Faculdade de Economia da Universidade de Coimbra
Grupo de Estudos Monetários e Financeiros (GEMF)
Av. Dias da Silva, 165 – 3004-512 COIMBRA, PORTUGAL
http://www4.fe.uc.pt/gemf/ - gemf@sonata.fe.uc.pt

JOHN T. ADDISON
PAULINO TEIXEIRA

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John T. Addison* and Paulino Teixeira**

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ABSTRACT

This paper examines the contribution of technological change to changes in the structure of relative employment and wages. Even if the nature of demand-side forces is fairly clear – international trade being of secondary importance because of the modest size of the between-industry employment shifts – the identification of the fundamental causes of skill-biased technological change, the techniques involved, and the manner of their adoption by firms is not transparent. Accordingly the skill-biased technological change diagnosis offers no real blueprint for policy other than the need for an increasingly better-educated labor force. The problems arise when one turns to the here-and-now, that is, the position of the currently skill-disadvantaged. Unfortunately, general solutions, although favored by politicians, are not available. Rather, there seems to be scope for carefully targeted programs that offer successive incremental improvements in the labor market prospects of truly disadvantaged workers whose education, skills and training are a significant impediment to their employment.

*Professor of Economics, University of South Carolina (U.S.A.) and Libera Università di Bolzano (Italy).

**Associate Professor of Economics, Faculdade de Economia, Universidade de Coimbra (Portugal).

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I. Introduction

This paper investigates the role of technology as a factor behind rising unskilled worker unemployment and falling relative (even real) wages. While much of the discussion concerns the U.S. experience, we have necessarily to range much further afield. Policy choices with respect to the skill-biased technological change argument do not in principle differ from those associated with the chief competing explanation for the deteriorating position of the low skilled, namely, heightened international trade. In both cases, the principal emphasis is on ways of upgrading skills, since no-one should favor trade protection or taxes on computers. Given the secular rise of unemployment in Europe, that region's situation is likely to admit of a wider variety of culprits and a different mix of solutions (e.g. greater wage flexibility). Nevertheless, technological change would seem to cast an important shadow even in Europe.

In focusing on the difficulties of unskilled workers, we will note estimates of the scale of the skills upgrading that may be necessary in the United States. At issue here is the ability of the market to redirect labor from lower to higher valued alternatives – the Mincerian correction. If the market response is insufficient there is the question of retraining versus income maintenance, or retraining versus subsidized employment. The long-run solution undoubtedly resides in the formal education system. But in the short run there is the question of how to deal with those with current skill deficits. It has to be admitted that in the United States, as elsewhere, these public retraining efforts have not been conspicuously successful. That said, the increasing number of quasi-experimental studies being conducted in the United States hold out the prospect of informing policy by providing important insights into what works at the demonstration level at least. In the interim, we do know that there is little scope for the massive manpower programs of yesteryear. Apparently, we are going to have to learn to be incrementalists.

The plan of the paper is as follows. First, we outline the biased technological change argument and comment upon its applications in the United States and Britain. Second, we consider limitations of the approach, drawing on some other pieces of evidence. Third, we examine the policy implications of biased technological change, reviewing U.S. estimates of the investments necessary to restore the relative wage position of the unskilled workers and the impact of past public policies serving those with skill deficits. Finally, we draw together the threads of the preceding arguments and reiterate some deficiencies of the "accounting framework."

II. Biased Technological Change

The backdrop to the biased technological change story at least in the United States (and Britain) is the rise in skill differentials at a time when the share of the workforce with higher qualifications (say, a college degree) has increased. Correspondingly, the relative (and, in the United States, the real) wage of unskilled workers has fallen and their unemployment has increased. The rise in the share of more educated workers in employment and in their relative wages is of course indicative of relative demand shifts in their favor. But these shifts could be predominantly sectoral (adversely affecting industries with a greater proportion of unskilled workers) or more pervasive and affecting all industries (such as might be produced by biased technological change).

Much work has been devoted to establishing whether between-industry or within-industry shifts explain changes in the employment shares, via a decomposition of aggregate changes in the structure of employment. The aggregate change in the proportion of skilled workers (ΔP) over a given time interval is given by:

$$\Delta P = \sum_{i=1}^{N} \Delta S_i \overline{P_i} + \sum_{i=1}^{N} \Delta P_i \overline{S_i} ,$$

where $P_i = \frac{Sk_i}{L_i}$ is the proportion of skilled workers in industry i (i = 1, 2, .., N) and

$S_i = \frac{L_i}{L}$ is the share of total employment in industry i. The bar operator signifies a time mean. The first term on the right hand side of the equation gives that part of the change in the aggregate proportion of skilled workers that is attributable to shifts between industries with different skill intensities, while the second term identifies the within-industry contribution stemming from changes in the proportion of skilled workers within sectors for given employment shares.

Table 1 provides estimates of the two component magnitudes using data for U.S. and U.K. manufacturing. The U.S. study by Berman, Bound, and Griliches (1994) covers no less than 450 four-digit industries, while Machin's (1996) British study is for a smaller sample of 100 three-digit industries. In both cases, the "dependent variable" is the change in the employment and wage shares of non-production labor rather than skilled and unskilled *per se*. (Machin also summarizes the results of using a finer definition of skill structure based on education shares, and reports that the latter are closely correlated with the non-production share; see also Berman, Bound, and Machin, 1997, p. 14).

[Table 1 near here]

On the basis of the table, it appears for the United States that there has been a long-term shift away from production labor. Thus, using the employment share measure, the shift toward non-production labor occurred at the rate of 0.069 percentage points per year in the earliest period, increasing to 0.299 points per year in the intermediate interval, and to no less than 0.552 points per year in the most recent period. As can be seen, parallel results obtain when using the wage share, which is another way of looking at the increase in the relative demand for skilled labor (given a Cobb-Douglas production function, a rise in the relative wage of skilled workers would only be accompanied by an increase in the wage share of skilled labor if technological change were biased in their favor). On this basis at least, the suggestion is that skills upgrading rather than sectoral shifts that might be associated with international trade (or deindustrialization) dominate. At the price of some imprecision, in the standard trade model – revisited in the next section – a trade-induced rise in the demand for skilled workers in advanced economies would yield a substitution of unskilled for skilled workers within sectors accompanied by a shift in the industry mix toward skill intensive output.

Some interesting historical perspective is added by Juhn and Murphy (1994), who construct demand indexes for various skill groups. The indexes measure the percentage change in the demand for a particular skill group (the five quintiles of the wage distribution) as a weighted average of percentage changes of different industries and occupations, where the weights are the group's initial employment distribution across these industrial and occupational categories. (The indexes are adjusted for relative wage changes, without which there would be understatement of demand shifts in groups with rising relative wages.)

It is shown that the relative demand for workers in the highest quintile of the wage distribution grew faster than the demand for the bottom quintile during the 1940s than in either the 1970s or the 1980s. What have changed, however, are the between- and within-industry components. In particular, during the 1980s the within-industry component accounted for the entire percentage point differential in demand growth between the highest and lowest quintile workers. In the 1940s by contrast, the within-industry component accounted for just 6 of the 15 percentage-point change in relative demand for skill. In short, the within-industry component accelerated in the 1980s (but see below). Juhn and Murphy (1994, p. 358) argue that this result means that "factors such as changes in product demand and international trade had only a minor influence during the 1980s." Rather, the facts on rising inequality are instead consistent with the biased technological change story (see also Murphy and Welch, 1993).

