill abundant country.

As a result, within each industry in the skill- (unskill) abundant country, transition from autarky to trade will decrease (increase) the demand for skilled workers.

To see this, note that:

$$\frac{S_i}{U_i} = \frac{a_{Si}X_i}{a_{Ui}X_i} = \frac{a_{Si}}{a_{Ui}}$$

$$\Rightarrow \quad \frac{\partial(S_i/U_i)}{\partial(w_S/w_U)} \leq 0$$

by cost minimization and the quasi-concavity of the underlying production function.

This is just an expression of the fact that for a single industry only substitution effects are at work. Note that within-industry substitution away from skilled workers will be compensated by a between-industry shift in employment toward skill intensive industries, which increase production for export.

Sector-biased Technological Change

Consider the effect of a change in the technology of production so that a skill-intensive sector becomes more efficient in a single country. Leamer (1994) reproduces the result that only the sector-bias of a technological change affects relative wages. That argument is most clearly demonstrated by a Lerner diagram (Figure 1) which corresponds to the zero-profit conditions (equilibrium condition (1) above) for the two traded goods that allow factor price equalization. (Assumption 6 guarantees existence of two such goods.) In the diagram the curves C1 and C2 are unit cost combinations of inputs in production of goods 1 and 2 respectively. Assuming that these goods are traded, their prices are taken as parameters under the small country assumption. The wage ratio w_u/w_s consistent with cost minimization at zero profit is the absolute value of the slope of the line AB tangent to unit cost curves C1 and C2. Now consider a Hicks-neutral technological improvement in the production of good 1, the skill-intensive good, which shifts C1 to lower levels of inputs at C1'. This shift is Hicks-neutral since at the old wage ratio the ratio of inputs S/U is unchanged. In the diagram this is reflected by CD being parallel to AB. Because the technological improvement occurred in the skill-intensive sector, it implies an increase in output of good 1, and increased demand for skills. This is expressed as a decreased relative wage of unskilled labour or a shallower slope of the new line EF joining the points of tangency with C1' and C2, the new equilibrium.

Note that, at the new equilibrium, *the ratio of skilled to unskilled labour is lower in each sector*. This is due to substitution away from skilled labour in each sector in response to an increase in the relative wage of skills, as above.

Skill-biased Technological Change

A skill-biased technological change is an exogenous change in the production function that increases the unit demand ratio a_{Si} / a_{Ui} at the current wage level. A sector neutral, skill-biased technological change is illustrated in Figure 2 in the shift of unit cost curves C1 and C2 to C1' and C2'. This change is sector neutral in the sense that both C1 and C2 shift towards lower levels of inputs in a way which reduces costs by the same proportion. The line CD, tangent to C1' and C2' reflects the new zero profit condition, and is parallel to AB, reflecting the same relative wages. These shifts are skill-biased as the new equilibrium ratios skilled to unskilled workers are higher than the old. (Rays from the origin are steeper.) While this sector neutral technological change may seem artificial it provides a useful point of comparison in the discussion below. Note that unlike sector-biased technological change and Stolper-Samuelson effects, skill-biased technological change directly increases the proportion of skilled labour employed in each sector.

Leamer Critique: Skill- vs. Sector-bias

One feature of technological changes in this model with fixed goods prices is that only the sector bias of technological changes has any effect on relative wages (Leamer, 1994). To see this, imagine sliding the isovalue curve C1' along unit cost line so that the point of tangency moves to a different ratio of skilled to unskilled workers. Any of those locations represent the same level of costs for production of good 1, so that the sector-bias of each of those technological changes is the same. Though the skill-biases of those locations differ, they all share the same solution for relative wages. Thus, in the small open economy model, a skill-biased technological improvement has no effect on relative wages except through the implied sectoral-bias. This argument appears particularly damning for the widespread conclusion of the literature. Local skill-biased technological change, the champion explanation of increased wage inequality among most labour economists, cannot have any effect on wages in the two factor Heckscher-Ohlin model with small, open economies.

Now consider a *pervasive* skill-biased technological change occurring simultaneously in all economies in the production of some traded good. In the integrated world economy, the response to such a change would be like that of a closed economy. SBTC would cause a disproportionate expansion of production of the good intensive in unskilled labour (good 2) as each industry reduces its proportion of unskilled labour. Under homothetic preferences that would induce a decrease in the relative price of good 2 and in the relative wages of unskilled labour. That decrease in the relative price of the good intensive in unskilled labour is illustrated as a shift of the unit cost curve from C2' to C2" as more inputs are required to provide the same value of output. That shift implies a decrease in the relative wages of unskilled labour, reflected in the slope of line EF, which is shallower than that of CD. Thus pervasive, sector-neutral, skill-biased technological change is a possible explanation for the increased skill premium even in the small open economy model.[6] Note that unlike the two alternative explanations of the increased skill premium, Stolper-Samuelson effects and sector-biased technological change, it implies within-industry increases in the proportion of skilled workers.

How general is the result? Consider relaxing the small economy assumption in the integrated equilibrium. The more we allow local conditions to affect world prices, the greater the effect of a local SBTC in increasing the relative price of the skill-intensive good and the relative wages of skilled labour.[7] Analytically, pervasiveness and bigness work in the same direction, allowing SBTC to affect relative wages through their effect on world prices. By the same token, both pervasiveness and bigness reduce the importance of sector-bias, as productivity gains which produce the sectoral increase in input demand are offset by reduced goods prices. Of course, barriers to free trade will also tend to work in the same direction, making local prices and wages more responsive to a local technological change and increasing the ability of a SBTC to increase the local skill premium. In any case, the effect of a pervasive SBTC on relative wages in the small open economy H-O model is robust to making the economy larger or more closed.

