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Special Issue on Technology, Productivity and Employment

Introduction

Knowledge, Skills and Growth: Some Economic Issues

R&D Externalities and Productivity Growth

The Dynamics of Innovation and Employment: An International Comparison

Technology and the Demand for Skills

Changes in the Demand for Skilled Labour in France, 1970-93

Asymmetric Growth Effects, Skill Mismatch and Unemployment Persistence

Technical Progress, International Trade and Low-skilled Labour

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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FOREWORD

Prepared by the OECD Directorate for Science, Technology and Industry, the *STI Review,* published twice yearly, presents studies of interest to science, technology and industry policy makers and analysts, with particular emphasis on cross-country comparisons, quantitative descriptions of new trends and identification of recent and future policy problems. Because of the nature of OECD work, the *STI Review* explores structural and institutional change at global level as well as at regional, national and sub-national levels. Issues often focus on particular themes, such as surveys of firm-level innovation behaviour and technology-related employment problems.

The articles in this issue have been selected from the papers presented at a Workshop on "Technology, Productivity and Employment: Macroeconomic and Sectoral Evidence", organised jointly by the OECD and the French Ministry of the Economy in June 1995. The Workshop was part of the activities undertaken at the request of the G-7 countries and the OECD Council on the relationship between technology, productivity and job creation in the framework of the follow-up to the *OECD Jobs Study.* Its purpose was to examine issues such as the role of technology in productivity growth, differing employment performances or widening wage differentials in OECD countries, and to assess their implications for policy making.

The views expressed in this publication do not necessarily reflect those of the Organisation or of its Member countries. The *STI Review* is published on the responsibility of the Secretary-General of the OECD.

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INTRODUCTION

The articles in this volume have been selected from the papers presented at a Workshop on **"Technology, Productivity and Employment: Macroeconomic and Sectoral Evidence"**, organised jointly by the OECD and the French Ministry of the Economy in June 1995. The Workshop was part of the activities undertaken at the request of the G-7 countries and the OECD Council on the relationship between technology, productivity and job creation, in the framework of the follow-up to the *OECD Jobs Study*. Its purpose was to examine issues such as the role of technology in productivity growth, differing employment performance or widening wage differentials in OECD countries and to assess their implications for policy making. It consisted of three half-day sessions, and a concluding half-day policy round table.

The analytical sessions of the workshop

The first session of the Workshop (Technology, Productivity and Growth) addressed the role of innovation and of technology diffusion in the process of economic growth. Papers stressed that productivity and growth are largely determined by the rate of technical progress and the accumulation of knowledge, and showed that the "knowledge-intensive" part of the economy is often the most dynamic in terms of output and employment growth. They examined the role of learning for realising the productivity potential of new technologies, and provided evidence that industry-level and economy-wide productivity depend both on the efforts that firms themselves make in developing new products and production techniques, and on the process of domestic and international technology diffusion.

While the papers in the session pointed to significant and positive impacts of R&D and of technology spillovers on productivity growth, the results presented suggested that the actual estimates depend on the approach used, the sector of the economy analysed, and on the source (public or private) of technology. In terms of technology diffusion, R&D embodied in intermediate and capital inputs was found to be particularly important for productivity growth in the services sectors of OECD countries. The role of the information and communication technology cluster of industries was also examined, and it was shown that information and communication technologies are the fastest growing and most pervasive of all the technologies currently diffusing through and across OECD economies. The role of international spillovers and of imported technology was stressed, with evidence suggesting that materials and equipment, as well as ideas sourced from abroad, contribute significantly to the productivity gains made by domestic industries.

The second session (Technology and Employment) examined evidence on the impact of technology on jobs at the macroeconomic and sectoral levels. The papers took very different approaches to the question: two papers used sectoral-level data to examine trends in employment in different OECD countries and to explore the determinants of employment performance at the level of individual industries; two other papers presented the results of large international studies undertaken recently on the issue of technology and employment performance; while the final paper in the session used an international macroeconometric model to simulate the impact of productivity growth on employment performance under different policy scenarios.

The papers tended to suggest that employment in OECD countries has grown fastest in the dynamic parts of the services sector, as well as in the high-technology, high-wage, skilled-labour part of manufacturing. Product-market restrictions in Europe were found in one study to be at least as important as labour market rigidities in explaining the weak employment growth, notably in services. Macroeconomic model simulations suggested that, in the short and the medium term, temporary increases in unemployment following a rise in productivity cannot be excluded, but that the proper functioning of adjustment mechanisms should prevent a substantial pick-up of unemployment for a prolonged period. The adjustment process is likely to be affected by policy so that, for example, lower real interest rates may substantially shorten the adjustment period.

Session 3 (Technology and Skills) addressed the increasing concern as to how the use of new technologies affects the demand for workers with different skills. This concern arises from the growing wage gap between skilled and unskilled workers in several countries (especially the United States and the United Kingdom), and the high unemployment rates among low-skilled workers in other countries where minimum wages are high. Many studies have argued that skill-biased technical progress substantially reduces the demand for low-skilled workers and generates mismatches between the skills required for the new jobs created and the existing skills of workers. The session examined the empirical evidence on skill-biased technical progress, and the importance of technology *vs.* that of other factors (trade, wage flexibility) for shifts in the demand for labour with different skills.

The papers presented in the session brought different perspectives, and different data, to address this issue of technology and skills. One approach taken by several researchers in identifying skill-biased technical change is to examine how the skill mix of workers has changed over time and, in particular, whether the increasing skill level of the workforce is the result of upskilling within many industries, or whether the overall skill level is increasing because high-skill sectors are gaining employment share. The evidence presented varied by country: in the United States and the United Kingdom the increased demand for skilled workers was more consistent with technology-based arguments, while in France the rapid increase in the number of educationally highly qualified was due to shifts in demand in favour of sectors and occupations for which human capital requirements are important, as well as an increase in the supply of graduates and a decline in relative earnings. A number of papers also explicitly addressed demand/supply mismatches, with one study concluding that their existence implies that wage flexibility alone will not decrease unemployment.

Policy conclusions

The Workshop concluded with a policy roundtable that discussed the implications of the analytical sessions for the formulation of policy in the area of technology, productivity and employment. In terms of technology and productivity, participants focused on the importance of the process of technology diffusion for realising economy-wide productivity gains and the existence of spillovers from innovative activities. These suggest the need for a policy environment that maintains a balance between measures that encourage innovation and those that remove obstacles for its diffusion, and that addresses all sectors of the economy, and notably services, and the interaction between them. A broader and more flexible policy framework towards technology and innovation was urged, one less centred on R&D and more aimed at promoting flexibility in the organisation of the firm and the workplace, and building human capital. Competition policy is also important in this respect: in order to facilitate effective linkages among R&D performers and to encourage spillovers, policy needs to be tilted to favour dynamic gains at the expense of short-term static welfare costs, notably by minimal restrictions on research joint ventures.

At the same time, the diversity of behaviour within industries militates against attempts to encourage specific sectors or technologies, while the mixed record of publicly supported innovative efforts implies the need for close scrutiny and assessment of existing programmes. Traditional methods of support of innovative effort need to be reviewed, with a possible shift away from R&D subsidies and towards policies that reduce technological uncertainties, reserving direct R&D support for cases of large market failures. The importance of an open international environment was highlighted by the fact that in the presence of imported technology, restrictions in trade or foreign investment will also bring costs to domestic producers who source inputs from abroad, in addition to the traditional welfare costs. The role of technology embodied in new capital equipment for productivity growth was also singled out, with the implication that the cost of capital as well as stable policy rules are both essential, both for bringing forth new investment, and for reducing labour adjustment costs associated with new technologies.

In terms of technology and employment, participants noted that what generates job growth is a broad set of factors and therefore the necessary policies also cover a broad spectrum. Many of the analytical studies presented found that product market shifts (including demand, trade and technology-induced shifts) are increasingly important. These changes reflect the adjustment by OECD countries to dynamic (knowledge-intensive) comparative advantage. In this context, product market restrictions were seen as important obstacles for tapping the pool of potential new jobs in the services sector, especially in Europe. Effective deregulation of product markets, both internal and external (*i.e.* also in terms of trade and foreign investment), in manufacturing as well as in services, is as important as (and sometimes even more important than) policies to create more flexible labour markets. While some participants urged that the removal of product market restrictions should be considered on a case-by-case sectoral basis, others warned that antitrust policy reform is complicated and, even when well-designed, can produce many unanticipated side effects.

Another issue discussed in the context of policies to maintain high rates of growth and employment was the importance of building up stocks of physical and human capital. While human capital was discussed at length in the Workshop, some participants felt that not enough attention was paid to physical capital and to the kind of policy environment that induces its ongoing accumulation. Capital-skill complementarity, and the output and employment expansion effects induced by capital accumulation suggest that sustaining private investment is critical for employment and skill growth, especially in rapidly changing environments. Among other things, this requires a level, liberalised and stable playing field, including the macroeconomic environment. At the same time, it was widely felt that macrostabilisation policy tools should not be used to accommodate "technology shocks", since such shocks tend to be continual, non-synchronised, often sectoral, with long and variable lags, while macrostabilisation policy is short-term and does little to increase adaptation of firms and workers to shocks.

The issues of skills and the quality of jobs being created as well as their remuneration were debated at length by the participants in the policy round table. The analytical studies presented at the Workshop did not produce a consensus on the universality of the skill-biased nature of technological change, with evidence being very country-specific, reflecting the fact that common problems can have very different explanations depending on the institutional set-up in different countries. While it was broadly agreed that a strong complementarity exists between technology and skills, it was also recognised that the way this is reflected in wages, profits or employment depends on institutional characteristics and differences. Furthermore, some studies showed that differences in skills and training tended to play only a limited role in explaining relative employment performance in different countries, suggesting that training is no guarantee against unemployment.

The existence or not of a skill bias in technical change has important implications for the design of policies. If technological change is indeed skill-biased, then how workers receive new skills – through publicly or privately sponsored training – is the main policy issue facing governments. If it is not, and these employment trends are the result of other forces, then training policies would not be appropriate or at least adequate by themselves. Nevertheless, participants felt that the increased demand for higher-skilled workers which is apparent in most countries seems to suggest that policies to upgrade human capital are a necessary part of any strategy to expand employment and create better jobs. It was, however, stressed that training is not sufficient in itself, and that any strategy aimed at addressing the problem of unemployment must have a number of dimensions, and touch on areas as diverse as technology policy, labour market institutions, competition policy and regulatory reform, as well as institutional reform.

The articles in this issue

In his contribution, D. Guellec ("Knowledge, Skills and Growth: Some Economic Issues") emphasises the role of knowledge accumulation in the process of growth in all its forms: the invention of new machines; quality improvement in equipment; as well as human capital accumulation. The article addresses two issues at the heart of "knowledge-based" economies: the dynamics of productivity, in particular with respect to the productivity slowdown; and income distribution, especially the increased wage dispersion between skilled and unskilled workers. With respect to the first issue, the article discusses two types of explanation of the so-called "Solow productivity paradox". The first maintains that the rate of technical change is not higher than before: there are more innovations, but innovation is more incremental. The second argues that the productivity slowdown is due to insufficient maturity of new technologies and insufficient adaptation of other factors. The latter explanation tends to support a temporary character of this slowdown, the former a permanent one.

The hypothesis that "biased technical change" is the source of the growing gap in wages (or unemployment rates) between skilled and unskilled labour is also examined in the article. Guellec proposes to link the present upsurge in wage and employment inequalities to two factors. The first is an increased demand in skilled labour, due not only to technical change but more broadly to the increased economic valuation of all forms of knowledge. At the root of this higher valuation of knowledge is the greater pace of competition which generates market instability. Missing the relevant information is more and more costly for firms, hence the importance of hiring employees able to deal with these management issues, at all levels in the hierarchy. In addition to strengthened demand pushing the wages of skilled labour upward, the second factor underlying the wage gap is the increased rents accruing to these employees. Employees whose decisions have more impact on the firm's performance in unstable markets will claim a bigger share in profits (*e.g.* stock options). In other words, managers are benefitting from higher rents.

P. Mohnen presents a critical survey of the econometric approach to the evaluation of externalities ("R&D Externalities and Productivity Growth"). Various methods have been used to measure the "pool of outside knowledge". In general this measure takes the form of a weighted sum of the R&D stocks of other sectors, where the weights measure the proximity. On the basis of the review of econometric studies to date, the author concludes that there is sufficient evidence to claim that R&D externalities exist. On average, studies estimate that the social rate of return on R&D exceeds the private rate by 50-100 per cent, with the magnitude of the social rate of return depending on the proximity between spillover sender and receiver. The domestic social rates of return to R&D show a great dispersion across industries, while there are clear signs of international R&D spillovers, and mixed evidence that spillovers are geographically localised. There is some evidence that spillovers reduce the demand for labour and intermediate inputs, while there is often complementarity between spillovers and either physical or own R&D capital (*i.e.* firms have to carry out R&D in order to benefit from outside R&D). R&D spillovers have been found to contribute significantly to total factor productivity growth at both the sectoral and economy-wide levels.

From these results, Mohnen draws a number of policy conclusions. First, when evaluating the justification for R&D subsidies, the social, rather than the private, rates of return should be taken into account. At the same time, it is not yet clear which sectors best diffuse R&D so that a sectoral specialisation in channelling R&D subsidies cannot be justified. Spillovers exist, but they are not a free good and firms must have the capacity to absorb outside knowledge: thus the provision of a good educational system and the support of basic research are essential elements in a strategy aimed at building human capital and absorbing outside knowledge. Other policy proposals in this context include a reform of the patent system aimed at increasing the level of disclosure on new products and processes, as well as ensuring that antitrust laws allow R&D co-operation. Finally, in the light of benefits from international R&D spillovers, it is imperative to keep open channels of transmission of technology from abroad such as foreign direct investment, licences, trade, joint research and exchange of information.

M. Pianta, R. Evangelista and A. Perani ("The Dynamics of Innovation and Employment: An International Comparison") examine the effects of technological and structural change on employment in the manufacturing sector of the six largest OECD economies. They show that the manufacturing industries showing the highest rates of investment and innovation experienced in the 1980s greater growth in output and employment. Technology has accompanied the process of structural change, favouring the emergence of new fields of activity which have provided new job opportunities. This "virtuous circle" between technology, growth and employment is however weaker in Europe than it is in the United States and Japan; in European countries, physical investments and innovation have often focused on the restructuring of traditional sectors and have been associated with large labour-saving effects.

The authors also examine more closely the case of Italy, drawing on detailed firm-level data on innovative activities which, in addition to R&D and patenting, cover also non-formalised research, design and engineering, and the shares of product and process innovations. They report an overall negative impact of technology on employment in Italian manufacturing, reflecting mainly the dominant role of process innovations and embodied technical change in firms' innovative activities. Job growth is only found in those industries that are characterised by higher design and engineering expenditures and by higher shares of product innovations. These results suggest that for a better understanding of the impact of innovation on employment, it is necessary to bring together a wider set of indicators of technological activities.

The article by E. Wolff ("Technology and the Demand for Skills") derives several measures of the skill requirements of jobs, and examines how these measures have evolved in the United States between 1950 and 1990. The article examines measures which relate to physical abilities like eye-hand co-ordination, dexterity and strength ("motor skills"); cognitive skills such as synthetic and analytic reasoning, numerical and verbal abilities, and years of schooling; and interactive (supervisory, leadership) skills. Cognitive and interactive skills are shown to have grown during the period, while motor skills have declined; but changes in the educational attainment of both the population and the workforce have outstripped changes in workplace skills, implying that although educational attainments have increased rapidly, the underlying skills of jobs have not increased as fast.

The article also decomposes the changes in the various measures of skills by changes in industrial composition. Generally, the shift in industrial composition has a smaller effect than the changes within industries, a finding similar to that of other papers. The regression analysis of the factors that affect the demand for skills performed in the article suggests that standard measures of productivity growth (both labour and total factor productivity growth) have little relation to skill growth. These variables are however only indirect measures of technology, and this makes the results difficult to interpret. The results also suggest that new vintages of capital seem to stimulate the demand for workers with both cognitive and interactive skills, while the growth of engineering and computer personnel in an industry appears to reduce the demand for workers with high motor skills.

The article by D. Goux and E. Maurin ("Changes in the Demand for Skilled Labour in France, 1970-93") also uses several different measures of skill, including occupation and education. Their analysis follows, and extends, analyses conducted in the United States, with the explicit intention of seeing to what extent developments in French labour markets contrast to those in the United States. There has been an increase in the supply of skilled workers in both countries between the 1970s and the 1990s – the proportion of the workforce with at least some university training has increased markedly. At the same time, there has been a very marked increase in the wage gap between college-educated and non-college-educated workers in the United States. This has not been the case in France, where between 1970 and 1993, the ratio of wages of workers with some college education to those without has actually decreased, although there has been a slight increase in more recent years.

As in other analyses, the authors also examine how the change in industry structure has affected the mix of workers. Although they find that the change of the educational mix is largely the result of changes *within* industries, they also find that changes in industry composition play a larger role in France than in the United States. It is not, however, clear whether these results contradict the skill-biased technical change hypothesis, and in fact this article demonstrates the inherent difficulty in comparing results across countries. France has quite different labour market institutions than the United States, the most potentially important being stronger collective bargaining and high minimum wages. The differences could thus reflect differences in these institutions, in technological change, or a combination of both. For instance, the authors show that the level of low-skilled unemployment is several times that for high-skilled workers. Skill-biased technical change could be manifesting itself as an increase in the unemployment rates for low-skilled workers.

The question of how technology might be related to the increase in the unemployment rates of low-skilled workers is addressed in the article by H. Sneessens ("Asymmetric Growth Effects, Skill Mismatch and Unemployment Persistence"). The article examines two alternative explanations of unemployment persistence: the first is relative wage rigidities and skill mismatch in the face of asymmetric growth related to biased technical change, de-industrialisation or globalisation and competition from low-wage countries; the second is a "hysteresis" phenomenon coming from the progressive disenfranchisement of long-term unemployed workers. An estimation of the model for a cross-section of European countries, and in more detail for France, yields the result that an increase in technical progress increases skill mismatch, and hence aggregate unemployment. The results also suggest that the large increase in French unemployment was a combination of increased minimum wages and technological progress.

Although these estimates are plausible, there is concern over the skill mismatch explanation. First, there is the question of how skill mismatch is defined and measured. Secondly, the results seem to run counter those of other authors who have had difficulty in showing that the rise in European unemployment is the result of skill mismatch. Finally, a third concern is the absence of a training component in the model. If workers realise that their skills are becoming obsolete, won't they invest to acquire new skills? This is an important point since in terms of policy, training and re-education may be substitutes for wage subsidies for low-skilled workers, as Sneessens suggests.

The article by J.-P. Cotis, J.-M. Germain and A. Quinet ("Technical Progress, International Trade and Low-skilled Labour") reviews the theory and evidence on the changing status of low-skilled workers in OECD countries and on the respective explanatory roles of technology, international trade and other institutional changes. The authors find that relative wages and/or employment opportunities of low-skilled workers have declined in the major industrialised countries, although the decline varies widely in extent from country to country and depends on how the labour market functions. At the same time, OECD countries have experienced an upward trend in the relative supply of skilled labour.

Explaining the declining status of low-skilled workers is complex and requires a general equilibrium approach that can account for all the direct and indirect impacts of the factors liable to affect the wage and employment conditions of low-skilled workers. The authors develop a simple model that illustrates the mechanisms at work. They also review the empirical literature on the causes of the decline, examining a number of potential explanatory factors: macroeconomic shocks, a "bias" in technical progress against low-skilled workers, the introduction into world trade of countries with low labour costs, the disappearance of entrepreneurial rent, and the weakening of labour-market institutions. They conclude that it is very hard to quantify the impact of the various factors, especially since they are interdependent. At the same time, they argue that the prevailing view of a "skill-biased" technical change is not entirely borne out by the evidence, while the role of international trade has probably been underestimated to the extent that research makes no allowance for the more contestable nature of markets.

George Papaconstantinou

KNOWLEDGE, SKILLS AND GROWTH: SOME ECONOMIC ISSUES

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SUMMARY

The developed economies are becoming increasingly knowledge based, in the sense that knowledge plays a growing and ever more central role in most economic processes. This may help explain three recent features of OECD economies: the productivity paradox; uncertainty on markets; and the increase in wage inequalities.

Economic growth is more than ever based on the accumulation of intangible capital (R&D, training), whose rate of return relative to physical capital has increased. The productivity paradox may be partly due to mismeasurement of the production of knowledge and a mismatch between an increased private, and reduced social, rate of return on technological innovation, due in turn to more rapid creative destruction.

The increasing importance of innovation in competitive markets has accelerated creative destruction, increasing the instability of market shares and gains ("winner takes all"). Along with institutional change, information technology has contributed to make goods and financial markets more volatile.

The growing role of knowledge results in increased earnings inequalities through two channels. First, demand for skilled workers, those who manage knowledge, is a result of the growing value of knowledge. Second, uncertainty due to market volatility and information asymmetry magnifies the informational rent accruing to decision makers, *i.e.* skilled workers.

I. INTRODUCTION

It is now generally recognised that contemporary developed economies are "knowledge based". The significant feature of the term is that knowledge, in all its forms, plays a growing and crucial role in economic processes such as competition, distribution and growth. Most new technologies concern the storing, processing and communication of information. Intangible investment is growing far more rapidly than physical investment. Firms with more knowledge ("core capabilities") are winners on markets. Transactions in goods, services, labour or financial capital increasingly involve information. Nations endowed with more knowledge (technology) are more competitive. Individuals with more knowledge (skills) get better paid jobs. This strategic role is at the root of increasing investment in all forms of knowledge by individuals, firms and nations. Knowledge of technology is not the only form of knowledge concerned, social and economic knowledge is also valuable. The growing complexity of interactions between economic agents makes it more difficult, and more valuable, to monitor one another's strategies and actions. In turn, monitoring requires information gathering and processing ("economic intelligence"). Failing to extend the definition of knowledge to include this social component would miss a central feature of the knowledge-based economy (KBE).

This is not to say that in the past knowledge was not important. To some extent industry faced the same fate two centuries ago. Manufacturing production existed before the rise of industry, in the sense that textile and other manufactured goods were produced, but not on the same scale as after the Industrial Revolution. At that time, agriculture, and not manufacturing, was the core and basis of economies. Manufactuing was historically carried out by craftsmen, a separate feature of traditional economies. To some extent the same is happening with knowledge, production of which has grown more rapidly over the last decades than any other type of good. Although no statistics are available, the volume of investment (notably R&D) devoted to the production of knowledge is a good indicator. As was the case for industry, the rise of knowledge as the core activity of the economy is occuring in a context of tremendous technological as well as institutional upheaval.

The economics of the KBE remain largely unexplored. Recently, sizeable advances have been made in many fields relevant to an understanding of the KBE. The economics of information deal with the contracts agreed upon by agents faced with incomplete and asymmetrical information. Industrial organisations have modelled market structures and competition related to technology. New trade theory incorporates technology as a main factor explaining international trade and competitiveness. Finally, new growth theory (NGT) formalises the role of technical change in economic growth, treating it as an endogenous factor subject to economic determinants.

This article examines some of these advances in order to shed some light on of the two questions at the heart of the KBE. The first is the dynamics of productivity. The productivity slowdown experienced since the early 1970s is a paradox in an economy based on technical change. The article presents the workings of technical change as a driving force behind economic growth, and its relationships with other factors such as physical and human capital. The second issue is income distribution. The widening wage gap, that is, the growing differential between skilled and unskilled labour compensation, has hit many economies during the 1980s. Rather than presenting a complete and consistent theory, this article aims to stimulate further thinking in directions that have been somewhat poorly explored in many other studies. A better understanding of the economics of the KBE is crucial to an understanding of key issues of OECD economies such as welfare growth and inequality.

II. THE DYNAMICS OF ECONOMIC GROWTH AND KNOWLEDGE IN THE KNOWLEDGE-BASED ECONOMY

Technical change is the driving force behind economic growth. This statement has long been recognised by scholars. But what is the driving force behind technical change? And what are the mechanisms that link (in both directions) technical change and economic growth? The purpose of NGT, which makes use of advances in other fields of economics (industrial organisation, economics of technical change) and in many ways draws on a long tradition in economics, paved by Adam Smith, Karl Marx, Joseph Schumpeter and Nicholas Kaldor among others, is to shed light on these two questions.

Knowledge is the lever by which human beings understand and then transform nature. Knowlege is made operational in various ways and can take various forms. It can be disembodied, in the form of blueprints or procedures. It can be embodied in material devices, machines or intermediate goods (physical capital). It can be embodied in human brains and bodies or in groups of individuals (human capital).

The stock of knowledge can be defined as the set of all the technologies available at a given moment, with no doubling counting. It is made operational (*i.e.* affects productivity) when it is diffused for use in many productive activities. At the outset, notwithstanding adaptation and incremental innovation by adopters, diffusion creates redundancy, not new knowledge *per se*. Multiplying the number of workers able to master a specific technology increases the stock of human capital, not the stock of knowledge. The technological level of an economy is measured not only by its stock of knowledge, as defined above, but also by its stock of human and physical capital. For instance, when a given device enters the stock of knowledge, the people able to master its use enter the stock of human capital, and the machines in which it is embodied enter the stock of physical capital. Interactions (both static and dynamic) occur between these three accumulation variables, as we will now show.

First, an increase in knowledge can take the form of an increase in human capital. When a new surgery technique is invented, most of the discovery is embodied in the team which made the invention. More generally, knowledge related to practice, know-how, is embodied in human capital only, and its expansion reduces to human capital accumulation. When the new technique is diffused to other teams, one can speak of human capital accumulation but presumably not of knowledge accumulation, except for the new knowledge generated by adopters.

Second, new knowledge is generated by human capital. Skilled workers, who master the state of the art in their field, are the source of innovation. In NGT models, the growth of knowledge results directly from the stock of human capital and the stock of knowledge. Researchers use existing theories and devices to create new ones: this is known as dynamic complementarity and is empirically documented by the higher average skill level of workers involved in research (proportion of engineers and doctorates).

Third is static complementarity. Technology is complementary to physical capital and to skilled labour. The methodology for using a given technology is part of that technology. The human component is necessary for the technology to be implemented, maintained, adapted to special uses (all uses are in some way special). A hammer is useless unless one knows how to use it. The efficient use of complex machines requires learning, which is better achieved by skilled workers. Case studies show that productivity levels achieved with the same machines vary greatly depending on the skill levels of the labour force using them (see OECD, 1994, Part II, pp. 125-126, for comparisons of performances achieved by plants using similar numerically controlled machines with workers of unequal skill levels). The complementarity between human capital and other forms of technology is recognised by most econometric studies on cross-section and panel data (Bartel and Lichtenberg, 1987; Crépon and Mairesse, 1994; Doms *et al.*, 1995). Moreover, under the (reasonable) assumption that the value of capital partly reflects its technological intensity, the often-shown complementarity between skills and capital intensity can also be interpreted in the same way (Krusell *et al.*, 1994; Doms *et al.*, 1995).

On the other hand, the theory has been put forward that technology is a complement for unskilled labour, or a substitute for skilled labour (Braverman, 1974). Under this hypothesis, technical change results in a de-skilling of the labour force. The mechanism at work here is the embodiment of a decreasing quantity of knowledge in the labour force as the knowledge stock grows, with an increasing share being embodied in machines and procedures. What are the determinants in the choice of embodying technology in one factor or another? A first answer is that there is no choice, the laws of nature determine the orientation of technical change. However, this answer is not consistent with the facts (*e.g.* Mockyr, 1990). A second answer is that the relative prices of factors induce the choice as to which technology is to be embodied. If factors are complementary, it is better to increase the productivity of the scarcest factor. Conversely, if they are substitutes, it may be better to improve the efficiency of the more abundant factor. Braverman's theory, in the line of Marx, is that capitalists act to weaken the position of workers in wage negotiations. Removing the control of knowledge from them is one means to this end (enhancing competition on the labour market by making workers more similar one to one another, all being deprived of specific skills).

The fourth form of interaction is the creation of new machines and skills through technical change. On the supply side the range of specialties in medicine for instance is extended by advances in knowledge of human health. Moreover, these advances enhance the demand for health care, since they increase the opportunity for better health. As a consequence, the rate of return on the investment in human capital increases. The same mechanism applies to physical capital, the accumulation of which is driven by opportunities created by innovation, especially technical innovation. This fact was recognised by Schumpeter, as well by as the neo-classical theory of growth.

Fifth, technical change is not a smooth process. It is more in line with what Schumpeter called creative destruction (Aghion and Howitt, 1992). Not only does technical change generate demand for new skills, it also reduces, or even destroys, the demand for existing skills. This reflects substitutability between technologies. This point is usually underestimated by scholars of macroeconomic growth since they use aggregate production functions, in which technology appears as a smooth and positive trend in factor efficiency. A different, more realistic picture may be that a given technology is associated with a distribution of efficiency among various factors (*e.g.* skill categories). The renewal of technology entails a change in the whole distribution of factor efficiency. Although the global result must be increased efficiency, it is possible that the own efficiency of some factors is reduced because the features of the previous technology that gave them a specific role have disappeared in the new technology. New technologies improve upon existing ones from a technical point of view but, from an economic point of view they force them out of the market, destroying their economic value. When a new technology takes over the market it tends to generate a renewal of demand for the required skills. The outcome will be either an increase or a decrease in the demand for human capital. However, historians and economists both point to a dominant trend towards higher demand. In other words, if both upskilling and de-skilling occur, the former dominates at the aggregate level and over the long run.