This latter interpretation is largely shared by both labor and trade economists (see Burtless, 1995). Empirical work designed to determine the magnitude of the effects of trade on changes in advanced economies, using either *factor content* analysis or *price effects* analysis, has conceded that trade effects have limited impact on the labor market prospects of different skill groups in general and unskilled workers in particular.[1] The notable exception to this statement is Wood (1994, 1995.) Interestingly, the prices of less skill intensive goods appear to have fallen only slightly, thereby limiting any downward pressure on unskilled wages from this transparent source. Some price effects are even perverse from a trade perspective, although price data is subject to chronic measurement problems. Similarly, the increased supply of unskilled labor in advanced economies – resulting from increased imports from developing nations – are too small to explain much of the fall in the relative wages of unskilled workers. Alternatively put, the share of total unskilled employment that would be employed in the tradeable goods sector in the absence of trade appears simply too small to have produced the large relative demand shifts observed in the last two decades, even allowing for feedback effects from declining unskilled wages to imports. Also detracting from the trade explanation, quite apart from the particular concatenation of rising skill wage and employment ratios within tradeables, is the evidence of relative demand shifts favoring skilled workers in non-tradeable sectors. Finally, demand shifts away from unskilled labor long preceded globalization.

The technological change explanation has received more direct support from studies that have sought to peer inside the black box of technological change by deploying proxies for technology. To illustrate, we will again draw upon the two studies cited in Table 1. Beginning with the study by Berman, Bound, and Griliches (1994), having earlier decomposed the increase in the non-production worker share of the wage bill and total employment into their between- and within-industry components, the authors regress within-industry shifts in the wage bill share (though not employment) on changes in output and changes in either capital or equipment and plant intensities. Dummies for the 1970s and 1980s are also included, given the finding that the change in the wage bill share is increasing through time. (A simple cost function is used to derive a share of non-production wages in total wages, from which evidence on the elasticity of substitution between production and non-production labor can (theoretically) be derived as well as the presence of capital-skill complementarity. This share equation is then first differenced to yield the basic estimating equation.)

The authors' estimates point to capital-skill complementarity and equipment skill complementarity, although capital accumulation does not contribute materially to the explanation of skill upgrading (see also below). Altogether, the independent variables explain around 12 percent of the variance in changes in the wage share of non-production workers. Adding in technology variables – specifically, the fraction of investments devoted to computers, and R&D intensity (the ratio of R&D expenditures to sales) – substantially improves the fit. The two proxies for technological change account for almost three-quarters of the observed shift away from production labor.

Second, similar results are reported by Machin (1996) for 16 two-digit U.K. manufacturing industries, using almost identical procedures but this time also presenting regressions for within-industry changes in the employment share of non-production workers. Machin reports separate regressions for his two technological change indicators: annual R&D intensities, and the number of innovations introduced/used. He finds that a one percentage point increase in R&D relative to sales increases the non-production worker wage bill share by 0.07 percentage points, and the employment share by 0.05 percentage points, although his results for innovations are only weakly statistically significant. Machin also provides disaggregative regressions using Workplace Industrial Relations Survey (WIRS) establishment data that allow him to evaluate the impact of increased computer usage. He finds among other things that increased computer usage is associated with increased employment shares of non-production workers and reduced employment shares at the lower end of the occupational employment range. This latter result goes some way to addressing the criticism (e.g. Bernard and Jensen, 1997) that important compositional effects consistent with trade theory might be hidden at industry level, namely, that a skill sub-industry might expand at the expense of its low-skilled sub-industry counterparts (see also Bound, Berman, and Machin, 1998).

Another well-known piece of evidence consistent with the biased technological change argument is Krueger's (1993) interesting analysis of computer usage and occupational earnings. He finds that working with computers (versus not working with them) is associated with a *cet. par.* increase in wages of between 15 and 20 percent. Moreover, his estimates imply that the expansion in computer use during the 1980s can explain up to 50.5 percent of the observed increase in the return to education.

Finally, we turn to the role of supply factors in all of this, since we have inferred that rising premia indicate that demand has outstripped supply in the case of the highly skilled. The best analysis here is that of Blackburn, Bloom, and Freeman (1990), who attempt to explain the deteriorating position of U.S. high school dropouts and high school graduates using a conventional demand and supply framework. On the demand-side, a shift-share analysis of the change in average wages received by less skilled workers is used (supplemented by a logarithmic earnings regression model with year dummies). This reveals that between 70 and 80 percent of the increase in the earnings gap between high school dropouts/graduates and college graduates over 1979-87 occurred within industries, again underscoring the relative unimportance of changes in the allocation of labor across industries.

The next step is to ascertain the contribution of supply side factors as well as institutional factors (specifically, minimum wages and declining unionization) to these within-industry shifts. The supply side analysis focuses on shifts in the relative supply of workers with different educational qualifications. Blackburn, Bloom, and Freeman first examine the increase in the differential between college trained and high school dropouts/graduates between 1979 and 1987, assuming there were no shifts in relative demand. Despite the growth in the proportion of college graduates in the overall workforce, the ratio of college educated (to high school educated) among those aged 25 and 34 actually declined after 1979. The suggestion is then that part of the increase in the observed differential(s) after 1979 could be due to this falling supply of young college graduates. And it is calculated that the decline could explain up to 30 percent of the growing differential of college educated younger workers. In other words, this amount of the differential potentially attributable to shifts in relative demand is in fact due to a supply shift. Next, assuming that the rate of increase in relative demand was the same in the 1980s as in the 1970s (when the differential was fairly stable despite a sizeable growth in the college educated population), the authors estimate how the slowed growth in the relative supply of college educated workers in the 1980s contributed to the change in differentials between the periods 1979-87 and 1973-79. It is reported that the deceleration in the growth of college educated manpower can explain much but by no means all of the increase in the growth of the wage gap. In other words, the suggestion is that shifts in relative demand in favor of the college educated accelerated in the 1980s. Lastly, the authors estimate that although the effect of (declining) minimum wages had minimal effects on differentials, the 13 percentage point fall in union density may have contributed up to one fifth of the decline in relative wages received by low skill workers during the decade of the 1990s.

The interest of this study is twofold. First, it seems to demonstrate that an accelerated shift in demand favoring more skilled workers and a reduced growth in their relative supply combined to increase U.S. wage inequality in the 1980s. Second, in the process it quantifies within a unified accounting framework the contributions of a number of factors making for declining wages among the unskilled. As we have seen, although this analysis is clearly supportive of skill-biased technological change, it does not accord that argument exclusive domain. We will return to this issue.

III. Qualifications and Points of Dissent

Despite its growing appeal in the U.S. and elsewhere, the skill-biased technological change parable has not gone unchallenged. The principal critique has been theoretical, while secondary criticisms have focused on the controversial issue of whether or not there has occurred an acceleration in the rate of technological change in recent decades, the neglect of other determinants of observed movements in skill differentials, and the assumed exogeneity of technical change, to include the possibility that trade competition has acted as the prime mover. We next examine each point in turn.

At root, the theoretical problem with the idea that biased technological change can explain the course of relative wage and employment developments stems from the imprecision of the argument. The principal criticism has centered on the issue of sector bias, namely, whether technical progress has been changing by more in one sector than another (Leamer, 1994). Where product prices are fixed and the situation is that of a one-sector, two-factor (skilled and unskilled) economy, then clearly it is the skill bias of technical change that alone determines relative factor prices.[2] However, for a two-sector, open-economy model with fixed prices it is the sector bias of technological change that matters in determining wage differentials. Consider, for example, the case of a technological change that makes a skill-intensive sector more efficient in a single country. The reduction in production costs implies increased production of the skill-intensive good. But the increased demand for skilled workers will raise their relative wages and in the process lead to their substitution by unskilled workers. In equilibrium, therefore, although the relative wage of skilled workers will rise the employment ratio will be unaffected in each sector.

