Non-Technical Summary

In many industrialized countries, high-skill and low-skill labor incomes have been diverging strongly. In other countries, unemployment rates among low-skill individuals have been increasing dramatically. While there is virtually unambiguous agreement that demand for high-skilled labor has been increasing in most, if not all industrialized countries, there is no agreement on the causes of the demand surge. This survey discusses potential explanations for these developments and the contribution that TSER-funded research in the "Innovation, R&D and Productivity" network has made in this line of research. I also discuss the view that labor market flexibility is instrumental in directing shocks from new technologies, trade or capital market liberalization towards either unemployment or wages. The survey finally turns to open research questions and discusses long-term policy responses to the recent developments.
1 Major Trends in Skills and Wages

Over the last decades, wage, skill and employment patterns have been changing dramatically in many industrialized nations. In some countries, there has been a drastic change in relative employment - employment of skilled workers has been rising, and the share of unskilled among the employed has decreased drastically. In countries like the U.K. and the U.S., these changes were accompanied by major increases in wage inequality. In Japan and many continental European nations, wage inequality (among the employed) has risen only very little or not at all while unemployment has been rising steadily, in particular among the low-skilled. In this survey, I will refer to both phenomena jointly as labor market inequality.

There is now considerable agreement that during the 1980s relative demand for highly skilled workers increased. The surge in demand presumably caused relative wages to rise in some countries, while employment patterns were affected in others. The wage trend in the U.S. was particularly remarkable, since it was accompanied by an increase in the supply of highly skilled labor. According to a number of observers, the demand shift was strong enough to overcompensate the downward pressure on wages for high-skilled labor created by an ever-increasing supply. Many authors even agree nowadays that increasing demand for skilled labor has not been confined to the 80s, but that it has been a long-term trend, possibly with some acceleration in the 80s. An even more radical conclusion comes from a study by Goldin and Katz (1998). They detect effects of technology-skill and capital-skill complementarities in the U.S. as early as in the first two decades of the century. These complementarities are as large as the ones observed in the two recent decades.

While there is little disagreement about the phenomenon per se, the controversy on what drives these developments is continuing. This survey provides a brief guide to the literature, and in particular to empirical results that have been produced under the auspices of the TSER network program on "Innovation, R&D and Productivity." Recent (and more detailed) surveys of the general literature have appeared in Levy and Murnane (1992), Autor, Katz and Krueger (1997), Bresnahan (1997) and the Spring 1997 symposium in the Journal of Economic Perspectives. The TSER literature on wages, employment and technology has recently been summarized by Chennels and Van Reenen (1997). Van Reenen (1999) focusses on the impact of new technologies on employment. His assessment can be seen as a complement to this survey.

2 Searching for Causal Links - Increasing Openness or Technology?

While the main topic of this survey is the relationship between technology and wages, it is helpful to consider the most popular alternative hypotheses in some detail. Typically, the search for causes of the observed developments focuses on two candidates. The first is

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1 Recent research suggests that this may also be an important phenomenon in developing countries. See Davidson (1995) and the discussion in Berman, Bound and Machin (1999, ch. V).

2 While there was some debate about the extent and existence of these effects in the 80s, it is by now generally acknowledged that these trends are not artefacts of measurement. For surveys of the international evidence, cf. Freeman and Katz (1995); OECD (1996); Gottschalk and Smeeding (1997); Davis (1992); Blau and Kahn (1996); Berman, Bound and Machin (1997); Berman and Machin (1995).
technology, or better said, an exogenous shift in the supply of technologies which favor the employment of high-skill individuals (skill-biased technical change). The second is increased openness of formerly separated economic systems. According to the most prevalent view, trade liberalization may have led to factor price equalization, i.e., wages for unskilled labor in industrialized countries are approaching wages for unskilled labor in other countries. This survey also considers another aspect of increasing openness, foreign direct investment which emerges as a consequence of the liberalization of capital flows, as an alternative cause in its own right.

Other alternatives have been put forth, but have played only a minor role in the literature. Supply shocks from immigration and increased female labor force participation (Topel 1997), the impact of cohort size (Welch 1979, Berger 1985), and changes in the demand for skill-intensive products (Topel 1993, Murphy and Welch 1993) have been analyzed in the case of the U.S., but the quantitative effects on wage inequality have apparently been minute. For many other countries, in particular European ones, these potential causes of labor market inequality still need to be assessed empirically. Changes in institutions may have been a stronger force in the U.S. than the aforementioned ones. Fortin and Lemieux (1997) estimate that about one third of the increase in female and male wage inequality in the U.S. can be traced to decreasing unionization, economic deregulation and the decline in the real value of the minimum wage. An even more extensive list of forces that may have been affecting the U.S. wage structure are presented in Leamer (1996a, p. 4).

The following two subsections briefly summarize the two dominant contenders in the race for explanations (trade vs. technology). I then briefly discuss the role of labor market flexibility in directing shocks to the demand for skilled labor into either increasing wage inequality or unemployment for the relatively low-skilled.

2.1 Increasing Openness

2.1.1 Trade with Developing Countries as a Determinant of Wages and Employment

Greater wage inequality and increased imports of manufactured goods from third world countries have roughly concorded in time. It is therefore not surprising that "globalization" has come under scrutiny as a potential contributor to the labor market developments. But the debate whether trade has contributed to the recent labor market development is beset with theoretical and empirical disagreements. Freeman (1995) notes that there appears to be a transatlantic divide, disagreement about how to analyze the contribution of trade to labor market inequality, a divide between professionals and populists, as well as disagreement between various sub-disciplines of economics.