The relative increase in the demand for skilled labour is not new (Abramowitz, 1989). Even the notion of "unskilled labour" has varied over time, reflecting the increase in the educational attainment of most of the population of developed economies. Many studies on the wage gap take as a proxy for unskilled workers, high school graduates (12 years in school), which can be compared with last century's skilled workers. Howell and Wolff (1992) find an increase in the use of interactive (*e.g.* management) and cognitive skills in US industry since 1960, whereas the use of motor skills (strength, dexterity) has decreased. Finally, a striking fact over the long run is that, although the ratio of skilled to unskilled labour has risen, the relative wages of the two categories do not exhibit any long-term trend (there is a succession of periods with increases and decreases). This means that the supply of skilled labour has grown at a pace consistent with demand, which is consistent with the notion that in the long run human capital accumulation reacts to the rate of return on education. The average number of years of schooling in the United States was 9.5 in 1950, and 12.5 in 1984 (Maddison, 1991).

The above discussion shows that human capital and technology are two faces of the same coin, two inseparable aspects of knowledge accumulation. To some exent the same can be said for physical capital. Accumulation of these factors goes hand in hand with innovation: one does not accumulate billion dollars of wheel-barrows or train millions of people as stone cutters. Only the appearance of new devices makes it worthwhile to invest and train.

The return to investment in knowledge in the KBE

Although recently put forward by growth theory, none of these features are new in the economy. The pace of industrial productivity has been more than 2 per cent a year in all the economies which underwent an industrial revolution, starting with the United Kingdom in the late 18th century (Mokyr, 1990; Maddison, 1987). Growth in patents filed in the United States by residents has ranged between 2 and 3 per cent a year from the 1850s on. The number of doctorates granted in the United States has grown by 5 to 7 per cent per year over the same period (US Bureau of the Census, 1975). The question then is: Is there something new in the economy to justify the term "knowledge-based economy"?

As is shown by statistical indices (*e.g.* those presented in OECD, 1995), the share of "intangible investment" in total investment is higher now that it has ever been before. If increased investment in information, R&D and human capital is taking place, one main reason for this must be that the rate of return on these factors has increased relative to investment in physical capital. For instance, in order to extend their production capacity, firms may find it more valuable to invest in a computerised network or a research facility, or to hire an expensive skilled employee, than to set up another plant.

The idea presented here, consistent with NGT, is that this increase in the rate of return on investment in knowledge is basically due to the technological level achieved by the industrialised economies, and is much influenced by institutional change (which in turn relates to technological change). Some of the mechanisms at work are the following:

- The higher per capita income achieved in the developed economies fosters the demand for specific (differentiated) high quality and new goods, which are technology intensive. Moreover, a larger market (due to higher levels of income) favours activities characterised by increasing returns to scale, such as R&D. Because of the complementarity between R&D and human capital, a higher rate of return on the former also favours the latter.

- Lower transportation costs (due to technology) extend the area in which firms compete, breaking down local, protected markets (especially national frontiers). An enlarged international market allows fuller exploitation of increasing returns to scale (the point here concerns *ex ante* increasing returns to scale; it can, and will, often happen that *ex post*, at the equilibrium, once firms have reacted to the size of the market, production batches of each good are actually lower than before). The focusing by firms on their "core capabilities", which has been a driving force in the restructuring of capital for the last 15 years, is consistent with this greater emphasis on economies of scale and scope.
- Intensification of competition increases the opportunity cost for a firm of having an (even slight) lag in technology *vis-à-vis* its competitors. In a protected and ill-informed market, a two- or three-year lag on competitors in the range of goods offered or cost levels was not a problem. This is no longer the case. Consumers are better informed due to their higher human capital and to lower information costs (due to technological advances), and they have access to an enlarged set of suppliers from abroad. In this sense technology allows markets to work more efficiently, which in turn calls for an earlier implementation of new techniques.
- Intensification of competition makes firms' strategies more complex. Forecasting market dynamics, assessing consumer needs, watching competitors' strategies, all become more valuable activities in a competitive economy, and they are all also information consuming activities (see following section).
- A lower relative price for information compared to other factors, since many technical advances in the last decades have taken place in information processing and communication. Activities centred on the processing of information, such as R&D, face lower costs than in the past. In turn, the development of IT is accelerated by demand, mainly through economies of scale.
- Information-related technology is a radical innovation with a broad range of applications in the economy. It is a new, "general purpose technology" (Bresnahan and Trajtenberg, 1994). Mastering it in order to use it efficiently requires agents to invest in complementary assets, especially knowledge. Software, skills, and organisation have to be adapted to this new technological context. Most of the corresponding investment is concerned with knowledge creation activities, which therefore face an increase in their rate of return.

The quantitative assessment of this new economic system is complicated by a lack of data. This is not only the fault of statisticians, but also of economists who have not yet sufficiently defined the concepts they want to measure (*e.g.* innovation or learning). Recently significant progress has been made in the right direction, further progress is, however, necessary to obtain accurate and complete measures of factors (human capital, technology in various forms) and of achievements (differentiation and renewal rate of goods, and their effects on users' productivity or well-being). It should also be noted that a better quantitative appraisal of technology would improve the measurement of physical capital in volume terms. The construction of hedonic prices for electronic components and medicines is a great improvement on existing measures.

The productivity paradox

How can the above framework deal with the "productivity paradox"? How is it possible that an economic trajectory ever more based on knowledge accumulation can result in a slowdown in productivity? How can a slowdown in productivity occur while the rate of return on investment in technology is increasing? Notwithstanding explanations which focus on statistical biases, two types of explanation related to technological dynamics can be offered. Although these explanations are not mutually exclusive (and may both be at work in the medium run), they provide contradictory forecasts for the long-run future of productivity.

First, as pointed out above, the knowledge-based economy generates a faster pace of product innovation because of the higher opportunity cost for a company of being a laggard. However, this does not imply a higher rate of technical change. Products are replaced more rapidly than before, but they are replaced by products with a lower novelty content. There is more product innovation, but innovation is more incremental. The rate of renewal of cars has greatly increased over the last 20 years (Guellec, Ralle and Glénat, 1994), but there is no evidence to show that the technological gap between a 1995 car and a 1975 car is wider than the technological gap between a 1975 car and a 1955 car. Goods change more frequently, but the changes are smaller. Similarly, the increased differentiation between goods provides consumers at any given moment with products closer to their specific needs and tastes. Of course, in the absence of a direct measure of technological achievement, it is difficult to assess the pace of technological change, and any statement on the subject can be challenged by many counter examples. Hedonic prices would provide a relevant instrument. In the case of cars, such indicators as power, gas consumption, braking distance, etc., would help. In the case of the computer industry, despite the perpetual sensation of accelerating change, it would appear that "Moore's law" (the power of ships doubles every 18 months) has applied with strong regularity since the 1960s.

This reorientation of innovation may have hurt the dynamics of productivity. Keeping in mind that a large share of productivity gains in manufacturing comes from learning-by-doing, and that this process is localised (specific to each good), then smaller production batches over a shorter period of time generate, *ceteris paribus*, lower productivity gains. For example in the automobile industry, the supplementary cost caused by differentiation is roughly estimated to be about 45 per cent (Quelch and Kenny, 1994). Moreover, the productivity of research is likely to be reduced. Greater differentiation entails overlapping programmes (between firms), less time for each firm to evaluate and imitate innovations by competitors before implementing its own projects (thus more duplication and errors), the necessity of building *ad hoc* tools for resolving problems which could have benefited some years later from advances in other fields of technology or science. The increase in the quantity of researchers and expenditures per patent filed, in all countries and sectors, over the last 20 years (Englander *et al.*, 1988), can be partly attributed to such a phenomenon. A complementary point raised by Young (1995) is that research aimed at differentiating and marginally improving goods generates less spillovers than research aimed at more extensive innovation. The latter, by definition, entails the creation of knowledge with a broader application, which can be used for further innovation. Although this is difficult to measure, a recent OTA report (OTA, 1995) provides some evidence that "firms have shifted a great portion of their R&D resources away from long-term investments and towards short-term projects. (...) Many central research laboratories at large companies – such as AT&T, IBM, GE, Kodak and Xerox – have been downsized and work more closely with product development divisions" (p. 15).

A second explanation focuses on the learning (in a broad sense) and implementation difficulties of new information technologies (David, 1991. The idea is modelled in Helpman and Trajtenberg, 1994). The principle of IT is simple (binary calculus with electronic means). But their implementation and the full realisation of their productivity potential require many complementary innovations and investments of various types (materials, manufacturing, for realisation; skills, organisation, software for implementation). Moreover, many of these complementary factors have not yet been identified (especially in the field of organisation). In this framework, the slowdown in productivity is interpreted as a delay due to the insufficient maturity of the new technologies and insufficient adaptation of other factors to these technologies.

The two theories presented above have in common thay they predict at the same time a renewal of technologies, an increase in investment devoted to innovation, and a slowdown in productivity. However, the mechanisms on which they rely are totally opposite. The first theory points to a decrease in intertemporal spillovers; that is, an accumulation of knowledge directed towards the short run (immediate benefit). The second theory, in contrast, refers to an innovation effort oriented towards the long run, with few immediate uses. There are long-run spillovers which will only be observable in the future This opposition does not exclude the possibility that both mechanisms are at work at the same time. On the one hand, lower information processing costs, increased world-wide competition, and larger market size drive firms to increasingly differentiate the goods they supply, to reduce delays (just-in-time), and improve quality. These improvements all require technological innovation of a very localised and applied nature, with very few spillovers. On the other hand, the mastering of new technologies requires investment in knowledge creation with few immediate results in productivity terms (longer-run spillovers). Such a scenario points to two ways in which IT have a negative impact on productivity growth: through lowering the cost of innovations with no spillovers, and through requiring investment in learning with few immediate effects on productivity. The two mechanisms lead to contradictory forecasts for the future of productivity. The first mechanism should continue to have an effect in the near future, with a low pace of productivity gains. But the second will vanish and will even have a reverse effect: the productivity potential accumulated will be realised in the future. Further empirical research, especially at the micro level, will be necessary to evaluate the relative strengths of these two trends.

III. TECHNOLOGY, INSTITUTIONAL CHANGE AND THE WAGE GAP

The question has been recently raised as to whether technological change is currently biased toward skilled labour. The issue is to explain the growing gap, in some countries in wages, in other countries in unemployment rates, between skilled and unskilled workers. Dispersion in wages began to increase in the late 1970s and concerns not only education levels but also workers' experience. US workers with low education and little experience experienced a 15 to 20 per cent drop in their real weekly wages in the period from 1979 to 1987 (see Table 1. A broad description of the phenomenon is presented in Cotis *et al.*, see this issue.).

The increase in the wage gap is not universal. It concerns the United States, the United Kingdom and Canada (and Swedish males) (OECD, 1994, Part II, p. 118). The reverse trend can be observed in some countries (the Netherlands, France), while in most countries the gap has not changed over the last 15 years. In the European countries, unemployment rates are higher for unskilled labour (two to three times the rate for skilled workers). This may be due to an institutionally "repressed wage gap" limiting price adjustment on the labour market (*i.e.* minimum legal wage). Due to new technology, the marginal productivity of

Table 1. **US real weekly wage changes for full-time workers (men)**[1]

	1963-71	1971-79	1979-87	1963-87
Education 8-11				
Experience 1-5	20.5	1.5	–15.8	6.2
Experience 26-35	19.3	–0.4	–1.9	17.0
Education 12				
Experience 1-5	17.4	0.8	–19.8	–1.6
Experience 26-35	14.3	3.2	–2.8	14.7
Education 16+				
Experience 1-5	18.9	–11.3	10.8	18.4
Experience 26-35	28.1	–4.0	1.8	25.9

1. Change in log average real weekly wage, multiplied by 100. Education and experience are expressed in years.
Source: Katz and Murphy (1992).

many unskilled workers falls short of the minimum wage, preventing firms from hiring them. However, there are other explanations for the unemployment gap. In a context of job shortages, skilled workers will take less-skilled jobs rather than remaining unemployed (substitution between skilled and unskilled workers).

To tackle the wage gap, other explanations have been proposed in addition to technical change (Bound and Johnson, 1992). International trade (increase in the world supply of unskilled labour), insufficient supply of skilled labour, growing competition in the labour market for unskilled labour (declining power of the unions). While recognising the role of these factors, most empirical studies have concluded that technical change is likely to be the main factor. First, these other explanations are partly refuted by the available data. For example, the greater use of skilled labour relative to unskilled labour has increased in all industrial sectors, independently of the degree of, and increase in, openness to foreign competition, which goes against the external trade thesis (Berman, Bound and Griliches, 1994). The issue, in this strand of analysis, is that technical change is mainly a "residual explanation", since it cannot be measured directly. Second, some direct evidence supports this explanation. Much new equipment (*e.g.* computers) is used mainly by skilled workers or is at least more likely to be present in plants where the skill mix is higher (Chennels and van Reenen, 1995). Moreover, at the individual level, workers who use computers seem to have higher wages than other workers with the same education and experience levels (Krueger, 1993) or they have higher increases in their wages (Entorf and Kramarz, 1995). The explanation could be that those workers who use computers have higher productivity levels than other workers, justifying higher wages.

The impact of technical change on the demand for skills and on the relative efficiency of various categories is hardly arguable. However, some puzzling facts must be mentioned when taking this mechanism as an explanation for the rising wage gap. First, what this strand of analysis tends to show is that there is complementarity between skills and technology. As stressed above, this is not new and can hardly account for the increasing dispersion of the wage structure, which is a more recent phenomenon. The 1970s were characterised by the opposite trend despite the rapid technical change that was at work during this period. Second, one of the most visible features to occur on the labour market in the 1980s was the rocketing salaries of CEOs. CEOs are at the top of the firm's hierarchy, but it is hardly possible to imagine that what happened in lower levels, to other managers and skilled workers, was of a radically different origin. And it is doubtful that a CEO's reward depends to any great extent on computer literacy. Therefore other explanations must also be found for other skilled workers. Third, inequality is not increasing only between skill categories. In the words of Paul Krugman, the increase of inequalities is like a fractal process, it develops not only between identified categories of workers but also within categories. If the rate of return on human capital was the only force at work there would be no reason for this. Heterogeneity between workers of equal skills must also be accounted for.

For the above reasons, this article argues that the hypothesis relating the wage gap to biased technical change through an increase in the demand for skilled labour is not sufficient. Technical change is not the only factor at work, and it does not operate only through demand. Only a general equilibrium approach can account for a shift in relative prices. This would entail examining, in addition to the demand side, the supply side and also the determinants of equilibrium prices. In an imperfect market such as the labour market, due to incentive issues and information asymmetry, equilibrium prices do not equalise supply and demand, which are not their only determinants. Moreover, factor income depends not only on labour market forces but also on other markets, for goods and for capital, which set the price for the services provided by various categories of labour.

The role of labour supply is rejected in some studies because the supply of skilled labour has increased continuously over the past decades. If, as stated above, increasing demand in human capital is a component of, as well as a complement for, technical change, what should be analysed is not the level but the change in human capital. This is usually the case for physical capital (whose price and demand grow together at the same time as those of human capital): it is not its level, but its variation, the investment rate, which is analysed. During the 1980s, the United States experienced a slowdown in the supply of college graduates, after a sharp acceleration in the 1970s. A careful statistical analysis shows that this slowdown in supply played a role that should not be underestimated (Katz and Murphy, 1992).

On the demand side, technical change has not been the only component of structural change. For the last 10 to 20 years the Western economies have experienced broad institutional change and a drift towards deregulation. In many areas where government and regulation controlled resource allocation in the past, decentralised mechanisms are being introduced to a greater extent. Financial markets are expanding, goods and services markets (national and international) are becoming more competitive, labour markets are becoming less regulated, and unions are weaker. As a consequence firms and individuals can no longer rely on strict regulation to constrain their own choices and those of their partners, customers or suppliers. They find themselves confronted with more numerous and complex problems to solve, and more information to process and communicate. These are skill-intensive activities. Competition has brought about changes in the organisation of firms, which have become less hierarchical and favour information communication (horizontal co-operation) in order to be more flexible in the face of an unstable environment. These changes can be empirically shown to be associated with the use of a higher skilled labour force able to communicate and decide (Greenan and Guellec, 1995; Greenan, 1995).

In a nutshell, deregulation has increased the shadow value of information, which in turn has increased the demand for the factors that gather and process it: computers and skilled labour. At the same time, competition has contributed to weakening the unions which in the past allowed unskilled labour to earn quasi-rents by restricting the price mechanisms of the labour market. At this stage we have a more complete picture of what is causing the increase in the wage gap; that is, the factors underlying relative demand and supply changes between skilled and unskilled workers. This story is rooted in the economic textbook, in the sense that relative factor prices tend to equal their relative marginal productivity and are fixed such as to clear markets (they make demand equal to supply at equilibrium). Moreover, this story claims that economic efficiency increased over the period, due to more competitive markets. What I would like to do now is to put forward some further thoughts, which do not contradict the above story, but which qualify certain aspects of it. These are preliminary assumptions, for which the theoretical and empirical framework has yet to be built.

Risk, market volatility and earnings

The central point that is challenged in the following is that markets work such that prices reflect only productivity; that is, growing income inequality reflects growing productivity differentials. Not only has increased competition reduced the rents accruing to unskilled labour, but it has also generated rents for some categories of skilled labour. Two complementary points should be emphasized. First, the "winner takes all" mechanism, especially on goods and financial markets; second, the efficiency wage.

Technical change initially concerns information processing and communication. An increasing proportion of the labour force, especially skilled workers, is involved in information-related activities. Information is first characterised by its public good features. The use of one piece of information by one agent does not preclude its use by another agent, with a near zero marginal cost. For instance, one information on a given market (*e.g.* a forecast of demand) can be diffused to any user with no cost other than its initial production cost; the cost of diffusion is negligible. This characteristic renders information very different from other goods and services which must be produced as many times as they are used, and whose customers must bear the whole cost of production. Consequently, there is no need to produce a same piece of information several times (roughly speaking). Competition in markets for such goods is of a "winner takes all" type (Rosen, 1983; Frank and Cook, 1995). A producer is not rewarded according to his marginal productivity, but according to his rank relative to other producers. If he is first (according to some criterion such as delay, quantity or quality), he will get most of the market. If he is second or after he will get practically nothing. There is no use for a second best or late market forecast, or for a second relativity theory. The case is strengthened when communication costs (and thus diffusion costs) fall, which as has happened over the last decades. This has coined the "superstar theory" since it applies perfectly to the entertainment and sports industries. But its range of application is much broader, and is currently being extended.

On many markets this phenomenon results from the Schumpeterian process of creative destruction. The firm using new technology displaces those firms based on the old one. It takes most of the market, earning a monopoly rent. This rent is temporary, because competitors, who are either imitators or innovators, will come into the market. If they are imitators, they will drive the market price down, the first innovative firm loses its rent, but can keep its technology. If they are innovators, the creative destruction process repeats itself; they push the incumbent out of the market, picking up both the rent and the market. In a sector where technology evolves rapidly, innovators face other innovators, and creative destruction is the normal way of things. The evidence cited above shows that the rate of renewal of goods has tended to accelerate in the recent past in many industries, which would tend to increase the range of markets on which the "winner takes all" mechanism applies.

Of course, reality is more complex. Goods can be horizontally differentiated, such that the second on the market supplies a piece of information slightly different from that supplied by the winner. It will therefore catch some share of demand. Producers can also find it worthwhile to segment the market, such that wealthy customers buy better, and more expensive, information than poorer ones. However, the above-mentioned economies of scale in the production of information set limits to these possibilities, limits which are narrower than for other types of goods. Product differentiation does not exclude informational economies of scale, but it does limit them. It implies that a large part of information is of a more local than general relevance. The "winner takes all" mechanism is spread among a larger number of agents, it is not suppressed (there are more races, thus more winners for a given number of runners, and the gains are somewhat diluted among these winners). For instance, a firm may gain on one market, but lose on another.

The expansion of the markets for information and the shortening of the life cycle of goods have widened the area in which the "winner takes all" mechanism dominates. However, it is not only technology which gives a prominent role to this mechanism. In many cases institutional change has substantially contributed, as for instance, on capital markets, where players fight over the appropriation of huge rents. The problem faced by an investor is to assess the value of an asset (*e.g.* a currency) at some time in the future. The judgement must not only be "quite good", it must be better (more accurate) than those of other investors, and available earlier. This is a race with a very skewed distribution of rewards. Laggards do not simply have lower benefits, they have losses. Moreover, what takes place on financial markets is a near zero sum game (the net gain due to better allocation is low compared with the huge flows involved). Not all participants can win, and the gains of some come from the pockets of others. This applies especially to currency markets and to the markets for corporate control (junk bonds, mergers and acquisitions). This has been illustrated by huge and sudden bankruptcies (*e.g.* Barings in 1995).

A direct effect of the "winner takes all" mechanism is to magnify the dispersion of gains for competitors, and thus the magnitude of risk (this does not exclude the fact that other factors, from the macroeconomy to international co-ordination, have contributed to make economic activities more risky over the last 20 years than for the previous 20 to 30 years). The increase in risk induces an increase in the shadow value of information, and therefore an increase in the return to the factors that manage it. Faced with such risks, firms wishing to raise or to trade in capital are induced to hire high-level experts that must be rewarded as such. This is not to say that the allocation of capital has not been improved by deregulation, but that there are costs associated with the workings of the market, and that the resources required for its functioning must be rewarded. In fact, those countries where the wage gap has widened, notably the United States and the United Kingdom, are those where deregulation took place earlier and was more far-reaching than elsewhere. This is a dimension of the KBE that should be stressed. Knowledge cannot be reduced to technological knowledge. It is not only the interaction with nature that is becoming more complex, but also the interaction between firms, and between people.

It should be noted that the point here is not social efficiency. In a "winner takes all" system the private value of information far exceeds its social value. To some extent this is similar to rent-seeking activities (Krueger, 1974; Murphy *et al.*, 1993). Such activities display increasing returns to scale that in some fields can trigger off a self-enforcing process of demand for skills. The need for you to hire an attorney is increased by the fact that your partners have an attorney: it is a kind of "vicious circle", corresponding to a non co-operative equilibrium in a prisoner's dilemma. The number of attorneys in the United States currently stands at more than one million, three times more than 20 years ago. The same holds true on financial markets (if your trader is less smart or less well equipped than your competitor's, you will lose money). The reason is that rent-seeking activities exhibit increasing returns. As a result, a large amount of resources are diverted away from productive activities into rent seeking.

Does the wage gap reflect only an efficiency gap?

As risk and rent seeking expand, a related move occurs in the mechanisms of wage setting; the spreading of incentive rewards. These forms of reward have in common that firms pay a premium over the market wage in order to assure that their employees do their best for their employer (moral hazard; see Shapiro and Stiglitz, 1984; Yellen, 1984). The rationale is that the worker's effort is, in many cases, not directly measureable by the employer. Only the outcome is measureable (production), which can be affected by external events whose direct impact is unknown. When observing the outcome, the employer cannot separate the employee's own contribution from external shocks. The outcome itself may be imperfectly observed (*e.g.* the quality of a manufactured good, or of a service such as health care). The worker concerned receives an informational rent, in the sense that if his effort was measureable, he would do the same amount of work for a lower compensation.

There are various forms of incentive rewards. One, used especially for positions managing risk, is profit sharing; that is, the attribution to the worker of a share of the outcome. For instance, stock options are often used for the top of the hierarchy. Why should such a type of reward result in higher wages today than did fixed rewards, say, 15 years ago? First, if managers share risk, they must be compensated (risk aversion). This is even more the case when the risk (variance in profits) is higher. Second, companies realised higher profits in the early 1980s than in the 1970s. Managers were in a position to require a larger slice of the cake. Finally, as stated above, in a less regulated world, managers' actions are likely to have a stronger impact on profits. They have more discretionary power since they are less constrained by regulations. A stronger relationship between effort and outcome justifies increasing the share of the outcome accruing to the worker.

Another form of incentive reward is an efficiency wage, which is an informational rent accruing to workers in order to limit moral hazard. In the words of Shapiro and Stiglitz (1984): "To induce its workers not to shirk, the firm attempts to pay more than the going wage; then, if a worker is caught shirking and is fired, he will pay a penalty. If it pays one firm to raise its wage, however it will pay all firms to raise their wages. When they all raise their wages the incentive not to shirk disappears again. But as all firms raise their wages, their demand for labour decreases, and unemployment results. With unemployment, even if all firms pay the same wages, a worker has an incentive not to shirk. For if he is fired, an individual will not immediately find another job." A punishment other than unemployment would be the possibility for the fired worker of finding only a much less well paid job. This threat is made feasible through the reputation mechanism (a trader fired from a bank because of large losses will hardly find another job as a trader in another bank!). Above-market wages are also tailored to attract applications from superior workers (adverse selection), and to reduce turnover among key workers having specific knowledge or having benefited from costly training.

Which factors influence the efficiency wage rate? High monitoring costs, significant possibilities for workers to vary their effort inputs, high costs for employers from shirking, high specific skills and costly training. Let us examine how these factors may have evolved over recent years. Increased codification of tasks performed by unskilled labour (David and Foray, 1995) may have reduced monitoring costs for these workers, and therefore their informational rent. With increasing instability on markets, a greater proportion of employees has to manage a larger quantity of information and take a growing number of decisions. In a stable world, decisions are more routine, their quality is easier to check, and there is more time to do so before the outcome. In the KBE, the cost of monitoring decisions becomes too high for it to be efficient. Employers are obliged to trust their decision-making employees, and that trust has to be paid for. As stressed above, market volatility also increases the cost for employers of mistakes by high-ranking employees. Firms are ready to pay a high price to escape the fate of Barings. Finally, investment in training by firms increased sharply in the 1980s in all OECD countries, thus increasing the cost for a firm of an employee leaving, and thereby improving the bargaining position of trained employees (*i.e.* skilled workers).

There are also contradictory tendencies. For instance, codification of tasks also concerns some skilled positions. Delayering and empowerment are improving the position of blue-collar workers with respect to intermediate jobs. Calvo and Wellisz (1979) point out that, in a hierarchical organisation, the optimal interlayer wage differentials are greater than the differentials in productivity. That is, there is a rent accruing to supervisors, which increases with the number of layers they have under them. The rationale is that, if a supervisor shirks, then the workers he supervises will also shirk. The higher the employee's position, the greater the potential loss to the firm. Delayering may have reduced these rents. On the whole, it does not appear that these trends towards more equality outweigh the factors enhancing inequality.

The above view accords with the fact that skill is only one dimension along which inequality has risen. In an imperfect labour market, workers of equal skill levels may earn different wages. After an adjustment period, more skilled workers (in a same statistically-defined skill category) will migrate to workplaces where rents are higher. This is consistent with the observation that, within the category of high school graduates, the wage differential related to differences in "cognitive skills" (measured by the test score of basic mathematics) was much higher in the 1980s than in the 1970s (Murnane *et al.*, 1995).

CONCLUSION

The main message of this article is that the emergence of knowledge as a central component of the economy, both as a traded good and as a factor, has been instrumental in changing many economic mechanisms, affecting growth, as well as uncertainty on markets and income distribution. Additional theoretical and empirical analysis will be necessary to assess the magnitude of the changes at work, and the specific role played by knowledge.

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R&D EXTERNALITIES AND PRODUCTIVITY GROWTH

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I. INTRODUCTION

This article presents a survey of the econometric evaluation of R&D externalities in relation to productivity growth. Although it inevitably overlaps with previous surveys, the focus here is to describe how econometricians have estimated those externalities, and to summarise their main findings.[1]

The article is organised as follows. In Section II, I explain what econometricians have in mind when they talk about R&D externalities. In Section III, I discuss the measurement of a critical variable in these studies, the pool of outside knowledge, and I briefly describe the modelling aspect. In Section IV, I summarise and interpret the main results that have been obtained in the econometric studies on R&D spillovers. Finally, in Section V, I discuss some policy implications of these results.

II. THE NOTION OF R&D EXTERNALITIES

For a theoretical economist, R&D externalities occur when the knowledge derived from the R&D activities of one producer has unintended consequences on the performance measures (profits, productivity, market shares, and so on) of other producers. On the dark side of it, the industrial organisation literature has dwelled on the incentive problems for doing R&D and the property right issues raised by the less than full appropriability of the R&D benefits. On the bright side, international trade and endogenous growth theorists have focused on the non-stationary property of growth and the prospects for competitiveness due to R&D spillovers.

Strictly speaking, for a theorist, the R&D externalities in a duopoly R&D Nash game cease to exist once the game becomes co-operative and the externalities are internalised by both parties. The empirical economist can hardly make such a distinction for lack of data on the perceived limits of the firm. He refers to spillovers when the R&D effects stretch beyond the boundaries of the R&D decision maker intentionally or not.