In an attempt to deal with this unpalatable theoretical prediction of trade theory, Berman, Bound, and Machin (1998) introduce the notion of *pervasive* skill-biased technological change, occurring simultaneously in all economies in the production of some traded good. The setting is again the open economy framework but now with endogenous prices. In these circumstances, the authors assert that skill-biased technological change will not only produce within-industry skill upgrading but also a widening skill differential as well. Their argument draws directly on Krugman (1995), who contends that where skill-biased technological change is pervasive, the responses are equivalent to those of the simple closed-economy model with two sectors, that is, raise the relative wages and employment of skilled workers. Under standard assumptions, Berman, Bound, and Machin (1998, p. 1247) argue that "skill-biased technological change releases less-skilled workers from industries, depressing their wages by depressing the world (relative) prices of goods intensive in less-skilled work."

Armed with this theoretical argument, Berman, Bound, and Machin then set out to establish that skill-biased technological change in manufacturing industry has indeed been pervasive. They first supplement the evidence in Berman, Bound, and Griliches (1994) and Machin (1996) (see Table 1) with findings on skill upgrading for an additional 10 countries for the 1970s and the 1980s. On average, the proportion of non-production workers in the sample increased by an average of 4 percentage points in the 1970s and by 3 percentage points in the 1980s. In all countries the large majority of the aggregate substitution in favor of non-production workers was due to substitution within industries (84.3% in the 1970s and 91.5% in the 1980s).[3] And in the 1980s, for 7 of the 10 countries evincing rising substitution the skill differential was also increasing. Having provided this evidence of pervasive skill upgrading, the authors proceed by offering cross-country correlations of changes in the within-industry proportion of non-production workers for the two decades. The correlations are overwhelmingly positive, and do not seem to be caused by changes in wages (i.e. a similar response of industries to a similar change in relative wages.). Rather, the correlations appear to be driven by three industries: machinery and computers, electrical machinery, and printing and publication. Separate information from case studies indicates that these industries introduced major skill-biased technologies during the sample period, as well as having the highest rates of investment in computers in the 1980s. On the basis of this evidence, the authors infer that microprocessors were likely the main cause of skill-biased technological change over the sample period. Finally, Berman, Bound, and Machin turn their attention to developing countries, arguing that skill-biased technological change is a global phenomenon, not simply confined to the advanced economies. The counterpoint is again the trade model’s implication that the relative wages of skilled workers should have declined in developing economies. Their evidence is a graphical exposition of changes in relative wages and GDP per capita for 24 developing countries over the decade of the 1980s, plus corresponding changes in the share of non-production workers in employment again by GDP per capita (this time for 27 countries). In the former case, it is found that many countries within the sample experienced an increase in the relative wages of non-production workers in the 1980s (the authors note that the correlation is "a precisely estimated zero") at a time when trade was liberalizing. Similarly, large increases in skill shares are observed over this interval (see also Richardson, 1995). Evidently, manufacturing employment in developing economies not only grew rapidly but also upgraded skills at the same time. Skill-biased technological change might have been one factor in this development. The authors concede that other sources such as increased capital investment and capital skill complementarity might have produced this result in less developed economies, possibly indexed by a seemingly positive association between non-production employment shares and GDP per capita. (Note, however, the widespread acceptance in the literature that the increase in capital investment for *developed economies* is likely to have been simply too small to have generated the observed increase in relative wages.)

Unfortunately, although these findings establish that technical change has been pervasive they do not provide closure on the role of skill-biased technological change in driving up the relative wages of skilled workers. This is because the underlying model exploited by Berman, Bound, and Machin (1998) is something of a special case, reflecting specific assumptions about production technology. Haskel and Slaughter (1998) correctly argue that the effect of skill-biased technological progress on skill differentials in the two-sector open economy is theoretically ambiguous, and that in many cases it remains the sector bias of pervasive technical change that is the main determinant of relative wage changes after all (e.g. where the degree of factor substitutability is small). For their part, Haskel and Slaughter attempt to test the effects of sector bias in skill-biased technical change by using the residuals from a cost-share equation (derived from a translog cost function) for non-production labor. In other words, the focus is on that part of skilled labor’s cost share that is not explained by factor price changes. Measured skill-biased technological change is then regressed on skill intensity: If the coefficient estimate on skill intensity is found to be positive (negative), the implication is that skill-biased technical change is concentrated in the skill-intensive (unskilled intensive) sectors. Haskell and Slaughter report for the United States and the United Kingdom that skill bias occurred in the unskill-intensive sectors in the 1970s and in the skill-intensive sectors in the 1980s. In both countries, skill differentials narrowed in the former interval and widened in the latter period. Results supplied for a further eight developed countries are more mixed but broadly supportive in that countries evincing a greater (lesser) degree of sector bias in skill-biased technical change tend to experience larger (smaller) increases in wage inequality.

This examination of skill-biased technological change within countries across sectors does not predict the relative importance of factor movements within and between industries, and does not therefore constitute a critical test. Moreover, if skill-biased technological change were largely sector neutral, as Bound, Berman, and Machin's (1998) cross-country findings might be viewed as suggesting, then there would of course be little or no difference across countries in the sector bias of technological change. For both reasons more empirical work is required on the importance of factor and sector bias. Finally, lest it be thought that Haskel and Slaughter elevate the role of the alternative trade explanation, we should note that in a separate investigation of the sector bias of both prices and technological change, they find that prices rather than technology were the dominant force behind the rise in U.K. wage inequality in the decade of the 1980s, but are unable to establish a firm link between domestic and international prices (Haskel and Slaughter, 1989).

Turning to the issue of the rate of change in technical progress, there has of course been little disagreement about the long run course of events. That is, the complementarity between capital and skill is well established (e.g. Griliches, 1969). But if there is consensus on the role of capital accumulation and technology in shifting demand in favor of higher order skills through time, controversy attaches to the suggestion that technology's impact accelerated in the 1980s and 1990s. This is the timing issue. In particular, Mishel and Bernstein (1996) have argued that the technological change story must proceed beyond its typical focus upon broad employment and education differentials to examine the entire skill and wage distributions (i.e. the demand for workers at various education and wage levels, where the latter are also assumed to proxy skill). The basic motivation here is the need to disaggregate.

Mishel and Bernstein's decomposition of within-industry wage inequality proceeds as follows. Their dependent variables reflect annualized changes in two measures of wage inequality, namely, between group inequality (or "education quantities," defined as the share of workers in a given education category) and overall wage inequality (or "wage quantities," defined as an industry's utilization of low, middle, or high-wage workers). Six education categories and five wage quantities are distinguished, and separate regressions run for each. The independent variables comprise a technology vector and a control for industry employment growth. Three technology indicators are deployed: the gross equipment stock and the gross computer stock per full time equivalent worker, and the share of scientists in each industry. Each variable is first differenced.

Because the effects of technological change can take the form of changes in the skill bias as well as changes in pace of technological change, the empirical model allows a distinction to be drawn between changes in complementarities and changes in the overall impact of technology through time. This is achieved by also interacting the technology covariates with time. (Three time periods are recognized: the 1970s, the reference period, the 1980s and the 1990s.) Changing complementarities are directly revealed by the (two) interaction terms. The overall impact of technology is obtained by multiplying the complementarities specific to each period by the average within-industry change in the relevant technology indicator over that period. Comparing these per period effects then establishes whether or not the effect of technology has accelerated through time. The reduced form model is estimated over just 34 manufacturing and nonmanufacturing private sector industries. Separate results are reported for specifications with and without the computerization covariate.