The theory of factor price equalization typically rests on a simple \( n \)-factor/\( n \)-goods model. In its simplest version, assume that there is an advanced country and a developing one, two types of labor (skilled and unskilled), and two types of goods (skill-intensive and low-skill-intensive). The advanced country is rich in skilled labor, the developing country in unskilled labor. In a world without trade, household preferences together with factor endowments determine factor

3 Putting it provocatively, Freeman (1995) titles his paper in the 1995 Journal of Economic Perspectives symposium „Are your wages set in Bejing?“ Freeman (1995) notes that this is a complete reversal of the debate in the 60s and 70s where developing countries largely feared that trade would impoverish them while there was virtually no concern about increasing trade volumes in industrialized nations.
prices. Typically, wages for unskilled labor will be higher in the advanced country than in the developing one. Once trade is introduced, the advanced country will import the low-skill intensive good and export the skill-intensive one. The low-skill labor embodied in imported products makes low-skill labor less scarce in the advanced country, hence its wage will fall c.p. Conversely, the increase in production of the skill-intensive product in the advanced country will lead to increased demand (and c.p. higher wages) for this type of labor. Ultimately, factor prices will be the same in the advanced and developing country.

So far for the simple trade story of the Heckscher-Ohlin model.\(^4\) A first glance at trade statistics shows that Western countries do indeed export skill-intensive products while they import low-skill-intensive ones. The opposite holds, by and large, for developing countries. However, the model seems to be at odds with a number of other facts as listed by Freeman in his 1995 survey in the *Journal of Economic Perspectives* on this topic. His conclusion is that there is sufficient theoretical evidence to suggest that trade may have contributed to changes in wage or employment inequality, but that the extent of that contribution needs to be assessed empirically.

Two methodologies have been employed to study the contribution of trade to labor market developments empirically: factor content and price effect studies. Factor content studies calculate from trade data the supply of low-skilled labor "embodied" in imported products and relate the computed factor content to sectoral changes in the skill and wage structure. The estimates from factor content studies differ, but there is general agreement that trade cannot account for more than 10 to 20 percent of the fall in demand for unskilled labor. An exception to this rule is the study by Wood (1994), who estimates that about half of the decline in demand for unskilled labor can be attributed to trade. Freeman argues that this result should be taken as an overestimate of the true trade impact, while the usual results may be considered as a lower bound.

There are numerous criticisms of the factor content studies.\(^5\) The presumably strongest criticism of factor content studies is that they completely disregard the *endogenous* determination of labor embodied in trade.\(^6\) For example, the threat of imports alone may exert considerable downward pressure on factor prices. Thus, studying the impact of "openness" on product prices should in principle be more revealing than studying the effect of factor content on employment and wage patterns.

But careful studies of price effects, such as those provided by Lawrence and Slaughter (1993), Sachs and Shatz (1994) or Krueger (1997) do not deliver a smoking gun in favor of trade as the main determinant of recent labor market developments.\(^7\) There has been (virtually) no fall in the relative price of goods produced in industries with high shares of unskilled labor in the U.S. Thus, these authors conclude that trade has presumably contributed very little to the

\(^{4}\) The extent to which it can be applied to a complex reality is subject to debate. Cf. Freeman 1995, Norman and Venables (1993) or Bhagwati and Dehejia (1994). For an empirical researcher, it is important that the labor market has some characteristics of contestable markets - under some conditions, trade may not even occur, but wages of unskilled workers decline nonetheless in order to counter the threat from potential imports (Freeman 1995, p. 21).

\(^{5}\) See also the survey by Freeman (1995, pp. 25-28).

\(^{6}\) See Deardorff and Haikura (1994) and Leamer (1996a/b) for a detailed analysis.

\(^{7}\) See also Krugman (1995) for an assessment with similar conclusions.
observed patterns of inequality. In a recent survey, Slaughter (1998) concludes that product price studies - while leading to a considerable refinement of the empirical toolbox - do not shed much light on the contribution of trade to labor market developments.

2.1.2 Foreign Direct Investment as a Neglected Alternative?

So far, very little attention has been given to the potential impact of foreign direct investment (FDI) on wage and employment inequality, as Markusen and Venables (1997) note. But economic theory clearly allows for such a relationship. A particularly promising theory of FDI flows, called the "knowledge capital theory" directly implies a skilled-labor bias and predicts (for some parameter constellations) an increasing wage-gap. However, the causality runs from investment liberalization via FDI to changes in the wage structure, not directly from technology or trade to wages.

The research summarized under the label of the "knowledge capital" approach starts from a number of stylized facts (Markusen 1995, 170ff.). FDI has surged, starting in the late 70s, mostly in a reciprocal fashion between industrialized nations. UNCTAD data indicate that the world FDI stock as a percentage of GDP rose from 4.6 percent in 1980 to about 10.1 percent in 1995. Considering only the seven largest developed countries in 1995, their inward FDI is about 13.4 percent of GDP, while outward FDI accounts for 16.5 percent of GDP. The fast growth in FDI has paralleled the growth in trade between developed countries. But the observed investment appears to be mostly horizontal in nature, and there is only very little evidence of complementarity between FDI and export activity. FDI is typically undertaken by large multi-national firms. MNEs are most prevalent in industries with high levels of R&D (relative to output), highly skilled personnel and considerable horizontal and vertical product differentiation. These latter empirical regularities make the choice of a model appealing in which a firm-specific knowledge base plays a major role. It is also natural to seek the source of this capital in R&D, innovation and marketing efforts, given the nature of industries in which FDI is most apparent. Moreover, the internalized exploitation of technologies within the confines of the MNE are consistent with the observation (familiar to any economist studying R&D) that licensing is a rather inefficient way of appropriating quasi-rents from innovation.