There are two main sources of R&D externalities (Griliches, 1979). The first type has to do with rent spillovers. They arise because quality improvements due to R&D are not well reflected in the prices at which goods and services are sold from upstream suppliers to downstream customers. Incorrect prices affect the measured outputs and inputs and hence the productivity growth of the supplier and of the producers down the line.[2] For the growth accountant, these rent spillovers are a measurement problem: if prices could be measured correctly, productivity growth could be attributed more correctly to its original source. But, these rent spillovers are also a fact of life. If the innovator could perfectly price discriminate, no rent spillovers would occur. In practice, rent spillovers are unavoidable given transaction costs and asymmetric information. This first type of externality could be referred to as a pecuniary externality: whatever the distribution of rents from R&D expenditures, the market reaches a new price equilibrium, which in perfect competition corresponds to a Pareto optimum. The second type of externalities are knowledge spillovers.[3] They relate to the diffusion of knowledge. Because of poor patent protection, inability to keep innovations secret, or reverse engineering, part of the benefits from R&D leak out. This public good aspect of R&D (non-rival and non-exclusive), which creates disincentives to engage in R&D, has mainly to do with intra-sectoral R&D spillovers (national or international). But there is more to it. A discovery in one firm, sector or country can trigger new avenues of research, inspire new research projects or find new applications in other firms, sectors or countries. Think of the synthetic fibre initially developed in the chemical industry and subsequently applied in the textile industry, or the first Japanese optical fibber developed in the glass industry and later perfected in the telecommunication industry (Kodama, 1990). This aspect has to do with inter-industry spillovers (national or international).

A distinction is thus made in the literature between the private (or own) and the social rate of return to R&D. The former relates to the benefits that are appropriated by the original R&D perform. The latter refers to the total benefits from R&D, *i.e.* the private rate of return plus all the indirect effects.

III. THE ESTIMATION OF THE SOCIAL RATE OF RETURN TO R&D

There are basically two ways to estimate the social returns to R&D: the case studies approach and the regression approach. Case studies examine in detail all the costs and benefits, direct and indirect, present and future, related to a particular R&D project in a particular sector (*e.g.* Griliches, 1958, on hybrid corn; Bresnahan, 1986, on computers; Seldon, 1987, on forest products; Bach *et al.*, 1992, on space programmes).[4] The regression approach consists in estimating either a production function (the so-called primal approach, which generally estimates an extended Cobb and Douglas) or a factor demand system derived from a dual representation of technology (the so-called dual approach, which generally is based on a flexible functional form of a variable cost function).

The regression approach involves estimating the return on outside R&D, *i.e.* its marginal productivity in the primal approach, its marginal cost reduction in the dual approach.[5] In both cases, a demand function can be appended to the model, in which case the return on R&D captures marginal shifts of both the technology and the demand functions.[6] To estimate these externalities, it is necessary to construct and to introduce in the specification of the producer model one or more variables representing outside R&D, *i.e.* the stock of accumulated and not yet depreciated knowledge from past R&D expenditures by other firms in the industry or by other sectors, regions or countries.

The question is how to aggregate the outside R&D stocks. The basic idea is to construct a weighted sum of the R&D stocks of other sectors, where the weights measure the proximity between the sender and the receiver of spillovers. For this purpose, a weighting matrix A of dimension $n \times n$ is constructed, where n is the number of sectors considered, and where the component *a* measures the proportion of *i*'s research that goes to *j*. We then have $S_{jt} = \sum_{i \neq j} a_{ij} R_{it}$, where S is the outside R&D stock and R is the own R&D stock of knowledge, and the social rate of return on R&D is $\rho_i = \gamma_{Ri} + \sum_{j \neq i} a_{ij} \gamma_{Sj}$, where γ_{Ri} is the private return on R&D in sector i and γ_{Sj} the return on outside R&D in sector j.

Various weights have been used (see Tables 1 and 2). The simplest way is not to weight at all. Ideally, however, it makes sense to give more weight to the R&D coming from a sector close to one's own. An aircraft manufacturer is more likely to benefit from the R&D in "precision instruments" than from research in the wood industry. The proximity could be based on the inter-industry flows of goods and services, capital goods, R&D personnel, patents, innovations, citations or R&D co-operation agreements, following the argument that the more *j* buys from *i*, be it intermediate inputs or capital goods, hires scientists from *i*, manufactures goods patented by *i*, uses the innovations introduced by *i*, cites *i's* patents in its own patent applications, or co-operates with *i* on R&D or beyond the research phase, the more it is technologically close to *i*. Since the diffusion of knowledge goes through all these channels and many more, I would interpret the a_{ij} coefficients in the weighting matrices more as proximity measures than as conductors of knowledge. The weights are generally constructed as X_{ij}/X_i, where X_{ij} is the flow from i to j and $X_i = \sum_j X_{ij}$, *i.e.* R&D flows out in proportion to *i's* sales ratios (the Terleckyj weights). But it could also flow out from *i* to *j* in proportion to *j's* purchase ratio from i ($a_{ij} = X_{ij}/Q_j$, where Q_j is the output of sector j) or to *j's* sales ratios to i ($a_{ij} = X_{ji}/Q_i$). It has also been argued that *j* could benefit from *i's* research indirectly, because *i* gives to *k* and *k* gives to *j* and that, consequently, the closeness would be better measured by the coefficients of the Leontief inverse.

Table 1. **R&D spillovers: primal approach**

Study	Data	Weighting matrix	Rate of return on outside R&D
Domestic inter-industry spillovers			
Raines (1968)	24 industries US	Unweighted sum within the same product field	0.56[1]
Terleckyj (1974)	20 manuf. industries US	I/O flows Investment flows	45 per cent (total) 78 per cent (private) 50 per cent (total)
	13 non-manuf. industries US	I/O flows Investment flows	187 per cent (total) 762 per cent (total)
Terleckyj (1980)	20 manuf. industries US	I/O flows	183 per cent (private)
Mansfield (1980)	20 manuf. industries US	I/O flows	0.27 to 0.54 (total) 0.37 to 0.74 (private)
Postner and Wesa (1983)	13 manuf. industries Canada	I/O flows	0.18 (intramural)[1] –0.26 (extramural)[1]
Hanel (1988)	12 manuf. industries Quebec	I/O flows	100 per cent
Odagiri (1985)	15 manuf. industries Japan	I/O flows	0 per cent
Wolf and Nadiri (1993)	50 manuf. industries US	I/O flows Investment flows	0 per cent (private or total) 11 per cent (private)
Yamada, Yamada and Liu (1991)	45 industries Japan	I/O flows Investment flows	–0.44 to 0.24[1] –0.16 to 0.37[1]
Goto and Suzuki (1989)	50 industries Japan	I/O and investment flows	80 per cent
Goto and Suzuki (1989)	45 industries Japan	Position vector in R&D space	4.3 per cent
Sveikauskas (1981)	102 industries US	Investment flows	861 per cent
Scherer (1982, 1984)	36 to 87 industries US	Patent flows	147 per cent
Griliches and Lichtenberg (1984*b*)	193 manuf. industries US	Patent flows	0 to 90 per cent
Englander, Evenson and Hanazaki (1988)	16 industries 6 countries	Canadian patent flows	–11 to 50 per cent
Levin and Reiss (1988)	116 lines of business US	Parameterised weights	0.77 (process R&D)[4] 0.59 (product R&D)[4]
Sterlacchini (1989)	15 manuf. industries UK	I/O flows Innovation flows	9 to 12 per cent 14 to 30 per cent

Table 1. **R&D spillovers: primal approach** *(cont.)*

Study	Data	Weighting matrix	Rate of return on outside R&D
Harhoff (1994)	443 firms Germany	Position in R&D space	0.03[1]
Hanel (1994)	19 industries Canada	Patent flows	2.6 per cent
Van Meijl (1995)	30 industries France	I/O flows Investment flows Patent flows	41 to 46 per cent 415 to 569 per cent 19 to 24 per cent
Vuori (1994)	27 industries Finland	Position in R&D space I/O and investment flows	83 per cent Insignificant
Ducharme and Mohnen (1996)	25 industries Canada	Patent flows I/O flows Leontief inverse	30 to 685 per cent
Domestic inter-firm spillovers			
Jaffe (1986)	432 firms US	Position in patent space	30 per cent of own rate
Jaffe (1988)	573 firms US	Position in patent space	0.10[1]
Sassenou (1988)	394 firms Japan	Unweighted sum	10 per cent of own rate
Mairesse and Sassenou (1989)	296 firms France	Unweighted sum	Equal to own rate
Fecher (1989)	292 firms Belgium	I/O flows	0.5 per cent
Crépon and Duguet (1993)	451 firms France	Unweighted sum	–0.18 to –0.34[2]
Raut (1993)	192 firms India	Unweighted sum	0.06 to 0.36[1]
Antonelli (1993)	92 firms Italy	Unweighted sum (regional)	0 per cent[1]
Henderson and Cockburn (1993)	R&D programmes 10 pharmaceutical international firms	Unweighted sum of competitive patents within a class	0.002 to 0.007[2]
Adams and Jaffe (1994)	19 561 plants chemical industry	Unweighted sum of other firms' R&D within industry	0.08[1]

Table 1. **R&D spillovers: primal approach** *(cont.)*

Study	Data	Weighting matrix	Rate of return on outside R&D
Specific R&D spillovers			
Jaffe (1989)	States US	Academic R&D	0.10[2] (direct) 0.60[2] (direct + induced)
Acs *et al.* (1992, 1994)	States US	Academic R&D	0.43[3] (direct)
Henderson and Cockburn (1993)	R&D programmes 10 pharmaceutical international firms	Unweighted sum of own patents in related programmes	0.03[2]
Klette (1994)	804 plants 3 industries Norway	Unweighted sum of R&D in plants	
		– *within same line* of business	Significant
		– across lines of business within same firm	Insignificant
		– across lines of business across firms	Significant
International spillovers			
Fecher (1989)	292 firms Belgium	Sectoral R&D from all OECD countries domestic I-O matrix	0 per cent
O'Sullivan and Röger (1991)	Aggregate 6 countries	Parameterised weights	0 to 43 per cent
Fecher (1992)	8 manuf. industries 11 OECD countries	Sum of sectoral R&D from 5 countries	0 per cent
Soete and Verspagen (1993)	Aggregate 23 countries	Foreign technology payments	0 per cent
		Sectoral R&D from 9 sectors weighted by imports	0 per cent
Park (1993)	Aggregate 10 countries	Unweighted sum	0.24 to 0.27[1]
Coe and Helpman (1993)	Aggregate 22 countries	Import-weighted foreign R&D	0.03 to 0.18[1]
Hanel (1994)	19 industries Canada	Percentage sales from foreign affiliates	0.2 per cent

Table 1. **R&D spillovers: primal approach** *(cont.)*

Study	Data	Weighting matrix	Rate of return on outside R&D
Vuori (1994)	27 industries Finland	Imported I/O and investment flows	Insignificant
Coe *et al.* (1995)	Aggregate 77 countries	Import-weighted foreign R&D	0.01 to 0.29[1]

Note: Only significant results are reported. The absence of significant results at the 5 per cent level is indicated by 0. Except for Sassenou (1988); Crépon and Duguet (1993); and Henderson and Cockburn (1993), all estimates are based on growth rate regressions.
1. Output elasticity.
2. Patent elasticity.
3. Innovation elasticity.
4. Unit cost elasticity (in absolute value, on average).

Source: Author.

Another set of measures of proximity is the distance between position vectors in different spaces, such as patent classes, qualifications of R&D personnel, lines of business or types of R&D. The idea is that the closer firms are in the kind of things they patent, the kind of scientists and engineers they hire, the kind of things they produce or the kind of R&D they do, the more they benefit from each other's research. The a_{ij} coefficients would then be distance measures, as for instance the uncentered correlation between vectors (see Jaffe, 1986).

Each of these measures has its weaknesses, as discussed in Archibugi and Pianta (1996). It is hard to dissociate the two kinds of spillover both theoretically and empirically. Even though intermediate input flows are the closest of all measures to the notion of rent spillovers, a great deal of technological information gets exchanged between a purchaser and a vendor, even besides the knowledge incorporated in the goods transacted. Patent and innovation flows are more likely than input-output flows to be indicators of knowledge transmission than of rent spillovers, although here also the spillover goes through the market (or at least a potential market) of licences, patent sales, and innovations. The set of measures based on position vectors is intuitively the most likely to represent knowledge spillovers of a tacit kind. Various studies have compared different weighting matrices on a common dataset and have come to conflicting conclusions.[7] There is no strong evidence in favour of one measure over the others nor in favour of the claim that the choice between measures matters greatly. It could even be argued that sometimes distant ideas are potentially more fruitful to a researcher than ideas from nearby.

Table 2. **R&D spillovers: dual approach**

Study	Data	Specification and weighting matrix	Social rate of return on R&D
Domestic intra-industry spillovers			
Bernstein (1988)	680 firms in 7 industries	Translog. Static equilibrium Unweighted sum	17 to 24 per cent[1] (industry rate)
Bernstein and Nadiri (1989)	48 firms in 4 industries US	Generalised quadratic cost of adjustment model K, R = quasi-fixed unweighted sum	9 to 16 per cent[1] (industry rate)
Domestic inter-industry spillovers			
Bernstein (1988)	680 firms in 7 industries	Translog static equilibrium Unweighted sum	19 to 26 per cent[1]
Bernstein and Nadiri (1988)	5 industries US	Same as Bernstein (1989)	11 to 111 per cent[2]
Bernstein (1989)	9 industries Canada	Generalised Cobb-Douglas Static disequilibrium R = fixed input parameterised weights	37 to 94 per cent[2]
Mohnen and Lépine (1991)	12 industries Canada	Generalised Cobb-Douglas Static disequilibrium K, R = quasi-fixed patent flows	11 to 314 per cent[2]
Bernstein and Nadiri (1991)	6 industries US	Translog cost of adjustment model K, R = quasi-fixed parameterised weights	18 to 111 per cent[1]
Specific R&D spillovers			
Nadiri and Mamuneas (1994)	12 industries US	Generalised Cobb-Douglas Static equilibrium public R&D spillovers	0.02 to 0.06[4]
Mohnen (1992*a*)	Total man. Canada	Generalised McFadden cost of adjustment model K, R = quasi-fixed high-tech imports from 5 sectors in 5 countries	1.1 per cent[3]

Table 2. **R&D spillovers: dual approach** *(cont.)*

Study	Data	Specification and weighting matrix	Social rate of return on R&D
Mohnen (1992*b*)	Total man. 5 countries	Generalised McFadden cost of adjustment model K, R = quasi-fixed unweighted sum	4 to 18 per cent[3]
Mohnen and Gallant (1992)	Total man. 5 countries	Same as Mohnen (1992*b*)	–3 to 24 per cent[3]
Bernstein and Mohnen (1995)	Total man. US/Japan	Generalised McFadden cost of adjustment model K, R = quasi-fixed parameterised weights	163 per cent (US)[2] 138 pour cent (Japan)
Bernstein (1995)	11 industries Canada/US	Generalised McFadden static equilibrium K, R = quasi-fixed R&D: same industry other country	31 to 162 per cent (Canada)[2, 5] 43 to 183 per cent (US)
Bernstein and Yan (1995)	10 industries Canada/Japan	Same as Bernstein (1995)	78 to 206 per cent (Canada)[2, 5] 26 to 73 per cent (Japan)

Note: Except for Mohnen and Lépine (1991), and Nadiri and Mamuneas (1994), all studies assume variable returns to scale. None, except Nadiri and Mamuneas (1994), allow for disembodied technical change. All consider four inputs (K, L, M, R), except for Bernstein and Nadiri (1989), who use value-added data, Mohnen and Lépine (1991), and Mohnen and Gallant (1992), who add a foreign technology payments variable, and Nadiri and Mamuneas (1994), who have no private R&D as an input. Only in Bernstein and Nadiri (1991) is output treated as endogenous. All use cost or restricted cost functions, except Bernstein and Nadiri (1991), who use a value function. The reported figures are mid-sample or average values.

1. Before-tax net of depreciation rate of return.
2. Before-tax gross of depreciation rate of return.
3. After-tax gross rate of return.
4. Cost elasticity.
5. Inclusive of domestic inter-industry R&D spillovers.

Source: Author.

A third idea is to estimate the a_{ij} weights econometrically. Let the data reveal the proximity among sectors or firms rather than imposing it through an arbitrary choice of measurement. The extent of the spillover can then no longer be dissociated from its productivity. Another problem is that, for lack of degrees of freedom, not all potential spillover sources can be estimated separately. Moreover, for reasons of multicollinearity between the individual stocks, it is unlikely that all spillover sources can be estimated significantly.

The construction of an international public R&D stock proceeds along the same lines. The proximity can be measured on the basis of trade flows, in particular high-tech products, foreign direct investments, international collaborations in research, flows of scientists and engineers, foreign technology payments, or international patenting.

Finally, it should be mentioned that some authors estimate the R&D spillovers from a knowledge production function, where R&D appears as an input and where the output is measured by patents (Jaffe, 1986; Crépon and Duguet; 1993, Henderson and Cockburn, 1993) or innovations (Acs *et al.*, 1992). Instead of looking at the effects of R&D spillovers in terms of welfare (as in the case study approach), or in terms of either output, average cost or TFP growth (as in the regression approach), this third dimension of R&D spillovers looks at the effects on technology indicators or the output side of R&D.[8]

IV. STYLISED FINDINGS

Before presenting the main results of this literature, a few prior remarks are in order. First, I shall limit myself to the studies which estimate an R&D spillover effect, excluding those which only measure a spillover pool or characterise the structure of inter-industry dependence, which could serve as a proximity measure. Second, I shall say very little of the studies which deal with innovative externalities other than those measured by R&D. Third, I exclude from my survey the case studies which are covered by Griliches (1992).

Table 1 lists the empirical studies using the primal approach, Table 2 those using the dual approach. The various studies are broken down by the kind of R&D spillovers which have been estimated: inter-firm, inter-industry, international, and of a specific kind (*e.g.* academic).

It should be said from the start that a direct comparison of all the estimates presented is an impossible task. Not only are the data, the model, the dimension of variation in the data, the weighting matrices for R&D spillovers different, but so also are a panoply of measuring details such as the assumed R&D depreciation rate, the lag structure of R&D (if there is any), the number of externality receivers included in the computation of the social rate of return, whether R&D is allowed to have only one or multiple receivers, whether the rates of return are gross or net of R&D depreciation, before or after tax, real or nominal, with or without marginal adjustment costs (if any), including or in excess of the normal rate of return (*i.e.* whether traditional inputs have been cleared of their R&D component), how TFP is defined, with how many inputs, over short or over long periods, and many more.[9] Only point estimates are reported in Tables 1 and 2. The purpose of these tables is to take stock of what has been done and to give some order of magnitude of the estimated externalities. Among the many estimates which are often reported in the same study, I have chosen the most representative one, and confined myself to significant estimates. It is not possible with a single figure to do justice to a full study. The figures reported are therefore to be taken with a grain of salt.

- There is sufficient evidence to claim that *R&D spillovers exist*. First, significant rates of return on outside R&D show up on quite a vast range of datasets and periods, with different models and with different measures of outside R&D. Secondly, various authors (for example Scherer, 1984; Griliches and Lichtenberg, 1984; Englander, Evenson and Hanazaki, 1988) have found that user R&D works better in magnitude and significance than sector-of-origin R&D in explaining TFP growth. Third, it has been argued that industry dummies in a pooled firm data estimation could be interpreted in terms of inter-industry spillovers, because they approximate a spillover variable which takes the same value for all firms in an industry. The dummy variable could reflect industry-specific opportunity effects, such as the closeness to science, technical knowledge from upstream materials and equipment suppliers, downstream users, government agencies and research labs.[10] Another sign of inter-industry spillovers is the result obtained by Link (1983) and Martin and Jaumandreu (1992), on US and Spanish data respectively, that purchased R&D (through licensing or the purchase of capital goods containing new technologies) is as important, if not more, than own R&D in explaining TFP growth.[11] It is not spillovers, strictly speaking, because the knowledge is purchased. But, if these royalty payments are not explicitly included in the regression, they will show up as knowledge spillovers.
- *On average, the social rate of return on R&D exceeds the private rate of return by 50 to 100 per cent.* The returns on outside R&D are less precisely estimated and more variable across studies than the returns on own R&D. The estimates are generally higher with studies using the dual approach. Similar orders of magnitude are obtained when R&D and their spillovers are evaluated in terms of patents: Jaffe (1986) estimates a marginal return (computed at data averages) of 2 patents per million dollars of own R&D and of 0.06 patents per million dollars of other firms' relevant R&D.

  The magnitude of the estimated social rate of return depends on the proximity between spillover sender and receiver, on the cost-reducing effect of the spillover on the receiving side and on the number of potential receivers. Outside R&D is probably less effective than own R&D, because it is not tailored to the needs of its recipient and because it requires some absorption effort on the part of the receiver. Hence its productivity is partly reflected in the returns to the own R&D. On the other hand, the social rate of R&D depreciation is likely to be much lower than the private rate. As regards the number of receivers and their proximity to the sender, the social rates of return are often underestimated, since only a small number of receivers are taken into account (*e.g.* in Mohnen and Lépine, 1991, only 15 to 75 per cent of the patent flow receivers). For lack of good data, the service sectors are rarely estimated and hence included in the computation of the social rates of return to R&D, while, as illustrated in Robson *et al.* (1988), non-manufacturing sectors are heavy users of innovations and patents.

- The domestic social rate of return to R&D shows *a great dispersion across industries.* In Table 3, I have tabulated the sectoral social rates of return on R&D in Canada and in the United States from the two econometric studies with the widest industrial coverage. Ducharme et Mohnen (1996) report that their estimates are not statistically different among industries for a given proximity matrix at a 5 per cent confidence level. However, there is some sizeable difference depending on the structure of the matrix adopted to compute those social rates of return. Not surprisingly, the patent matrix confirms the factual evidence from the innovation diffusion (see Pavitt, 1984; Robson *et al.* 1988; Patel and Soete, 1988) and the patent diffusion (see Scherer, 1982; Englander, Evenson and Hanazaki, 1988, Table 8; Mohnen and Lépine, 1991, Table 1). The sectors chemical products, non-electrical machinery, and scientific instruments are highly diffusing (the so-called "core" sectors), whereas aircraft and parts are also classified by Patel and Soete (1988) as sectors with only localised or internal diffusion. The input-output matrix of intermediate input flows seems to be more diffusing than the patent flow matrix. As discussed above, the two matrices might not capture the same kind of effects. The approach that estimates the weights (Bernstein, 1989; Bernstein and Nadiri, 1988, 1991) identifies only a small number of spillover receivers (never more than three), partly for the statistical reasons mentioned above. Non-electrical machinery, refined petroleum, and scientific instruments are often identified as such.
- *Estimated spillovers are more often positive than negative.* In a world of certainty and free disposal, R&D spillovers are expected to have beneficial effects, since it is reasonable to assume that firms do not adopt new ideas which reduce their profits. However, one can raise a number of arguments claiming that R&D can have detrimental effects on profit, productivity growth or welfare. For strategic reasons, firms may feel obliged to enter an R&D race without necessarily benefiting from it. R&D spillovers can increase or decrease the price that a producer can charge for his product, depending on whether the new product from outside R&D is substitutable or complementary to the firm's own product. New products can displace old ones. This process of creative destruction can be harmful if innovators

Table 3. **Domestic social rates of return on R&D: sectoral level**

Percentages

	Ducharme and Mohnen[1] (1996) Canada			Bernstein[2] (1995)	
				United States	Canada
	Patent matrix	Leontief inverse	I/O matrix	Unweighted sum	
Mining and wells	118	110	178		
Coal, petrol. and gas	149	162	321		
Food and beverages[3]	62	61	56	183	145
Rubber and plastics	98	65	307	44	155
Textiles	18	53	207		
Pulp and paper[4]	139	87	101	99	126
Primary metals				111	52
Ferrous		157	104		219
Non-ferrous		124	75	101	
Metal fabricating	145	94	209	157	154
Machinery	140	49	161	85	161
Transportation equipment				88	32
Aircraft	54	28	63		
Other transp. equipm.	50	52	75		
Electrical products				96	158
Telecom. and electronics	88	38	135		
Electronic computer	91	29	197		
Other electrical	113	47	151		
Non-metallic mineral	122	50	215	132	111
Refined petroleum	158	70	126	174	126
Chemical products				98	49
Pharmaceuticals	163	26	94		
Other chemical	138	94	180		
Scientific instruments	153	30	172		
Miscellaneous manuf.	148	54	107		
Transportation		29	84	189	
Communication services	29	48	242		
Electric power	29	51	189		
Other services	95	524	81		

1. Includes domestic inter-industry spillovers to the other ten industries and the international spillovers within the industry.
2. Includes all domestic inter-industry spillovers.
3. Includes tobacco in Ducharme and Mohnen.
4. Encompasses wood and wood products in Ducharme and Mohnen.

Source: Author.

do not have time to recover their R&D investments. Firms may have to incur heavy adjustment costs to learn the new technologies. This is the argument advanced by Adams (1990) to explain why it takes time before seeing positive returns from R&D in the data. Finally, R&D can reduce welfare when firms use R&D as a strategic tool to raise entry barriers, or when firms are obliged to duplicate R&D to stay in the race. Crépon and Duguet (1993) find strong evidence of negative R&D spillovers when measured in terms of patents.[12]

- *Spillovers are present at all levels of aggregation.* Henderson and Cockburn (1993) find, in a production of knowledge type of approach, that the elasticity of own patenting in a particular class with respect to own patenting in related classes is higher than with respect to competitors' patenting in that class and, to an even lesser extent, with respect to competitors' patenting in other classes. But the three externality sources yielded positive spillover effects in their study. Jaffe (1988), who classifies firms into technological (patent) clusters, finds the spillover effect to be localised within those clusters.[13] Adams and Jaffe (1994) report that R&D performed in plants with other product fields is one-third as effective as R&D of the same plant. However, Bernstein (1988) reports that the inter-industry spillovers decrease unit cost more than the intra-industry spillovers, although in his sample the number of intra-industry externality receivers is such that intra-industry spillovers contribute more to the social rate of return than inter-industry spillovers. Aggregate studies show above-normal rates of return on R&D (see Mairesse and Mohnen, 1990). Spillovers are implicitly included in the aggregate R&D coefficients (at the sectoral level for inter-firm spillovers, at the national level for inter-industry spillovers). It is somewhat puzzling that aggregate studies do not systematically produce the same social rates of return as firm-level studies, unless, as argued by Griliches (1994), the depreciation rates of knowledge and hence the R&D stocks ought to be different at different levels of aggregation.
- There are also clear signs of *international R&D spillovers.* Coe and Helpman (1993) put the average world-wide rate of return on R&D investment in the G-7 countries at 152 per cent. The spillovers are a positive function of trade and therefore very much country-dependent. Trade-dependent R&D spillovers from the North to the South are reported in Coe *et al.* (1995). Park (1993) also reports that the spillovers are larger for the smaller countries and the more open economies, the largest spillover source being the United States. O'Sullivan and Röger (1991) find no spillovers of other industrialised nations to the United States, no spillovers between Europe and Japan and the spillovers from the United States to Japan limited to high-tech R&D. Bernstein and Mohnen (1995) obtain significant and strong spillovers from the United States to Japan, but not the reverse. Bernstein (1995) estimates intra-industry R&D spillovers for 11 manufacturing industries between the United States and Canada. In general, he finds the effects to be more important from the United States to Canada than the other way round. In a similar study involving Japan and

Canada, Bernstein and Yan (1995) find little international spillovers from Japan to Canada, but quite substantial ones in the other direction. There are no uniform results regarding the relative size of the returns on own R&D, domestic R&D spillovers, and international spillovers.

- There is some *mixed evidence that spillovers are geographically localised.* The argument is that ideas, especially tacit information, are more easily transmitted when people have the chance to meet eye to eye, around conference tables, at meetings, on tennis courts and at parties. Codified knowledge can be easily transmitted by paper, fax or e-mail. Hence evidence of strong localised sources of learning does not prevent some spillovers from taking place at a distance. Jaffe (1989), using patents as a measure of output, finds only weak evidence that spillovers are facilitated by the geographic proximity of firms and universities within a state. Acs *et al.* (1992, 1994), using innovations as a measure of output, find a significantly positive effect for geographic proximity. Jaffe *et al.* (1993), using patent citations to measure the trail of knowledge, obtain a geographic match between a patent citation and the original patent with a greater probability than expected from a patent of approximately the same time period and technological class. However, citations in the same class are not more likely to be localised than citations of different technological classes. Adams and Jaffe (1994) report that the productivity of plants' R&D decreases with the geographic and technological distance: R&D performed by plants of the same company localised outside the state are 10 to 20 per cent as effective as R&D performed within the state.

  However, in the biotechnology field, Audretsch and Stephan (1994) and Zucker *et al.* (1994) have shown that geographic proximity *per se* is not the whole story. The former find that the contacts biotechnology firms have with academic scientists are far from being predominantly local; it all depends on the role played by the scientist in the firm. For monitoring reasons, founders of biotechnology firms are more likely to be local. Advisors need not be local. The latter provide econometric evidence showing that what really matters are connections of star scientists to new biotechnology enterprises. Spillovers are thus internalised by a market contract between a researcher and a firm.
- Some results have been obtained regarding the *effects of R&D spillovers on factor demands.* Generally R&D spillovers are found to be substitutes for labour and intermediate inputs, *i.e.* the spillovers decrease the demand for variable inputs for given levels of output. This is not surprising since spillovers are generally cost decreasing. Very often a relationship of complementarity shows up between R&D spillovers and either physical or own R&D capital. The complementarity between own and outside R&D confirms the absorption hypothesis emphasised by Cohen and Levinthal

(1989) and further illustrated by Foray and Mowery (1990): firms have to carry out some R&D to be able to benefit from outside R&D. Mohnen and Gallant (1992) find foreign technology payments in such forms as licenses, royalties, and financing for foreign R&D to be substitutes to foreign R&D spillovers.