The authors' estimates are not favorable to the accelerated technological change argument, even if it is generally the case that greater *levels* of technology are associated with proportionately fewer high school equivalent workers and fewer middle and lower paid workers (namely, the bottom three-quarters of the wage structure). As far as the educational quantity (i.e. education upgrading) regressions are concerned, the large majority of interaction terms between the relevant technology indicator and the time period are statistically insignificant. That is, there are no signs of the complementarities shifting through time. Disregarding statistical significance, the estimates do not suggest a more profound effect for technology than for other factors, such as industry shifts. Furthermore, there are no signs of an acceleration in the overall impact of technology (the "technology effect," namely, the product of complementarity and the pace of technological change). For females, the results with respect to complementarities are much the same, including mixed effects for the individual technology indicators, although there is at least the suggestion of some modest acceleration in the technology effect.

For wage quantities much the same negative conclusions hold, but in this case the result follows from technological change being less biased in the 1980s than in the 1970s for men in the bottom half of the distribution; correspondingly for the more skilled groups (the top 25 percent) technological change was less favorable. A similar result was found for the overall impact of technology. The pattern of complentarities for women is somewhat differentiated from that of men – for example, the observed shifts were uniformly adverse for low wage women in the 1980s and 1990s – but once more there is no support for an accelerated technology effect adversely impacting the bottom half or three-quarters of the wage distribution and favorably impacting the top half.

These findings are at odds with other studies of skill-biased technological change as measured by computerization at a more disaggregate level (but see below). For example, Autor, Katz, and Krueger (1998) report that rapid skill upgrading within detailed industries accounts for most of the growth in relative demand for college-educated workers, particularly since 1970, and that across datasets the rate of skill upgrading has been greater in more computer-intensive industries (see also Krueger, 1993).[4] Moreover, Johnson's (1997) indicative calculations suggest this acceleration might have occurred. Johnson first computes the overall skill level of the population based on college and high school equivalents. The ratio of college-equivalent labor to high school-equivalent labor is termed "relative skill supply." This magnitude can then be compared with the observed relative wage for the two groups to gauge the extent to which the relative demand for higher-skilled labor has been shifting. Specifically, under assumptions of flexible relative wages and exogenous relative supply, the relative demand shift is the percentage change in the relative wage multiplied by the elasticity of substitution plus the percentage change in relative supply. Estimates of this shift in favor of skilled workers are 3.6 percent (per year) for the interval 1963-70, 3.7 percent for 1970-79, 4.7 percent for 1979-89, and 5.0 percent for 1989-93. In short, the suggestion is one of an acceleration in skill-biased technical change since 1980. But the movement is scarcely dramatic and, taken in conjunction with Mishel and Bernstein's (1996) findings, might serve to reinforce the suggestion that the skill-biased technological change story has more explicitly to accommodate the role of other explanations for wage and employment development over the last few decades, the specific caveat here being the level of aggregation in both studies.

It is of course appropriate to place some of these other factors in a wider context. The lesser degree of wage flexibility in Europe *vis-à-vis* the United States is an obvious starting point in any such inquiry because of the maintained hypothesis of full employment in the preceding analysis. At one level, wage rigidities would suggest that unemployment across skill groups should be more evenly distributed in Europe.

However, the correlation between changes in wage inequality and changes in the skill-unskilled employment ratio are poorly determined across OECD nations. To cite just one component argument, German workers in the bottom decile of the real wage distribution earn twice as much as their U.S. counterparts and yet experience similar unemployment rates. The explanation for this phenomenon is conventionally couched in terms of their better training (Nickell and Bell, 1996; see also the discussion in Franz, 1999, p.21). Although this distinction can easily be overdrawn (see, for example, Harhoff and Kane, 1997), the concatenation of rising skilled worker unemployment alongside that of unskilled workers in the face of typically more stable real wage differentials does redirect our attention to the supply-side component of the skill-biased technological change story, and also the role of collective bargaining.[5] Both issues have attracted more scrutiny in Europe because of the greater analytical interest in structural unemployment in that region and its stronger union movement. Manacorda and Manning (1999) argue that, since there have always been shifts in relative demand, the pertinent question is whether these shifts have been matched by equivalent changes in the relative supply of skills. Using a one-dimension measure of skill based on observed human capital (schooling), they conclude that the main driving force behind rising wage inequality in the United States and the United Kingdom has been increasing skill mismatch. Little mismatch is reported for continental Europe, which result the authors attribute to a better supply of skills and more intense upgrading. By way of interpretation, Manacorda and Manning choose to emphasize the role of labor market monopsony, it being alleged that centralized bargaining and legislated minima in continental Europe are helpful in this regard, favoring unskilled workers not only in terms of relative wage development but also in relative employment (see also Manacorda and Petrongolo, 1999, for further evidence on the skills mismatch in Europe). Note, however, that relative employment is only part if the story. Another is unemployment – Krugman’s famous "other side of the coin" analogy. Yet another is the effect of skill-wage compression on the supply of skills.

The contribution of collective bargaining to employment and skill outcomes is made more explicit in the treatment by Blau and Kahn (1996), who use data on male wages for a panel of ten OECD nations (including the United States). Key to the authors' analysis is the manner in which market forces reward the productive skills of individuals. Blau and Kahn first report evidence from on a regression of a number of measures of wage inequality (the dispersion in log wages, various percentile differentials, and wage differences between high- and low-skill groups) on the degree of centralization of pay determination – the other explanatory variables are the log of relative female labor supply and relative net supply. Less centralized bargaining regimes are found to be associated with greater wage dispersion. The authors next report evidence of a tenuous link in the sample between the wage gaps and differences in the relative demand and supply of skills (after Katz and Murphy, 1992). Finally, they calculate that had the United States the same distribution of skills as the other countries in the sample, the wage gap between the 50th and the 10th percentiles would narrow while that between the 90th and the 50th percentiles would increase, although overall wage variation would still remain much higher in the United States than elsewhere. The conclusion of this study is that although the countries in the sample do not differ all that markedly in productive characteristics, those characteristics are nonetheless differentially rewarded. Most notably, skills have bigger returns in the United States.

We conclude on a rather pessimistic note pertaining to the endogeneity of technical change (and wage differentials). In part this question is intimately related to the debate between trade theorists and labor economists because of the allegation of the former (especially Wood, 1994) that much technological improvement is in fact trade induced. Interestingly, however, Haskel and Slaughter (1999) report that although foreign price pressures have stimulated technical change in the United Kingdom the induced technical change is sector neutral and hence – on their model – has little effect on wage inequality. But the issue is much broader than this. In reviewing the literature on technology and wages at *industry, firm, plant, and individual levels*, and distinguishing between the effect of technology on skill structures on the one hand and that of technology on wages on the other, Chennels and van Reenan (1999) conclude that endogeneity bias is likely to more of a problem in the latter area. Indeed, they argue that "the computer-wage correlation cannot be interpreted as simply the causal effect of technical change on enterprise wages. More likely it reflects the fact that the best technologies are likely to be used by the most able workers who were already earning higher wages" (Chennels and van Reenan, 1999, p. 31). That said, there is more research on the endogeneity problem (as well as unobserved heterogeneity) in the wage literature than in the area of technology, where there have been few attempts to develop instruments (e.g. R&D tax credits) that ameliorate statistical problems associated with the fact that firms make technology and skills decisions simultaneously. The wider problem is that there have been few studies of the manner in which technological change translates into higher demand for skills, or has a basis in the supply of existing skills.

The bottom line is that, although skill-biased technological change can be associated with the upgrading of the labor force, the jury is still out on the nature of its contribution to observed changes in the wage structure (which is undoubtedly partly an issue of sectoral bias). This more attenuated conclusion is mandated by the associative nature of the test procedures adopted in the literature, still inadequate representation of the supply side, and of course a variety of statistical problems (such as the endogeneity of technological progress). All of this is not to elevate in importance the role international trade – the independent influence of which is currently still modest on most estimates – even if some evidence of skill bias in the literature is also consistent with a trade-induced deterioration in the position of skilled workers. One notable omission in much of the literature is the role of collective bargaining and wage policy for lack of a better word. We have reported some progress in this area but the tests are frankly even less discriminating than those employed in the skill-bias literature. Nevertheless, wage flexibility is assumed in the standard models and departures from it patently need explicit incorporation in mainstream treatments and will require consideration of a wider range of outcome indicators than relative employment rates and relative wages by skill group.