The logic of the models focuses on knowledge capital as an asset that has joint input characteristics. For example, by spending some amount on R&D, the firm develops a new product. The design for the product can be passed along at zero cost to a foreign affiliate which will then produce the good without incurring the development costs. Purely local firms may not be able to compete in such a market, since they incur the full cost of R&D per domestic unit of output. If transport costs are relatively high, production of the product by foreign subsidiaries will look particularly appealing in comparison to exporting a good produced in the home country.

The comparative statics of these FDI model results are of particular interest. Markusen (1995) shows that the models predict a growing agglomeration of "innovative" or headquarter activities and the opposite for production. But most important, investment liberalization

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8 Note that the FDI hypothesis does not build on the growing volume of trade between developing and advanced countries.

9 Of course, these also account for a large share of total export volume, and about one-third of international trade is captured by within-MNE flows of goods and services. Thus, distinguishing between trade and FDI as potential causes of labor market developments will be difficult.
implies a skilled-labor bias, potentially triggering an increase of real wages for skilled labor in both home and host countries. Depending on parameter constellations, wages for unskilled labor may rise, too, since investment liberalization has first-order efficiency effects. One should note that this effect is not one of increased trade - actually, FDI flows may be a substitute for trade in these models.

There are alternative explanations for observed FDI flows. The classical hypothesis in the horse race for greatest explanatory power is the factor-proportions hypothesis. But while it has appeal, it generates one prediction that is strangely at odds with the facts: according to the factor proportions story, FDI flows should be directed predominantly into host countries that differ in terms of labor abundance and other factor shares from the home country. This prediction turns out to be the Achilles heel of the theory, as is apparent from even a cursory inspection of the data. Empirical tests (Brainard 1997, Fors 1997) have been able to deliver some support for key predictions from "knowledge capital" models.\(^\text{10}\)

It should be promising to include this hypothesis in empirical work on widening wage gaps. A broad assessment of the contribution of FDI to labor market developments has not been attempted as of yet. One explanation for the lack of such an analysis is the data problem (cf. Brainard 1997). But it seems clear that the FDI story is sufficiently different from the trade explanation sketched in section 2.1.1 to warrant more specific empirical efforts.

### 2.2 Skill-Biased Technical Change

The major alternative to the aforementioned explanations for recent labor market trends concentrates on technological progress, and in particular on skill-biased technical change. According to this hypothesis, it is changes in technology itself which have led to increases in the demand for high-skilled labor. In its simplest form, this argument points to exogenous shifts in the availability of technologies that favor the employment of skilled labor. Proponents of this theory point to new technologies such as information technology which have now diffused into all industries in advanced countries.

The appeal of this theory is that it immediately accounts for the fact that labor market changes, may they affect the wage structure or employment patterns, have been found to be within-industry effects, just as the employment of new technologies has been pervasive across industries. The Achilles heel of this theory is that it has been difficult to identify technical change with directly measurable phenomena (such as the number of new computers installed, etc.). Therefore, many studies have proceeded by first trying to rule out alternative explanations (such as trade or supply effects) before coming to the conclusion that technology is the culprit.

Wage bill studies – either at the industry or the establishment level - have provided strong evidence that technology may be a driving force behind the increasing demand for skilled labor. Two particularly important studies for the U.S. are Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1997). The former authors apply long-difference estimators to four-digit industry level data. They use computer investment and R&D expenditures as observable measures of technology. The wage bill share of non-production workers is affected positively

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\(^{10}\) As is the case with trade, one may want to argue that FDI is driven to some degree by technology itself. To the extent that incentives for R&D increase, incentives for choosing FDI over trade will increase as well in the Markusen (1995) model, *ceteris paribus*. 
by these measures. The Autor/Katz/Krueger study applies the same technique to a much longer
time period from the early 1940s to the 1990s. They find that measures of computer use exert
a positive effect on the wage bill share of skilled workers.

Enterprise-level studies have yielded more modest results. In particular those studies that are
based on the U.S. LRD database – a large panel dataset containing detailed data on large
manufacturing plants – have produced remarkably weak results. Doms, Dunne and Troske
(1997) find evidence of skill-bias in the cross-section, but this result becomes insignificant once
they use the time series dimension of the data. Latent heterogeneity (caused by some
unobserved variable) may thus be the true cause of labor demand changes, but the results may
be equally well accounted for by measurement problems in the technology variables.

An early study looking for correlates of inter-industry wage premia was provided by Dickens
and Katz (1987). Their study points to a large number of factors positively correlated with
wage premia, among them the industry’s R&D intensity. Allen (1996) detects a similar
 correlation – the increase in the return to schooling in the U.S. was most pronounced in
industries with high R&D intensity. Numerous other studies have demonstrated that there is
apparently a stable cross-sectional relationship between changes in the wage structure on the
one hand, and the technological refinement of the industry. But such cross-sectional
correlations just point to interesting issues, they cannot be interpreted as positive evidence of a
causal link between technology and wages. Studies making use of the presumably highest-
quality data do again call for a cautious assessment: Dunne, Haltiwanger and Troske (1997)
find that the wage and productivity dispersion observed in the LRD data are hard to explain by
any observable measures. Computer investment accounts for virtually none of the rise in wage
or productivity dispersion. Yet, computers are highly correlated with changes in the share of
skilled labor employed in these plants. These results pose a new puzzle: why does computer
investment affect the skill distribution, but does not show up in wage and productivity
dispersion?