- Some results have also been obtained regarding the determinants or the *endogeneity of R&D spillovers*. When Klette (1992) lets the revenue elasticity with respect to outside R&D depend on the firms' technological position in the Norwegian industry, only the technologically advanced firms seem to benefit from other firms' R&D programmes; the average firm experiences a negative spillover effect. The same result is obtained by Harhoff (1994) with German firm data: only high-tech firms benefit from R&D spillovers. Bernstein (1988) notices that firms with relatively small propensities to invest in R&D tend to consider the R&D performed by their rivals within the industry as a substitute for their own R&D, whereas firms with relatively large R&D cost shares invest more, partly in order to assimilate intra-industry R&D spillovers. Various studies have found that small firms benefit more, in terms of patenting and innovations, from university-based research spillovers than large firms, who rely more on their own R&D (Link and Rees, 1990; Acs *et al.*, 1994; Audretsch and Vivarelli, 1994).
- *R&D spillovers by kind of R&D* have a similar ranking in magnitude as the corresponding own R&D. Government-financed R&D is generally found not to exert significant spillovers (Terleckyj, 1974, 1980; Wolff and Nadiri, 1993; Hanel, 1988; Lichtenberg, 1992). Nadiri and Mamuneas (1994) estimate that public R&D yields a higher social rate of return than public infrastructure capital, but a return lower than previous estimates from industrial or total R&D at the sectoral level. Some work has been done regarding the spillovers from academic R&D, regarded as basic R&D. Adams (1990) constructs a stock of academic knowledge for each sector not from R&D data, but from article counts in nine scientific fields weighted by the shares of scientists from these fields in total sectoral employment. The spillover is measured as the weighted sum of own knowledge stocks weighted by the sectoral positions in fields of scientific employment. He estimates contributions of own and spillover academic knowledge to TFP growth over the period 1966-80 of 60 and 40 per cent respectively. Jaffe (1989) presents evidence that the research conducted by universities in a state produces spillovers in terms of corporate patents granted in that state: the direct elasticity for four technical fields is approximately 0.1. The figure is even larger (0.6) when the inducement effect on corporate R&D is combined with the effect on patents granted. Acs *et al.* (1992) obtain a result at least twice as high when the R&D output is measured by actual

innovations instead of by patents granted (*i.e.* only successful innovations, whether patented or not). Finally, Levin and Reiss (1988) found higher spillovers for process R&D than for product R&D.

- *R&D spillovers contribute significantly to total factor productivity growth* (TFP). When TFP is defined with respect to the conventional inputs, the residual contains three components, disembodied technological change, the own R&D and R&D spillover:

  $$\dot{TFP}_t = \alpha_T + \alpha_R \dot{R}_t + \alpha_S \dot{S}_t.$$

  The contribution of R&D spillover is given by the output elasticity of the spillover times the growth rate of outside R&D. TFP growth contributions from outside R&D can be quite high despite low rates of return, because of the growth in the stock of outside R&D.[14] Joly (1993) attributes between 10 and 50 per cent of output growth in the major OECD countries to R&D growth, depending on the periods and the countries, Adams, 40 per cent of US TFP growth to R&D spillovers. Mohnen (1992*a*) estimates that foreign R&D in Canada earns a rate of return ten times lower than own R&D, yet he evaluates the Canadian TFP growth contribution from foreign R&D at 50 per cent of the contribution from domestic R&D. Bernstein and Mohnen (1995) attribute 66 per cent of the TFP growth in Japan to US R&D growth. Bernstein (1995) and Bernstein and Yan (1995) report mostly positive spillover contributions to TFP growth at the sectoral level.

- There is *mixed evidence regarding the hypothesis of a decline in the externality effects of R&D.* It is corroborated by Griliches and Lichtenberg (1984) and Sterlacchini (1989). Scherer (1982) accepts it on aggregate data, but rejects it on less aggregated data. Englander, Evenson and Hanazaki (1988) accept it on disaggregated data, but not with great statistical significance. Adams and Jaffe (1994), on plant data, do not find a serious drop in the productivity of outside R&D before and after the 1980s. Even if the productivity of outside R&D has not declined, the contribution of R&D and its spillover to the productivity slowdown in a growth accounting exercise can be substantial, because R&D has slowed down. Adams (1990) evaluates that the decline in academic knowledge (both own and borrowed) accounted for 15 per cent of the TFP slowdown in the United States between 1953-66 and 1966-80. Nadiri and Mamuneas (1994) attribute a substantial role to public R&D in the explanation of the TFP slowdown in the United States since 1969. However, van Meijl (1995) obtains evidence of increasing spillovers over time, especially spillovers in information technology. The surge of this technology is presumed to have increased the efficiency of R&D and the magnitude of R&D spillovers by making information more codified.

V. POLICY RECOMMENDATIONS

The evidence presented above suggests at least the following conclusions regarding science and technology policy:

- Spillovers exist and have to be accounted for when evaluating the returns of government-financed R&D, or the justification of R&D subsidies and tax incentives. The returns to compute from a dollar of tax forgone should be the social, not the private, returns.
- We are not yet in a position to justify channelling R&D subsidies into particular sectors on the grounds that they produce high R&D spillovers. Some sectors might be highly diffusing in terms of patents and innovations, but less so in other dimensions of proximity. In other words, we know too little about how knowledge is created and transmitted to recommend a sectoral specialisation in R&D.
- It is a fact that the benefits of R&D are not fully appropriable. But many studies show that spillovers are not a free good. Firms must have the capacity to absorb outside knowledge. Therefore a sound research policy would be to provide a good educational system and to support basic research in universities so as to endow the economy with a human capital ready to absorb outside knowledge and to adjust to new technologies. Besides, various studies have found that academic R&D produces strong spillover effects and encourages private R&D.
- Since firms have to do their own R&D in order to stay abreast of what goes on in other R&D departments, the argument of disincentives from incomplete appropriability of R&D benefits loses its strength. In reforming the patent system or in implementing other means of protecting intellectual property rights, the disclosure of information argument should not be overshadowed by the incomplete appropriability argument.
- According to Coase's theorem we know that firms have a natural tendency to co-operate and internalise externalities in the absence of transaction, co-ordination and information costs. Hence another policy aimed at diffusing new knowledge, and possibly at creating research synergies, is to bend the anti-trust laws and to allow R&D co-operative efforts.
- Since international R&D spillovers exist, it would be wise to keep the door open to channels of transmission of technology from abroad such as foreign direct investment, licences, trade in high-tech products, joint research and exchange of information.

Much of the R&D spillover story remains a black box. A lot of effort has been devoted to finding out whether spillovers of various sorts exist and how substantial they are. They have shown that spillovers are a fact to be taken into account in modelling growth and in prescribing R&D policies. But, we still know little about how spillovers get transmitted, where they originate and where they go, how long it takes for them to propagate, or how they can be captured.

NOTES

1. For some recent surveys on R&D spillovers, see DeBresson (1990), Torre (1990), Griliches (1992), Hall (1995), Mohnen (1990), Nadiri (1993).
2. For a formal modeling of the first externality dimension, see Griliches and Lichtenberg (1984).
3. The terms "rent" and "knowledge" spillovers are borrowed from van Meijl (1995).
4. For more references to case studies, see Griliches (1992).
5. The return on outside R&D is somewhat of a misnomer, as outside R&D is most of the time modelled as manna falling from heaven.
6. For a critical comparison of the primal and the dual approaches, see Mairesse and Mohnen (1994).
7. Comparing I/O commodity flows and flows of investment goods, Terleckyj (1974) and Wolff and Nadiri (1993) find stronger effects in size and significance with investment goods than with I/O flows. Yamada, Yamada and Liu (1991) find more of a positive effect via investment goods and more of a negative effect via intermediate inputs. Goto and Suzuki (1989) find, for the Japanese electronics technology, significant spillovers with an R&D position measure of spillover, but not with intermediate inputs and investment flow matrices. Sterlacchini (1989) obtains higher spillovers via innovation flows than via intermediate input flows. Hanel (1994) obtains similar results whether R&D spillovers are measured using the Canadian patent data and the intermediate input flows constructed by the OECD (see Papaconstantinou and Zaidman, 1993; Sakurai, Wyckoff and Papaconstantinou, 1993). Robson *et al.* (1988) report a high correlation between the sectoral distributions of US patents and UK innovations. Ducharme and Mohnen (1996) compare 20 weighting matrices on 25 Canadian industries in terms of returns on outside R&D and social rates of returns on sectoral R&D. They find that the estimated marginal productivities of outside R&D differ according to the weighting matrix but not in any significant way. However, the social rates of return on R&D, which depend on both the estimated marginal productivities and the propagation effects, show significant differences in ranking and in magnitude between some of the weighting matrices for some industries. Van Meijl (1994) presents evidence suggesting that costs of production are predominantly affected by rent spillovers and product demand by knowledge spillovers. Moreover, knowledge spillovers via patent flows seem to dominate in the high-tech sectors, rent spillovers via intermediate inputs in the other sectors.

8. Some authors also examine R&D spillovers in terms of economic performances such as market values (Megna and Klock, 1993), trade balances (Audretsch and Yamawaki, 1988), profits or Tobin's q (Jaffe, 1986), or new products (Zucker *et al.*, 1994).
9. For an account of these measurement problems, see Griliches (1979, 1992, 1994) and Hall (1995).
10. See Levin *et al.* (1985), Levin and Reiss (1988) and Cohen and Levinthal (1989) for the measurement of such variables.
11. Odagiri (1983), however, finds little support for a positive contribution of patent royalty payment to output growth for Japan.
12. Of course, negative spillovers in terms of patents are not incompatible with positive spillovers in terms of knowledge or productivity, because patenting is itself an endogenous decision depending on the strength of the perceived patent protection.
13. It is not quite clear how technology classes are related to industrial classifications. Jaffe (1986) notices some correspondence between technology clusters in the patent space and industry categories, and reports similar econometric results whether he uses cluster or industry dummies.
14. In more general models, TFP growth is also explained by returns to scale, disquilibrium in factor holdings and markup-prices. The spillover component can be decomposed into domestic and foreign R&D spillovers.

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THE DYNAMICS OF INNOVATION AND EMPLOYMENT: AN INTERNATIONAL COMPARISON

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ABSTRACT

In this article the effects of technological and structural change on employment are investigated for the manufacturing sectors of the six largest OECD economies. First, a conceptual framework is proposed, highlighting the key links to be addressed in the empirical analysis. Second, the changes which have taken place in production, productivity and employment over the last decade are described. The role of investment and patenting as indicators of embodied and disembodied technological change is also investigated, and a positive impact on employment changes is found.

The statistical analysis shows that technological and structural changes are able to explain to a large extent the employment patterns in the manufacturing sectors for the aggregate of the six largest advanced economies and for most national cases. In Italy, on the other hand, employment growth proves to be unrelated to increases in production, investment and patenting.

Finally, an exploratory analysis of a more detailed set of data taken from the Italian innovation survey is presented, showing that a better understanding of the complex links between technology and employment will require a broader range of indicators of innovative activities.

I. INTRODUCTION

The renewed interest in the employment impacts of technological change comes at a time when OECD economies count more than 35 million unemployed and continue to expand their innovative efforts. Since the early 1980s the advanced countries have substantially increased their technological activities, measured by several available indicators such as R&D expenditure, number of researchers, number of patents, direct surveys on innovation. Growing investments and use of new intermediate goods have led to large-scale adoption of a range of new technologies – information and communication technologies, new materials, new manufacturing systems – across the whole economy.

Many studies have investigated the contribution that such innovative efforts have offered to the competitiveness and growth of countries, industries and firms.[1] Much less attention, however, has been paid to the employment impact of technological change. In fact, most recent studies of unemployment have largely confined themselves to developments within the labour market, focusing on the short-term impact of demand ("Keynesian unemployment") and wage levels ("classical unemployment"), or on the "mismatch" between demand and supply of labour due to the skill composition of the workforce or the lack of flexibility of labour market regulations.

Such approaches ignore a key cause of present unemployment, that is the role of technological change, with its long-term impact on the economic structure and its direct and indirect effects on the use of labour.[2]

While the issue of "technological unemployment" has been investigated at length by classical economists, the present employment impact of innovation appears further complicated by the pressure of international competition on increasingly open economies and by the globalisation of production and technology, all factors resulting in an acceleration of innovation and structural change. In the following section therefore a conceptual framework is offered to enable the relationships between technological innovation, globalisation and employment to be explored.

The empirical analysis provided in this article investigates the employment changes in the last decade in manufacturing sectors in the six largest OECD economies – the United States, Japan, Germany, France, the United Kingdom and Italy. They are related to the patterns of structural change in the sectoral composition of industry and to the different forms of technological change, namely that embodied in investment and the innovative outputs of a disembodied nature (proxied by patents).

The data and methodology used are presented in Section III, with an overview of the changes in employment, value added and productivity in 36 manufacturing sectors.

Section IV introduces the technology variables (investment and patents) showing the different relationships which emerge between innovation, growth and employment in the six countries at the level of 19 manufacturing sectors. A more formal analysis of the determinants of employment change is also carried out.

The inadequate representation of innovative activities by the variables generally available – such as R&D, patents and investment – leads in Section V, in the case of Italy, to the exploration of a more detailed set of variables drawn from the innovation survey. These include information on the direct effect of innovation on the use of labour in firms, and data on the total cost of innovations, including expenditure on R&D, design and engineering, and innovative investment.

The conclusion sums up the evidence on the link between innovation, structural change and employment, and suggests some directions for further research.

II. A CONCEPTUAL FRAMEWORK

Figure 1 offers a framework for exploring the relationships between technological innovation, globalisation and employment. Process innovations (introduced mainly through new investment) and product innovation (based on internal innovative activities as well as on new intermediate or capital goods) lead to the well-known contrasting effects of increasing productivity and replacing labour on the one hand, and of creating new markets, demand and production on the other hand, through different compensation mechanisms (see Vivarelli, 1995).

In a context of globalisation of production and markets, however, innovations have a rapid international diffusion. The result is greater competition and a new international division of labour, in terms of both the sectors of a country's activity and the different phases of production localised in each nation.

This process changes countries' shares in the value added of global production. Greater competition reinforces the pressure to increase productivity, giving greater role to specialisation advantages. This, together with the emergence of new innovation-led fields of activity, leads to the increased pace of structural change, resulting in a different sectoral composition of national economies.

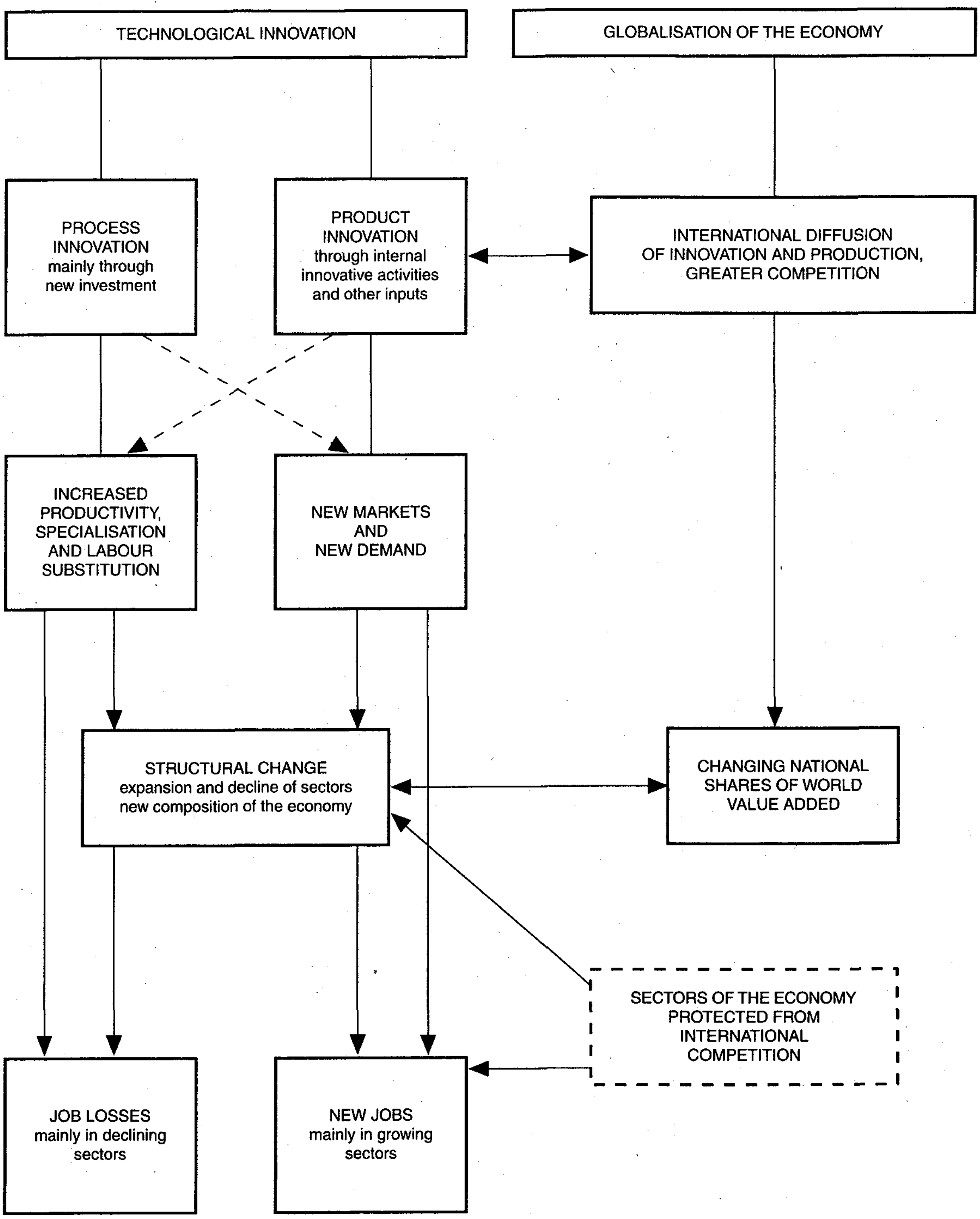
The impact on employment is therefore the net result of:

- job losses due to the direct labour-displacing effect of innovation and to the decline of particular sectors; and
- job gains due to the employment-creation effect of technological change and of the growth of expanding sectors.

The part of the economy which is sheltered from global competition – many private services, the public sector, non-profit activities – should not be forgotten in this context, because many compensation mechanisms operate here, and in fact a large part of the new employment of advanced countries has been created in these sectors.[3]

This approach makes it possible to address the question of employment by looking at the combined impact of technological and structural change. The processes outlined above can be best investigated empirically through sectoral analysis. First, a sectoral study can account for the structural change in the economy. Second, the sources and patterns of innovation and the forms of their introduction tend to be sector-specific. Third, for the purposes of international comparison, the sectoral level offers adequate data and makes it possible to identify structural patterns in a more satisfactory way than can be obtained from firm-level studies.[4]

Figure 1. **The impact of innovation and structural change on employment**



Source: Author.

While the sectoral analysis should include the whole economy, the focus in this article is on manufacturing industry, mainly due to the availability of data, but also to the nature of innovative activities. In most manufacturing sectors the internal generation of know-how and the adoption of innovations first introduced elsewhere are combined in the process of technological change, while in most other sectors – agriculture, private services and government – the latter is by far the dominant form of innovation.

Finally, the examination of the six largest OECD economies makes it possible to identify the different outcomes that the processes outlined above may have. Far from being a deterministic process, the economic and employment outcomes of technological change are the result of social processes, where institutions, government policies and social relations play a major role, alongside the developments in technology and the strategies of firms. Therefore we expect to find different patterns and performances across countries, also rooted in their structural differences.

Drawing from this analytical framework, the key questions addressed in this article are the following:

What is the relationship between the pattern of structural change and changes in employment?

The starting point of the empirical analysis is a combined description of the sectoral patterns in employment, in economic activity (measured by value added), and in the resulting changes in productivity.

While we can expect employment to grow in expanding sectors and fall in declining ones, the actual relationship may be more complex and less obvious and may differ across countries. The dynamics of employment may reveal different elasticities relative to changes in production, and a lower employment elasticity may account for the present widespread pattern of "jobless growth".

Furthermore the role of productivity growth needs to be clarified: is it obtained though the displacement of labour, or through the expansion of production? These questions are addressed in Section III.

How can technological change be measured, and its employment impact estimated?

While R&D expenditure has long been used as the main indicator of innovative activities to be related to economic performance,[5] in this article two other variables are used for all six countries and a few more will be tested in the case of Italy.

The first variable is the growth of gross fixed capital formation (investment), which plays a double role: first, as an indicator of process innovations and of the technological changes embodied in new capital goods, generally acquired from other sectors; and second, as an indicator of the expansion of production capacity due to the patterns of structural change and to product innovations.

It is unfortunate that these two roles of investment cannot be separated, as they are expected to have contrasting effects on employment. On the one hand, process innovations tend to reduce employment in the sector where they are introduced. On the other, investment associated to expansion of capacity and introduction of product innovations is expected to increase employment (see Vivarelli, Evangelista and Pianta, 1995, and Section V below for some evidence in the case of Italy).

This "expansionary effect" associated with structural change, however, can be identified to some extent by looking at the association between changes in investment and in value added; the closer the two patterns, the more relevant the "expansionary effect" is likely to be.

The second variable is the number of patents granted in the United States, which accounts for the internal innovative activities of individual sectors, directly associated to product innovations. In spite of some methodological problems,[6] patent data at the sectoral level are closely correlated to R&D expenditure and have the advantage of representing an indicator of the innovative outputs which are considered to be of international relevance and of some market value.

Patenting activity may thus be considered a proxy for the ability of sectors to generate new products and know-how, although product innovations introduced in a particular sector generally also require the use and adaptation of innovations generated elsewhere, as well as new capital outlays.

The employment impact of the technology variables is expected to be positive in the case of patents (proxy for product innovations); in the case of investment, it will be negative if the "process innovation effect" is dominant, and positive if the "expansionary effect" prevails. The latter case can be characterised by a close association of investment to value added and patenting patterns.[7]

III. THE SECTORAL DYNAMICS OF VALUE ADDED, EMPLOYMENT AND PRODUCTIVITY

A first empirical evidence of the relationships between structural change and employment is provided in this section using data from the OECD STAN database (December 1994) for 36 manufacturing sectors (ISIC classes) for the six largest OECD countries (the United States, Japan, Germany, France, the United Kingdom and Italy).

The variables considered include value added (in constant prices), employment (number engaged) and productivity (value added per employee), measured as average annual rates of change from 1980-82 to 1990-92. The three-year averages are introduced in order to avoid cyclical effects and to provide a solid picture of the changes in industrial structure over the last decade.

The evidence is summarised in three figures. Figure 2 shows for the aggregate of the six countries (G-6) the rates of change of value added and employment, illustrating the overall pattern of structural change which has taken place in the last decade in the most advanced countries. A clear positive relation is evident, and the 36 sectors can be grouped into three clusters:

- *Growth sectors*, where value added and employment have both increased, including plastic, printing, office computing, aircraft, drugs, electrical apparatus, food, motor vehicles and other chemicals.
- *Declining sectors*, with an opposite pattern of decline in both value added and employment, including leather, footwear, iron and steel, petroleum refining, tobacco.
- *Sectors in restructuring*, with growth in production and a fall in employment, containing all remaining sectors and the values for total manufacturing.[8]

The growth sectors appear to be associated with greater technological intensity, an issue already pointed out in studies carried out by the OECD (OECD, 1994*a*, Chapter 4, 1996*b*).

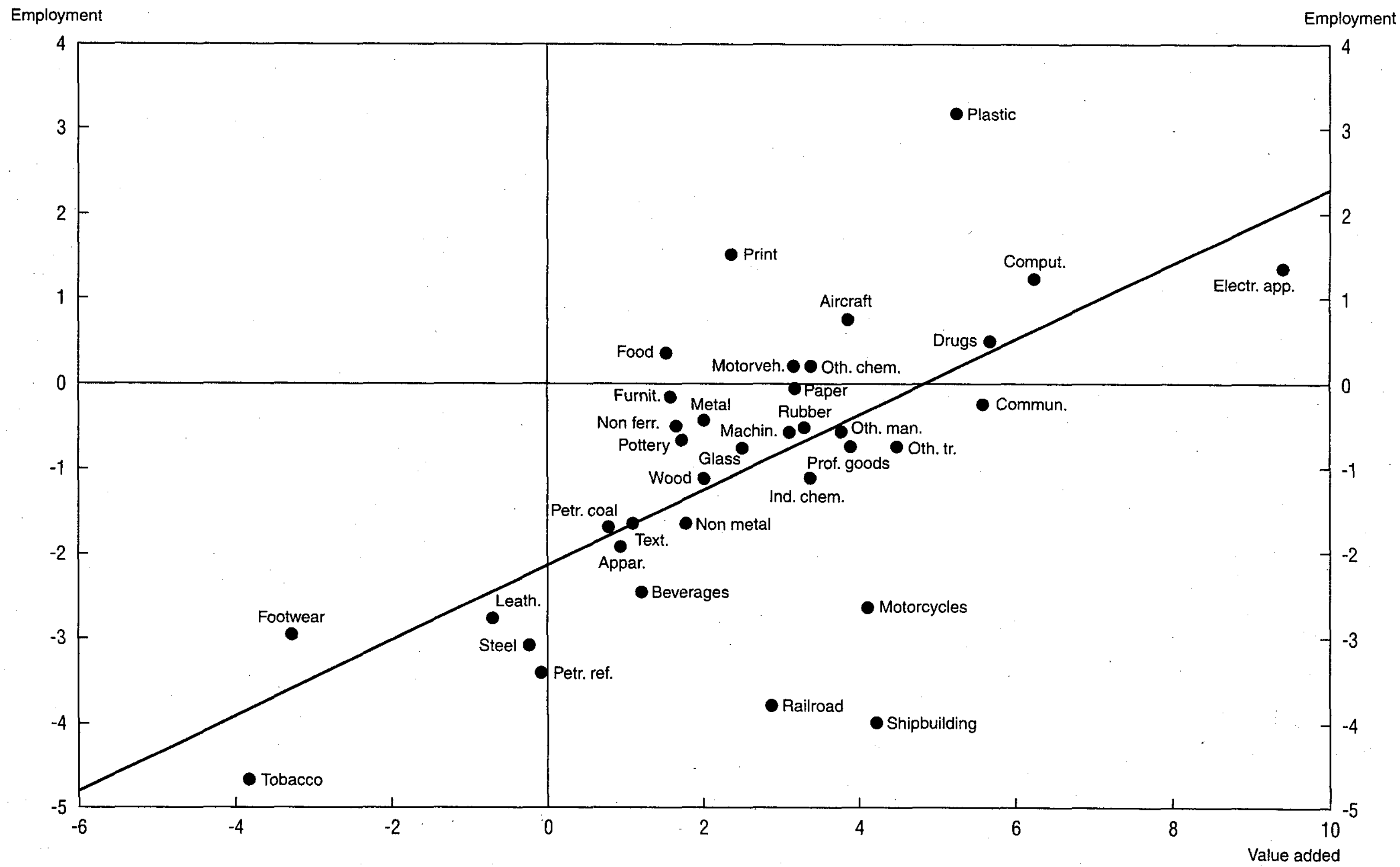
If we look behind the G-6 aggregate, the patterns of the United States, Japan and the four European countries show a rather different distribution, presented in Figure 3.[9] It becomes apparent that Japan has the majority of its manufacturing sectors in the growth quadrant, while Europe has most of its industries in the restructuring quadrant, with the United States showing an intermediate position.

The contrasting performances of Europe and Japan become even more evident when the growth of productivity is plotted against changes in employment, as shown in Figure 4. While for Japan no association is evident and several sectors show positive employment and productivity changes, for Europe a clear negative relationship emerges; the manufacturing sectors where productivity has increased tend to be those where employment has fallen. Again the distribution of the United States is intermediate between these two cases.[10]

These patterns suggest that the G-6 aggregate conceals a variety of different relationships between structural change and employment at the national level. These are investigated in the following section.