3. TESTING THE IMPLICATIONS OF ALTERNATIVE EXPLANATIONS

Evidence from the United States and the United Kingdom

The US and the UK experienced the greatest increase in the skill premium among developed countries in the 1980s.[8] The manufacturing sectors of both countries, in which most trade occurs, experienced large reductions in employment and a trend increase in the share of non-production workers in employment, as shown in Figure 3. We treat non-production workers as skilled and production workers as unskilled, and justify that classification below.

Let Sn_i be the share of non-production workers in manufacturing employment in industry i ($Sn_i = S_i / (S_i + U_i)$). The analysis in Section 2 predicts that an increase in the relative wages of non-production workers implies a decrease in Sn_i if the cause is a Stolper-Samuelson effect or sector biased technological trade (biased toward the skilled sector), whereas an increase in Sn_i, accompanied by an increase in the relative wage, is evidence of pervasive skill-biased technological change. Consider the average change in Sn_i, weighted by employment,

$$\sum_i \Delta Sn_i \overline{S_i}$$

where S_i is the employment share of industry i. Table 1 reports that for American manufacturing the average annual increase in Sn_i (i.e., the within-industry increase) is 0.387 percentage points between 1979 and 1987. For the UK the comparable figure is 0.301 between 1979 and 1990. In both countries relative wages of non-production workers increased: in the US the non-production/production worker wage ratio rose from 1.53 in 1979 to 1.57 in 1987 and to 1.64 in 1990; in the UK the ratio rose from 1.31 in 1979 to 1.50 in 1990. Substitution of production for non-production workers, despite the increase in their relative wages, is evidence of skill-biased technological change in both countries.[9]

To put these magnitudes into context, consider how much of the aggregate increase in the proportion of non-production workers is due to substitution within industries. The change in aggregate proportion of non-production workers can be decomposed into two components, one due to reallocation of employment *between* industries with different proportions of skilled workers and another due to changes in the proportion of skilled workers *within* industries:

$$\Delta Sn = \sum_i \Delta S_i \overline{Sn_i} + \sum_i \Delta Sn_i \overline{S_i}$$

where an overstrike indicates a simple average over time. Table 1 reports that these within-industry components are not only positive, but quite large, accounting for 70 per cent of the aggregate increase in the US share of non-production workers and 82 per cent of the British. In the presence of increased relative wages for skilled labour, the only explanation we have from the model for that within-industry skill upgrading is skill-biased technological change.[10] [11]

A weakness in these measurements is that they require the strong assumption that within observed industries a homogeneous good is produced with identical production functions so that the response to a relative wage change within an industry is a pure substitution effect. Alternatively, each industry 'within' term could contain a number of dissaggregated 'between' (between goods and production processes) terms in it, allowing a composition effect that could reverse the substitution effect. For example, *increased* skill intensity for the exported high-skill product could occur if the industry is a combination of high- and low-skill subindustries, so that opening up to trade caused the high-skill subindustry to expand its share of production within the industry.[12] [13] The second and fourth columns of Table 1 address this concern by reproducing 'within-between' decompositions at the *plant* level carried out by Dunne, Haltiwanger and Troske (1996) and Machin (1996b), respectively. Here the potential for composition effects is limited by looking at changes in employment within plants. (A definitive decomposition of this type is impossible as changes in goods prices could increase demand for skilled labour through substitution across goods within plants while SBTC may also imply a sector-bias, reducing the prices of skill-intensive goods and increasing demand for skilled labour through shifts of production between goods across plants.) Within-plant substitution toward non-production labour accounts for 71 per cent of the aggregate substitution toward non-production workers in the American LRD[14] and for 83% in the British WIRS. Following the implication of H-O theory we interpret this substitution toward skilled labour within plants as evidence for SBTC, despite an increase in relative wages.

More concrete evidence that this within-industry (and within-plant) skill upgrading reflects technological change is available from three sources. Within-industry increases in the proportion of non-production workers are correlated with indicators of technological changes such as investments in computers, investment in R&D and significant innovations (Berndt, Morrison and Rosenblum, 1994; BBG; Autor, Katz and Krueger, 1997; Machin, 1996b; Machin, Ryan and Van Reenen, 1996; Siegel, 1995).[15] Case studies such as those conducted by the BLS Office of Productivity and Technology can give use some sense of the nature of the actual innovations involved (Mark, 1987). These often mention innovations that lowered, or are expected to lower, production labour requirements. Along similar lines, as part of the NBER -Sloan Plant Visit program, we saw evidence that microprocessor technologies played a key role in allowing production processes to be programmed, monitored and centrally controlled, replacing tasks formerly performed for the most part by production workers.

Examples from two plant visits can help illustrate skill-biased technological change. We visited a metal fabrication plant where metal was stretched and thinned to precise specifications by a large number of machines working in parallel. The old technology involved one operator per machine who monitored by eye, stopping and adjusting the process when necessary. The new system allowed three machines to be monitored and controlled by a single operator at a console, and run three times as fast, resulting in a ninefold increase in labour productivity. In a modernized steel mill we saw a steel rolling line controlled by tens of operators and technicians at consoles in a cavernous building that formerly housed thousands of production workers. The new line ran faster and produced more output than the old. In visits to several manufacturing plants in these and other industries we saw evidence that microprocessor technologies played a key role in allowing processes to be programmed, monitored and centrally controlled, replacing tasks formerly performed for the most part by production workers.

Outsourcing

A potential problem with the evidence cited above on within-industry substitution toward skilled labour is that firms may ‘outsource’ low-skill parts of the production process abroad, replacing in-house production with imported materials. Imagine a production process made up of high-skill and low-skill subprocesses. The H-O effect would be to increase imports of the low-skill and exports of the high-skill, increasing the ratio of skilled to unskilled labour in the aggregated production process. This apparent contradiction of Stolper-Samuelson is empty, since unskilled labour is replaced with imported materials.