Searching for effects at the level of the individual worker has not been an entirely promising
exercise, either. In principle, it would be rather comforting if one could show that individuals
using new technologies at the workplace receive higher wages than other employees,
controlling for observable (and hopefully for unobservable) characteristics. Such a result would
provide us with knowledge on the mechanism by which technologies affect the demand for
different types of labor and skills. In a well-known paper, Krueger (1993) found positive wage
effects of computer use at work using CPS cross-sectional data. Objecting to his causal
interpretation of this relationship, DiNardo and Pischke (1997) employed German data very
similar to the CPS to show that while there is a positive and significant coefficient for the
computer dummy variable, similar positive effects emerge for individuals using pencils, though
these effects are stable over time while the computer effects increase. In their view, latent
heterogeneity introduces spurious correlations in these cross-sectional regressions.

Entorf and Kramarz (1997) use matched individual-firm level data from France to test for a
direct association between wages and the use of new technologies. The results do not provide
strong support for the view that individuals using new technologies are remunerated better
than their low-technology colleagues. However, they detect some evidence of a positive
interaction effect between new technology use and experience on wages. One might argue that

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11 See, *inter alia*, Dunne and Schmitz (1995), Tan and Batra (1997), Casavola et al. (1997); Bartel and
while there are no clear wage effects, the use of new technologies may give employees greater job security. In an extended paper, Entorf, Gollac and Kramarz (1997) confirm the Krueger results in cross-sectional regressions. But their data show that the very same workers receiving a cross-sectional computer "premium" received higher remunerations prior to the introduction of the new technologies. At best, the returns to computers are between 2 and 4 percent – far lower than the cross-sectional estimates which are between 15 and 20 percent. They also estimate multinomial logit specifications of employment trajectories, allowing for individual fixed effects and a large number of firm and individual level observables. Employment effects are at best short-lived – there is no long-term job protection originating from the use of computers. Taken together, these results pose the problem how the potential impact of technology is channeled through from firms to individuals, even there is no (or only a very small) computer effect for individuals.

Adding to the sober character of these results, there has been a major theoretical criticism by Leamer (1996a). He argues that many of the studies ruling out a role for trade in determining labor market outcomes have been ignorant with respect to trade theory. One of the key concepts of trade theory, the Heckscher-Ohlin model, has not been taken seriously. Furthermore, he brings to the attention of researchers in this field that factor-biased technical change alone will not affect the wage structure and that instead, in a multi-sector model it would take an industry bias in order to yield such effects. Leamer refers to this result as the "factor price irrelevance theorem." Hence, the focus on factor bias may be misleading altogether.

A direct response to Leamer's critique has been delivered by Berman, Bound and Machin (1997) (referred to as BBM) who use the modelling framework preferred by Leamer to show that pervasive technical change may very well affect wages – contrary to the conclusion drawn by Leamer. Their theoretical argument can be captured by noting that as frictions to trade disappear more and more, the world is approximately described by a closed, yet global economy. For such an economy, pervasive technical change will have wage structure effects again (Krugman 1995). Their theoretical results suggest a number of hypotheses that can be tested. First, pervasive technical change should produce a within-sector shift towards greater employment of skilled labor in all developed nations. Second, these shifts in the skill structure are strongly correlated across developed nations.

Besides analyzing data from the U.K. and the U.S. for the time period from 1970 to 1990, BBM test these predictions using data from the United Nations General Industrial Statistics Database, concentrating on ten of the top twelve countries in that dataset for which detailed data are available. It is clear from these statistics that the share of non-production workers (the proxy for skilled labor) is increasing in the manufacturing sectors of all these countries, and that the increase is largely within rather than between industries. Recall that these changes take place despite increasing or flat relative wages in the 80s. Moreover, BBM show that the shifts in labor composition are highly correlated across countries, supporting their claim that technical change has been pervasive. Their claim is also bolstered by the observation that skilled labor has seen relative wage increases in developing countries as well – contrary to predictions from a simple Heckscher-Ohlin model.

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12 This result was established in the late 1950s. See Haskel and Slaughter (1999) for a discussion.

13 This conclusion is also apparent in the work of Katz and Summers (1989) and Krueger and Summers (1987) who study the cross-country correlation of wage changes.
Other research in the aftermath of the Leamer critique has also tried to pay attention to the points raised by Leamer. Harrigan and Balaban (1999) estimate the relationship between wages, technology (measured as TFP), prices and factor supplies. Their results are noteworthy in three ways. First, they find that both price changes and capital accumulation increased the relative wages of skilled workers in the U.S. Second, they suggest that the "Factor Price Insensitivity Theorem", brought into the debate by Leamer, does not hold in their data. Third (and perhaps most importantly), they find large capital stock elasticities which they interpret as indirect support for those who view technical change embodied in new capital goods has played a major role in the U.S. labor market experience. Haskel and Slaughter (1999) study the developments in the U.K. labor market from the 1950s to the 1970s and set up a "horse race" between trade and technology. Trade is measured as the change in product prices, and technological change is operationalized via TFP growth. Their results indicate that wages have been affected strongly by trade, but not by technology. Technological developments in themselves may have been determined by trade pressures.

2.3 The Role of Labor Market Flexibility

Some countries have witnessed major changes in the wage structure, while in others, relative wages have largely been unaffected, but relative employment patterns have shifted towards more high-skilled labor. Economists have captured this dichotomy in an appealingly simple model which is often taken as self-evident economic truth.\footnote{For a formal model supporting this view see Davis (1996).} According to this view, labor market flexibility is seen as the key variable directing shocks from potential demand drivers (new technologies, trade or capital market liberalization) towards \emph{either} unemployment \emph{or} wages. This stylized view is expressed in Figure 1, where the left-hand diagram refers to a prototypical labor market with low flexibility and the right-hand side graph gives a stylized description of the development in labor markets with relatively high flexibility.