Figure 2. **Changes in value added and employment in the G-6 countries, 1980-82 to 1990-92**

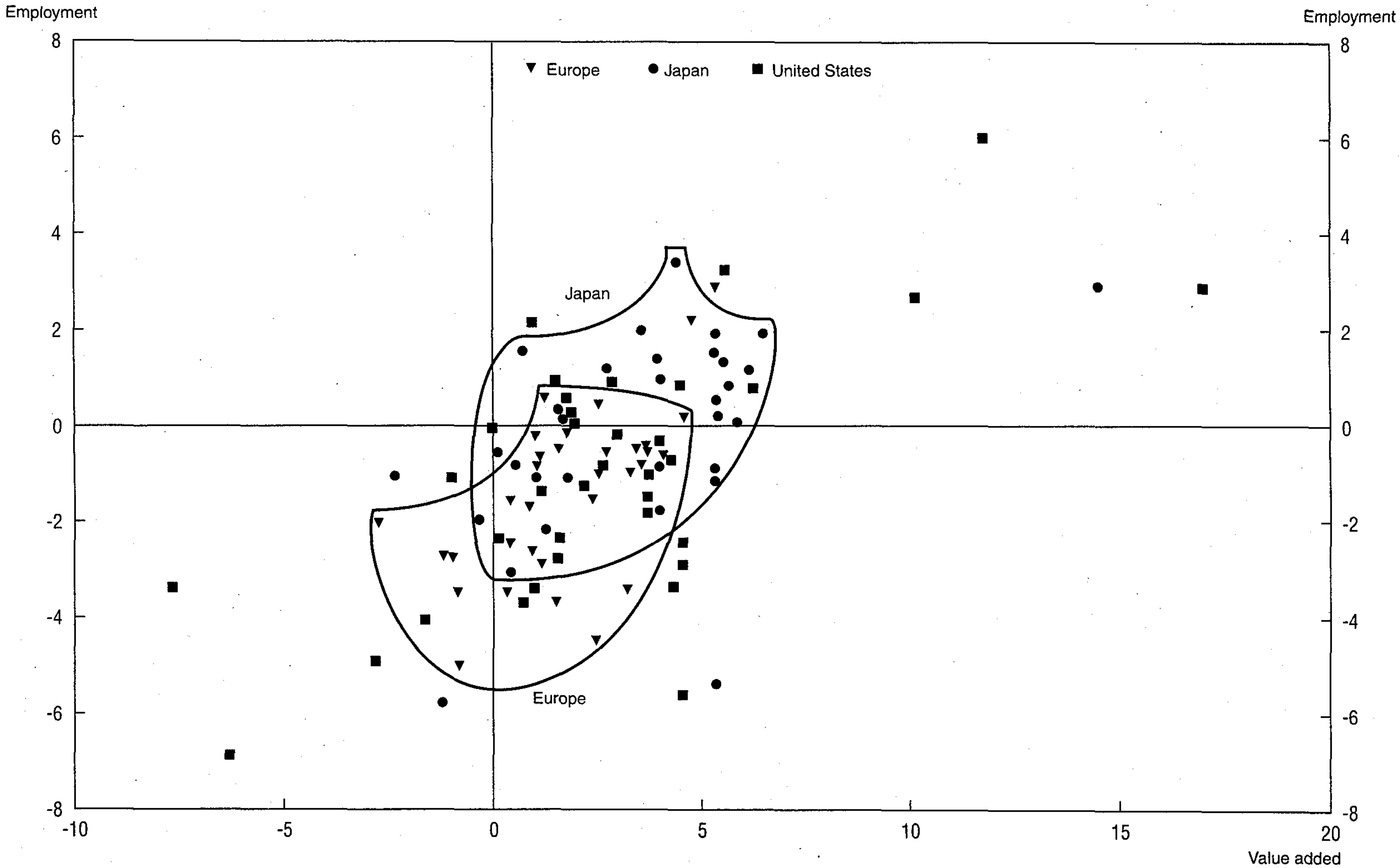
Percentage annual rates of change



Note: G-6: United States, Japan, Germany, France, United Kingdom and Italy.
Source: Author.

Figure 3. **Changes in value added and employment in Europe, Japan and the United States, 1980-82 to 1990-92**

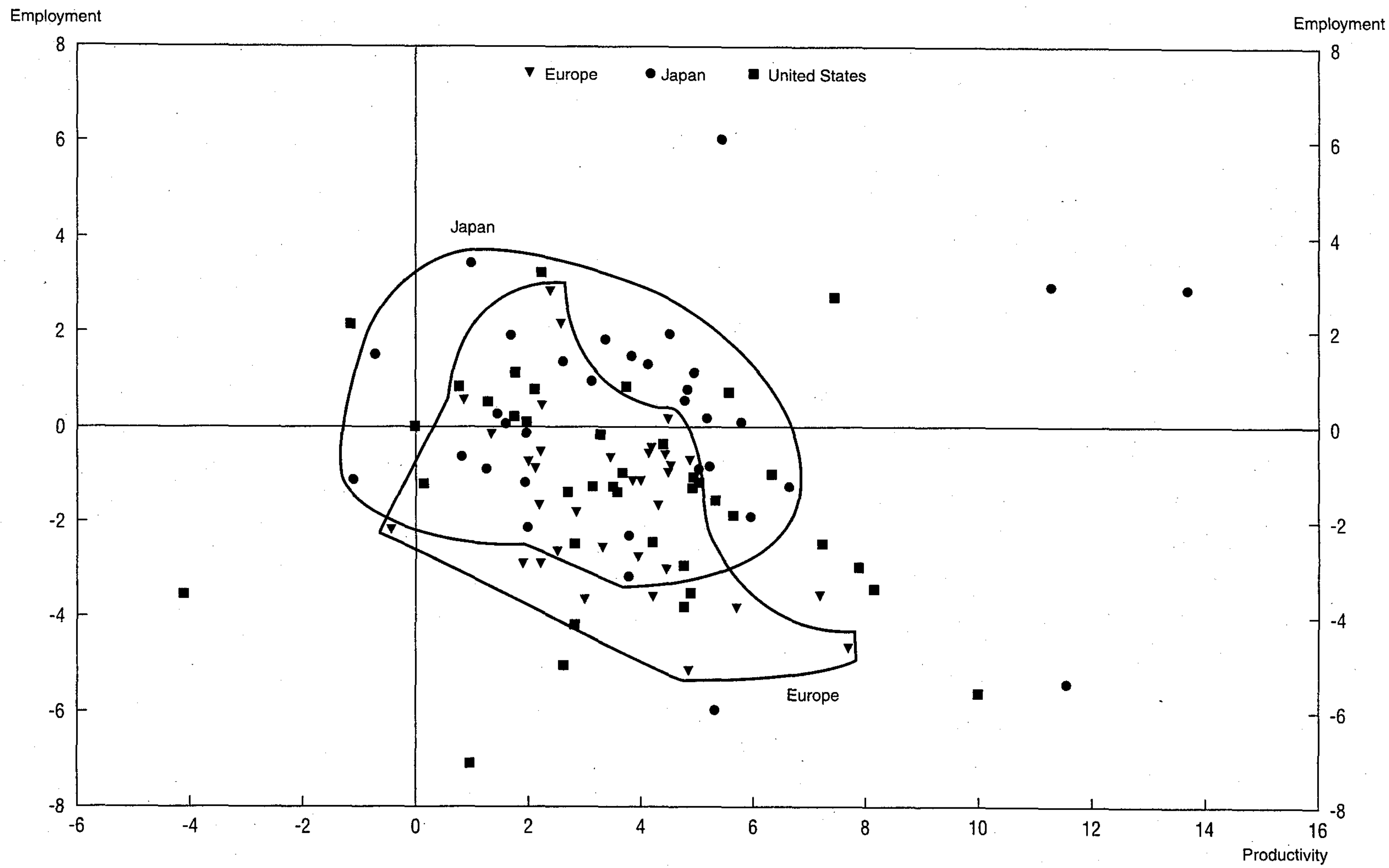
Percentage annual rates of change



Note: Europe: Germany, France, United Kingdom and Italy.
Source: Author.

Figure 4. **Changes in productivity and employment in Europe, Japan and the United States, 1980-82 to 1990-92**

Percentage annual rates of change



Note: Europe: Germany, France, United Kingdom and Italy.
Source: Author.

IV. AN INTERNATIONAL COMPARISON

In the comparison of the six major OECD countries, two new variables have been included (also expressed as average annual rates of change between the 1980-82 and 1990-92 averages) – gross fixed capital formation[11] and the number of patents granted in the United States to inventors of the six countries, taken from the US Patent and Trademark Office database.[12]

In order to use these variables, a higher level of aggregation was required and all economic and technological variables have been considered for 19 manufacturing sectors.[13] Table 1 provides an overview of the relationships among the five variables; simple correlation coefficients have been calculated across the 19 sectors for the six countries considered.

For the G-6 aggregate, the growth rates for employment, value added, investment and patents are always strongly (and significantly) correlated. Productivity grows in parallel to value added (partly due to way in which the variable is defined) and has a small (non-significant) negative link to employment.

The same pattern of relationships is broadly common to the United States, Japan and to the group of four European countries. In the United States, however, value added and investment are unrelated and patents show no association to other variables (probably due to the use of domestic US patents). In Japan patents are linked to productivity rather than to investment.

In Europe the only difference from the G-6 aggregate is that the negative relationship between employment and productivity is stronger and significant. Looking at individual European countries, the same structure of relationships emerges in Germany, France and the United Kingdom, with differing patterns found only for patents.

In Italy, however, the pattern of associations is markedly different. The close association between employment, value added and investment, common to the other countries, does not emerge. The only strong and highly significant correlations are the negative one between productivity and employment growth, and the positive one between productivity and value added.

For the aggregate of the advanced economies, the sectors showing the highest rates of investment and innovation experienced greater growth of output and employment in the 1980s. Technology, in other words, has accompanied the process of structural change, favouring the emergence of new fields of activity which have provided new job opportunities. The "compensation mechanisms" of technological unemployment appear to have operated at the level of the G-6.

However, such a process becomes more uneven when the individual countries – especially the European countries – are considered, because the benefits of the compensation effects are distributed as a result of a competitive process,

Table 1. **Correlations between growth rates of economic, technological and employment variables**

Real annual rates of change from the 1980-82 to the 1990-92 averages, 19 manufacturing sectors

Correlations between	G-6	Europe 4	United States	Japan	Germany	France	United Kingdom	Italy
Employment-Value added	0.57***	0.62***	0.53***	0.52**	0.63***	0.48**	0.59***	0.18
Employment-Productivity	–0.28	–0.51**	–0.28	–0.06	–0.55***	–0.61***	–0.32*	–0.65***
Employment-Investment	0.87***	0.75***	0.66***	0.67***	0.64***	0.42**	0.72***	0.07
Employment-Patents	0.50**	0.69***	0.14	0.32*	0.86***	0.77***	0.54***	–0.04
Value added-Productivity	0.55***	0.35*	0.67***	0.82***	0.24	0.39**	0.56***	0.60***
Value added-Investment	0.58***	0.61***	0.23	0.22	0.32*	0.42**	0.60***	0.02
Value added-Patents	0.56***	0.40**	0.23	0.66***	0.50**	0.25	0.47**	0.37**
Productivity-Investment	–0.09	–0.24	–0.32*	0.13	–0.29	–0.09	–0.01	0.002**
Productivity-Patents	0.28	–0.39**	0.12	0.57***	–0.62***	–0.55***	0.07	0.28
Investment-Patents	0.45**	0.63***	0.21***	0.31	0.40**	0.24	0.57***	–0.38*

Note: Significance levels: * 90 per cent; ** 95 per cent; *** 99 per cent. G-6 includes all six countries; Europe 4 includes Germany, France, the United Kingdom and Italy.

Source: ISRDS-CNR, calculations from the OECD STAN database, December 1994.

which is also affected by the sectoral specialisation of individual countries. In Europe, and particularly in Italy (countries which are less present in the "growing sectors" of Figure 2), the "virtuous circle" linking technology, growth and employment is much weaker, and the gains offered by productivity growth have resulted in job losses. In Italy, rather than leading to the expansion of new activities, investment and innovation have focused on the restructuring of traditional sectors of the economy, and are associated with large labour-saving effects.

On the basis of the empirical evidence presented so far, a more detailed analysis of the impact of structural and technological change on employment can be developed.

From the discussion in Section II above, the changes in employment can be interpreted as the result of technological innovation and structural changes in the sectoral composition of economies. The variables available make it possible to estimate these impacts on employment.

The role of structural change is accounted for by changes in sectoral value added; the impact of product innovations, and more generally of innovative activity internal to sectors, can be proxied by the growth of patenting; finally, investment is linked to the expansion of production capacity in sectors and to process innovations. However, the strong association among investment, value added and employment shown above suggests that the dominant factor in investment patterns is the "expansionary effect". In the regression analysis we would therefore expect postive signs from all three variables.

The analysis was first carried out pooling the six countries and the 19 sectors. The regressions were then repeated separately for each country on the 19 sectors available. Table 2 shows the results.

In the pooled analysis, all three variables have a positive sign and highly significant coefficients (the adjusted R-squared is 0.45). However, even when the value added variable is removed (column *b*) the regression maintains its strength; the two coefficients remain positive and increase their significance (the adjusted R-squared is 0.41).

These results suggest that the effects of technological and structural change are closely associated (and difficult to disentangle with the available indicators). They are able to explain to a large extent the employment changes in the manufacturing sectors of the six largest advanced economies.

The relevance of technological and structural change points to fundamental, long-term dynamics shaping employment patterns and leaves little room for explanations based soley on short-term labour market patterns.

The role of industrial structure also emerges from the different results obtained from the regressions for the six countries. The growth of value added appears moderately significant only in the United States and Germany.

Table 2. **Regression estimates**

Dependent variable: rate of change of employment

	Pool of 6 countries and 19 sectors		United States	Japan	Europe 4	Germany	France	United Kingdom	Italy
	(a)	(b)							
Constant	–2.603	–2.268	–1.684	–2.017	–3.133	–2.896	–4.47	–3.68	–1.669
Value added	0.204 –(2.951)***		0.314* (2.384)	0.151 (1.038)	0.231 (2.416)**	0.28 (2.022)*	0.269 (1.522)	0.191 (0.989)	0.296 (1.045)
Investment	0.227 (4.618)***	0.258 (5.181)***	0.369 (3.344)***	0.342 (2.505)**	0.228 (3.670)***	0.211 (3.277)***	0.103 (0.944)	0.35 (2.147)**	0.027 (0.118)
Patents	0.152 (2.460)**	0.226 (3.872)***	–0.072 (0.402)	–0.029 (0.151)	0.392 (4.234)***	0.681 (5.865)***	0.75 (4.271)***	0.141 (0.717)	–0.076 (0.296)
Adj. R-squared	0.449	0.409	0.505	0.393	0.448	0.858	0.624	0.479	–0.129
F-statistics	(30.582)***	(38.728)***	(7.111)***	(4.668)**	(20.447)***	(37.362)***	(10.422)***	(6.523)***	(0.389)
Number of cases	109	109	19	18	19	19	19	19	18

Note: T-statistics between brackets. Significance levels: * 90 per cent; ** 95 per cent; *** 99 per cent.

Investment has the greatest and most generalised positive impact on employment growth, with the only exceptions being France and Italy. Patents show a positive and significant link to employment only in Germany and France. The lack of association for Japan may be due to the high growth rates of patenting in the United States experienced in most sectors, including those of lower technological intensity.

Overall, the regressions largely account for the employment changes in all countries, with the exception of Italy, where no variable is significant. Only in Italy are the increases in production and technological activities of the manufacturing sector unrelated to the employment changes of the last decade. While for the advanced countries as a whole the expansion of innovation-led activities in growing sectors has partially offset the job losses caused by technological change and greater competition, there is no evidence of the operation of such a compensation mechanism in Italy. The Italian case is discussed at some length in the following section as it offers the opportunity to use a more detailed set of indicators of innovative activities.

V. A MORE DETAILED LOOK AT INNOVATIVE ACTIVITIES AND THEIR EMPLOYMENT IMPACT IN ITALY

The sectoral analysis carried out in the previous sections has three major limitations:

- First, the technological indicators – patents and gross investment – used as proxies for disembodied and embodied technological activities do not account for all aspects of the complex innovation process. In particular, activities such as non-formalised research, design and engineering are not covered by such variables.
- Second, investment in fixed capital remains a rather crude proxy for firms' embodied technological activities and there is a need for a specific indicator of the introduction of process innovations, as opposed to the prevalent "expansionary effect" of investment.
- Third, sectoral comparisons do not allow the overall effect of technological change on employment levels to be captured, that is the *net result* of the structural changes and compensation mechanisms of innovation taking place across industrial sectors and across countries.

A step forward can be offered by innovation survey data, which provide an enlarged set of quantitative and qualitative indications on firms' innovative activities. Here we summarise the evidence of work in which additional technological indicators have been used (Evangelista, 1995; Vivarelli, Evangelista, Pianta, 1995).

The first Cnr-Istat innovation survey on manufacturing industry provides data on the consequences of the introduction of innovations during 1981-85 on the use of the main factors of production.[14] Data refer to 8 220 Italian innovative firms. In addition to questions on the nature and cost of their innovative activities – expenditures for R&D, design and engineering (D&E), innovative investment; shares of product and process innovations, etc. – firms were asked whether the innovations introduced had led to an increase, a decrease, or no change in the use of labour and fixed capital.

These data allow the specific impact of technological activities on employment to be identified in a direct way. At the aggregate level, the net impact of innovation on the use of labour for all manufacturing industry can be illustrated. At the sectoral level, differences in innovation and employment patterns may emerge.

Table 3 presents innovative firms in 30 manufacturing sectors, classified according to the effect of innovations introduced during 1981-85 on the use of labour and fixed capital. The values of a sub-sample of an additional 2 701 innovative firms are also shown.[15]

The first two columns in the table show normalised indices of the effects of innovation on labour and fixed capital. They are calculated as the difference between the number of firms declaring that innovation had a positive effect on the use of labour (or capital), and those declaring a negative effect, divided by the total number of firms. These values can be read as synthetic indices of the size of the labour-saving effects of innovations (in the case of a negative sign of the first index), or of their capital-deepening effects (in the case of a positive sign of the second index).

For manufacturing as a whole, innovation has no effect on employment in 45 per cent of the 8 220 firms studied: 2 671 firms responded that the introduction of innovations had led to a reduction in the number of employees, with 1 811 firms stating the opposite effect. Few sectors show a positive effect on employment; these accounted for 25 per cent of the sample in terms of employees, and 18 per cent in terms of sales.[16]

A different picture emerges when the sub-sample of the 2 701 most innovative firms is taken into account. In this group, innovative activities had a slight positive effect on employment, with 831 firms declaring an increase in the use of labour, and 728 reporting reduced employment. However, an overall increase in the use of labour is found only in firm-size classes with fewer than 200 employees; larger firms have experienced job losses. The net effect on the absolute number of jobs is therefore also likely to be negative in the sub-sample.[17]

Table 3 also shows large differences across industrial sectors. As far as the effects of innovations on the use of labour are concerned, positive indices are found in industrial sectors with higher technological opportunities, *i.e.* sectors

Table 3. **Effects of innovative activity on the use of labour and fixed capital**

Number of firms broken down by industrial sector

Industrial sectors (NACE)	Normalised differences[1]		Use of labour			Use of fixed capital			No. of firms
	Use of labour	Use of capital	No effect	Increase	Decrease	No effect	Increase	Decrease	
Aircraft	0.44	0.94	5	9	2	1	15	0	16
Pharmaceuticals	0.26	0.69	64	65	25	37	112	5	154
Textile machinery	0.20	0.71	40	38	19	24	71	2	97
Electronic eq. and comp.	0.15	0.64	37	31	18	21	60	5	86
Radio, TV and comun. eq.	0.06	0.70	46	36	29	23	83	5	111
Metal machinery	0.06	0.64	137	84	66	74	198	15	287
Electrical appl.	0.05	0.60	36	25	21	21	55	6	82
Gen. mechan. engin.	0.04	0.57	528	264	228	341	630	49	1 020
Energy and gas	0.00	0.84	7	6	6	3	16	0	19
Chemicals	0.00	0.64	150	93	93	94	228	14	336
Synthetic fibres	0.00	0.82	3	4	4	2	9	0	11
Office machinery, computing	0.00	1.00	3	4	4	0	11	0	11
Precision instruments	–0.01	0.68	62	40	42	34	104	6	144
Electrical comp.	–0.03	0.61	166	101	112	110	251	18	379
Leather	–0.05	0.56	61	32	39	48	79	5	132
Plastics	–0.07	0.66	157	101	130	105	270	13	388
Metal products	–0.16	0.59	503	192	356	350	658	43	1 051
Food	–0.16	0.65	137	65	117	81	222	16	319
Sugar, drinks	–0.17	0.63	89	44	79	65	140	7	212
Paper, printing	–0.17	0.61	192	84	158	149	275	10	434
Non-metals, minerals	–0.19	0.59	245	114	224	201	362	20	583
Other transport	–0.19	0.67	40	14	30	28	56	0	84
Other manufacturing	–0.19	0.55	76	22	51	53	89	7	149
Footwear, clothing	–0.20	0.55	199	66	147	167	236	9	412
Motor vehicle comp.	–0.21	0.71	67	33	68	40	124	4	168
Metals	–0.22	0.53	74	21	53	52	87	9	148
Textiles	–0.22	0.62	302	127	285	217	470	27	714
Wood, furniture	–0.23	0.56	281	81	213	186	356	33	575
Rubber, plastics	–0.37	0.63	28	14	47	29	58	2	89
Motor vehicles	–0.44	1.00	3	1	5	0	9	0	9
Sub-sample of most innovative firms	0.04	0.71	1 142	831	728	625	1 997	79	2 701
Total sample	–0.10	0.61	3 738	1 811	2 671	2 556	5 334	330	8 220

1. Number of firms which have increased their use of the production factor minus number of firms which have decreased their use of the production factor/total number of firms.

Source: Vivarelli, M., R. Evangelista and M. Pianta (1995).

producing capital goods (specialised machinery and electrical/electronic components) and science-based sectors such as pharmaceuticals and aircraft. Negative indices are found in scale-intensive and/or capital-intensive sectors and in traditional industries characterised by the use of innovations generated by specialised-supplier sectors.[18]

Data on the various components of total innovation costs, and on the number of product and process innovations allow the employment effects of the different innovative patterns to be identified in more detail.[19] An empirical investigation was carried out (see Vivarelli, Evangelista and Pianta, 1995) on data for 30 manufacturing sectors.[20] The variables studied include expenditure per employee devoted to total innovative activities, broken down into R&D, design and engineering and innovation-related investment; shares of product and process innovations were also used.

Across the 30 sectors, a positive effect on labour use is found to be correlated with higher innovation costs, and in particular with design and engineering expenditure, as well as with the share of product innovations. On the other hand, a negative link emerges for process innovation and no association is found for the R&D variable. This result reflects the strength, in the Italian industrial structure, of the specialised-supplier sectors in the mechanical and electrical fields, whose product-oriented innovative strategies have resulted in good economic performances.

The joint effect of these different aspects of innovative activity was explored using a multiple regression analysis, which confirmed the pattern of associations described above, while showing significant negative effects of process innovations and R&D expenditures per employee.[21]

The surprising result for R&D might reflect the weak technological and economic performance of the Italian firms competing in high-tech sectors; these firms have largely relied on restructuring and process innovations, reducing their employment levels.[22]

The specific role of process innovations was demonstrated in another regression; controlling for total innovation expenditure of sectors, the impact of process innovations on employment continued to be negative and highly significant.[23] In both high and low technology sectors, process and product innovations have opposite and statistically significant effects on the use of labour. Such contrasting effects are likely to be a common characteristic of the innovation-employment link, beyond the specificity of the Italian industrial structure.

The results of the new survey on innovations introduced by Italian firms in 1990-92, carried out as part of the EU-sponsored Community Innovation Survey, generally confirm the polarisation between product and process innovations, while the employment impact up to 1994 appears less clear (all manufacturing sectors show job losses), due also to the recession and the export boom induced by the 1992 devaluation. In Pianta (1996), when 15 manufacturing sectors are studied, total innovation expenditures (R&D, design and engineering, innovative investment, etc.) per sales turn out to be inversely related to the employment performance of the sectors, which is most strongly correlated to the growth of exports. In other words, in the early 1990s, the smallest number of job reductions are found in the low-technology, export-oriented sectors, while the heaviest employment losses take place in those industries which spend more on innovation. These preliminary results will be followed up by a more disaggregated investigation, controlling for the impact of macroeconomic factors on the link between innovation and employment performance.

CONCLUSIONS

In this article the employment changes in the manufacturing sectors of the six largest OECD economies are found to be closely related to the effects of technological and structural change. Indicators such as value added, investment and patents show strong positive links to sectoral employment patterns, highlighting fundamental, long-term dynamics. Such variables, however, do not allow the specific (and sometimes contrasting) effects of different aspects of innovative activities to be disentangled. The statistical analysis has captured mainly the "expansionary effect" of investment and the positive contribution of product innovations (proxied by patents). These appear to be the answers to the two questions posed in Section II.

Across manufacturing sectors, technological change appears to have accompanied the process of structural change, favouring the emergence of new activities offering new employment. From this perspective, the "compensation mechanisms" of technological unemployment appear to have operated at the level of the group of the most advanced economies.

Such growth opportunities, however, are captured by countries after a strongly competitive process, where national specialisations and technological advantages are crucial. The European countries, and particularly Italy, are less present in the most dynamic sectors at world level. They therefore find it harder to benefit from the "virtuous circle" linking technology, growth and employment which operates at the global level. Conversely, some negative effects of technological change (process innovations in particular) emerge clearly.

In the case of Italy, the lack of association between technology and employment patterns found using investment and patent data conceals the picture revealed by more detailed indicators, drawn from by the innovation survey. An overall negative impact of technology on employment in Italian manufacturing is found, mainly due to the dominant role of process innovations and embodied technical change in firms' innovative activities. An opposite labour-increasing pattern has been found only in sectors characterised by higher design and engineering expenditure and higher shares of product innovations.

The results of the exploratory analysis on Italian data suggest that in order to better understand the employment impact of innovation, a promising direction is the integration of a wider set of indicators of technological activities. These are required in order to capture the different specific effects of the complex process of technological change on job creation and destruction in advanced economies. It is on this ground, shaped by the long-term changes in the economic structure, that the dynamics of employment changes can be identified, rather than in the short-term working of labour markets.

NOTES

1. Among a large literature, the effects at the country level are reviewed in Fagerberg (1994) and Pianta (1995); at the sectoral level see Dosi, Pavitt and Soete (1990); Scherer (1992); Amendola, Guerrieri and Padoan (1992).
2. Recent studies on technology and employment, using a variety of approaches, include Freeman, Clark and Soete (1982); Freeman and Soete (1987, 1994); Leontief and Duchin (1986); Boyer (1988); Pasinetti (1981, 1990); Sylos Labini (1990); Meyer-Krahmer (1992); Pini (1995); Rifkin (1995); Vivarelli (1995). Studies developed in the framework of OECD activities include OECD (1994*a*); Caracostas and Muldur (1995); Papaconstantinou (1995*a*, 1995*b*); Petit (1995); Sakurai (1995), and have led to the Report on *Technology, Productivity and Job Creation* (OECD, 1996*b*).
3. Part of the growth of private services is associated to the transfer of activities previously carried out within large manufacturing firms; this may affect the patterns of structural change in a different way across sectors and countries.
4. Firm-level analyses were presented at the joint US Commerce Department-OECD Conference on "The effects of Technology and Innovation of Firm Performance and Employment", Washington, DC, 1-2 May 1995. In general, while they can show that the most innovative firms also perform better in employment terms, they can hardly identify the net effect of technological change on employment at the sectoral (or aggregate) level.
5. A large empirical literature has investigated the economic impact of R&D at the sectoral level. In OECD (1996*b*) a more sophisticated analysis has investigated the technological intensity of sectors based on their R&D expenditure, integrated by the R&D intensities of intermediate goods and capital inputs derived from input-output matrices.
6. The patent data used are described in Section IV. For a discussion of the strengths and weaknesses of this indicator and a comparison with other indicators, see Archibugi and Pianta (1992, 1996) and OECD (1994*b*).
7. However, this investigation of the impact of investment and patenting carried out by a sector on employment performance ignores the inter-sectoral diffusion of innovations which are not embodied in capital goods. This might be investigated using the inter-sectoral patent matrix developed using Canadian patents which reports their sector of origin and of expected use. An additional problem arises since product innovations of a given sector are often process innovations for its user sectors (see Simonetti, Archibugi and Evangelista, 1995).

8. The full list of "sectors in restructuring" is the following: communications, paper, furniture (with minor job losses), rubber, machinery, other transport, other manufacturing, professional goods, metal products, non-ferrous metals, pottery, glass, wood products, industrial chemicals, non-metallic minerals, textiles, wearing apparel, petroleum and coal, motorcycles, railroad equipment, beverages and shipbuilding. While such a sector distribution is not particularly stable when different years or a higher aggregation are used, it provides an indication of the patterns of structural change in the G-6 aggregate.

9. For total manufacturing, the rates of change of value added and employment differ significantly across the three areas. Employment has increased by an annual rate of 1.09 per cent in Japan and fallen by 0.58 per cent in the United States, and by 1.08 per cent in Europe. Value added has increased by 5.68 per cent in Japan, 2.38 per cent in the United States, and 1.94 per cent in Europe.

10. For the manufacturing industry as a whole, Japan shows a higher elasticity of employment relative to value added than the United States or Europe. Conversely, the same increase in productivity leads to higher job losses in Europe than in the United States, and to small job gains in Japan.

11. Data are taken from the same STAN database, and have been converted to constant 1985 prices using GDP deflators. Obviously data on investment in machinery and equipment alone would have been preferable, but these data were not available.

12. The number of patents granted in the United States is one of the most widely used technology indicators at the sectoral level. The United States are the largest and most advanced market for technology, and for foreign countries the number of patents obtained in the United Stats is a good indicator of their technological activities at international level. However, the data are less reliable as an indicator for the United States itself, as they record the patents obtained in the domestic market, which tend to be more numerous, of lower quality, and more uniformly distributed across sectors than patents obtained abroad (see Archibugi and Pianta, 1992,1996; OECD, 1994*b*).

13. All STAN-based variables (employment, value added, productivity and investment) were analysed at the 22 ISIC class disaggregation. US patent data are available by 41 SIC classes and a preliminary concordance was established, covering 19 of the 22 ISIC classes (excluding the ISIC classes: Wood products and furniture, Paper and printing, Other manufacturing). For patents, the SIC classes of Ordnance and Other industries were excluded, and the remainder attributed to the 19 ISIC classes considered.