While it is hard to measure such outsourcing, let alone its impact on US employment, we have done some simple calculations which suggest that outsourcing cannot be responsible for the bulk of the changes we observe. The 1987 Census of Manufacturing included a direct question regarding the purchase by establishments of foreign materials. These data show that in 1987 the total cost of material purchased by establishments from foreign sources was 104 billion dollars, or 8 per cent of all materials purchased and 30 per cent of all imported manufactured goods. Foreign materials purchased include substitutes for domestically produced materials, as well as substitutes for products that would have been produced within the purchasing establishment’s own industry. While we know of no reliable way to distinguish uses for the material purchased from foreign sources, we note that census data show that only a small fraction (<10 per cent) of purchased materials come from an establishment’s own industry.[16] This fact suggests that only a small fraction of foreign materials purchased represent outsourcing (as they do not replace domestic production in the same industry).

In our calculation we assume that imported materials displace production but not non-production labour. In particular, we assume that imported materials embody the same amount of production labour as do domestically produced goods in the same industry, but no non-production labour. Thus, for each industry, we calculate that the number of production workers displaced by outsourcing as of 1987 as (imported materials/total shipments) × production employment. These calculations suggest that the employment of production workers would have been 2.8 per cent higher in 1987 had there been no outsourcing. This translates into a 0.76 percentage point increase in production workers' share in total employment. Within-industry, production workers' share had dropped 4.22 percentage points between 1973 and 1987. Thus, this calculation would suggest that outsourcing could directly account for 16 per cent of the decline in the production worker share of employment that occurred over this time period.

While we expect that only a fraction of the materials that an establishment purchases from foreign sources will represent outsourcing, the Census category misses one dimension of outsourcing. The census instructions state that "items partially fabricated abroad which reenter the country" should not be included as "foreign materials". Such items would normally enter the country under items 806 and 807, schedule 8 of the Tariff Schedule of the United States. In 1987 the value of such items totaled a not insignificant 68.6 billion dollars. However, the automobile industry that accounted for only 3 per cent of total skill upgrading accounted for roughly two-thirds of such imports. Eliminating both the auto industry and domestic content of such items reduces the 68.6 billion to 14.0 billion or roughly 0.5 per cent of the value of manufacturing shipments that year **S** too small a quantity to matter very much (US International Trade Commission, 1988).

Outsourcing may be important in some industries. For example, as of 1987, 806 and 807 imports represented 57 per cent of imports in the auto industry and 44 per cent of imports of semiconductors. A calculation similar to the one above suggests that these imports are sufficient to account for more than 100 per cent of the shift away from production workers that occurred in the auto industry and one-third of the shift that occurred in semiconductors.[17] However, the point is that foreign outsourcing is concentrated enough in specific industries that it is hard to imagine it can account for anything more than a small fraction of the total within-industry shift away from production labour.

Our estimates are crude, but they err on the side of overestimating the effects of outsourcing on demand for production workers: not all foreign materials represent outsourcing. For those that do, some non-production labour is certainly embodied in the domestic production replaced by outsourcing. Still, these calculations suggest that while outsourcing might be important for some industries, it cannot account for the bulk of the skill upgrading that occurred within manufacturing over the last two decades.[18]

A Correspondence between Measures of Skill

All of the work we discuss in this paper is based on manufacturing data in which the only available measure of skill is the proportion of non-production workers in employment. This measure is viewed with skepticism by Leamer (1994), who points out that skilled jobs such as line-supervisor, product development and record keeping are classified as production worker jobs, while jobs such as sales delivery, clerical, cafeteria and construction are classified as non-production. BBG defend the production/non-production classification, showing that the proportion of non-production workers follows the same trend increase as the proportion of skilled workers in U.S. manufacturing.[19]

A powerful new data set offers a way of examining how the production/non-production classification compares to educational and occupational measures of skill. The Worker Establishment Characteristics Database (Troske, 1994), matches individuals from the Census of Population in 1990 to plants in the Census of Manufactures in 1989. Combining the educational and occupational information we find a close correspondence between the different classifications of skill: 75 per cent of non-production workers are in white collar occupations, while 81 per cent of production workers are in blue collar occupations. Details are given in the Appendix and in Table A1.

While there seems to be lots of scope for the non-production/production categories not to correspond with other measures of skill, these are the exceptions rather than the rule. For the educational and occupational categories in the Appendix Table A1, they correspond quite well. This one cross section does not conclusively demonstrate a correspondence between *changes* in the proportion of non-production workers and changes in other measures of skills, but we find it convincing enough to adopt the non-production/production classification as our measure of skill.

Evidence from Manufacturing Sectors of the Developed World

If the dominant cause of increased relative wages of skilled workers in the US and UK is *pervasive* SBTC, then it must be occurring in other developed countries. The United Nations General Industrial Statistics Database (United Nations, 1992) contains manufacturing employment data for a large number of countries categorized into 28 consistently defined industries. We are interested in the most productive economies under the assumption that they are most likely to use the same production technologies as the United States. From the set of countries without data problems we define our developed sample as the top twelve countries, ranked by GNP/capita in 1985. They range from the United States ($16,910) to Belgium ($8290). Appendix Table A2 gives the rankings. The table also reports employment shares of non-production workers in manufacturing in the 1970s and 1980s. The non-production employment share has generally increased in both the 1970s and 1980s in our developed sample. In eight of the twelve countries total manufacturing employment fell through the 1980s.