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**Figure 1**

Relative Wages and Unemployment

To give a concrete example for a (presumably) low-flexibility market, unemployment of unskilled German workers increased substantially during the 80s and early 90s while the distribution of earnings was remarkably stable (Steiner and Wagner 1998). But the German
economy is affected by technological change and international competition about as much as the U.S. economy. Why do labor market outcomes differ when the underlying changes affect both economies equally? The standard explanation rests on the assumption that institutional factors play a much larger role in Germany than in the U.S. These factors - the story suggests - lead to a rigid wage structure. Causes of rigidity include effective wage floors set by collective bargaining agreements, the unions' egalitarian wage policies aiming at uniform relative wage increases, and high earnings replacement ratios in income support programmes.

But not all observers are fully convinced that these factors have contributed to the high unemployment rates of unskilled workers in Europe, and in Germany in particular. Moreover, it has been difficult to demonstrate that there is indeed a trade-off between wage inequality on the one hand and employment inequality on the other. For a small cross-section of developed market economies, an OECD report (OECD 1996) indicates the existence of a significant positive relationship between unemployment rates and earnings inequality. But this correlation is not robust - it disappears when first differences of unemployment rates rather than their levels are considered.

Blau and Kahn (1996) cover a larger number of countries and find that employment ratios of low-skilled workers are lower in countries with a more compressed earnings distribution than in the U.S. But there results are criticized by Leuven et al. (1997) who show that using an alternative measure of skill may change the results drastically. Using a skill classification based on literacy scores, Leuven et al. (1997) they find that a simple demand-supply model does a fairly good job in explaining differential wage inequality between the U.S. and Germany on the one hand, and between Sweden and the Netherlands on the other. Given that technological developments and trade have affected these countries in very similar ways, these results raise the thorny question whether the performance of the respective educational systems in these countries has caused differences in the supply response to rising demand for high-skilled labor.

Nickell and Bell (1995) provide a particularly detailed study in which they compare the development of relative unemployment rates and wages by skill groups in several OECD countries. They conclude that there is no evidence whatsoever supporting the notion of the aforementioned trade-off. A comparative study including the U.S., Canada and France has been provided by Card, Kramarz and Lemieux (1996). These authors find again little evidence for the wage-employment inequality trade-off.

On the basis of a similar methodology as employed by these authors, Krueger and Pischke (1997) and Beissinger and Möller (1998) find for Germany that there is no significant correlation between the change in the employment-to-population ratio disaggregated by age-education cells and the respective wage in the base period. Considering other studies for the case of Germany, Steiner and Mohr (1998) point out that many of the studies which find a significant negative relationship between the relative employment of unskilled labor and relative wages rely on the estimation of standard partial-equilibrium labor demand models. They also argue that estimated substitution elasticities between unskilled and skilled labor vary considerably between the various studies.

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16 Nickell (1997) is particularly sceptical on this point.
While many of these studies have been critical of the trade-off sketched in Figure 1, there is one remarkable supportive account. Hunt (1997) finds in her study of female labor market participation in East Germany that the pleasant drop in gender wage inequality (by about 10 percentage points) was accompanied by the unpleasant withdrawal of a large number of women from the labor market. The hazard of leaving employment over the time period from 1990 to 1994 is largely determined by the 1990 wages. Competing risks analysis demonstrates that the wage has its effect through the demand side via lay-offs. This would be consistent with the hypothesis that union wage rises have caused the least productive to be laid off. While the supply arguments (a reduction in child care) have been given much importance in the public debate in Germany, Hunt finds that this hypothesis cannot explain much of the employment trend.\(^{17}\) The quasi-experimental nature of the data makes the results from this study particularly intriguing.

In conclusion of this subsection we can say that the view according to which labor market flexibility determines whether shocks to relative labor demand are channeled into wage or employment effects certainly has been an appealing one. Yet, it is not uncontested and the empirical support in favor of it is somewhat weak. Much remains to be done to test this model more thoroughly, particularly because it is so appealing to policy-makers.

### 3 The TSER Contribution to the Debate

#### 3.1 A Look at TSER Studies

While the (potential) impact of technology on wages has only been one aspect of the TSER project "Innovation, R&D and Productivity", a large number of papers related to the topic of this survey has been presented at various conferences and workshops. This section discusses the evidence from some of these studies and their contribution to the literature.\(^{18}\) Doing so, I draw partly on a previous survey by Chennells and Van Reenen (1998) and the TSER project reports.

A large number of studies use industry-level data to study the relationship between wages and its determinants. Other studies employ firm or establishment level data. In most cases, a measure of average wages (either for all employees or by skill group) is used as the dependent variable in a wage regression. The objective is then to explore possible partial correlations of wage growth to measures of technology, export and import orientation and control variables. Panel data techniques are used in some studies to strengthen the case of a causal link between technology and wages.

Machin and Van Reenen (1996) use Global Vantage data on firms from Italy, France, the U.K. and Germany to model the average wage as a function of lagged R&D per worker, the capital-labor ratio and other controls. Since R&D disclosure is subject to selectivity effects, the explicitly control for it. In this paper, a significant positive effect of R&D intensity remains, even after the selectivity controls and fixed effects have been introduced. In terms of their

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\(^{17}\) Unfortunately, relatively little has been done so far to relate the labor demand changes in East Germany to the literature discussed in this survey.