IV. Policy

As a practical matter, the policy recommendations of proponents of the two main explanations for widening wage (and employment) differentials in favor of skilled workers – skill-biased technological change and trade – do not differ in substance. Thus, both groups emphasize the role of education, training/retraining, and earned income tax credits, *inter al*. Protectionism is seen as reducing societal welfare, no less than a tax on computers. As a result, much less is heard today of trade-adjustment assistance, certainly that financed by taxes on imports, and still less of import restrictions *per se*. This is not to deny that remnants of protectionism linger on in the notion of "destructive competition" and arguably in the *social clauses* of trade agreements, but rather to argue that there is widespread acceptance that the benefits of trade and technological progress dominate the costs. Yet, as Richardson (1995, p. 52) has argued, the actual policy recommendations being mooted have something of an appeal to parenthood! This is perhaps understandable, given the generality of the diagnosis of the problems occasioned by technology and globalization. Expressed another way, our understanding of the sources of skill-biased technological change, and the technologies involved is too rudimentary to offer much specific assistance to policy design.

There is of course broad agreement that greater resources should be channeled into formal education, not least at the primary and secondary levels, so as better to prepare the next generation of workers for the labor market. This is indicated by the high private and social returns to schooling and the transparency of certain problem areas (e.g. the role of adverse family circumstances).[6] To be sure, analysts vary in the emphasis that they would place on competitive innovations (such as education vouchers and changes in tax policy to favor individual write-offs) but the consensus is there, underwritten by the Mincerian notion of "universal complementarity" (namely, the positive association between formal schooling and post-school investments). *Vulgo*: training begets training.

The consensus as regards future generations of workers breaks down when it comes to formulating policies for those with current skill deficits. A useful backdrop to the debate is provided by calculations of the scale of human capital investments necessary to make whole the losses sustained by unskilled workers in recent years. Some such indicative estimates have been made by Heckman, Roselius, and Smith (1994) for the United States, where the earnings losses in employment have been most profound. Using data from Blank (1994), the authors first compute the human capital investment required in 1989 dollars to restore the real earnings of male high school dropouts and high school graduates to their real 1979 levels. The second calculation is the necessarily higher amount needed to restore the earnings ratios between these two lesser skilled groups and college graduates, while maintaining the 1989 earnings of college graduates. The sums are staggering: $426 billion in the first case, and $1.66 trillion in the second. They clearly dwarf U.S. manpower program outlays, both actual and envisaged.

These estimates clearly overstate the investments involved if supply responds and low skills become scarcer (helped by a likely slowdown in labor force growth). As matter of fact, there are signs that the gap between college and high school graduates has reached a plateau. Although Mincer's (Wall Street Journal, 1996) projections of a major decline in the wage premium enjoyed by college-educated over high-school graduates have proved over-optimistic, history is on his side. Thus, for example, the supply response to massive shifts in the relative demand for skilled workers over 1910-40 was apparently of a sufficient magnitude to keep the differential between the high-school educated worker and his or her less-educated counterpart in check (Goldin and Katz, 1995). That being said, Johnson (1997) cautions that there will have to be a large increase in U.S. college attendance rates after 2010 to prevent a rise in wage inequality because of a new phenomenon, namely, the relatively high education levels of retirees.[7]

On the other hand, the Heckman-Roselius-Smith estimates are understated to the extent that 10 percent is an over-ambitious return on the human capital investment. And it is here that there are grounds for some pessimism. Although 10 percent is perhaps not an unreasonable assessment of the return on training investments in the private sector (Lynch, 1993), it may be argued that low skill workers are currently not being trained because it is not profitable for firms to do so. There is the further point that almost no government programs approach such a yield, although the disparity undoubtedly in part reflects the selection by the private sector of those whose returns from training are likely to be high.

Let us consider each point in turn. Heckman, Roselius and Smith deny the existence of pervasive under-training on the part of (U.S.) employers. They make a good general case, and back up their arguments with an interesting comparison between apprentices in the much-vaunted German apprenticeship system and U.S. high school completers (who have a similar quantity of completed education prior to entering the labor market). Among other things, the incremental gains to completing each (versus not doing so) are broadly similar, and the slope of the earnings profiles for each are even closer. In short, considerable caution has to be exercised before concluding that U.S. employers under-train. That said, that there are some empirical regularities that may still point to under-investment, such as the result that past on-the-job training adds to productivity on the new job but not to the wage on that new job.

It is of course conventional to speak of *market failure* in the provision of private sector training. Such arguments have long been used to justify government mandates requiring firms to offer additional general training. The standard externalities argument (i.e. poaching) was undercut by Becker's (1962) theoretical distinction between general and specific training. Becker’s argument does not admit of market failure other than that arising from union wage setting and/or minimum wages that limit the ability of the worker to pay for his or her own training via a lower wage, or from credit constraints that limit the scope for borrowing against a higher future earnings stream. However, the market failure argument has however recently been reformulated (see the essays contained in Booth and Snower, 1996). The key theme of the modern market failure argument is that training is neither exclusively general nor specific. In these circumstances, under-provision of training can result if there is uncertainty at the time the investment is undertaken and if there is monopsony power. As a result, some firms can benefit from the training of workers by others, thereby producing a wedge between the social and private benefits of training. (Additional theoretical arguments can of course be bolted onto this revisionist apparatus to bolster the case; examples include labor-capital complementarities and the interaction between skills and innovative performance.) It is of course only a short step from acceptance of these arguments to arrive at the diagnosis of a pervasive low-skill, bad-job trap, requiring intervention to shepherd the parties to a new and improved equilibrium.

But it is one thing to locate potential sources of market failure, yet another to identify the scale of the problem, and again quite another to design effective policies if these are indicated. The U.S. empirical evidence simply does not really point to substantive market failure in the provision of private-sector training. Here we broadly agree with the conclusion of Heckman, Roselius, and Smith (1994, p.113) that "the lack of interest in private firms in training disadvantaged workers indicates the difficulty of the task and the likely low return to that activity."

But if it is not efficient by and large for the private sector to train workers with existing and emerging skill deficits, what is to be done for those marginalized by the broad market forces of skill-biased technological change and international trade? Bluntly expressed, something has to be done. For their part, Heckman, Roselius, and Smith argue that if it is not efficient for the private sector to train the low skilled, then the optimal strategy would be redistribution/income maintenance pure and simple. That is, not only to continue focusing resources on the highly skilled, but also to offer them heightened support and then tax them to pay for the maintenance of the marginalized low skilled. Alternatively put, efficiency considerations would contraindicate taxing the most highly skilled to pay for programs aimed at the lesser skilled, since it reduces the incentive of the former to invest in skills.

Yet efficiency is not the exclusive basis for policy. Thus, it is widely accepted (and ultimately conceded by these authors) that the work ethic is a basic value – fostering socially desirable values among those who work – and is therefore to be nurtured. The interesting question that then arises is whether worker training should be subsidized or the resources instead directed into job subsidies. Heckman, Roselius, and Smith see the former as an inefficient transfer policy as well as an inefficient investment policy for low-skill workers. Their reasons are not altogether transparent, although they seem to be based in part on the authors' pessimistic evaluation of government training programs, coupled with the optimizing decisions of the private sector not to train the unskilled. This conclusion is in fact better directed at policies in respect of older workers. More generally of course, the flexibility of wages attenuates the force of the job subsidy option for the United States, although not in countries characterized by wage rigidity.