14. The survey methodology and results are discussed in ISTAT, 1990; Archibugi, Cesaratto and Sirilli, 1991; Evangelista, 1995, 1996. A new survey was carried out on innovations introduced in the 1990-92 period, in the framework of the EU-sponsored Community Innovation Survey. However, in the new questionnaire the question on the impact of innovation on the use of labour and capital was dropped. Preliminary analyses on the employment impact of innovation based on these data are recorded in Pianta, 1996; and Cesaratto and Stirati (1996).

15. These firms are defined as those which have introduced both product and process innovations using at least one internal technological source, such as R&D or patents.
16. The results would also appear to be consistent with the heavy loss of jobs – one million in the 1981-85 period – experienced by the Italian manufacturing industry.
17. The effects of innovation are strongly related to firm size. Larger firms tend to show stronger labour-saving and capital-deepening effects. From such patterns, we can expect that the index on the use of labour reported in Table 3 would tend to underestimate the actual number of job losses associated with technological change in Italian manufacturing. Table 3 also shows that innovative activities have had a general capital augmenting nature. Only a very low percentage of firms has declared that innovative activities have led to a decrease in the use of fixed capital. The capital-deepening nature of innovative activities is more relevant among the group of most innovative firms, and is higher in large than in small firms.
18. Indices equal to zero are found in a few industrial sectors, some of which (Energy, Office machinery and Synthetic fibres) include a very limited number of firms. The data show the existence of significant sectoral differences in the effects of innovative activities on labour.
19. In this empirical investigation the focus is on innovations introduced by firms within each sector. The problems of intersectoral flows of innovations have been addressed in DeBresson, Sirilli, Hu and Luk (1994); and Cesaratto, Mangano and Massini (1995).
20. Data for individual firms are not available due to data confidentiality.
21. In the regression the index of the use of labour was related to the following variables: R&D (with a negative and significant coefficient); D&E (with a positive and highly significant coefficient); and innovative investment (with a negative and slightly significant coefficient). The R-squared was 0.33 (see Vivarelli, Evangelista and Pianta,1995).
22. This is confirmed by the fact that large Italian manufacturing firms – which account for the majority of R&D expenditures – show higher shares of process innovations.
23. Obviously, the same estimates using the share of product innovations would lead to the same results with the opposite signs.

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TECHNOLOGY AND THE DEMAND FOR SKILLS

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SUMMARY

Using skill indices derived from the *Dictionary of Occupational Titles* linked to employment matrices for census years 1950 to 1990, I find that both cognitive and interactive skills showed positive growth over this period in the United States, while motor skills experienced an absolute decline. Growth in all three workplace skill indices peaked in the 1960s. The growth of cognitive skills fell between the 1960s and 1970s, and again between the 1970s and 1980s. Investigation into the factors that affect the demand for skills indicates that growth in total factor productivity is generally de-skilling. Other dimensions of technological activity – particularly capital-labour growth, R&D intensity and computerisation – have a positive relation to the change in substantive complexity and interactive skills.

I. INTRODUCTION

The US economy has undergone major structural changes since 1950. First, there has been a gradual shift of employment from goods-producing industries to service-providing industries. Second, since the 1970s at least, the availability of new information-based technologies has made possible substantial adjustments in operations and organisational re-structuring of firms. This has been accelerated, in part, by sharply increasing competition from imports. Evidence from industry level case studies indicates that this restructuring is likely to have important consequences for the level and composition of skills required in the US workplace (see Adler, 1986; Zuboff, 1988).

The direction and extent of changes in skill levels over the longer run has, however, been more uncertain, with case studies often finding a de-skilling of the content of production jobs, and aggregate studies finding little change or at most a gradual upgrading in overall occupation mix (see Spenner, 1988, for a survey of this literature). These trends have considerable policy significance since they help determine education and training needs. One important result of this article, for example, is that a growing mismatch has been occurring between skill requirements of the workplace and educational attainment of the workforce, with the latter increasing much more rapidly than the former.

The second section of this article documents changes in aggregate skill levels of the workplace over the period 1950 to 1990. I rely mainly on the *Dictionary of Occupational Titles* (DOT), which offers direct measures of the skill requirements of detailed jobs (see Rumberger, 1981, for example). Cognitive, interactive and motor skill indices from the fourth edition of the DOT (see US Department of Labor, 1977) are linked to consistent employment matrices for Census years 1950, 1960, 1970, 1980, and 1990 (267 occupations by 64 industries).[1] I also use standard measures of workforce skills based on educational attainment. Comparisons in the trends of the two types of measures are highlighted in this section.

Section III of the article investigates skill trends at the sectoral level. Here it will be clear that some industries have been more dynamic than others in both upgrading and downgrading skill requirements. Differences in skill change between goods and service industries receive special attention. Changes in aggregate skill levels result from both changes in skill requirements at the industry level and structural shifts in employment patterns across industries. The former is normally interpreted as deriving from changes in technology and the latter from shifting patterns of demand. The last part of Section III provides a decomposition of changes in aggregate skill levels into these two components.

Section IV of the paper analyses the role of technological change in explaining the changing demand for skill. This deserves some comment. The notion that technological change may stimulate the demand for more skilled or better educated labour emanates from the work of Arrow (1962) and Nelson and Phelps (1966). Arrow introduced the notion of learning-by-doing, which implies that experience in the application of a given technology or new technology in the production process leads to increased efficiencies over time. One implication of this is that an educated labour force should "learn faster" than a less educated group. Industries with more rapid rates of technological progress may thus favour workers with greater potential for learning.

In the Nelson and Phelps model, it is argued that a more educated workforce may make it easier for a firm to adopt and implement new technologies. Firms value workers with education because they are more able to evaluate and adapt innovations and to learn new functions and routines than less educated ones. In this model, too, technological change may stimulate the demand for skilled workers.

Several studies provide evidence (both direct and indirect) of a positive relation between the pace of technological activity and the demand for educated labour. Welch (1970) analysed the returns to education in US farming in 1959 and concluded that a portion of the returns to schooling results from the greater ability of more educated workers to adapt to new production technologies. Bartel and Lichtenberg (1987), using industry-level data for 61 US manufacturing industries over the 1960-80 period, found that the relative demand for educated workers was greater in sectors with newer vintages of capital. They inferred from this that highly educated workers have a comparative advantage with regard to the implementation of new technologies.

A related finding is reported by Mincer and Higuchi (1988), using US and Japanese employment data, that returns to education are higher in sectors undergoing more rapid technical change. Another is from Gill (1989), who calculated on the basis of US Current Population Survey data for 1969-84 that returns to education for highly schooled employees are greater in industries with higher rates of technological change.

In Section IV, regression analysis is employed to relate the change in skill indices to various measures of technological activity, including traditional measures of total factor productivity growth, as well as computer intensity, research and development intensity, and capital vintage. The regressions are performed at the industry level, for the period from 1970 to 1990.[2]

II. AGGREGATE SKILL TRENDS, 1950-90

Measures of labour skills

Labour skills appear in a wide variety of dimensions. Jobs are defined by a set of tasks requiring some combination of motor skills (physical strength, manual dexterity, motor co-ordination), perceptive and interpersonal skills, organisational and managerial skills, autonomy and responsibility, verbal and language skills, diagnostic skills (synthetic reasoning abilities) and analytical skills (mathematical and logical reasoning abilities). Perhaps the best source of detailed economy-wide measures of skill requirements for the period since 1960 is the fourth (1977) edition of the DOT. For some 12 000 job titles, it provides a variety of alternative measures of job-skill requirements based upon data collected between 1966 and 1974.[3] On the basis of this source, four measures of *workplace skills* are developed for each *occupation*, as follows:

- *General Educational Development (GED).* On a scale of one to six, GED measures mathematical, language and reasoning skills and is taken directly from the DOT.
- *Substantive Complexity (SC).* SC is a composite measure of skills derived from a factor analytic test of DOT variables by Roos and Treiman (Miller *et al.*, 1980, Appendix F). The results provided strong support for the existence of such a factor: it was highly correlated with General Educational Development, Specific Vocational Preparation (training time requirements), Data (synthesising, co-ordinating, analysing), and three worker

aptitudes – Intelligence (general learning and reasoning ability), Verbal and Numerical. Both GED and SC measure cognitive skills and are highly correlated across industries.

- *Interactive Skills (IS).* IS can be measured, at least roughly, by the DOT "People" variable, which, on a scale of 0-8, identifies whether the job requires mentoring (0), negotiating (1), instructing (2), supervising (3), diverting (4), persuading (5), speaking-signalling (6), serving (7) or taking instructions (8). For comparability with the other measures, we have rescaled this variable so that its values range from 0 to 10 and reversed the scoring so that mentoring, the highest form of interactive skill, is now scored 10 and taking instructions is scored 0.
- *Motor Skills (MS).* MS is measured by another factor-based variable from the Miller study (1980, p. 339). Also scaled from 0 to 10, this measure reflects occupational scores on motor co-ordination, manual dexterity and "things" – job requirements that range from setting up machines and precision working to feeding machines and handling materials. These traditional shop-floor skills have been the focus of much of the de-skilling debate.

Another measure of workplace skills is derived from the 1970 Census of Population data:

- *Median Years of Schooling-1970 (EDUC-1970).* Median years of schooling is computed for each occupation in 1970 on the basis of actual schooling attainment reported by respondents in the 1970 Census of Population. In a sense, this measure gives us a "constant educational requirements" measure by occupation, in contrast to the actual educational attainment of workers in each occupation on a year-by-year or "current" basis. This is analogous to constant dollar versus current dollar output series. If the actual skill requirements of each occupation remain constant over time, then EDUC-1970 serves as an indicator of the changes in the educational *requirements* of the workplace. We shall return to this point below.

Average industry skill scores are computed as a weighted average of the skill scores of each occupation, with the occupational employment mix of the industry as weights. Computations are performed for 1950, 1960, 1970, 1980, and 1990 on the basis of occupation by industry employment matrices for each of these years constructed from decennial census data. There are 267 occupations and 64 industries. Since occupation and industry classifications have changed substantially with each census, we used Commerce Department compatibility tables for 1950-60, 1960-70 and 1970-80 to produce consistent matrices for 1950, 1960, 1970, and 1980. Fortunately, there were only very minor changes in classification between 1980 and 1990.

It should be emphasized at the outset that no attempt is made to account for changes in the skill content of specific occupations. Such a project would require a comparison of skill levels over successive editions of the DOT. Moreover, the last edition was published in 1977. There is some evidence that the skill content of some jobs does change over time. Hirschhorn (1986) notes the increasing importance of diagnostic skills and synthetic reasoning abilities with the use of programmable automation. Similarly, Zuboff (1988, pp. 75-76) writes that operators increasingly require a new kind of thinking, which "...combines abstraction, explicit inference, and procedural reasoning". However, the evidence from studies that have looked across all occupations suggests that there are changes in skill content in both directions, and the net effect is small (see Horowitz and Hernstadt, 1966; Spenner, 1983, pp. 830-831).

Another point worth noting is that, if the skill requirements of a job change substantially, then the US Bureau of the Census classifies this as a new occupation. The number of occupations contained in the Census data has grown considerably over time – particularly between 1960 and 1980, when the number increased from 277 to 505. It is probably not unreasonable, therefore, to assume that, *on average*, the skill levels of occupations have remained largely unchanged over the 1950-90 period.

Educational attainment has also been employed to measure the skills supplied in the workplace. The usefulness of schooling measures is limited by such problems as variations in the quality of schooling both over time and among areas, the use of credentials as a screening mechanism, and inflationary trends in credential and certification requirements. Indeed, there is some empirical evidence that years of schooling may not closely correspond to the technical skill requirements of the jobs (see Rumberger, 1981, for example).

For comparison purposes, we have also constructed three measures of the actual educational attainment of the adult population or workforce in each of the Census years: *i)* per cent of the adult population aged 25 and over with a high school degree; *ii)* percentage of the adult population aged 25 and over with a college (B.A.) degree; and *iii)* mean schooling of the workforce (see notes to Table 2 for sources and methods). These measures are based on economy-wide data (mainly household surveys) for the population but are not available at the industry level. Moreover, unlike EDUC-1970, these measures are based on current educational data for each of the Census years and may thus be interpreted as an indicator of *workforce skills.*

Broad occupational trends

I begin with general trends in the occupational composition of employment over the period 1950 to 1993. As shown in Table 1, some of the changes have

Table 1. **Distribution of employment by occupational group, 1950-93**

Percentages

Occupational group	1950	1960	1970	1977	1988	1993
Professional, technical and kindred	8.6	10.8	13.8	14.6	16.1	17.5
Administrators and managers except farm	8.7	10.2	10.2	10.3	12.4	12.9
Clerical	12.3	14.5	17.4	17.7	15.9	15.6
Sales	7.0	6.5	6.1	6.2	12.0	11.9
Craft and kindred	14.2	12.9	12.8	13.1	11.9	11.2
Operatives	20.4	18.6	18.2	15.7	11.3	10.4
Labourers, non-farm	6.6	6.0	5.0	5.3	4.2	3.9
Private household	2.6	3.3	2.0	1.3	0.8	0.8
Service except private household	7.8	9.3	10.5	12.7	12.6	13.1
Farmers and farm managers	7.4	4.0	2.1	1.5	3.0	2.8
Farm labourers	4.4	3.9	1.8	1.5		
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: US Bureau of the Census (1978), *Historical Statistics of the US: Colonial Times to 1970,* Bicentennial Edition, Part 2, Washington, DC; US Bureau of Labor Statistics (1979), *Handbook of Labor Statistics 1978;* US Bureau of Labor Statistics (1990), *Handbook of Labor Statistics 1989;* and US Bureau of the Census (1994), *Statistical Abstract of the United States, 1994.*

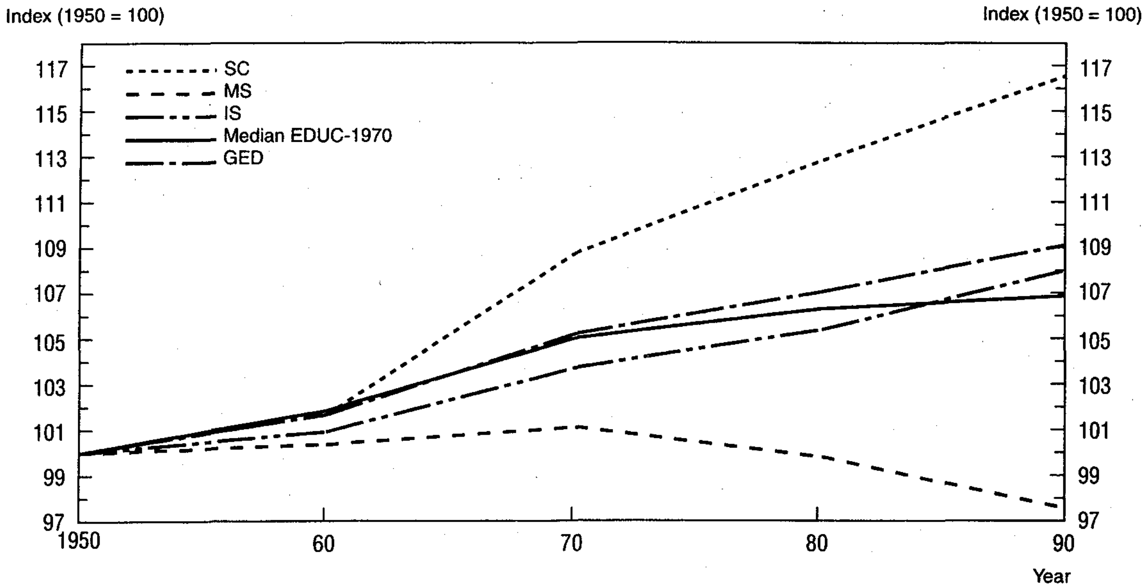
been quite dramatic. Professional and technical workers doubled as a share of employment, from 8.6 per cent in 1950 to 17.5 per cent in 1993. Managers and administrators also increased substantially as a proportion of the workforce, from 8.7 to 12.9 per cent. Clerical workers grew as a share over the same period, from 12.3 to 15.6 per cent. A much higher proportion of the labour force were also engaged as sales workers by 1993, with most of the increase apparently occurring during the 1980s.[4] The other major increase occurred for service workers (excluding private household workers), whose share rose from 7.8 to 13.1 per cent.

The other occupational categories all declined as a share of employment. The proportion of the labour force employed as craftsmen fell from 14.2 to 11.2 per cent and as operatives (that is, machine and transportation operators) from 20.4 to 10.4 per cent. Non-farm labourers (that is, unskilled workmen except those employed on the farm) declined from 6.6 per cent of employment to 3.9 per cent. Domestic servants and other household workers declined as a proportion of the employed labour force from 2.6 to 0.8 per cent. Finally, farmers, farm managers, and farm labourers together fell from 11.8 per cent of total employment to only 2.8 per cent. In sum, the post-war period witnessed a sizeable relative reduction in blue-collar work and a corresponding increase in white-collar jobs, particularly professional and technical positions.

Trends in aggregate skill levels

The results portrayed in Figure 1 show that, with the exception of motor skills, changing employment patterns have had the effect of raising the skill requirements of jobs between 1950 and 1990. Of the five indicators of workplace skills, the average SC level in the economy as a whole had the highest growth, 16 per cent over the four decades. GED and EDUC-1970 grew slower, at 9 and 8 per cent, respectively, while IS increased by 7 per cent. MS, on the other hand, showed a 2 per cent decline over the 40 years.

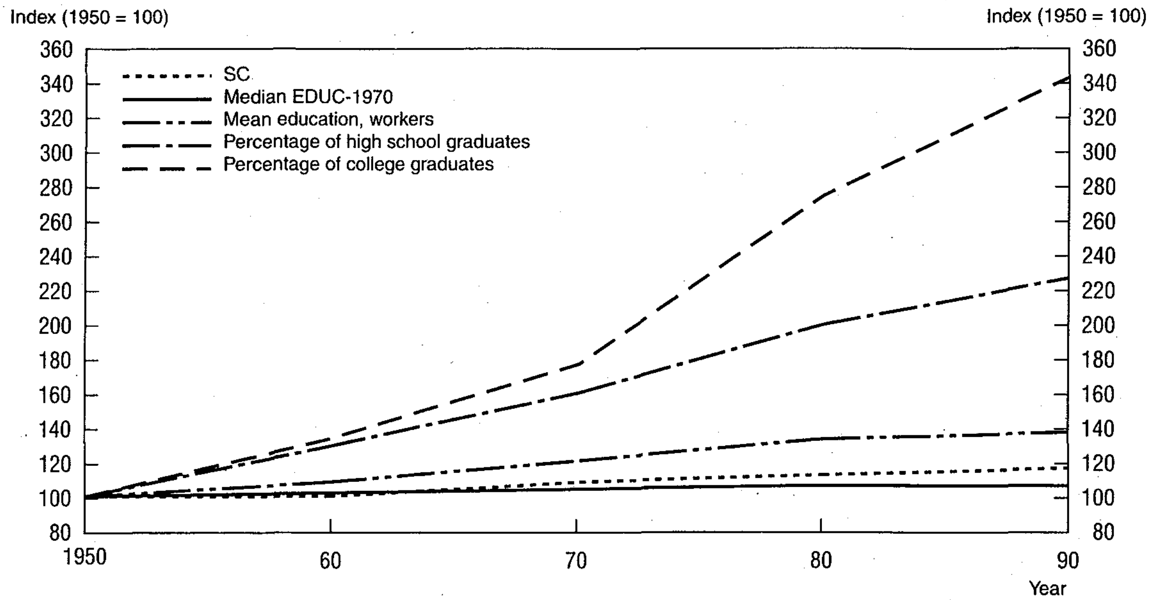
Figure 1. **Mean skill score by type and year**
1950-90



Source: Author.

Growth in workplace skills was dwarfed by increases in the educational attainment of the workforce and adult population, particularly as evidenced in the rescaled Figure 2. The fraction of the adult population (25 years of age and over) with a high school diploma or better more than doubled between 1950 and 1990, from 34 to 78 per cent, while the proportion of adults who had completed at least four years of college more than tripled, from 6.2 to 21.3 per cent. The mean schooling level of employed workers grew slower than these first two indicators, at

Figure 2. **Actual educational attainment and skills**
1950-90



Source: Author.

38 per cent over the forty-year stretch, but at five times the rate of GED and EDUC-1970. Thus, the educational attainment of the population increased considerably faster than the educational requirements of the workplace in the post-war period.

Another striking result is the pronounced slowdown in the rate of growth for all five measures of workplace skills, with the exception of IS, between the 1960s and the 1980s, after a rapid acceleration between the 1950s and 1960s (see Table 2 and Figure 3). Skill growth was quite low during the 1950s. Between the 1950s and 1960s, it increased more than four-fold for SC, tripled for IS, more than doubled for both GED and MS, and rose by more than half for EDUC-1970. Skill growth peaked in the 1960s. Between the 1960s and 1980s, it fell off by half for SC and GED. The annual rate of growth in EDUC-1970 declined from 0.30 per cent in the 1960s to 0.12 per cent in the 1970s, and 0.05 per cent in the 1980s. The growth in MS, which was positive in the 1950s and 1960s turned negative in the 1970s and 1980s. The annual growth in IS fell from 0.27 per cent in the 1960s to 0.18 per cent in the 1970s, but then rebounded to 0.25 per cent in the 1980s.

Patterns of skill growth generally correlate with changes in the broad occupational composition of the labour force. The growth in SC, GED, IS and EDUC-1970 over the four decades reflects the increasing share of professionals

Table 2. **Annual rate of change of workplace and workforce skills, total economy, 1950-90**

Percentages

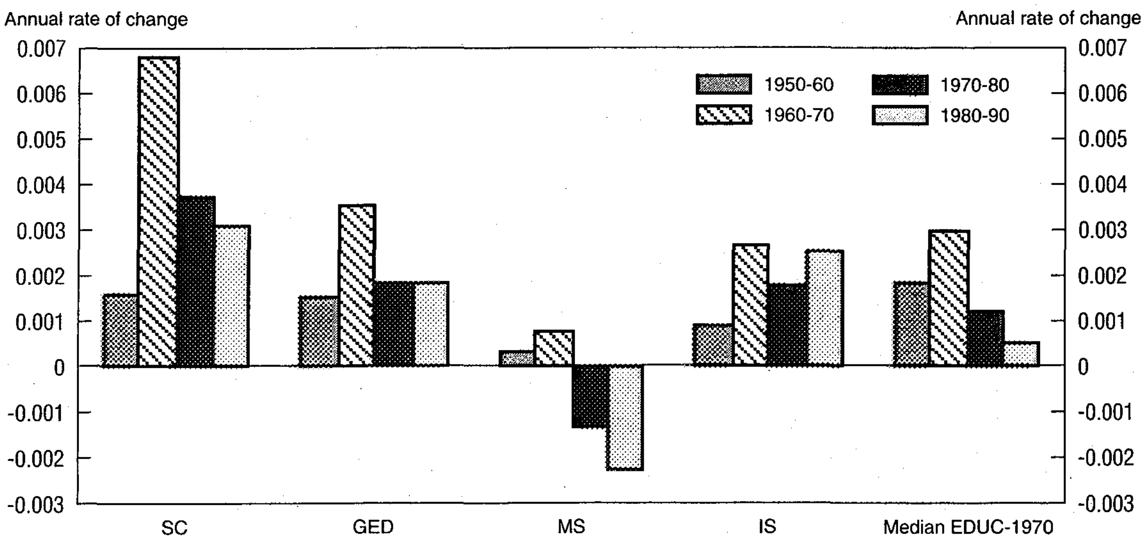
Skill dimension	1950-60	1960-70	1970-80	1980-90	1950-90
A. Workplace skills					
Substantive complexity (SC)	0.16	0.68	0.38	0.31	0.38
General educational development (GED)	0.15	0.35	0.18	0.18	0.22
Interactive skills (IS)	0.09	0.27	0.18	0.25	0.20
Motor skills (MS)	0.03	0.07	–0.13	–0.23	–0.06
Median year of schooling, 1970 (EDUC-1970)	0.19	0.30	0.12	0.05	0.16
B. Workforce skills					
Percentage of adults with 4 years of high school or more [1]	2.62	2.14	2.17	0.74	1.92
Percentage of adults with 4 years of college or more [1]	3.00	2.74	4.35	1.32	2.85
Mean years of schooling of employed workers [2]	0.91	1.10	0.83	0.31	0.79

1. Kominski and Adams (1994), Table 18. Adults refer to persons 25 of age and over.
2. US Bureau of Labor Statistics (1993), *Labor Composition and US Productivity Growth, 1948-90,* Table 8, p. 11. Figures are for the private business sector. Mean schooling is calculated by weighting educational attainment of workers by hours of work.

Source: Author.

Figure 3. **Growth in workplace skills**

By decade, 1950-90

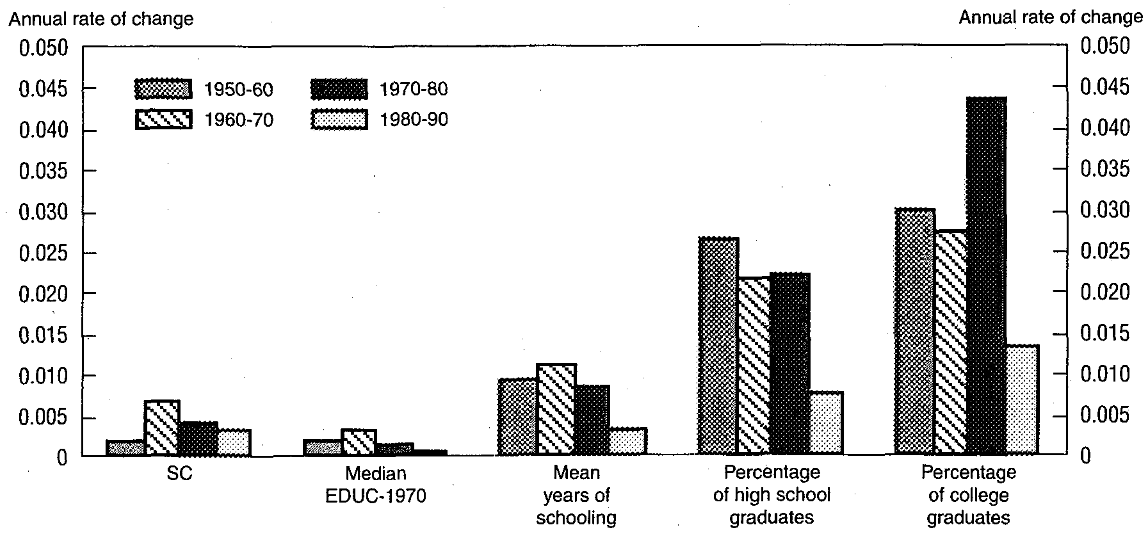


Source: Author.

and managers in the workforce, while the decreasing share of craft workers and operatives in employment appears responsible for the post-war decline in motor skills. The decade-by-decade correspondence is a bit rougher. The peak growth in cognitive skills during the 1960s seems to be due to the particularly rapid increase in the share of professionals in the labour force over that period (3 percentage points). The decline in motor skills after 1970 seems to be attributable to the very sharp reduction in the fraction of operatives in the workforce dating from that year. The rebound in IS growth in the 1980s correlates with the large jump in the share of managers and administrators employed in the economy (about 2 percentage points).[5]

Figure 4 contrasts the growth in workplace skills with trends in the educational attainment of the population and the workforce. As noted above, the growth in educational attainment has been considerably greater than that of workplace skills. Here, we focus on the time pattern over the four decades. Of the three measures of educational attainment, only the mean education of the workforce has the same pattern as cognitive skills, with the rate of growth rising between the 1950s and 1960s and then falling off in the 1970s and again in the 1980s. However, interestingly, the difference in the growth in mean schooling is relatively small between the 1950s, 1960s, and 1970s, whereas it is much lower (by about two-thirds) in the 1980s.

Figure 4. **Growth in workplace and workforce skills**
By decade, 1950-90



Source: Author.

The growth in the percentage of adults with a high school education or more is highest in the 1950s, falls off somewhat in the 1960s, remains about the same in the 1970s, and then declines sharply in the 1980s. The growth in the proportion of adults with a B.A. or more declines somewhat between the 1950s and 1960s, peaks in the 1970s, and then falls off substantially in the 1980s. These results again emphasize the lack of correspondence between the growth in the demand for cognitive skills (as reflected in the direct skill measures) and the supply of such skills, as reflected in the educational attainment of the population.

III. SKILL CHANGES AT THE INDUSTRY LEVEL

There are striking differences in skill requirements among industries in the US economy. These are shown in Table 3 for nine major industrial groupings in 1970 (see also Figure 5). Mean substantive complexity (SC) scores ranged from a low of 3.6 in manufacturing to a high of 5.1 in finance, insurance, and real estate (FIRE, for short). SC levels were about a fifth higher in services than in goods-producing industries. Median education levels (EDUC-1970) were about 10 per cent higher in the service industries than in the goods sectors. The highest EDUC-1970 was recorded in the other services sector, which includes a wide range of business and personal services, at 13.2 years, followed by FIRE (13.0 years) and the government sector (12.8 years). The lowest median education level was found in agriculture (10.3 years).