\(^{18}\) The set of studies considered here is not complete as of yet. The names of authors of TSER-related contributions are printed in bold in this section.
effect size, technology seems to be a more potent determinant of wages in the U.K. and Germany than in France and Italy.\(^{19}\)

**Van Reenen (1996)** estimates average wage regressions in first-differenced form, using Datastream data on about 600 U.K. corporations. The key right-hand side variables are counts of major innovations, introduced as a distributed lag. These measures turn out to have significant positive effects on average wages, even after controlling for potential endogeneity. Van Reenen interprets these effects as a form of rent sharing. According to this interpretation, innovations do not just raise profits at the firm level, but some of these rents are distributed to workers. Yet, some form of impact on the wage distribution may also be at work.

**Chennels and Van Reenen (1997)** study the development of wages in the U.K., using data on 900 British plants for 1984 and 1990 from the Workplace Industrial Relations Survey (WIRS). Unfortunately, they can only obtain matched data for a panel of 100 plants, since the original surveys were not designed for a panel data approach. They have relatively detailed data as to the use of micro-electronic technologies and computers and can control for a large number of potentially confounding effects (such as unionization, part-time work, firm size etc.). In standard OLS regressions, they find a significant effect of technology on wages, but this effect disappears once they use instrumentation to safeguard against endogeneity distortions.

**Machin, Menezes-Filho and Van Reenen (1998)** employ Datastream data on about 660 firms, covering the period from 1983-94. They observe in these data the directors' pay as well as total wages. Using GMM methods to safeguard against potential correlations between regressors and error terms, and using quasi-differencing to control for latent heterogeneity, they find a positive and significant R&D-earnings elasticity for workers and for directors.\(^{20}\)

**Greenan, Mairesse and Topiol-Bensaid (1998)** conduct a mainly descriptive assessment of the links between computerization, wages and productivity growth in France. Their data originate from the SUSE (unified system of firm statistics) system and contain information on about 2,900 manufacturing and 2,500 service sector firms. Their cross-sectional results confirm results from a previous French study (**Greenan and Mairesse 1996**) as well as U.S. studies such as Lichtenberg (1995) and Brynjolfsson and Hitt (1995) which show a consistently positive relationship between productivity and the extent of computerization. In the time series dimension, the relationship between computerization and productivity vanishes again (as has been observed in other studies). More importantly for the purpose of this survey, changes in the skill structure of the firm are also correlated with computerization - the proportion of non-production workers rises with the extent of computerization. These results are qualitatively similar to those of Berndt and Morrisson (1995) and Autor, Katz and Krüger (1997). However, they have not been confirmed by all research teams. For example, Doms, Dunne and Troske (1997) do not detect such a relationship at the firm level.

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\(^{19}\) Note that the result on Germany is not at all inconsistent with the observation that there is been little wage dispersion in Germany (cf. Steiner and Wagner 1998). Quite to the contrary: if the unskilled in Germany have a greater chance of leaving employment, and if R&D intensive firms are particularly prone to shed unskilled labor, then wages will rise although the typical dispersion measures need not change by much.

\(^{20}\) The latter elasticity is twice as high as the elasticity for workers' earnings. The difference between workers and directors may be partly driven by changes in the degree of diversification of the firm which are presumably correlated with R&D intensity. Cf. Rose and Shepard (1997).
Steiner and Wagner (1998) provide an assessment of wage inequality in Germany. They criticize earlier results and show that neglecting data issues (the inclusion of fringe benefits) in wage data can lead to the spurious conclusion that wage inequality has been rising. According to their results, earnings inequality in Germany has increased very little in the 1980s. Their decomposition analysis based on estimated earnings functions reveals that the relative stability of the German earnings distribution in the 1980s has not resulted from large compensating changes in the composition of the labor force on the one hand, and changes in the returns to human capital on the other. While both of these components have changed little in the observation period, the former rather than the latter component has contributed to the small increase in earnings inequality observed in the register data used in the study. Work by Giles et al. (1997) and Gosling (1997) confirms the result that Germany has been spared from increasing wage inequality. But Giles et al. also point to other interesting differences between Germany and the U.K. Over the life cycle, there is much higher wage growth in Germany than in the UK, and wage inequality is not increasing over the life cycle as it is in the U.K. Given these differences, the incentives for skill acquisition (in particular with firm-specific characteristics) ought to be more developed in Germany than in the U.K.

Falk and Koebel (1997) study labor demand in Germany. Four commonly provided explanations for the shift in labor demand for different skill groups are investigated: the substitutability of inputs; the own-price sensitivity for different types of labor; the effect of economic growth and the impact of technological change. During the period of 1977-1994, the rate of biased technological progress against unskilled workers seems to be large in the traded as in the non-traded goods industries. Furthermore, in three out of five sectors considered, technological change is biased towards high-skilled labor.

Steiner and Wagner (1997) analyze the economic factors which have contributed to the dramatic decline of the employment share of unskilled labor in German manufacturing, in particular the role played by the relatively rigid earnings structure. Potential effects of intensified international competition and skill-biased technological change on the relative employment and earnings position of unskilled workers are also discussed. They find that the substitution elasticity between unskilled and skilled labor is rather low. The decline in the employment share of unskilled workers attributable to an inflexible earnings structure therefore seems to have been modest compared to the trend decline in the skills ratio. Steiner and Wagner also find only modest effects from international competition and technological change on the employment share of unskilled labor.