The authors are quite correct in noting the low returns to these programs *vis-à-vis* the private returns to training. (For an accessible review of these programs, see LaLonde, 1995. See also Heckman, LaLonde, and Smith, 1999) Abstracting from selection considerations, the issue is whether this is the correct metric. If one argues that reaching the currently disadvantaged is an incremental process, however, one may offer a more upbeat evaluation for two reasons. First, although existing programs geared toward the truly disadvantaged do not appear sufficient to lift such workers out of poverty, the recorded gains in employment and earnings can be nontrivial, especially for adult women, and pass a benefit-cost test (see Orr et al., 1996). One can view this as providing an important (selective) first step on which to build and integrate such workers into the economic mainstream. To be sure, there are some major problem areas; a classic example being the palpable failure of Job Training Partnership Act programs for youth. The second important point to make is that U.S. public programs for displaced workers as well as disadvantaged workers are of considerable diversity. Out of this diversity, we are beginning to discern the glimmerings of what may be effective policies (e.g. on the sharply differentiated returns to the courses undertaken by displaced workers in community colleges, see Jacobson, LaLonde, and Sullivan, 1997). We note parenthetically that many of the programs are being evaluated using experimental techniques.

Currently, although there is emphatically no training blueprint, the rich tapestry of U.S. demonstration projects and mix of program services is both informative and as a strategy has the decided advantage of helping avoid some of the classic government failures of monolithic manpower programs of the past. The basic analytical requirement here is to make assignment to different program services truly experimental. On the basis of such experiments, the comparative merits of training versus job subsidies can be evaluated. And it may well be the case that new initiatives will indeed have to be more intensive than in the past. There is decidedly no quick fix for the disadvantaged. But their number is likely to fall well below the levels implicit in the pessimistic calculations of Heckman, Roselius, and Smith.

We have said little about Europe in all of this. One reason is that much less is known about the effects of manpower policy initiatives in Europe than in the United States.[8] In principle, it might be argued that presumably less disadvantaged European workers (see section III) have more to gain from their exposure to training programs than their U.S. counterparts. Yet we have little guidance from European studies as to what programs work for reasons having to do with program design, and some clear evidence of bad policies (see Lechner, 1998). Given the scale of some European wage-subsidy programs, the deadweight, substitution, tax, and displacement effects analyzed by Calmfors (1994) also seem especially relevant. One potentially positive development, however, is the *employment chapter* of the European Union, by virtue of the open coordination device, the identification of best practice or peer review, and benchmarking at member state level. This new European employment strategy could well assist in identifying programs that are particularly effective for specific groups with substantial labor market problems, even if it would be unwise to view it as a purely technocratic response to the problems identified in the present treatment (Addison, 2000).

Finally, there is continuing controversy over the effects of factors other than skill-biased technological change (and international trade) on relative wage development; factors that may be expected to loom larger in Europe than the United States and which have spawned treatments that take explicit account of unemployment. These vary according to the break with the conventional skill-biased technological change (and trade) model(s), and may thus discount mismatch. One interesting source of disagreement that has arisen here is the effect of collective bargaining on unskilled worker employment and wages. Some observers claim that the (relative) position of unskilled workers is helped by centralized collective bargaining while others assert that it is harmed (both by reason of wage rigidity and overall wage development). Proponents of the latter view would tie manpower policy closely to the institutional reform of wage policy, while supporters of the former position would link manpower policy to demand side developments.

V. Conclusions

This review has focused on the contribution of technological change to changes in the structure of relative employment and wages. There seems no doubt that skill-biased technological change underpins much of the skills upgrading observed over the course of the present century. There are also some indications of a (worldwide) technology shock in the 1980s and 1990s, further favoring skilled workers but, to put it mildly, this phenomenon is the subject of no small controversy. If there is considerable agreement on skill-biased technological change as the dominant demand-side influence – international trade being of secondary importance because of the modest size of the between-industry employment shifts – its contribution to relative wage development is less obvious. At one level, the skill-biased technological change story has been criticized for failing to take account of trade theory, within which framework even the effects of pervasive skill-biased technological change on relative wages are ambiguous. This criticism would appear correct but at issue is the empirical relevance of the sector-bias in skill-biased technological change argument since its implication of between-industry upgrading seems contraindicated, unequivocally so over a longer time span than the last two decades. At another level, albeit related, the supply side of the skill-biased technological change story is under-developed. The analysis of relative wages within the skill-biased technological change framework is typically based on comparisons of movements in relative wages and indices of skill-adjusted labor supply, assuming values for the elasticity of substitution between skill groups. This approach has yielded some interesting insights (including, as we have seen, instances of a deceleration in the growth in supply of U.S. college-trained manpower) but makes a large number of assumptions regarding the labor market, including full employment and flexible wages that clearly do not have universal applicability across countries and time. Similar issues also arise when the analysis of skill-biased technological change is instead embedded within a trade framework, namely, the assumption that workers are mobile across sectors. Further development of the supply side is evidently called for. Obvious limitations on how far the wages of less-skilled workers can fall are unions, minimum wages, and minimum welfare levels. Some progress has been made in integrating wage inflexibility within a skill-biased technological change framework but has more often led to more general methodologies based on mismatch.

The role of skill-biased technological change as the key (albeit not sole) demand-side determinant seems unassailable. This is because technological proxies such as R&D expenditures and computer investment have been found to have positive and statistically significant effects on the employment and wage bill shares of non-production/skilled workers in country and cross-country studies alike. Furthermore, this result does not appear to have been driven by aggregation and, while the correlation may not just reflect causal relationships, endogeneity is unlikely to be a major problem. In particular, the rapid degree of within-industry upgrading of skills appears to have been driven by computers. For the reasons noted earlier, we cannot necessarily say the same of the positive association between wages and computer use. This conclusion is underscored by micro-econometric studies that suggest the relation is highly sensitive to controls for firm heterogeneity and the endogeneity of the innovation.

Even if the nature of demand-side forces is fairly clear, the identification of the fundamental causes of skill-biased technological change, the techniques involved, and the manner of their adoption by firms is not transparent. Accordingly the skill-biased technological change diagnosis offers no real blueprint for policy other than the need for an increasingly better-educated labor force. This 'solution' of a long-term commitment to increasing, say, the share of individuals who go to university seems appropriate given universal complementarity and is also favored by those who instead attribute skill upgrading and the immiserization of the unskilled to international trade. Beyond that, supporters of both schools would also allow for the corrective mechanism of market forces, although we detect little conviction that market-induced supply shifts will suffice unaided. The problems arise when one turns to the here-and-now, that is, the position of the currently skill-disadvantaged. General solutions, although favored by politicians, are not available here. We are unaware of any evidence to indicate that large-scale manpower programs work, and the reach of this statement is not just confined to the United States. Rather, there is scope for carefully targeted programs that offer successive incremental improvements in the labor market prospects of truly disadvantaged workers whose education, skills and training are a significant impediment to their employment and for whom no Mincerian correction is in sight.

Endnotes

[1] The idea behind factor content analysis is that foreign labor input in imported goods adds to domestic labor supply, while domestic labor input in exported goods subtracts from domestic supply. The impact of trade on the skill differential is calculated by combining these labor supply shifts with separate estimates of labor demand elasticities (see, *inter al.*, Borjas, Freeman and Katz, 1992; Revenga, 1992; Wood, 1994, 1995). Price effects analysis on the other hand eschews measurements based on trade volumes in favor of trade prices, and is directly linked to the basic Stolper-Samuelson theorem briefly summarized earlier (studies include Lawrence and Slaughter, 1993; Sachs and Shatz, 1994; Desjonqueres, Machin, and Van Reenan, 1997; and Fitzenberger, 1999). The basic idea here is that trade-induced price declines (increases) in a sector make that sector unprofitable (profitable). Relative wages have then to fall (rise) to restore the zero profit constraint of competitive equilibrium.