Interactive skills (IS) were almost twice as high in services as in goods-producing industries. The top three sectors in terms of IS were the same as for EDUC-1970: the other services sector; FIRE; and the government sector. Manufacturing had the lowest IS level. In contrast, motor skill (MS) levels were 14 per cent higher in goods industries than in service industries. Not surprisingly, construction had the highest MS level, followed by manufacturing and mining. Wholesale and retail trade had the lowest MS score.

The addendum to Table 3 provides another bifurcation of jobs – in this case, into production and non-production workers on the basis of the US Bureau of Labor Statistics definition for the manufacturing sector. Production workers are blue-collar workers with the exception of service workers, while non-production workers include white-collar and service jobs. This division has been used in many recent productivity and earnings studies, such as Berman, Bound, and Griliches (1994), to distinguish between skilled and unskilled workers.

The results show that production workers score much higher than non-production workers in SC and IS but the difference in educational attainment is less pronounced. Moreover, as expected, production workers have substantially higher motor skills. Moreover, the standard deviation of skill scores is

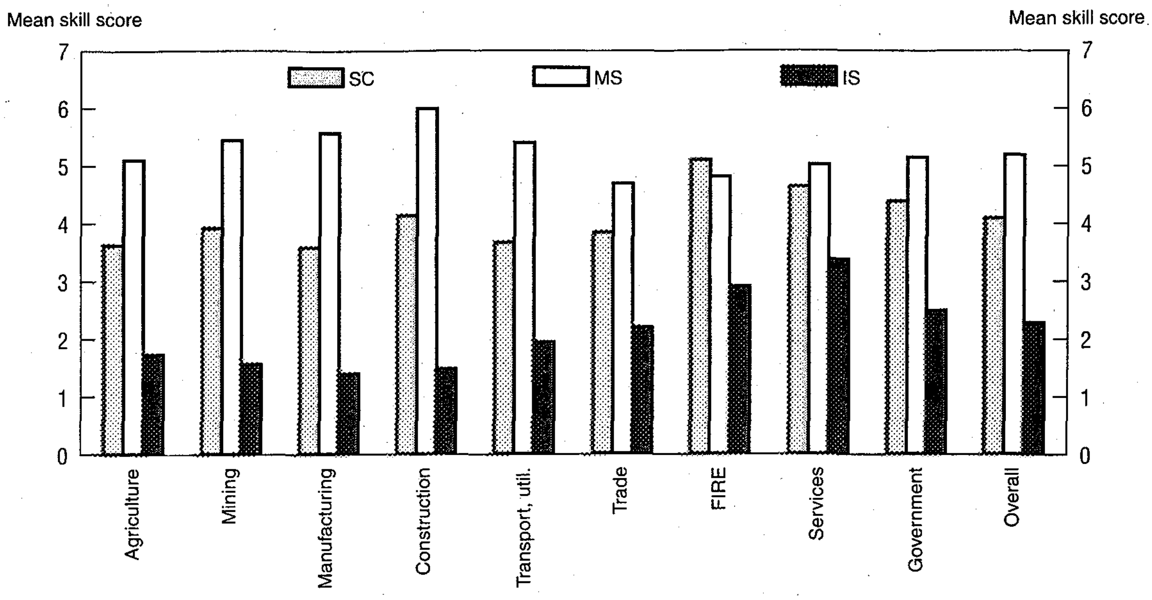
Table 3. **Mean skill scores by major industry in 1970 and percentage change over 1950-90**

	Mean skill score, 1970				Percentage change, 1950-90			
	SC	MS	IS	EDUC-1970	SC	MS	IS	EDUC-1970
Agriculture	3.62	5.09	1.73	10.3	0.2	−1.4	0.6	5.0
Mining	3.90	5.44	1.56	11.7	32.0	−2.2	9.6	8.7
Construction	4.13	6.00	1.46	11.4	23.1	−0.8	6.3	5.0
Manufacturing	3.57	5.56	1.38	11.9	20.4	−2.1	5.6	4.3
Transportation, communications and public utilities	3.69	5.41	1.94	12.0	13.1	−2.3	3.0	2.2
Wholesale, retail trade	3.82	4.66	2.21	12.1	1.0	4.2	0.3	−0.1
Finance, insurance, and real estate	5.09	4.79	2.91	13.0	20.4	−5.4	11.2	5.2
Other services	4.66	5.01	3.38	13.2	11.9	−2.5	6.5	5.9
Government	4.38	5.12	2.51	12.8	9.9	−1.6	4.6	1.8
Goods industries[1]	3.68	5.55	1.52	11.7	15.7	−0.6	4.2	6.0
Service industries[2]	4.37	4.88	2.84	12.8	10.2	0.4	5.4	3.9
Total	4.07	5.17	2.27	12.3	16.5	−2.5	8.1	6.8
Addendum:[3]								
Production workers	3.03	5.75	1.09	11.07				
	(1.53)	(1.19)	(1.26)	(0.87)				
Non-production workers	4.73	4.80	3.01	13.08				
	(2.03)	(1.83)	(2.07)	(1.89)				

1. Goods-producing industries are defined as: 1) agriculture; 2) mining; 3) construction; 4) manufacturing; and 5) transportation, communications and public utilities.
2. Service industries are defined as: 1) wholesale and retail trade; 2) finance, insurance, and real estate; 3) other services; and 4) government services.
3. Production workers include craft workers, operatives, and labourers. Non-production workers include all others. The standard deviation is shown in parentheses.

Source: Author.

Figure 5. **Mean skill score by industry, 1970**



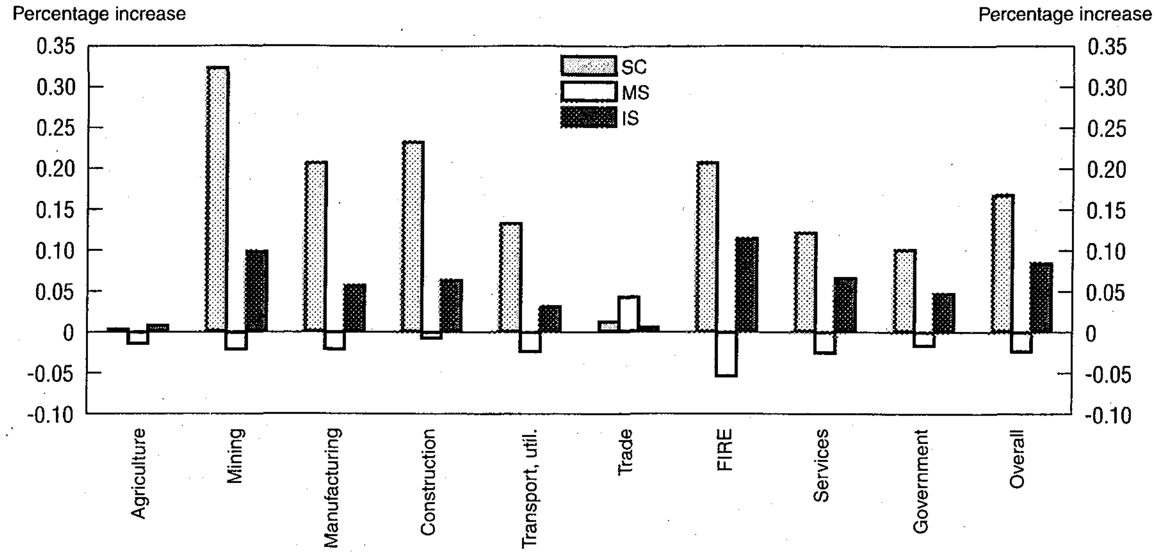
Source: Author.

considerably higher among non-production than production workers, indicating that the former are a more heterogeneous group. These results suggest caution in using production versus non-production workers as a demarcation between skilled and unskilled jobs.

Some industries have also been more dynamic than others in both upgrading and downgrading skill requirements. Interestingly, SC scores have grown much faster in goods industries than in service industries over the years from 1950 to 1990 – 16 versus 10 per cent (also see Figure 6). Mining led the way with a 32 per cent increase, followed by construction (23 per cent) and then manufacturing and FIRE (both at 20 per cent). Agriculture and the trade sector experienced almost no change in SC levels.

The same is true for EDUC-1970 (where jobs are rated according to their 1970 educational requirements). EDUC-1970 grew by 6.0 per cent in goods industries and 3.9 per cent in services. Mining, again, was at the top of the list (8.7 per cent increase), followed by FIRE (5.2 per cent), and then agriculture and construction (both at 5.0 per cent). Growth in educational requirements was lowest in the trade sector – slightly negative over the period. The upgrading of SC and educational requirements in the goods industries reflects the more rapid growth in white-collar jobs than blue-collar ones, particularly from the industrial restructuring of the 1980s.

Figure 6. **Percentage increase in industry skill score**
1950-90



Source: Author.

Interactive skills grew slightly more in services than goods industries. Growth was strongest in FIRE, at 11.2 per cent, followed by other services (6.5 per cent), and, surprisingly, mining (6.5 per cent). Growth was weakest in agriculture (0.6 per cent).

Unlike the other measures in this table, motor skills requirements declined after 1950. This was true of every major industry except trade. While case studies have suggested that de-skilling has occurred via the decline in the skill content of many blue-collar jobs, these industry results indicate that changes in occupation employment patterns within industry also contributed to a reduction in the demand for manual skills.

Substantive complexity, interactive skills, and motor skills represent three relatively independent dimensions of job skills. Looking at Figures 5 and 6, we can see quite clearly that industries that are strong in one dimension of skill need not be strong in the other dimensions as well. For example, while FIRE ranked highest in SC in 1970 it ranked second in IS but last in MS. Moreover, industries that grew rapidly in one skill direction did not necessarily grow in others. FIRE, for example again, had the highest growth in IS, ranked third highest in SC growth but recorded the lowest growth in MS. This stresses the importance of considering multiple dimensions of skills rather than a single one, such as educational attainment, that is used in most studies on this subject.

Industry effects on aggregate skill growth

Changes in aggregate skill levels result from both changes in skill requirements at the industry level and structural shifts in employment patterns across industries. The former is normally interpreted as deriving from changes in technology and the latter from shifting patterns of demand.

Before presenting a formal decomposition, it is helpful to look at the broad changes in employment composition by industry over the post-war period (see Table 4). One of the most dramatic changes has been in agriculture, which accounted for 14 per cent of employment in 1950 and only 3 per cent in 1993. This relative decline has been going on for at least the last 100 years. In 1929, for example, the fraction of total employment accounted for by agriculture was 22 per cent. The proportion fell to 14 per cent in 1947, 8 per cent in 1960, and 4 per cent in 1978. The major decline in employment in the agricultural sector was from the exodus of owners of small farms and their families.

Table 4. **Distribution of employment by major industry, 1950, 1970, and 1993**

Percentages

	1950	1970	1993
Agriculture	13.7	4.7	2.7
Mining	1.7	0.8	0.5
Construction	4.5	4.8	4.0
Manufacturing	29.1	26.1	15.7
Transportation, communications and public utilities	7.7	6.1	5.0
Wholesale and retail trade	17.9	20.2	22.8
Finance, insurance, real estate	3.6	4.9	5.8
Other services	10.2	15.5	26.7
Government	11.5	16.9	16.6
Total	100.0	100.0	100.0

Source: Council of Economic Advisers (1994), *Economic Report of the President, 1994.*

Another major change occurred in manufacturing, whose share of total employment fell by almost half, from 29 per cent in 1950 to 16 per cent in 1993. In absolute terms, employment in manufacturing peaked in 1980 at 20.3 million workers and has since fallen to 17.8 million in 1993. Much discussion has recently ensued over this development, which has been labelled by some as the "deindustrialisation" of America. However, it should be noted that much of the decline in employment in manufacturing is due to the high (labour) productivity growth of this sector. In fact, manufacturing accounted for almost the same share of total output in the early 1990s as it did in the early 1950s.[6]

The share of employment in mining also declined rather precipitously between 1950 and 1993, from 1.7 to 0.5 per cent. The share of employment in transport and public utilities also fell over this period, from 7.7 to 5.0 per cent, while the proportion of workers in construction remained roughly constant, about 4 per cent.

If the share of employment fell in agriculture, mining, manufacturing, and transport and utilities, where did it increase? The answer is the service sectors, which absorbed most of the growth of employment in the post-war period. The proportion of total employment in wholesale and retail trade increased from 18 to 23 per cent, the per cent in finance, insurance, and real estate from 3.6 to 5.8, the per cent on government payrolls from 12 to 17, and the share in other services (personal and business) from 10 to 27 per cent. In sum, two major developments characterised the post-war period. The first was the shrinking share of workers employed in agriculture and manufacturing, and the second was the shift of the workforce out of goods-producing sectors into services.

Changes in overall skill levels are a result of changes in the skill levels of individual industries (through changes in occupational mix) and employment shifts among industries. We can formally decompose the change in overall job skill requirements into an industry and occupation effect, as follows.

Let M = the occupation-by-industry employment matrix, where m_{ij} shows employment of occupation i in industry j;

e = vector with unit entries;

$L = eM$ = (row) vector showing total employment byindustry;

p = (row) vector showing the distribution of employment among industries; where:

$$p_j = L_j / \sum L_j;$$

s = (column) vector showing the average skill level of each industry j;

$\sigma = ps$ = the overall or economy-wide average skill level of employed workers.

Then, for instantaneous changes,

$$d\sigma = pds + (dp)s.$$

Since our data are for discrete time periods, we use the discrete form,

$$\Delta\sigma = p\Delta s + (\Delta p)s, \qquad [1]$$

where $\Delta s = s^2 - s^1$, $\Delta p = p^2 - p^1$, and superscripts refer to time period. The results are based on average period weights, which provide an exact decomposition.

The results are shown in Table 5. During the 1950s, all the growth in Substantive Complexity (SC) was due to changes in the occupational composition of the workforce within industry (by our interpretation, technological change). In

Table 5. **Decomposition of the change in overall skill levels into an occupation mix and industry shift effect, 1950-90**

Period	Change in average skill level (Δσ)	Decomposition[1]		Percentage decomposition	
		Occupation mix effect (pΔs)	Industry shift effect [(Δp)s]	Occupation mix effect (pΔs)	Industry shift effect [(Δp)s]
A. Substantive complexity (SC)					
1950-60	0.060	0.068	–0.008	113.9	–13.9
1960-70	0.267	0.150	0.118	56.1	43.9
1970-80	0.156	0.068	0.088	43.4	56.6
1980-90	0.134	0.038	0.096	28.6	71.4
1950-90	0.617	0.324	0.293	52.5	47.5
B. Motor skills (MS)					
1950-60	0.016	–0.018	0.034	–114.0	214.0
1960-70	0.038	–0.017	0.056	–45.1	145.1
1970-80	–0.068	–0.019	–0.049	28.5	71.5
1980-90	–0.114	–0.012	–0.102	10.2	89.8
1950-90	–0.128	–0.067	–0.061	52.2	47.8
C. Interactive skills (IS)					
1950-60	0.019	0.027	–0.007	136.6	–36.6
1960-70	0.060	0.053	0.007	87.9	12.1
1970-80	0.040	0.024	0.016	59.8	40.2
1980-90	0.059	0.016	0.042	27.8	72.2
1950-90	0.178	0.120	0.059	67.1	32.9
D. Median education, 1970 (EDUC-1970)					
1950-60	0.220	0.206	0.014	93.6	6.4
1960-70	0.362	0.242	0.120	66.9	33.1
1970-80	0.148	0.081	0.067	54.5	45.5
1980-90	0.064	0.041	0.023	64.1	35.9
1950-90	0.794	0.570	0.224	71.8	28.2

1. See equation [1] of the text.
Source: Author.

fact, employment shifted slightly in favour of industries with below average SC levels. During the 1960s, the period of greatest overall growth in SC, both the occupational mix effect and the industry shift effect were positive and strong. If the industry shares of employment had remained unchanged, economy-wide mean cognitive skill levels would have grown by 0.15, over twice the increase of the 1950s. However, higher-skilled industries experienced greater than average employment growth (the industry shift effect), which accounted for an additional 0.12 increase in mean cognitive skills. During the 1960s, a bit over half of the growth in average SC was attributable to changes in occupational mix.

The contribution of the occupational mix effect fell off sharply between the 1960s and 1970s, from 0.150 to 0.068, and again between the 1970s and 1980s, from 0.068 to 0.038, while the industry shift effect fell off slightly. As a result, overall SC growth declined in the 1970s and again in the 1980s. Moreover, the industry shift effect, which accounted for less than half of overall SC growth in the 1960s, accounted for over 70 per cent in the 1980s.

A very similar pattern is evident for our fixed educational requirements variable, EDUC-1970, and for interactive skills (IS) with regard to occupation effects. In both cases, almost all the growth in average skills during the 1950s was attributable to changes in occupational composition. Moreover, between the 1950s and 1960s, the occupational mix effect increased in importance (almost doubling for IS), and then fell off sharply in the 1970s and again in the 1980s.

There is a difference in the pattern of industry effects between EDUC-1970 and IS. In the case of the former, the industry shift effect fell off sharply between the 1960s and 1970s and again between the 1970s and 1980s, so that the growth in overall EDUC-1970 likewise fell off sharply. Moreover, the occupation mix effect was the dominant component of overall skill gain during the 1970s and 1980s. In the case of interactive skills, the industry shift effect became stronger after the 1960s, so that overall IS growth in the 1980s was about the same as in the 1960s. Moreover, the industry shift effect accounted for over 70 per cent of the overall growth in IS in the 1980s.

Changes in motor skills (MS) show a very different pattern from the other three skill measures. The occupation mix effect was negative and of very similar magnitude in each of the four decades, reflecting the shift of employment within industry from blue-collar to white-collar jobs. The industry shift effect was positive and relatively strong in both the 1960s and 1970s, favouring industries with above-average motor skills and accounting for the positive increase in motor skills over these two decades. However, the industry effect turned negative in the 1970s and even more negative in the 1980s, reflecting the dramatic shift of employment toward service industries and accounting for the decline in overall MS growth in those two periods.

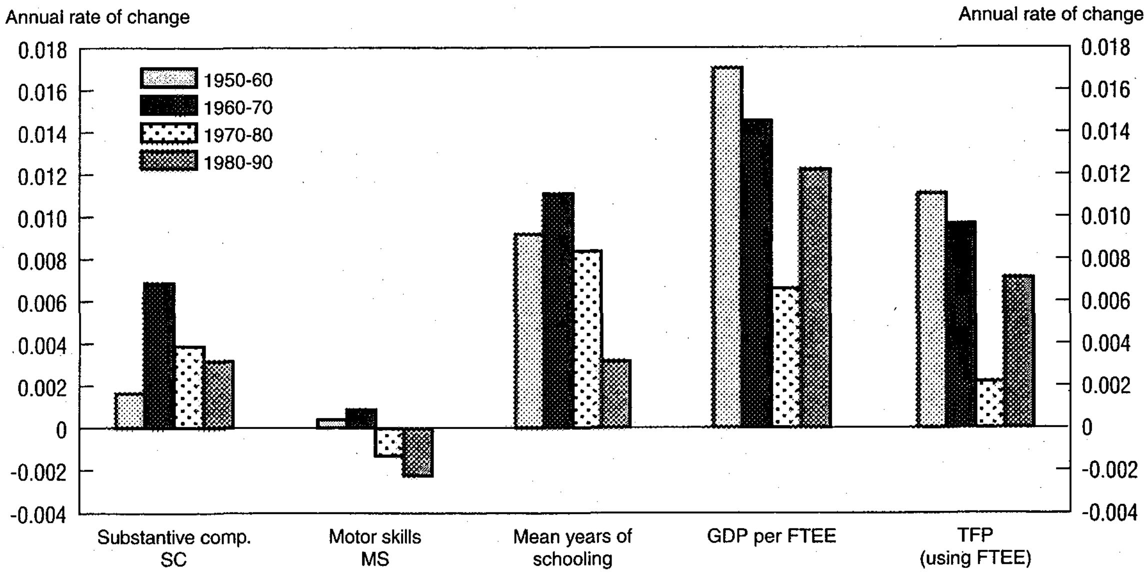
It is also interesting to note that over the entire 1950-90 period, changes in average SC and MS levels were about equally attributable to technological change (52 per cent) and to shifting demand patterns (48 per cent). However, about two-thirds of the upgrading in IS levels and over 70 per cent of the increase in EDUC-1970 were accounted for by the occupation mix effect.

IV. TECHNOLOGY AND SKILL GROWTH

The literature cited in the introduction above suggests that there may be a strong correlation between skill growth and the pace of technological change. The analysis begins with some descriptive statistics, illustrated in Figure 7. I use two standard measures of productivity growth – GDP per Full-time Equivalent Employee (FTEE) and total factor productivity growth, measured using GDP for output and FTEE and gross capital stock for inputs.[7] Also shown in the diagram are the growth in SC, MS, and the mean education of the employed workforce.

Labour and TFP growth show a very similar time pattern. Both are strongest in the 1950s (1.7 and 1.1 per cent per year, respectively), fall slightly in the 1960s, and then precipitously in the 1970s (to 0.7 and 0.2 per cent per year,

Figure 7. **Growth in skills, education and productivity**
By decade, 1950-90



Source: Author.

respectively), and then show a partial recovery in the 1980s (to 1.2 and 0.7 per cent per year, respectively). In contrast, the growth in both SC and mean years of schooling of the workforce increases between the 1950s and 1960s and then declines in the 1970s and again in the 1980s. MS growth also increases between the 1950s and 1960s and falls off in the 1970s and 1980s, but in this case MS growth is negative in the latter two periods. On the basis of these decadal averages, there does not appear to be any clear correspondence between the growth in skill demand (or educational attainment) and the growth in productivity.

I next turn to regression analysis to analyse formally the relation between skill change and technological advance. Because of differences in industry classification schemes in the underlying data sources, I use 43 industries in the regression analysis. Moreover, because of data limitations, the period of analysis is limited to 1970-90. The primary sample consists of pooled cross-section time-series data, with observations on each of the 43 industries in 1970-80 and 1980-90, for a total of 86 observations. A second sample, limited to the 30 goods-producing industries for a sample size of 60, is also used. The error terms are assumed to be independently distributed but may not be identically distributed and I use the White procedure for a heteroschedasticity-consistent covariance matrix in the estimation (see White, 1980).

The dependent variable in the regressions is the change in skill level over the ten-year period. I use five measures of technological activity: *i)* average annual rate of total factor productivity growth (TFP growth); *ii)* investment in office, computer and accounting machinery over the previous seven years per FTEE (OCA/FTEE); *iii)* ratio of expenditures on research and development to industry sales (R&D/Sales); *iv)* the ratio of computer programmers, computer systems analysts, computer specialists, n.e.c., and engineers to FTEE (CSE/FTEE); and *v)* average annual growth rate of the ratio of gross capital stock to FTEE (K/L Growth), which may be interpreted as an indicator of the rate at which new vintages of capital are introduced into the industry.

Other control variables are introduced as well. Relative factor prices between capital and unskilled labour are used to control for the possibility of capital-skill complementarity. Capital intensity, measured as the ratio of capital to output, is also used. High capital intensity may reflect the continued use of old technologies and methods of production that rely upon large scale operations and high shares of semi-skilled workers with specialised mechanical skills. A dummy variable distinguishing the 1970-80 from the 1980-90 period (DUM8090) is also introduced.

A number of structural and organisational dimensions of production may have independent effects on the demand for skills. These include: *i)* the share of employees in an industry covered by union contracts (%UNION); *ii)* the share of employees working in large establishments (defined here as those with 500 or more employees); *iii)* industry employment growth; and *iv)* a dummy variable distinguishing goods from service industries.

International competitiveness, as measured by the ratio of imports to industry gross output (IMP/GDO) and the ratio of exports to industry gross output (EXP/GDO), may also affect the rate of skill change. Industries competing against imports and those competing in international product markets may be forced to upgrade skills faster in order to remain competitive.

Results are shown in Table 6 for the change in three skill dimensions, SC, IS, and MS. I have selected the regression form with the highest adjusted R^2-statistic (or, correspondingly, the lowest standard error of the regression). Of the five technology variables, the strongest effects come from the growth in capital-labour

Table 6. **Regressions of skill change on technology and other variables**[1]

	Dependent variable					
Independent variables	Change in substantive complexity (SC)		Change in interactive skills (IS)		Change in complexity skills (MS)	
	All industries	Goods only	All industries	Goods only	All industries	Goods only
Constant	0.047*	0.074***	0.074***	0.150***	–0.013	–0.030
	(1.71)	(2.87)	(2.28)	(5.07)	(0.48)	(0.86)
TFP growth	–0.929	–1.019*	–0.613	–1.020***	–0.287	–0.304
	(1.50)	(1.74)	(1.57)	(3.32)	(0.96)	(1.29)
Ln(OCA/FTEE)	0.012	0.032**	0.017*	0.019**		
	(1.22)	(2.53)	(1.83)	(1.92)		
R&D/Sales	0.011*	0.004	0.010**	0.0077**		
	(1.71)	(0.59)	(2.58)	(2.03)		
Ln(CSE/FTEE)					–0.040***	–0.027***
					(4.66)	(2.78)
K/L growth	1.963***	1.909***	1.209***	1.126**	–0.291	0.262
	(3.34)	(3.11)	(2.78)	(2.26)	(0.57)	(0.80)
% UNION			–0.061	–0.159***	0.166**	0.073
			(1.11)	(2.97)	(2.30)	(1.11)
IMP/GDO				–0.078		
				(1.15)	(1.15)	
EXP/GDO				0.490*	0.528*	0.402
				(1.70)	(1.68)	(1.41)
DUM 8090			0.0018***	0.0042***	–0.0016*	–0.0014*
			(1.91)	(2.97)	(1.69)	(1.69)
R^2	0.24	0.38	0.39	0.67	0.31	0.33
Adjusted R^2	0.20	0.33	0.34	0.61	0.26	0.26
Std. error	0.14	0.11	0.088	0.059	0.097	0.063
Sample size	86	60	86	60	86	60

Table 6. **Regressions of skill change on technology and other variables**[1] *(cont.)*

1. The "all industries" sample consists of pooled cross-section time-series data, with observations on each of the 43 industries in 1970-80 and 1980-90, for a total of 86 observations. The "goods only" sample is limited to the 30 goods-producing industries for a sample size of 60. The coefficients are estimated using use the White procedure for a heteroschedasticity-consistent covariance matrix. The absolute value of the t-statistic is shown in parentheses below the coefficient estimate.

Key:

- TFP growth : average annual rate of total factor productivity growth, using full-time equivalent employees (FTEE) and gross capital stock (*Source:* NIPA on diskette).
- Ln (OCA/FTEE) : natural logarithm of the sum of constant dollar purchases of office, computer and accounting machinery over previous 7 years per FTEE (*Source* for OCA: BIE computer tape; *Source* for FTEE: NIPA on diskette).
- R&D/Sales : ratio of expenditures on research and development to industry sales (*Source:* National Science Foundation, *Research and Development in Industry,* various years).
- Ln (CSE/FTEE) : natural logarithm of the ratio of computer programmers, computer systems analysts, computer specialists, n.e.c., and engineers to FTEE (*Source* for computer specialists and engineers: decennial Census data).
- K/L growth : average annual growth rate of the ratio of gross capital stock to FTEE (*Source:* NIPA on diskette).
- % UNION : share of employees covered by union contracts (*1970:* Freeman and Medoff, 1979; *1980:* Kokkelenberg and Sokell, 1985).
- IMP/GDO : ratio of industry imports to industry gross output (*Source:* US input-output tables).
- EXP/GDO : ratio of industry exports to industry gross output (*Source:* US input-output tables).
- DUM 8090 : dummy variable which equals one for the 1980-90 period and zero otherwise.

* Significant at the 10 per cent level (two-tailed test).
** Significant at the 5 per cent level (two-tailed test).
*** Significant at the 1 per cent level (two-tailed test).

Source: Author.

intensity. The growth in both cognitive and interactive skills is strongly and positively linked to the rate of new investment, though the change in motor skills is not.

Both the rate of computerisation (OCA/FTEE) and R&D intensity (R&D/Sales) have a significant positive effect on the change in interactive skills. Computerisation also has a positive and significant relation to the growth in SC among goods industries only but not among all industries, whereas the coefficient of R&D intensity is positive and significant at the 10 per cent level for the change in SC among all industries but insignificant among goods industries only. Neither variable has much measured effect on the change in motor skills but the ratio of computer specialists and engineers to employment (CSE/FTEE) bears a very significant negative relation to MS change.

TFP growth generally has a negative effect on skill growth, though the variable is significant in only two of the six specifications. This result suggests that technological change by itself tends to simplify tasks and thus reduce reliance on skilled workers in all dimensions. This result is consistent with product life cycle models. As originally argued by Vernon (1966, 1979), the creation of a new industry or product line usually entails high start-up costs, the development of specialised processes, the training of labour for new skills, and so on. However, once this technology is in place, there is constant pressure to routinise the technology so that it becomes cheaper to use. If it becomes routinised, then it may not have to rely on expensive, highly trained labour nor on special production processes to supply its inputs.

Relative factor prices between capital and labour (as well as their change over time) fail to appear as significant determinants of skill change. Of the organisational variables, only the per cent of employees in unions (%UNION) has any significant effect on skills. It has a negative and significant effect on the change in interactive skills among goods industries – presumably by retarding the substitution of higher skilled (managerial and administrative) workers for lower skilled (operative) workers – and has a positive and significant effect on the growth in motor skills among all industries – probably by supporting craft workers and operative jobs.