Steiner and Mohr (1998) question the hypothesis of a trade-off between more jobs for unskilled workers on the one hand, and a less equal earnings distribution on the other. This paper builds on and extends previous work for Germany by Steiner and Wagner (1997) who find a rather low substitution elasticity between unskilled and skilled male labor for the whole manufacturing sector of about -0.3 and a trend decline in the skills ratio of about 3% per year. Given these estimates, the authors conclude that even reductions in the relative earnings of unskilled workers on a scale observed for the U.S. labor market would not have been sufficient to bring employment of unskilled workers in West German manufacturing back to previous levels. In this paper, they extend their analysis for the manufacturing sector to the whole German economy and analyze the economic factors which have contributed to the dramatic decline of the employment share of unskilled labor in German manufacturing, in particular the role played by the relatively rigid earnings structure. They also present some stylized facts on relative earnings and employment trends in the German economy since the mid-1970's.
Fitzenberger (1997) uses an industry-level dataset matched with individual-level wage information for the German economy. He follows Leamer (1996a) by employing a Heckscher-Ohlin-Samuelson model to give his estimates some more structure than is usually the case in this literature. His results are noteworthy, since they support both trade and technology arguments. Skills come in three groups (low-skilled labor, skilled labor and high-skilled labor). Wages have been increasing disproportionately for the low- and high-skilled labor groups, though by very little if the U.S. experience is taken as a benchmark. Employment trends have been in favor of high-skill labor, exclusively. Fitzenberger shows that both import competition and total factor productivity have been increasing disproportionately in those industries which make intensive use of low- or high-skill labor. He interprets this result to be consistent with trade effects affecting low-skilled labor, and technology effects impacting mostly on high-skilled labor. In a recent extension of this work, Fitzenberger (1999) devises a structural model in which the centralized wage bargaining process in Germany is considered explicitly. His model is one of the first to actually open the black box of wage-setting. While the results of this estimation attempt are still preliminary, some success in linking centralized bargaining and union power to wage inflexibility is apparent in this paper.

Büttner and Fitzenberger (1999) employ quantile regression techniques to use the information from the German wage distribution more fully than is typically the case. They argue that in labor markets with central wage bargaining wage flexibility varies systematically across the wage distribution: local wage flexibility is more relevant for the upper part of the wage distribution, and flexibility of wages negotiated under central wage bargaining affects the lower part of the wage distribution. Using a random sample of German social-security accounts, they estimate wage flexibility across the wage distribution by means of quantile regressions. The results support their hypothesis, as employees with low wages have significantly lower local wage flexibility than high wage employees. This effect is particularly relevant for the lower educational groups. On the other hand, employees with low wages tend to have a higher wage flexibility with respect to national employment.

3.2 Common Themes and Problems

The labor market developments at hand constitute major shifts, and it is difficult to argue that there is a mono-causal explanation available. Moreover, as the debate of the last few years has shown, the relevant question is not so much whether it has been increasing trade and capital flow liberalization or technology which caused the changes in labor demand patterns. Rather, the proper question is to ask which part of the change can be accounted for by these and potential other factors. What defeats any attempt to come to firm conclusions at this point, however, is a mix of methodological and of data problems.

Chennels and Van Reenen (1997) have already pointed to a number of problems that most of these studies share, in particular those that consider technology as a potential contributor to recent labor market developments. The practice of identifying technology with a time is definitely outdated by now. More recent studies have attempted to use actual measures (such as R&D or the extent of computerization) which are directly related to technical progress. But since some of these may be determined endogeneously, the results should be taken with a large grain of salt. Unfortunately, attempts to instrument these variables have not met great success - typically, the instrumented variables turn out to be insignificant. That does not mean that technology has no role in determining the structure of wages. It is well-known that the medicine of instrumentation applied here may in some case be too strong for the patient. If we have only weak instruments (and finding strong ones is the classical problem in this approach),
any information contained in the regressors may be sufficiently watered down to generate insignificant results. One should note that this is a problem common to all studies, may they concentrate on trade or technology. Moreover, technology may cause trade to grow, and vice versa, the threat of imports may spur firms to engage in technical change. Only few studies have tackled these complex relationships in some way.

A cautioning note regarding the operationalization of "skills" comes from the aforementioned study by Leuven et al. (1997). They essentially ask whether it is appropriate to use simple skill measures (e.g., educational degrees or work experience in the well-known Blau and Kahn (1996) study) for the purpose of cross-country comparisons. Arguably, the same question may be posed for long-term studies within a given country.

The choice of the unit of observation is another serious concern in this literature. On the one hand, aggregate data (at the industry level) is more easily available than firm or establishment-level information, in particular if international comparisons are attempted. But this convenience may have a price if one seeks to identify causal relationships. As Dunne, Haltiwanger and Troske (1997) point out, recent research suggests that the overall increase in wage inequality between workers in the U.S. is closely related to an increase in wage dispersion between establishments. In consequence, the preferred type of data to study and decompose changes to the wage structure should be at the establishment level. However, the availability of European studies at the micro-level has been limited by data availability. The French statistical system has produced the qualitatively most advanced datasets to tackle these problems, but much more could be done with additional data of this type.

Finally, Leamer's (1996a/b) criticism of labor economists' work in this area (in particular of factor content studies) has left a visible mark in the research field. Attempts have been made now to better justify the estimation framework, using partial- and general-equilibrium models as the foundation. But the research is still very much in flux, and established positions that were still held by a majority of economists (such as the relative irrelevance of trade as a contributor to labor market developments) is now less palatable than it used to be. Quite to the contrary, it seems that the trade explanation (which looked defeated several years ago) has gained in acceptance, witnessed by the large number of recent studies focussing on the contribution of trade to labor market inequality. Many contributions are now set up as "horse races", allowing both trade and technological progress to assume an explanatory role in the respective multivariate analyses.

4 Promising Avenues for Research

While it may be difficult to draw long-lasting conclusions at this point, it is definitely possible to identify promising avenues for new research. The first suggestion concerns the impact of new technologies on the organization of firms and markets, and in particular the

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21 One of the problems that empirical work faces in many European countries is the lack of such data. Many national statistical systems have been astonishingly resilient against attempts to exploit their micro-data in more effective ways.