[2] This is exactly the scenario assumed in much of the technological change empirical literature. Thus the ratio of skilled to unskilled worker employment may be regressed on the corresponding skill differential, where the skill-biased technology parameter is specified as a constant term - or replaced by an assumed correlate such as computer usage. In each case, a positive coefficient suggests evidence of skill-biased technological change. Import penetration has on occasion been added this sparse formal representation in order to gauge the trade argument (e.g. Machin and van Reenan, 1998).

[3] Similar findings are reported for the wage bill share measure.

[4] Interestingly, Krueger's study has been critiqued by DiNardo and Pischke (1997), who report that use of his methodology with German data produces the result that working with pencils yields a wage premium no less than working with computers! Using the German Qualification and Career Survey, which contains information on a variety of tools used on the job, one of the authors' specifications suggests a return to computers of 18.6 percent in 1991 and to pencils of 13.5 percent. Since everyone can use pencils, the inference might be that the return to computers is a selection effect - increased computer use picks up some unobserved skill whose return has also increased through time - albeit one that is not easily identified with standard statistical procedures. But,

in the final analysis, DiNardo and Pischke are more critical of the use of the computer variable as a direct indicator of technological change than they are of the notion that technological change underpins observed changes in wages .

[5] Nickell and Bell (1996) attempt to differentiate between neutral shocks (affecting the employment of all skill groups equally) and relative adverse labor market shocks. Indeed, their estimates, using a CES function to generate the structure of demand, suggest that adverse relative shocks account for less than one fifth of the average rise in unemployment in Germany, the Netherlands, Spain, Canada, and also, interestingly enough, the United Kingdom. The latter result conflicts with Machin's (1996) study (see section II). However, Machin (1996, p. 145) does note that as far as pay inequality is concerned his analysis neglects many important transformations of the U.K. labor market in the 1980s associated with the radical labor market reform agenda of successive Conservative administrations; changes, he admits, that favored non-manual over manual workers. That said, Nickell's (1995) parallel analysis, using different demand specifications, confirms the dominance of relative shocks for the United States, where they are estimated to account for four-fifths of the rise in unemployment, 1963/68 to 1983/88.

[6] For a review of the apparent success of high quality early childhood interventions in yielding subsequent labor market benefits to the disadvantaged, see Heckman, Lochner, Smith, and Taber (1998).

[7] Much of the large increase in the relative supply of educated workers in the past was achieved by the replacement of retirees with low average levels of schooling by young persons with higher average levels.

[8] For a review of 39 mostly non-experimental studies of employment and training programs in nine European countries, see Heckman, LaLonde, and Smith (1999).

References

Addison, John T. 2000. "Social Policy in the EU: The New Emphasis on Education and Training Under the Treaty of Amsterdam," paper presented at the First Biennial Conference of the Hong Kong Economic Association, Hong Kong, December 16.

Autor, David H., Lawrence F. Katz, and Alan B. Krueger. 1998. "Computing Inequality: Have Computers Changed the Labor Market," *Quarterly Journal of Economics* 113 (November): 1169-1213.

Becker, Gary S. 1962. *Human Capital*, New York: Columbia University Press.

Berman, Eli, John Bound, and Zvi Griliches. 1994. "Changes in the Demand for Skilled Labor: Evidence from the Annual Survey of Manufactures," *Quarterly Journal of Economics* 109 (May): 367-397.

Berman, Eli, John Bound, and Stephen Machin. 1997. "Implications of Skill-Biased Technological Change: International Evidence," Working Paper No. 6166, National Bureau of Economic Research.

Berman, Eli, John Bound, and Stephen Machin.1998. "Implications of Skill-Biased Technological Change: International Evidence," *Quarterly Journal of Economics* 113 (November): 1245-1279.

Bernard, Andrew B., and J. Bradford Jensen. 1997. "Exporters, Skill Upgrading, and the Wage Gap," Journal of International Economics 42 (February): 3-31.

Blackburn, McKinley L., David E. Bloom, and Richard B. Freeman. 1990. "The Declining Economic Position of Less Skilled American Men," in Gary Burtless (ed.), A Future of Lousy Jobs? The Changing Structure of U.S. Wages, Washington, D.C.: The Brookings Institution, pp. 31-67.

Blank, Rebecca M. 1994. "Employment Strategies: Public Policy to Increase the Work Force and Earnings," in S. Danziger, G. Sandfur, and D. Weinberg (eds.), Combatting Poverty: Prescriptions for Change. Cambridge, Massachusetts: Harvard University Press.

Blau, Francine D., and Lawrence M. Kahn. 1996. "International Differences in Male Inequality: Institutions versus Market Forces," Journal of Political Economy 104 (August): 791-837.

Booth, Alison L., and Dennis M. Snower (eds.). 1996. Acquiring Skills - Market Forces, Their Symptoms and Policy Responses, Cambridge, England, Cambridge University Press.

Borjas, George J., Richard B. Freeman, and Lawrence F. Katz. 1997. "How Much Do Immigration and Trade Affect Labor Market Outcomes?" *Brookings Papers on Economic Activity* (1): 1-90.

Burtless, Gary. 1995. "International Trade and the Rise in Earnings Inequality," *Journal of Economic Literature* 33 (June): 800-816.

Calmfors, Lars. 1994. "Active Labor Market Policy and Unemployment – A Framework for the Analysis of Crucial Design Features," *OECD Economic Studies* 22: 7-47.

Chennels, Lucy, and John van Reenan. 1999. "Has Technology Hurt Less Skilled Workers: An Econometric Survey of the Effects of Technical Change on the Structure of Pay and Jobs," Working Paper No. W99/27, Institute for Fiscal Studies, London.

Desjonqueres, Thibaut, Stephen Machin, and John van Reenan. 1999. "Another Nail in the Coffin? Or Can The Trade Based Explanation of Changing Skill Structures Be Resurrected?"
Scandinavian Journal of Economics 101 (4): 533-554.

DiNardo, John E., and Jörn-Steffen Pischke. 1997. "The Returns to Computer Use Revisited: Have Pencils Changed the Wage Structure Too?" Quarterly Journal of Economics 112 (February): 291-303.

Fitzenberger, Bernd. 1999. "International Trade and the Skill Structure of Wages and Employment in West Germany," Jahrbücher für Nationalökonomie und Statistik 219 (July): 67-89.

Fitzenberger, Bernd, and Stefan Speckesser. 2000. "Zur wissenshaftlichen Evaluation der Activen Arbeitsmarktpolitik in Deutschland: Ein Überblick," Discussion Paper No. 00-06, Center for European Economic research/ZEW, Mannheim.

Franz, Wolfgang. 1999. "Real and Monetary Challenges to Wage Policy in Germany at the Turn of the Millenium: Technical Progress, Globalization and European Monetary Union," Discussion Paper No. 99-48, Center for European Economic Research/ZEW, Mannheim.

Freeman, Richard B. 1995. "Are Your Wages Set in Beijing?" *Journal of Economic Perspectives* 9 (Summer): 15-32.

Goldin, Claudia, and Lawrence F. Katz. "The Decline of Non-Competing Groups: Changes in the Premium to Education, 1890 to 1940," Working Paper No. 5202, National Bureau of Economic Research.

Griliches, Zvi. 1963. "Capital Skill Complementarity," *Review of Economics and Statistics* 51 (November): 465-468.

Harhoff, Dietmar, and Thomas J. Kane. 1997. "Is the German Apprenticeship System a Panacea for the U.S. Labor Market?" *Journal of Population Economics* 10 (May): 171-196.