Among the developed countries we study, the employment share of skilled labour increased in all twelve in the 1970s and 1980s. Relative wages of skilled labour either increased or remained constant in most.[20] A common description of European labour markets in the 1980s is that they share the same phenomenon of decreased demand for less-skilled workers but differ in how it is expressed. In the US and UK where wages are flexible, the relative wages of the less-skilled declined sharply, while in other countries collective bargaining and minimum wages moderated the decline in relative wages but caused high levels of unemployment.[21]

Table 2 reports the increased proportion of non-production workers in manufacturing employment and the percentage of that increase due to within-industry components in the 1970s and 1980s. Across countries with very diverse labour market institutions, two common features stand out:

1) an increased proportion of non-production labour in manufacturing
2) substitution toward non-production workers within industries in the 1980s, despite increased or flat relative wages of non-production workers.

Not only was within-industry substitution positive, it was quite large, accounting for most of the increase in the aggregate in all countries (except Belgium where it accounts for 49 per cent). Large within-industry skill upgrading, despite rising or constant relative wages, is evidence of skill-biased technological change in each of these countries. Taken together, they provide evidence for pervasive skill-biased technological change in the developed world.

A limitation of this data is this 28 industry classification which is much more aggregated than those reported in Table 1, allowing more room for composition effects to masquerade as within-plant effects. But note that the 28 industry ‘within’ figure for the US in Table 2 is only 3 per cent higher (as a proportion of the aggregate change) than the comparable 450 industry figure in Table 1, so a 28 industry decomposition may provide a good approximation of the substitution and composition effects at the finer levels of disaggregation that we report in Table 1.

In many of these countries within-industry skill upgrading increased more in the 1970s than in the 1980s. However, this should probably not be interpreted as evidence of an overall slow-down in the rate of SBTC. In most of these OECD countries the relative wages of non-production workers decreased during the 1970s, but increased or remained stable during the 1980s.[22] These changes in relative wages would tend to induce within-industry skill upgrading during the 1970s and downgrading during the 1980s through substitution effects. Without netting out these substitution effects (something that would be hard to do), it is impossible to tell whether the rate of SBTC accelerated, remained constant or decelerated during the 1980s. (Bound and Johnson, 1992; Katz and Murphy, 1992). Similarly, we are reluctant to interpret differences across countries in terms of the rate of within-industry skill upgrading as evidence of cross country patterns in the rate of technological change. Rather, these patterns could plausibly reflect cross country differences in other factors that effect wage setting. Some of the cross-country variation in changes in the relative wages of non-production workers seems to be due to cross-country variation in the supply of college educated workers. The overall pattern is consistent with a trend increase in both supply and demand of skills, with either accelerated demand or decelerated supply in the 1980s increasing the skill premium, while local changes in supply affects relative wages as well.

In summary, in the ten developed countries for which we have manufacturing data in the 1970S90 period, we find widespread within-industry substitution towards skilled labour despite either constant or increased relative wages in the 1980s. Applying the predictions of the analysis in the last section, this pattern indicates *skill-biased technological change in all of these countries*.

4. CROSS-COUNTRY CORRELATIONS: A FURTHER TEST OF PERVASIVE SKILL-BIASED TECHNOLOGICAL CHANGE

In this section we test implications of the *pervasiveness* of skill-biased technological change. In section 2 we argued that the more pervasive the SBTC, the greater its potential to affect relative wages. Casual empiricism suggest that microprocessors, the most likely source of this technological change, have indeed become ubiquitous throughout the OECD. The empirical literature has tied indicators of technological change with substitution towards skilled workers such as investment in R&D, significant innovations, increased investment in computers and in other 'high tech' capital.[23] In the previous section we showed evidence for SBTC in our sample of OECD countries. Still, if SBTC is pervasive, there is another testable implication that we can check. We should find the same industries increasing their proportion of skilled workers in different countries.

Cross-country Correlations

Pervasive skill-biased technological change implies that within-industry changes in the use of skills be positively correlated across countries producing that good. So we test for pervasive SBTC by examining cross-country correlations of changes in the use of skills (? Sn).

Table 3 presents a correlation matrix of corr(? Sn_{ci} S_{ci}, ? $Sn_{c'i}$ $S_{c'i}$), the cross-country within-industry changes in the share of non-production workers for nine developed countries.[24] Stars denote a significant correlation at the 5 per cent level. Note that the correlations are nearly all positive (34 of 36) and some are quite high. Indeed, 13 of the 36 are significant at the 5 per cent level. The shift toward increased use of non-production workers has for the most part occurred within the same industries in different countries.[25]

The cross-country correlations suggest that technological change in several of the countries is quite similar. The strongest positive correlation is between the UK and the US, but a group of countries (especially Denmark, Finland, Sweden, the UK and the US) have very similar within-industry changes in the proportion of non-production employment. Consider the US on the one hand, and Sweden, Denmark and Finland on the other. These are economies with very different labour market institutions and very different trade and macroeconomic experiences in the 1980s. The similarity in the pattern of decreased use of production workers despite their different experiences is compelling evidence for common technological changes as an underlying cause of decreased demand for unskilled labour.

Industries with Large Skill-biased Technological Change

The industries that drive the correlations in Table 3 indicate what the nature of these technological changes may be. Figure 4 displays the scatterplot of US within-industry terms against those of the UK. The US-UK correlation is mainly due to the large common increases in the share of non-production employment in four industries: Machinery (& computers), Electrical Machinery, Printing and Publishing and Transportation.

A more systematic way of looking for industries with large effects is to estimate industry effects in a country-industry panel. In a regression of 'within' industry terms on country and industry indicators,

$$wit_{ci} = \Delta S n_{ci} \overline{S}_{ci} = \sum_{i=1}^{I} \alpha_i + \sum_{c=1}^{C} \beta_c + e_{ci}$$

the α_i are the average industry terms once country means have been removed. A well estimated industry effect will reflect a within term common to many countries, while a large industry effect is evidence of increased use of skills in at least one country-industry.