22 See Haegeland and Klette (1997) for a study which uses match establishment-worker data in Norway.
complementarity between them.\textsuperscript{23} Even if one is convinced that the increasing demand for high-skilled labor and concomitant changes in the wage or employment patterns in some countries is driven by skill-biased technical change, the way in which new technologies impact on employment and wages has been treated in most studies as a (big) black box. In particular, it would be naive to assume that the implementation of new technologies is orthogonal to other decisions, such as the organization of the firm. Bresnahan, Brynjolfsson and Hitt (1998) are particularly concerned about modelling co-inventions by information technology users which can be interpreted as complementary changes in the organization of work. Taking up the framework developed by Milgrom and Roberts (1990), they find complementarities between IT use and new workplace organization. The latter is characterized by broader job responsibilities for line workers, more decentralized decision-making, and self-managing teams. Both IT and new workplace organization are complements with worker skill. It would be helpful to have additional studies following this model of research in order to open the black box of technology diffusion and adoption.

The second suggestion concerns the mechanisms by which micro-, meso- and macro-level are linked to each other. Most of the studies looking at individuals’ wages and technology use come to the conclusion that there is very little direct incremental remuneration for workers using advanced technologies. While this may still be plausible in an economy that reacts to changes in relative demand for skilled labor by shifting employment rather than wage patterns, this is difficult to understand in the case of the U.S. or the U.K. Moreover, the study by Dunne, Haltiwanger and Troske (1997) suggests that technology affects changes in the dispersion of the mix of workers across plants, but not the dispersion of wages and productivity. The simple demand/supply framework used so far may be outdated – a new framework in which heterogeneity of plants is modelled explicitly may be required to come to new insights.

5 Conclusions for the Policy Community

While scientists can sometimes afford to take their time in search for the best (i.e., most precise) explanation, policy-makers often have to make decisions before the dust has settled. Do the research results summarized here hold any suggestions and insights that can be helpful in this process? Clearly, policy interventions should not ignore causal relationships. Ideally, they should be based on detailed knowledge of these. But some implications can be deduced irrespective of the exact cause of recently observed labor market inequality.

Note first that the discussion among economists has boiled down to a battle between two major hypotheses attempting to explain the growth of labor market inequality – increased openness (in particular, trade with developing countries) and skill-biased technological progress. Given the impressive list of potential causes in Leamer (1996a, p. 4), this reduction of the number of candidates constitutes some progress already.

But it also brings home that policy decisions will not be easy ones. Wage and employment inequality can have desasterous consequences for economic incentives and growth. Inequality may undermine fiscal systems by fostering the shadow economy and by increasing the incentives for deviations from lawful conduct. Yet, the most promising culprits for growing

\textsuperscript{23} This point is not new. As Levy and Murnane (1992, p. 1374) put it: "Finding ways to get into the 'black box of firms' may be critical to learning more about the factors that influence firms' choices of technology and their consequent demands for different types of skills."
inequality – technological progress and trade – also have first-order positive welfare implications. These are sufficiently strong to deter most economists from asking for any restriction on either of them. Instead, economists typically ask for fewer restrictions, e.g., on incentives for research and development or on trade. What can be then done to counter the negative consequences of inequality? It is not too difficult to conclude that human resource policies will play a prominent role in long-term policy decisions, and that there is little in the short run that can be done, save transfer policies to those who are disadvantaged by the labor market developments.

Skills are taken to be exogenous in most of the studies considered before. Yet, policy-makers seeking to identify long-run responses to the new developments will have to come to grips with production of skills itself, and thus with market and state incentives to supply skills. These questions may require new approaches and research efforts, although some interesting research results have already come up. Consider the literature on training incentives, i.e. the motivation for generating and improving skills. Since Becker (1964) provided an elegant conceptual distinction between specific and general human capital questions in this field looked settled. But more recent research has emphasized that the simple rule “the individual pays for general, the firm pays for specific human capital” does not fit the data well (Pischke 1996; Acemoglu and Pischke 1997; Harhoff and Kane 1997). Knowing more about the incentive structures underpinning privately provided training could turn out to be very important when it comes to adjust institutions and policies to the new labor market challenges. This challenge has been taken up in recent TSER-related papers by Dearden et al. (1997) and by Blundell et al. (1996, 1997).

The problem is made more complex precisely because new technologies are now being generated at a rate that surpasses the usual learning process. Some research within the TSER network has produced evidence that the rate of skill obsolescence is increasing, and that it is particularly high in industries with fast technical change (Blechinger and Pfeiffer 1997). Such a result gives credence to the often-heard statement that the age of a once-and-for-all learning episode followed by several decades of work that are based on the prior educational investment may be over. Such an insight (if it does indeed hold) would call for a drastic revision of educational and training policies. Implementing such improved policies will definitely require a better understanding of the interaction between learning, skills and labor market outcomes. Research conducted under the auspices of the TSER project "Innovation, R&D and Productivity" has hopefully contributed to these new insights; most certainly, the network conferences and workshops have provided an important forum of European scientific exchange. Even more importantly, a follow-up programme under the title "Growth, Inequality and Training" is under way and seeks to tackle questions that are closely related to the ones discussed here.

24 See the contributions in Booth and Snower (1996) for a recent collection of such results.

25 To give an example, some participants in the German debate about new forms of training and learning have called for a “modularized version” of the apprenticeship system such that young apprentices as well as older workers who seek to update their knowledge participate in the same training classes either at the firm or at vocational schools.
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