Haskel, Jonathan. 2000. "The Trade and Labor Approaches to Wage Inequality," Discussion Paper No. 2476, Center for Economic Policy Research, London.
Haskel, Jonathan, and Matthew J. Slaughter. 1998. "Does the Sector Bias of Skill-Biased Technological Change Explain Wage Inequality?" Working Paper No. 6565, National Bureau of Economic Research.

Haskel, Jonathan, and Matthew J. Slaughter. 1999. "Trade, Technology, and U.K. Wage Inequality, " Discussion Paper No. 2091, Center for Economic Policy Research, London.

Heckman. James J., Rebecca L. Roselius, and Jeffrey A. Smith. 1994. "U.S. Education and Training Policy: A Re-evaluation of the Underlying Assumptions behind the New Consensus." In Lewis C. Solmon and Alec R. Levenson (eds.), *Labor Markets, Employment Policy, and Job Creation*, Boulder, Colorado: Westview Press, pp. 83-121.

Heckman, James J., Robert J. LaLonde, and Jeffrey A. Smith. 1999. "The Economics and Econometrics of Active Labor Market Programs," in Orley Ashenfelter and David Card (eds.), *Handbook of Labor Economics Vol. 3A*, Amsterdam: Elsevier, pp. 1865-2097.

Heckman, James J., Lance Lochner, Jeffrey Smith, and Christopher Taber. 1999. "The Effects of Government Policies on Human Capital Investment, Unemployment and Earnings Inequality," in *Third Public GAAC Symposium: Labor Markets in the U.S.A. and Germany*, Center for European Economic Research/ZEW, Mannheim, pp. 305-336.

Jacobson, Louis, Robert J. LaLonde, and Daniel G. Sullivan. 1997. "The Returns From Community College Schooling for Displaced Workers." Unpublished paper. Chicago, Illinois: Federal Reserve Bank of Chicago.

Juhn, Chinhui, and Kevin M. Murphy. 1994. "Relative Wages and Skill Demand, 1940-1990." In Lewis C. Solmon and Alec R. Levenson (eds.), *Labor Markets, Employment Policy, and Job Creation*. Boulder, Colorado: Westview Press, pp. 343-360.

Johnson, George E. 1997. "Changes in Earnings Inequality: The Role of Demand Shifts," *Journal of Economic Perspectives* 11 (Spring): 41-54.

Lawrence, Robert Z. and Matthew J. Slaughter. 1993. "Trade and U.S. Wages: Giant Sucking Sound or Small Hiccup?" *Brookings Papers on Economic Activity, Microeconomics* 2: 161-226.

Lechner, Michael. 1999. "Comment [on Heckman *et al.*]," in *Third Public GAAC Symposium: Labor Markets in the U.S.A. and Germany*, Center for European Economic Research/ZEW, Mannheim, pp. 340-348.

Katz, Lawrence F., and Kevin M. Murphy. 1992. "Changes in Relative Wages, 1963-1987: Supply and Demand Factors," *Quarterly Journal of Economics* (February): 35-78.

Krueger, Alan S. 1993. "How Computers Have Changed the Wage Structure: Evidence from Microdata, 1984-90." *Quarterly Journal of Economics* 108 (February): 33-60.

Krugman, Paul. 1995. "Technology, Trade and Factor Prices," Working Paper No. 5355, National Bureau of Economic Research.

LaLonde, Robert J. 1995. "The Promise of Public Sector-Sponsored Training Programs," *Journal of Economic Perspectives* 9 (Spring): 149-68.

Leamer, Edward. 1994. "Trade, Wages, and Revolving Door Ideas," Working Paper No. 4716, National Bureau of Economic Research.

Lynch, Lisa M. 1994. "Payoffs to Alternative Training Strategies at Work," in Richard B. Freeman (ed.), *Working Under Different Rules*. New York: Russell Sage Foundation, pp. 63-95.

Machin, Stephen. 1996. "Changes in the Relative Demand for Skills," in Alison L. Booth and Dennis J. Snower (eds.), *Acquiring Skills - Market Failures, Their Symptoms and Policy Responses*. Cambridge, England: Cambridge University Press, pp. 129-146.

Machin, Stephen, and John van Reenan. 1998. "Technology and the Skill Structure: Evidence from Seven Countries," *Quarterly Journal of Economics* 113 (November): 1215-1244.

Manacorda, Marco, and Alan Manning. 1999. "Just Can't Get Enough: More on Skill-Biased Change and Labor Market Performance," Discussion Paper No. 412, Center for Economic Performance, London School of Economics.

Manacorda, Marco, and Barbara Petrongolo. 1999. "Skill Mismatch and Unemployment in OECD Countries," *Economica* 66 (May): 181-207.

Mishel, Lawrence, and Jared Bernstein. 1994. "Is the Technology Box Empty? An Empirical Examination of the Impact of Technology on Wage Inequality and the Employment Structure," Washington, D.C.: Economic Policy Institute.

Mishel, Lawrence, and Jared Bernstein. 1996. "Technology and the Wage Structure: Has Technology's Impact Accelerated Since the 1970s? Washington, D.C.: Economic Policy Institute.

Murphy, Kevin M., and Finis Welch. 1993. "Industrial Change and the Rising Importance of Skill," in Sheldon Danziger and Peter Gottschalk (eds.), *Uneven Tides - Rising Inequality in America*, New York: Russell Sage Foundation, pp. 101-132.

Nickell, Stephen. 1995. "The Collapse in the Demand for the Unskilled and Unemployment Across the OECD," *Oxford Review of Economic Policy* 11 (Spring): 40-62.

Nickell, Stephen and Brian Bell. 1996. "Changes in the Distribution of Wages and Unemployment in OECD Countries," *American Economic Review, Papers and Proceedings* 86 (May): 302-308.

Orr, Larry L., Howard S. Bloom, Stephen H. Bell, Fred Doolittle, Winston Lin, and George Cave. 1996. *Does Training for the Disadvantaged Work? Evidence from the National JTPA Study*. Washington, D.C.: The Urban Institute Press.

Revenga, Ana L. 1992. "Exporting Jobs? The Impact of Import Competition on Employment and Wages in U.S. Manufacturing," *Quarterly Journal of Economics* 107 (February): 255-284.

Richardson, J. David. 1995. "Income Inequality and Trade: How to Think, What to Conclude," *Journal of Economic Perspectives* 9 (Summer): 33-55.

Sachs, Jeffrey D. and Howard J. Shatz. 1994. "Trade and Jobs in U.S. Manufacturing," Brookings *Papers on Economic Activity* (1): I-84.

Wood, Adrian. 1994. *North-South Trade, Employment and Inequality,* Oxford: Clarendon Press.

Wood, Adrian. 1995. "How Trade Hurt Unskilled Workers," *Journal of Economic Perspectives* 9 (Summer): 57-80.

Wall Street Journal. 1996. "A U.S. Education Gap Levels Off. Difference for College/High School Hits Plateau." *Wall Street Journal*, July 22, pp. A2, A5.

Table 1: Changes in the Employment and Wage Bill Shares of Non-Production Labor and Between- and Within-Industry Decompositions, U.S. and U.K. Manufacturing Industry

	Employment Share			Wage Bill Share		
Sample	Total change[a]	Between industry - component	Within-industry component	Total change[a]	Between industry - component	Within-industry component
U.S., 1959-73	0.069	-0.009	0.078	0.051	-0.018	0.069
U.S., 1973-79	0.299	0.112	0.187	0.293	0.085	0.208
U.S., 1979-87	0.552	0.165	0.387	0.774	0.306	0.468
U.K., 1979-90	0.367	0.066	0.301	0.668	0.114	0.554

Note:[a] Annualized percentage point rate of change in the relevant share.
Sources: U.S. - Berman, Bound, and Griliches (1994), Table IV, p. 37.
U.K. - Machin (1996), Table 7.2, p. 134.

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