Table 4 reports the three largest of the statistically significant estimated industry effects. Three industries: Electrical Machinery, Machinery (& computers) and Printing & Publishing, together account for 40 per cent of the average within-component across countries. A full set of estimated industry effects is reported in Table A3. Case studies indicate that these industries introduced significant skill-biased technologies during this period, especially in the automation of control and monitoring of production lines.[26] For example, a principal source of SBTC in the printing and publishing industry was automated rather than manual sorting and folding of newspapers.

5. GLOBAL SKILL-BIASED TECHNOLOGICAL CHANGE?

What about the developing world? According to the H-O approach, in a country that is abundant in unskilled labour the opening-up to trade that occurred in the 1980s should have a negative Stolper-Samuelson effect on the relative wages of skilled workers. Thus H-O and SBTC hypotheses have opposite predictions for relative wages in LDCs. The literature reports that relative wages of skilled labour have *risen* in some, though not all, LDCs undergoing trade liberalizations in the 1980s (e.g., Feliciano, 1995; Hanson and Harrison, 1995; Robbins, 1996; Feenstra and Hanson, 1996a). Figure A1 reproduces that result using the UN data, showing that a number of developing countries experienced an increase in the relative wages of non-production workers in manufacturing between 1980 and 1990.

Stable and rising relative wages are particularly interesting, considering that almost all of these countries experienced considerable increases in the proportion of skilled labour in manufacturing over the 1980s, as illustrated in Figure A2.[27] For the developing world, that increase in the proportion of skilled labour was generally accompanied by rapid growth in manufacturing employment (see Table A2 and Wood, 1994). While H-O logic implies that increased trade should reduce relative demand for skilled workers in LDCs, their manufacturing sectors are expanding rapidly and upgrading skills at the same time. Besides the effects of trade, some other effect must have more than compensated to keep wages of non-production workers stable especially as their proportion increased quickly in the 1980s. Skill-biased technological change is one possible explanation. Other causes could be increased investment and technology transfer, combined with capital-skill complementarity, or decreased protection of industries intensive in unskilled workers. Nevertheless, these findings raise the intriguing possibility that SBTC is at work in the developing world as well as the developed.

6. CONCLUDING REMARKS

In this paper we have presented evidence that the kind of skill-biased technological change which occurred in the US has been pervasive across the OECD. Our data show that : a) substitution towards skilled labour within industries occurred in all ten developed countries that we studied in the 1970S90 period, despite constant or increasing relative wages of skilled labour, and b) the same manufacturing industries that substituted towards skilled labour in the US did so in other developed countries as well. The industries with common, large within-industry contributions to skill upgrading are machinery (& computers), electrical machinery and printing & publishing. Together, these three account for 40 per cent of the within-industry increase in the relative demand for skills. Case studies reveal that all three of these industries underwent significant technological changes associated largely with the assimilation of microprocessors.

Based on this evidence alone, it would be hard to distinguish the effects of SBTC from those of capital-skill complementarity. Previous work (BBG) has found that capital accumulation in US manufacturing was not large enough to generate the observed increase in relative wages using cross-sectional estimates of the elasticity of substitution. Similarly, it would be hard to distinguish the effects of SBTC from those of a general increase in the quality of skilled labour, due to improved sorting or improved human capital production. We feel that pervasive improvements in the quality of skilled labour are unlikely unless they are caused by some pervasive technological effect.

The debate in the literature over the effects of SBTC on relative wages has often turned on the relevance of the small, open economy assumptions (Freeman (1995), Leamer (1996)). Pervasiveness allows SBTC to reduce the relative wages of the unskilled even in a model that assumes small, open economies because its occurrence in a large number of countries allows analysis of the integrated equilibrium as if the OECD were a closed economy. In the context of that model, to calculate the size of the effect of different factors, we must gauge their relative effects on world goods prices. The relative price of skill-intensive to low-skill-intensive goods is in turn set by the factor content embodied in increased supplies of goods to the OECD. Using the American experience as a guide we see that the factor content of SBTC in manufacturing alone implies a decrease in the proportion of less skilled (production) workers about eight times that attributable to increased trade. Referring back to Table 1, in the 1979S87 period, during which demand for less-skilled workers dropped sharply in the US, the factor content of SBTC accounts for at least 70 per cent of the displacement of unskilled workers (i.e. the increase in the proportion of skilled workers) in U.S. manufacturing. The factor content of trade accounts for about 9 per cent (BBG, Table IV) in the US.[28] For the OECD as a whole, 70 per cent would be a typical figure for SBTC, but 9 per cent would be generous for the effects of trade as the US experienced a much greater increase in trade with the developing world than OECD as a whole. Assuming that demand elasticities are approximately the same for imports and domestic production, that calculation implies that the effects of SBTC on relative wages are an order of magnitude larger than those of increased trade with the developing world.

Even if pervasive SBTC is a principal explanation, there is no reason to believe that it is the sole explanation for increased relative demand for skills. Stolper-Samuelson effects and institutional changes, such as decreased unionization and decreased minimum wages, all occurred during this period and undoubtedly contributed to increased relative demand for skills, though the evidence weighs against any of these causes as a principal explanation. Deviations of the supply of skill from a long run trend increase also play a role in determining relative wages. European OECD countries do show considerable variation in the rate of growth of skill supply which appears to be negatively correlated with changes in their skill premia in the 1980s, suggesting that the H-O short run can last for long enough for supply effects to be observed. In an integrated equilibrium long-term fluctuations in supply of skilled labour in the entire OECD will affect relative wages. This is an interesting topic for future research.

Though the evidence we present is only from manufacturing, where measurement is easiest, the effects of SBTC on wages may be just as important in the service sectors. In retail and financial services, for example, microprocessor based information processing technologies have dramatically changed accounting and secretarial work (Levy and Murnane, 1996). At a more aggregate level, Bound and Johnson (1992), Murphy and Welch (1992) and Katz and Murphy (1992) all present evidence of within-industry skill upgrading in other sectors, despite increased relative wages of skilled workers. This within-industry skill upgrading outside of manufacturing also occurred in the same industries in the US and the UK. The correlation of within-industry terms between the US and UK across the 15 industries outside of manufacturing is 0.93.[29] That high correlation is largely due to very rapid skill upgrading in financial services in the two countries. Skill-biased technological change outside of manufacturing may have also been pervasive and is an additional likely cause of decreased demand for less skilled workers.

Pervasive skill-biased technological change suggests several avenues for interesting research. The source of SBTC, its rate of flow across borders, the identification of the technologies involved and especially the likely implications for labour demand in the receiving country are all interesting and relevant. This is especially true for developing countries in which technological changes could exacerbate current high levels of income inequality.

APPENDIX
A CORRESPONDENCE BETWEEN MEASURES OF SKILL

The Worker Establishment Characteristics Database, constructed at the Center for Economic Studies (Troske, 1994), matches individuals from the Census of Population in 1990 to plants in the Census of Manufactures in 1989. For 2490 large manufacturing plants we have information from the Census of Population about the demographics of a sample of employees. Using the educational and occupational information we construct estimates of the number of employees in each education or occupation category in a plant. A regression of these estimates on the number of production and non-production workers in a plant allows estimation of the distribution of non-production (production) workers across educational and occupational categories.

Let the probability that a worker is in educational category j conditional on being a non-production (production) worker be $ß_{jn}$ ($ß_{jp}$). The expected number of type j workers in a plant is $E_j = ß_{jn}E_n + ß_{jp}E_p$, where E_n and E_p are the number of production and non-production workers, respectively. We have X_j, a noisy measure of E_j (the true 1989 employment figure). A regression of X_j on E_n and E_p estimates $ß_{jn}$ and $ß_{jp}$.

Table A1 reports estimates for education and occupation groups.[30] The restriction that the sum over categories j of $ß_{jn}$ ($ß_{jp}$) is one has been imposed. Looking at the educational distribution, the median non-production worker has some college, with 66 per cent having some college or more education. The median production worker has a high school education, with 61 per cent having high school or less. Occupational categories show an even closer correspondence to the production/non-production classification. 75 per cent of non-production workers are in white collar occupations (48 per cent are managers and professionals, 25 per cent are technicians, in sales or in administrative support and 2 per cent are in services). 81 per cent of production workers are in blue collar occupations.[31]

A possible explanation for this close correspondence is that Census of Manufactures respondents ignore the definitions and classify hourly workers as production and salaried workers as non-production, which corresponds more tightly with the other measures of skill than do the definitions. If that is the case, the correspondence may hold between *changes* in the proportion of non-production workers and changes in other measures of skills as well.[32]

ENDNOTES

1. Calculated for high school graduates with 5 years of labour market experience in Current Population Survey from Bound and Johnson (1995), table 1.

2. Source: OECD (1992, 1993). For specific countries, the 1979–92 increases in unemployment were: 5.0 per cent to 10.1 per cent (U.K.); 3.2 per cent to 7.7 per cent (Germany); 7.6 per cent to 10.7 per cent (Italy); 5.9 per cent to 10.2 per cent (France). All are considerably larger than the American increase from 5.8 per cent in 1979 to 7.4 per cent in 1992.

3. The H-O model has been criticized, as its property of perfectly elastic labour demand curves is inconsistent with evidence that labour supply affects wages (Freeman (1995)). One way to reconcile those two views is to recognize that the H-O model applies only in the long run, so that the short and long run effects of a local SBTC or of an increase in trade may differ. Since the trend increase in relative demand for skilled labour seems to have persisted for decades, long run models deserve consideration.

4. US Department of Labor, 1982a, 1982b, 1986.

5. To see this fully in the N=2 case differentiate (1) to get $dw = A^{-1} dp$ since $dAw=0$ by cost minimization. The result follows from A being positive semi-definite. For $N>2$, a positive definite 2x2 matrix exists by assumption 6, and its inverse is used.

6. Homothetic preferences are sufficient but not necessary for the increased skill premium. Krugman (1995) points out that a limit on the cross-elasticity of demand will do.

7. For a clear graphical presentation of this argument see Baldwin (1994). The integrated equilibrium behaves like the closed economy analyzed in Jones (1965).

8. The US college/HS ratio for males increased by 14% in 1979**S**89. The UK non-manual/manual wage ratio increased by 15% for men and 23% for women in 1979**S**91 (see Katz, Loveman and Blanchflower, 1995).

9. Lawrence and Slaughter (1993) present the same argument for the U.S. These results are from Berman, Bound and Griliches (1993,1994) and Machin (1996b), who make similar arguments.

10. Capital skill complementarity is a possible explanation in a more general model of production. In previous work BBG found that it accounts for very little skill upgrading in US manufacturing.

11. Clearly SBTC could account for between industry skill upgrading as well.

12. Wood (1991) and Bernard and Jensen (1993) raise this point and the symmetric argument for importing industries.

13. A similar objection is that within industries (or plants) the product mix may respond to changes in international prices with more skill-intensive goods substituted for less skill-intensive, creating apparent within-industry skill upgrading. BBG (1994) find only very small correlations between within-industry upgrading and increased imports, indicating very little skill upgrading due to shifts in final product mix.

14. Bernard and Jensen (forthcoming) perform a similar decomposition on a balanced panel of plants in the LRD rather than the Census sample and find a smaller within plant proportion of 54% for the 1979**S**87 period. Dunne et al (1996) attribute the difference in results to the use of sampling weights to impute values for unobserved plants in the LRD and to the choice of period.

15. In contrast, Doms, Dunne and Troske (1997) find that skill upgrading is not positively correlated with a measure of adoption

of specific technologies.

16. Data drawn from the materials files of the 1987 Census of manufacturing shows that 2 per cent of materials purchased originate in the same four-digit industry as purchased the material. 7 per cent originate in the same three-digit industry.

17. Figures on the overseas production of semiconductors (U.S. International Trade Commission, 1982) are consistent with these calculations.

18. Feenstra and Hanson (1996b) use a somewhat different method to estimate the magnitude of foreign 'outsourcing'. Using census of manufactures data, they multiply materials purchased by the proportion of imports in their source industry. Their estimate is that 11.5% of materials could represent outsourcing, rather than the 8% reported by BBG. Feenstra and Hanson emphasize that contract work could explain the difference between these estimates, since it is included in imports, but not in imported materials. Nevertheless, both figures are likely to be substantial overestimates, as most imported materials probably do not replace in house production. Using regression techniques, Feenstra and Hanson estimate that outsourcing can account for as much as 51 per cent of the within-industry shift away from production labour. However, given the calculation reported in the text, this estimate seems improbably large. What is more, in unpublished work Baru (1995) uses regression techniques and measures similar to those used by Feenestra and Hanson, but when calculating her measure of outsourcing, Baru uses only purchases within the same three digit industry. She finds no association between her more narrowly defined measure and skill upgrading.

19. Sachs and Shatz (1994) also discuss the suitability of a production/non-production classification as a measure of skill in their appendix.

20. The US, UK, Austria and Denmark experienced large increases in the skill premium. Australia, Japan and Sweden had modest increases. Germany and Italy had no change. Finland had a modest decrease and Belgium had a large decrease. We lack information about Norway and Luxembourg. (Freeman and Katz (1994) supplemented by calculations for manufacturing from UN data for countries not covered in the former.)

21. Freeman and Katz (1995) and Krugman (1995) offer this interpretation of inequality in OECD labour markets.

22. These effects, in turn, are likely to be a symptom of decelerating skill supply. While all these countries show a trend increase in the proportion of college educated in the labour force in the 1970s, that proportion decelerated almost uniformly in the 1980s (OECD, 1995; Barro and Lee, 1997). In the short run or in an integrated equilibrium, supply can affect relative wages even if the small open economy assumptions of section 2 apply in a longer run.

23. Berndt, Morrison and Rosenblum (1994), BBG, Machin (1996b).

24. Luxembourg has been dropped as it has only six observed industries in this period. Norway and Germany was dropped for lack of employment share figures in 1980**S**90.

25. Other authors have found similarities between manufacturing sectors in differenct countries. Both Katz and Summers (1989) and Krueger and Summers (1987) have found that the wages of workers in the same manufacturing industry have high positive correlations across countries.

26. US Department of Labor, (1982a, 1982b).

27. Widespread skill upgrading in the developing world is also reported in a literature survey by Davidson (1995).

28. For a justification of the use of factor content calculations in approximating the effects of trade flows on relative wages, see Krugman (1995) or Deardorff and Staiger (1988).

29. The measure of skill is post-secondary education in this calculation. Authors' calculation from the US Current Population Survey and the UK Labour Force Survey, 1981S91.

30. We thank Ken Troske for performing this analysis.

31. The intercept terms in this regression should be zero. Their significant difference from zero may be due to a correlation between the proportions (ß's) and plant size. Note that the intercept is an out-of-sample prediction for large plants so light effects of size on ß's may cause large shifts in the intercept.

32. Unfortunately, we could not check the plant level correspondence of measures of skill in other countries. A similar exercise at the 2 digit industry level using manufacturing and labour force surveys indicates that the correlation of non-production/production categories with educational categories is similar in the UK to that in the US (Machin, Ryan and Van Reenen, 1996).

TABLE 1
CHANGES IN EMPLOYMENT STRUCTURE IN THE UK AND THE US IN THE 1980s

	United States	United Kingdom		
Time Period	1979S87	1977S87	1979S90	1984S90
Number of Industries/ Plants	450	360,000	100	402
Level of aggregation	4-digit SIC	plants	3-digit SIC	plants
Data Source	Annual Survey of Manufactures	Census of Manufactures	Census of Production	Workplace Industrial Relations Survey
Annual Change in Non-production Employment Share (in percentage points)	0.552	0.483	0.367	0.41
Within-industry/plant component (per cent)	.387 (70)	.341[1] (71)	.301 (82)	0.34 (83)
Between-industry/plant component (per cent)	.165 (30)	.077 (16)	.066 (18)	0.07 (17)
Annual Change in Non-production Wage Bill Share	0.774	-	0.668	-
Within-industry/plant component (per cent)	.468 (60)	-	.554 (83)	-
Between-industry/plant component (per cent)	.306 (40)	-	.114 (17)	-

Note: 1. The Dunne *et al* (1996) decomposition also includes a small negative cross-product term and a positive net entry term for the effect of entering and exiting plants.

Sources: UK S Machin (1996b), Tables 7.2, 7.3; US industries S Berman, Bound and Griliches (1994), Table IV, US plants S Dunne, Haltiwanger and Troske (1996) Table 1.

TABLE 2
PROPORTION OF INCREASED USE OF SKILLS "WITHIN" INDUSTRIES

Country	Change in % non-production 1970S80 (annualized)	% within 1970S80	Change in % non-production 1980S90 (annualized)	% within 1980S90	Note
US	0.20	81	0.30	73	
Norway	0.34	82	.	.	1970,80,n/a
Luxembourg	0.46	112	0.30	143	
Sweden	0.26	70	0.12	59	
Australia	0.40	87	0.36	99	1970,80,87
Japan	.	.	0.06	121	n/a*,81,90
Denmark	0.36	83	0.41	87	1970,80,89
Finland	0.42	83	0.64	79	
W. Germany	0.48	89	.	.	1970,79,n/a
Austria	0.46	89	0.19	73	
UK	0.41	91	0.29	94	
Belgium	0.46	59	0.32	49	1970,80,85

Notes: The proportion within is the sum over 28 industries of $(dn_{it} * S_i)/dPn_t$ in period t where S_i is $[(Emp_{it}/Emp_t)+(Emp_{it-1}/Emp_{t-1})]/2$, the share of manufacturing employment in industry i, averaged over time.

* The sampling frame changed for Japanese data between 1970 and 1981.

Source: United Nations General Industrial Statistics Database.

TABLE 3
CROSS-COUNTRY CORRELATIONS OF WITHIN-INDUSTRY CHANGES IN PROPORTION NON-PRODUCTION: 1980-90

	US	Sweden	Australia	Japan	Denmark	Finland	Austria	UK
Sweden	.43*							
	(.02)							
Australia	.28	.19						
	(.14)	(.34)						
Japan	.32	.02	-.22					
	(.11)	(.94)	(.26)					
Denmark	.73*	.36	.37	.33				
	(.00)	(.06)	(.05)	(.09)				
Finland	.59*	.39*	.51*	.14	.80*			
	(.00)	(.04)	(.01)	(.47)	(.00)			
Austria	.22	-.17	.52*	.12	.51*	.46*		
	(.26)	(.37)	(.01)	(.54)	(.00)	(.01)		
UK	.76*	.18	.51*	.19	.76*	.64*	.61	
	(.00)	(.36)	(.01)	(.32)	(.00)	(.00)	(.00)	
Belgium	.18	.00	.01	.22	.11	.09	.37	.15
	(.44)	(.99)	(.97)	(.37)	(.63)	(.71)	(.10)	(.53)

Notes:

1. These are cross-country correlation coefficients of within-industry changes in non-production employment shares,

$$wit_{ci} \;'\; ?Pn_{ci}\overline{S}_{ci}$$

where i is an industry index and c is a country index.

2. The number in brackets is the significance level of a test that the correlation is zero. Standard errors in parentheses. A * denotes a significant correlation at the 5 per cent level.
3. The sample was restricted to countries with GNP/capita of over $8000 US in 1985 (the top 12 in Table A2) and over twenty consistently defined industries observed in 1980-1990.
4. The 28 industries in this classification are listed fully in Appendix table A3.
5. All correlation coefficients are calculated using a full set of 28 industries, except those involving Japan (27 observations), Belgium (20 observations) and Japan & Belgium (19 observations).

Source: United Nations General Industrial Statistics Database.

TABLE 4
SELECTED INDUSTRY EFFECTS IN WITHIN-INDUSTRY TERMS: 1980-90

In a regression of ‘within’ industry terms on country and industry indicators,

$$wit_{ci} = \Delta Pn_{ci}\overline{S}_{ci} = \sum_{i=1}^{I} \alpha_i + \sum_{c=1}^{C} \beta_c + e_{ci}$$

the following industry effects are statistically significant and represent more than 10% of the within component of the increase in the proportion of Non-production workers in employment. A full set of industry effects are reported in Table A3.

Industry	Industry Effect /Within Component	Avg share of industry in employment
Printing & publishing	.100 (.041)	.061
Machinery (incl. computers)	.146 (.045)	.117
Electrical Machinery	.156 (.037)	.096
Sum (3 industries)	.402	.273
Number of observations	249	
Root MSE	.116284	

Notes: 1. Data are scaled so that the estimated coefficient represents the ratio of the industry effect to the cross country average "within" component.
2. The root mean squared error of the left-hand side variable is .126295.
3. Standard errors are calculated using the White heteroskedasticity robust formula.

Source: United Nations General Industrial Statistics Database.

TABLE A1
WHAT IS A NON-PRODUCTION WORKER IN US MANUFACTURING?

Education group (highest level achieved)	constant	non-production	production	R-square
<HS	9.82	.01	.03	.28
	(1.05)	(0.01)	(.001)	
HS	35.52	.23	.58	.91
	(5.33)	(.004)	(.005)	
Some College	-20.96	.30	.30	.93
	(2.71)	(.003)	(.004)	
College-	15.06	.31	.07	.81
4 year dg.	(3.58)	(.004)	(.005)	
>College	-9.31	.15	.01	.68
(>4 yr dg.)	(2.13)	(.002)	(.003)	

Note: Calculated from the Worker-Establishment Characteristics Database for 2490 large plants. The left-hand side variable in each row is the estimated number of workers of that type in the firm. The right-hand side variables are the number of production and Non-production workers. Coefficients are interpreted as the proportion of Non-production (production) workers of each type. Each column of coefficients is restricted to sum to one. We thank Ken Troske for performing this calculation.

TABLE A1 (Continued)
WHAT IS A NON-PRODUCTION WORKER IN US MANUFACTURING?

Occupation groups: (occ codes)	constant	non-production	production
Mgr & Prof	-20.72	.48	.08
(<=199)	(5.27)	(.005)	(.006)
Tech, Sales & Admin. Support	18.74	.25	.08
(203-389)	(2.17)	(.002)	(.003)
Service	-0.76	.02	.03
(403-469)	(0.54)	(.001)	(.001)
Farm-Forest & Fish	0.15	.001	.000
(473-499)	(.06)	(.0001)	(.0001)
Precision Prod	-21.64	.11	.33
(503-699)	(2.86)	(.003)	(.004)
Operators & Fabricators	11.42	.10	.38
(703-791)	(3.99)	(.003)	(.005)
Labourers	12.82	.03	.10
	(1.95)	(.002)	(.003)

Note: Calculated from the Worker-Establishment Characteristics Database for 2490 large firms. The left-hand side variable in each row is the estimated number of workers of that type in the firm. The right-hand side variables are the number of production and Non-production workers. Coefficients are interpreted as the proportion of Non-production (production) workers of each type. Each column of coefficients is restricted to sum to one. We thank Ken Troske for performing this calculation.