Import competition does not appear to affect skill change. However, industries which export a high percentage of their output have a higher than average growth in interactive skills (at least among goods industries) and a faster growth in motor skills (among all industries). The former result may reflect the need for additional administrative layers to compete successfully in international markets, whereas the latter may reflect the need to upgrade craft and operative jobs in order to produce higher quality output for the international market place.

CONCLUSION

Between 1950 and 1990, all three indices of cognitive skills – substantive complexity, general educational development, and median years of schooling measured in 1970 – showed positive growth, as did interactive skills. Motor skills, on the other hand, experienced an absolute decline. Growth in all five workplace skill indices peaked in the 1960s. In the case of cognitive skills this was due to both strong occupation and industry effects; in the case of interactive skills this was due to a very strong occupation effect; while in the case of motor skills this was accounted for by a very strong industry effect.

Skill growth was lower in the 1950s, 1970s, and 1980s in all five dimensions. The growth of cognitive skills fell between the 1960s and 1970s and again between the 1970s and 1980s, due mainly to declining occupation effects. This suggests that the bias in technological change toward workers with cognitive skills was strongest in the 1960s but fell rather sharply in the 1970s and again in the 1980s. Despite stories of radical industrial restructuring in the 1980s, occupation effects were at their lowest level in this period for cognitive skills. This result casts doubt on recent analyses which posit a particularly strong technological bias in favour of educated workers during the 1980s.

The growth in interactive skills fell sharply between the 1960s and 1970s, but then recovered in the 1980s due to a strong industry effect. The growth in motor skills turned negative in the 1960s and became even more negative in the 1980s, due mainly to the sharp shift in employment toward service industries.

Overall, there is no evidence of de-skilling in the 1980s, except for motor skills. However, the rate of increase of cognitive skill levels slowed down in the 1970s and 1980s, though the rate of growth of interactive skills in the 1980s was almost the same as in the 1960s.

Changes in the educational attainment of both the population and the workforce outstripped changes in workplace skills. These results emphasize the lack of correspondence between the growth in the demand for cognitive skills (as reflected in the direct skill measures) and the supply of such skills, as reflected in the educational attainment of the population. Indeed, they suggest that in both the 1970s and 1980s the educational system in the United States has been producing far more educated workers than the workplace can absorb.

Investigation into the factors that affect the demand for skills indicates that technological change, as measured by the growth in total factor productivity, seems to be de-skilling, though the results are relatively weak (the coefficients are generally not statistically significant). This result is consistent with product life cycle models, which emphasizes the constant pressure to routinise new technology so that it becomes less reliant on skilled labour. However, the result appears to conflict with those of Mincer and Higuchi (1988) and Gill (1989), who found higher returns to schooling in industries undergoing more rapid technical change.

I find that other dimensions of technological activity – particularly the pace of new investment as reflected in the growth in the capital-labour ratio, R&D intensity, and the rate of computerisation – has a positive relation to the change in substantive complexity and interactive skills. Bartel and Lichtenberg (1987) also found that new vintages of capital stimulate the demand for more educated workers. On the other hand, the ratio of computer specialists and engineers to total employment within an industry has a very significant negative effect on the growth in motor skills, suggesting that their efforts are aimed at reducing the skill requirements of production-line workers.

Unionisation generally has a negative effect on interactive skills and a positive effect on motor skills, a result that may be due to the retarding effect of unions on the substitution of higher skilled (management) workers for lower skilled (operative) workers. While import penetration does not seem to affect skill change, export-oriented industries appear to upgrade both interactive and motor skills more rapidly than domestically-oriented industries.

NOTES

1. This section extends the analysis contained in Howell and Wolff (1991), which was based on actual census employment matrices for 1960, 1970, and 1980 and a statistically constructed matrix for 1985.
2. This section updates previous econometric analysis (Howell and Wolff, 1992), which was conducted on skill change from 1970 to 1985.
3. For a discussion of some of the limitations of these data, see Miller *et al.* (1980) and Spenner (1983).
4. The data show an increase in the share of sales workers from 6 per cent in 1977 to 12 per cent in 1988. However, these numbers should be interpreted with some caution, because the Census Bureau changed its classification of sales jobs during the 1980s.
5. Apparent anomalies are that interactive skills grew faster in the 1960s than the 1950s, whereas the share of managers in total employment grew faster in the earlier decade; and that motor skills had positive growth in the 1950s while the share of both craft workers and operatives in the labour force declined.
6. If a sector's output share remains constant and its labour productivity growth is greater than average, then its share of total employment must, of consequence, fall. This mecanism is often referred to as the "unbalanced growth" effect. See Baumol, Blackman and Wolff (1989), Chapter 6, for more discussion.
7. The data source is the *US National Income and Product Accounts*, supplied on diskette by the US Bureau of Economic Analysis.

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CHANGES IN THE DEMAND FOR SKILLED LABOUR IN FRANCE, 1970-93

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I. LABOUR DEMAND IN RELATION TO SKILLS, TECHNICAL PROGRESS AND INTERNATIONAL TRADE: FRANCE, 1970-93

Most of the Western economies have had to adapt to the same changes in the social, technical and international environment – higher education levels, the introduction of new technologies and the emergence of the countries of the South in international trade. These changes give rise to imbalances and inequalities that take highly differing forms and vary greatly in their severity from country to country. In the United States the debate centres on increased disparities in remuneration: during the 1980s, wage differentials between the most highly educated, on the one hand, and the workforce least endowed with human capital, on the other, widened sharply.[1] The dominant feature of the American labour market appears to be an ever increasing demand by firms for highly qualified personnel, in the face of which the educational input seems to be becoming inadequate: the educated are increasingly in demand and ever more expensive (see, for example, Bound and Johnson, 1992).

French firms are also availing themselves of a better educated workforce than was the case 20 or so years ago. Nevertheless, the labour market on this side of the Atlantic appears to be under far less strain from the demand by firms for highly qualified personnel. The problem would appear to be more one of excess supply coming out of the educational system, and a lowering in the status of diplomas (Goux and Maurin, 1994). Furthermore, the increasing recourse to more highly educated and experienced personnel is accompanied in France by high long-term unemployment among the less well qualified. These disparities in employment and unemployment are no less disturbing than the disparities in remuneration seen in the United States; they embody the same risk of "dualisation" of the economy.

The aim of this article is to analyse the changes in the French labour market in order to better understand the erosion of the value of diplomas as well as the scarcity of employment opportunities for the less well qualified. We shall attempt to define more clearly the role played by changes in the demand for labour, on the one hand, and that of changes in labour supply, on the other.

Following a presentation of the data (Section II), the main trends in employment and relative earnings in France are described (Section III). We shall then distinguish two major kinds of explanatory mechanism.

- First, we shall analyse those factors that tend to modify the sectoral and occupational structure of labour demand (Section IV). One such factor could be changes in the actual structure of domestic demand for goods and services. Another factor may be differentiated trends in labour productivity, which may be rapid in some sectors and slow in others. Lastly, the development of international trade may itself be the source of new outlets for certain industries, and of difficulties and loss of markets for others. To the extent that these reallocations of activity tend to shift overall labour requirements towards activities making extensive use of human capital, they may explain why requirements for qualified workers are becoming increasingly pressing at the macroeconomic level.
- Second, we shall analyse the mechanisms that tend to modify labour composition *within* the different branches of activity (Section V). The first of these mechanisms is that labour supply is in evolution: all other things equal, an influx of educationally qualified personnel tends to make human capital relatively more abundant and less expensive, and thus favour its substitution for other production factors. Next, other factors may modify the demand for labour *within* the various economic activities. Changes in the prices of inputs may, for example, stimulate (or inhibit) their substitution for particular kinds of labour. Above all, technical change may prove to be "biased" towards some kinds of labour rather than others. Much recent research in the United States has concluded that technical change plays a preponderant role (Bound and Johnson, 1992; Mincer, 1991).

II. THE DATA

The common feature of the different surveys upon which we have drawn for this article was that all were carried out by the French National Institute of Statistics and Economic Surveys (INSEE):

- the series of annual Labour Force Surveys for the period 1975-93, supplemented by various sets of sectoral data on production and foreign trade from the national accounts system;
- the series of Surveys on Education and Occupational Qualifications (*Enquête Formation et Qualification Professionnelle* – FQP) carried out in 1970, 1977, 1985 and 1993. These surveys are customarily carried out two or three years after the general population census (also organised by INSEE);

– various surveys on labour organisation and working conditions supplementing the Labour Force Surveys of 1987, 1991 and 1993.

Labour Force Surveys

The sample used for the Labour Force Surveys (LFS) is representative of the population over 15 years old. The sampling fraction is around 1/300: more than 140 000 people are surveyed each year. The information available on all employed persons is of the usual kind: educational level, age, occupation, and the branch of activity of the employing enterprise.[2] In this article the standard 38-heading classification by branch of activity (NAP40), as well as a 6-heading classification of occupations[3] and a 5-heading classification of educational level, have been used.[4]

The LFS also provides fairly comprehensive information on the length of the working week. In calculating the number of hours worked per year, we relied as far as possible on the length of the usual working week. For persons whose hours of work are irregular, we used the number of hours worked in the week prior to the survey.

Information is also available on individual remuneration (including monthly and annual bonuses and additional payments) since 1982. Between 1982 and 1989 this information was gathered for 19 monthly salary brackets (reducing the annual bonuses and additional payments to a monthly equivalent). The salary brackets were 500 francs for salaries of less than 5 000 francs a month, 1 000 francs for salaries of between 5 000 and 10 000 francs, and 5 000 francs for salaries above 10 000 francs. It was decided to estimate the salary using the mid-range of the bracket. Between 1990 and 1993, salary data were collected directly.

Annual series of jobs and of volume of work by sector, occupation, age and educational level can be derived for the period 1975-93[5] from the various Labour Force Surveys, by aggregation of the individual data items. The figures for the period 1982-93 may also be used to compile annual series of wages bills and hourly wages for the same criteria of sector, occupation, education and age.

Compared with the usual sources used to analyse labour demand (administrative sources or surveys conducted in enterprises), the LFS has the advantage of covering the whole of the gainfully employed population with no restrictions as to employing sector or size. Furthermore, it enables workers' educational levels to be characterised not only within each sector, *but also within each type of occupation.*

We supplemented this sectoral sample group of annual data on employment and education by drawing upon the sectoral data of the national accounts system – annual data on the levels of imports, exports and domestic consumption of each of the goods and services of the economy, as well as sectoral production and value added.

The Surveys on Education and Occupational Qualifications

The Surveys on Education and Occupational Qualifications (*Enquête Formation et Qualification Professionnelle* – FQP) were conducted by INSEE in 1970, 1977, 1985 and 1993. The last survey was conducted on a sample of 18 000 people between the ages of 20 and 64. The three previous surveys had been conducted on a larger sample, some 45 000 people. The information yielded by these samples is fully comparable to that of the LFS concerning educational level, age, occupation and activity sector. All respondents also state their earnings in the year preceding the survey, and the number of months of activity to which those earnings correspond, distinguishing between months of full-time and part-time occupation.[6]

Taken as a whole, the FQP Surveys can be used to construct data on jobs and wages by sector and by occupation that are fully compatible with the series derived from the Labour Force Surveys. They may also be used to construct pseudo-sample groups of individuals for the period 1970-93 which are especially useful for estimating the changes in the returns to wages from educational qualifications and job experience in France in the long term.

Compared with the Labour Force Survey, the FQP Survey has the disadvantage of being conducted on a smaller sample and of being carried out less frequently. On the other hand, it has the merit of providing information on volume of work and wages since 1970, whereas the LFS only provides this kind of information since 1982.

Surveys supplementing the Labour Force Survey

INSEE annually conducts a survey supplementing the LFS on a sub-sample of some 20 000 people. The theme of these supplementary surveys in 1987 and 1993 was the Working Techniques and Organisation of the Labour of Workers in Employment (known as the TOTTO surveys).[7] The theme in 1991 was Working Conditions (the CT survey). The samples are representative of the French employed population (sampling fraction around 1/1 000). Each of these surveys may be used to estimate the number of individuals (by occupation and sector) who claim to use a microcomputer (or word processor), and also how many claim to use a computer terminal.

Furthermore, the three surveys may be used to establish how many individuals may have occasion in the course of their work:

- to operate or superintend a robot, or any other piece of equipment capable of automatic three-dimensional movement;
- or to use a numerical command (NC) machine tool (or a machining centre);
- or to superintend (and/or run) a completely automated installation;
- or, lastly, to use video and/or telemonitoring equipment.

Taken together, in 1993 as well as in 1991 and 1987, the surveys supplementing the Labour Force Survey may be used to assess the utilisation ratio of computer equipment, on the one hand, and the use made of new industrial technologies (robots, numerical control, telemonitoring) on the other.

III. JOBS, UNEMPLOYMENT AND RELATIVE EARNINGS: SOME TRENDS

In France, as in most of the industrialised countries, the development of the educational system has been accompanied for several decades by a continuous rise in the education level of the working population (Tables 1*a* and 1*b*). Today most workers have at least one occupational qualification. In 1970, three-quarters had not obtained any qualification beyond the school-leaving certificate. In 1993, nearly 17 per cent of jobs were held by graduates from universities or comparable

Table 1*a*. **Evolution in the structure of employment by sex and educational level**

Percentages

Educational level	Structure in 1970	Rate of evolution by sub-period				Structure in 1993
		1970-77	1977-85	1985-93	1970-93	
Men						
No diploma	23.4	–25.9	–17.6	–15.1	–48.2	12.1
CEP, CAP, BEP, etc.	36.3	–3.0	–5.0	–11.8	–18.7	29.5
Bac or equivalent	4.5	22.4	–1.7	21.9	46.7	6.6
Bac + 2 years	0.8	43.7	134.2	41.0	374.6	3.9
Higher than Bac + 2 years	2.0	55.6	13.2	44.5	154.4	5.1
Women						
No diploma	8.8	–10.4	–14.5	–1.9	–24.9	6.6
CEP, CAP, BEP, etc.	18.9	17.1	3.6	–9.5	9.7	20.7
Bac or equivalent	3.2	51.2	4.4	41.5	123.2	7.2
Bac + 2 years	1.3	12.1	160.1	31.4	283.1	5.0
Higher than Bac + 2 years	0.8	79.0	51.5	59.3	331.9	3.3
Total	100.0					100.0

Abbreviations:
CEP: Certificat d'Études Primaires (primary school-leaving diploma, now abolished).
CAP: Certificat d'Aptitudes Professionnelles (vocational training diploma).
BEP: Brevet d'Études Professionnelles (vocational training diploma).
Bac: Baccalauréat (advanced high school-leaving diploma; a prerequisite for admission to university).
Note: Between 1970 and 1977 the share of men without educational qualifications in employment fell by 25.9 per cent. Overall, between 1970 and 1993 that share fell by 48.2 per cent: it fell from 23.4 per cent in 1970 to 12.1 per cent in 1993. Employment is measured in months of effective labour, *i.e.* it is related to full-time employment.
Field: Persons in paid employment in the year preceding the survey.
Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

Table 1*b*. **Evolution in the structure of employment by sex and educational level**

Percentages

Educational level	Average annual rate of change			
	1970-77	1977-85	1985-93	1970-93
Men				
No diploma	–4.2	–2.4	–2.0	–2.8
CEP, CAP, BEP, etc.	–0.4	–0.6	–1.6	–0.9
Bac or equivalent	2.9	–0.2	2.5	1.7
Bac + 2 years	5.3	11.2	4.4	7.0
Higher than Bac + 2 years	6.5	1.6	4.7	4.1
Women				
No diploma	–1.6	–1.9	–0.2	–1.2
CEP, CAP, BEP, etc.	2.3	0.4	–1.2	0.4
Bac or equivalent	6.1	0.5	4.4	3.6
Bac + 2 years	1.6	12.7	3.5	6.0
Higher than Bac + 2 years	8.7	5.3	6.0	6.6

Note: Between 1970 and 1977 the share of men without educational qualifications fell on average by 4.2 per cent annually. Overall, between 1970 and 1993 that share fell by 2.8 per cent annually. Employment is measured in months of effective labour, *i.e.* it is related to full-time employment.
Field: Persons in paid employment in the year preceding the survey.
Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

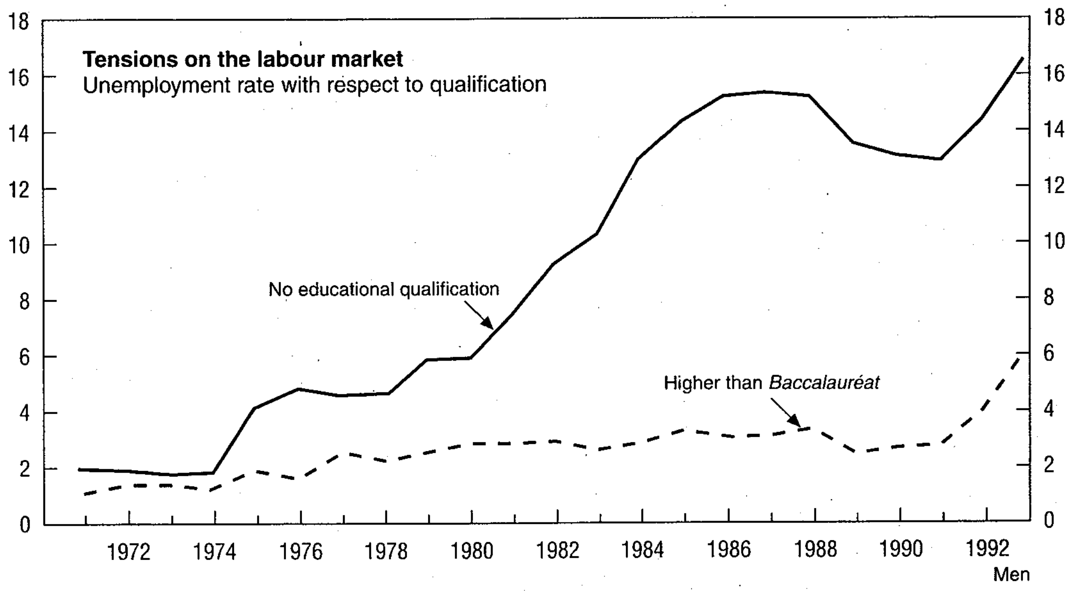
institutions of higher education compared to scarcely 5 per cent 25 years earlier.[8] Superimposed on this rise in the general level of education is another basic trend, namely the progressive arrival of women in the various levels of enterprises and the civil service. The majority of paid jobs in France are now held by women, compared with less than one-third only 20 years ago.

Swift as they may have been, these changes are not peculiar to France, but rather form a common background for most of the industrialised countries: more and more women are being employed and educational levels are rising. These changes undoubtedly have their origins in the democratisation of Western educational systems, and in their opening up on a vast scale to all the strata of society.

Wage differentials in France

The supply of labour follows the same underlying trends from country to country, but different economies are adapting to these trends in different ways, and are not all giving rise to the same disparities in earnings or in unemployment. France is experiencing, above all, long-lasting and selective unemployment, the rise in which has largely affected the youngest and the less well educated: between the beginning of the 1970s and the beginning of the 1990s, the unemployment rate among young workers with little in the way of qualifications rose appreciably, and has now reached more than 15 per cent (Figure 1). Over the same period the unemployment rate among persons with a higher educational qualification never exceeded 3-4 per cent, with the exception of the brief recession of 1993.

Figure 1. **Evolution of unemployment with respect to education levels**



Source: Employment Surveys, 1971 to 1993, INSEE.

In France, on the other hand, the evolution of relative earnings is tending towards a reduction in the inequality of earnings between individuals with different educational qualifications and of different ages (Goux and Maurin, 1994; Baudelot and Glaude, 1989). Thus the average earnings of men with qualifications higher than *Baccalauréat* + 2 years – first degree, masters' degree, engineering degree, etc. – in 1993 was 2.6 times the earnings of men with no diplomas. In 1970, the difference was 3.5 times (Table 2*a*). This narrowing in the structure of earnings by qualification is due in part to the reduction in the average age of the most highly qualified personnel: those with less experience have lower earnings. Increasingly, also, women make up a larger share of qualified personnel than was the case only 10 or 20 years ago; women who, all other things equal, are less well paid than their male colleagues. Even allowing for these structural effects, however, the erosion in the relative earnings of graduates is still appreciable.

Table 2*a*. **Evolution in relative earnings between 1970 and 1993**

Educational level	Relative earnings (reference: earnings of unqualified women)			
	1970	1977	1985	1993
Men				
No diploma	1.37	1.36	1.25	1.26
CEP, CAP, BEP, etc.	1.90	1.77	1.57	1.58
Bac or equivalent	2.73	2.47	2.15	2.02
Bac + 2 years	2.96	2.30	2.12	2.18
Higher than Bac + 2 years	4.76	4.05	3.34	3.26
Women				
No diploma	–	–	–	–
CEP, CAP, BEP, etc.	1.29	1.27	1.25	1.24
Bac or equivalent	1.70	1.71	1.52	1.48
Bac + 2 years	1.84	1.79	1.66	1.66
Higher than Bac + 2 years	2.73	2.29	2.04	2.15

Note: In 1993 the average earnings of men whose qualifications were higher than the Baccalauréat + 2 years (engineering school, bachelor's degree, thesis, etc.) were 3.26 times those of unqualified women; the factor was 4.76 times in 1970. Earnings were estimated in constant francs per month of effective labour, *i.e.* were related to full-time employment.

Field: Persons in paid employment in the year preceding the survey.

Source: EOQ Surveys 1970, 1977, 1985 and 1993, INSEE.

Likewise, when wages at the time of retirement are compared to starting wages, some narrowing of the gap is to be noted in succeeding generations, above all for those with few educational qualifications: following a working life of 20-30 years, persons born between 1936 and 1945 who did not pass the *Baccalauréat* were earning a real wage roughly 60 per cent higher than at the start of their working life (Table 2*b*). The same calculation for members of the next generation (born between 1943 and 1952) reveals that their real wage had increased by only 40 per cent over a working life of the same duration (20-30 years).[9]

These developments are the exact opposite of what is observed in the United States, where education and work experience are currently increasingly better remunerated. In the United States during the 1970s the wage differentials between college graduates and non-college graduates initially fell by exactly the same proportions as in France, by around 15 per cent, but subsequently rose again by more than 30 per cent in less than a decade (Bound and Johnson, 1992; Katz and Murphy, 1992).

Table 2*b.* **Effect of experience on earnings: weaker for the more recent generations**

	Effect of experience on the generations born between:	
	1936 and 1945	1943 and 1952
Men, qualification lower than the Bac	1.62	1.42
of which:		
No diploma	1.57	1.41
CEP, CAP, BEP or equivalent	1.63	1.42
Men, Bac or higher equivalent	1.86	1.75
of which:		
Bac or equivalent	1.90	1.56
Bac + 2 years (DEUG, DUT, etc.)	1.68	1.73
Higher than Bac + 2 years	1.76	1.83
Women, qualification lower than the Bac	1.65	1.41
of which:		
No diploma	1.66	1.41
Cep, CAP, BEP or equivalent	1.64	1.42
Women, Bac or higher equivalent	1.71	1.62
of which:		
Bac or equivalent	1.78	1.57
Bac + 2 years (DEUG, DUT, etc.)	1.66	1.59
Higher than Bac + 2 years	1.60	1.66

Note: The average earnings of men with a qualification lower than the *Baccalauréat,* born between 1936 and 1945, rose by 62 per cent (1.62) between the start and the middle of their working life. For more recent generations, born between 1943 and 1952, the increase has been only 42 per cent. A person is considered, by convention, to be at the start of his or her working life at between the age of 25 and 34, and halfway through at between the age of 40 and 49.
Field: Persons in paid employment in the year preceding the survey.
Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

The selective effect of unemployment

Unemployment itself may be one possible explanation for the narrowing of wage differentials in France. Crudely stated, large-scale, persistent unemployment allows employers to be more selective in filling vacancies and to accept only the "best" applicants. The stagnation in the return on education in France may perhaps be more apparent than real, and indirectly reflect the increased selectivity of the labour market for the less well educated. In order to examine this problem, we calculated very simple gain functions using different pseudo-sample groups of personal data from the four FQP Surveys (1970, 1977, 1985, 1993), using

Table 3. **Evolution in the relative earnings of older employees by sex and educational level**

Educational level	Average structure	Relative earnings, 40-44 years old//25-29 years old			
		1970	1977	1985	1993
Men					
No diploma	16.2	1.09	1.15	1.23	1.29
CEP, CAP, BEP, etc.	32.3	1.29	1.37	1.40	1.30
Bac or equivalent	5.4	1.79	1.64	1.73	1.58
Bac + 2 years	2.1	2.16	1.88	1.69	1.54
Higher than Bac + 2 years	3.3	1.98	1.90	1.95	1.94
Women					
No diploma	8.5	0.87	1.06	1.08	1.03
CEP, CAP, BEP, etc.	22.2	1.17	1.16	1.18	1.21
Bac or equivalent	5.1	1.37	1.51	1.57	1.47
Bac + 2 years	3.0	1.37	1.35	1.26	1.49
Higher than Bac + 2 years	1.9	1.79	1.72	1.50	1.42
Total	100.0				
Relative average earnings		1.28	1.32	1.34	1.31

Note: In 1977 the average earnings of men without educational qualifications, 40-44 years old, were 1.15 times those of men without educational qualifications 25-29 years old. Average relative earnings are estimated from the total of average relative earnings for each type of work weighted by the average weight of these types of work over the period 1970-93 (Column 1). Employment is measured in months of effective labour, *i.e.* it is related to full-time employment.
Field: Persons in paid employment in the year preceding the survey.
Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

Heckman's procedure to neutralise the selectivity of unemployment.[10] The results of these estimates do not cast doubt on the diagnosis arrived at from the raw data:

- The selective effect of unemployment is evident in France over the period 1970-93, but the erosion of relative earnings of graduates is also a reality (Table 4). The wage differential between those with higher educational qualifications and unqualified individuals decreased annually by between 1 per cent (for short-course graduates; *Baccalauréat* + 2 years) and 2.5 per cent (for long-course graduates; more than *Baccalauréat* + 2 years) on average. According to our estimates, the wage differentials between holders of the *Baccalauréat* and holders of technical training diplomas (CAP and BEP) also decreased by around 1 per cent annually. The wage differentials between holders of technical training diplomas and the unqualified also decreased in the same proportions (Table 5). In a study of the same period, Bayet and Cases (1994) find similar trends with different data.[11]

Table 4. **Probit model of unemployment, 1970-93**

Explanatory variables	Estimate	(Student's T)
Intercept	–1.25	(–17.8)
Survey year (ref.: 1993)		
1970	–0.39	(–3.7)
1977	–0.32	(–3.4)
1985	–0.01	(–0.1)
Marital status (ref.: divorced)		
Unmarried	0.00	(0.1)
Married	–0.58	(–12.1)
Widowed	–0.18	(–1.7)
Nationality (ref.: French)		
Foreign	0.27	(7.6)
Place of residence (ref.: Paris)		
The provinces	0.07	(2.7)
Sector of activity (ref.: heavy industry)		
Light industry	–0.07	(–2.5)
Service sector, unestablished	0.01	(0.2)
Service sector, established (not State)	–0.31	(–8.7)
State	–0.69	(–11.6)

Survey year	1970	1977	1985	1993
Educational qualification (ref.: CAP, BEP, etc.)				
None	0.17	0.32	0.33	0.73
	(1.8)	(4.0)	(6.2)	(15.4)
CEP	0.14	0.17	0.22	0.36
	(1.4)	(2.0)	(3.6)	(5.5)
BEPC, BE or equivalent	0.35	0.36	0.02	0.33
	(2.5)	(3.2)	(0.2)	(4.3)
Technical *Baccalauréat,* BP, BEI,	0.22	0.05	–0.11	0.13
Baccalauréat, Part 1	(1.4)	(0.4)	(–1.0)	(1.5)
General *Baccalauréat*	0.61	0.18	0.21	–0.03
	(3.5)	(1.0)	(1.9)	(–0.3)
DEUG, DUEL, BTS, DUT (Bac + 2 years)	0.65	–0.40	–0.26	0.52
	(2.5)	(–1.0)	(–1.7)	(7.1)
Middle and upper secondary, engineering,	0.25	0.22	–0.14	–0.16
paramedical	(1.3)	(1.4)	(–1.1)	(–1.6)
Age (ref.: 50 years or more)				
20 to 29 years	–0.35	–0.28	–0.15	–0.21
	(–4.6)	(–4.3)	(–2.8)	(–3.9)
30 to 39 years	–0.40	–0.38	–0.33	–0.47
	(–4.6)	(–5.0)	(–5.9)	(–8.7)
40 to 49 years	–0.31	–0.39	–0.27	–0.28
	(–3.7)	(–4.9)	(–4.3)	(–5.4)
–2 Log (L_a/L_o)	2 494.1			
Number of observations	52 369 (*of which:* 1 443 unemployed)			
Number of parameters	52			

Field: Men, employed and unemployed in May 1970, 1977, 1985 and 1993.
Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

Table 5. **Evolution in the relationship between earnings, work experience and educational level, 1970-93**

Independent variables	Dependent variable: log (wage)	
	$\hat{b}$	Student's T
Mills' ratio	0.220	30.6
Experience	0.015	91.5
Experience[1]	–0.001	–45.9
Date	0.005	5.2
Date × Experience	–0.00003	–1.5
Date × Experience[1]	0.00001	8.3
Qualification (ref.: strictly above Bac + 2 years)		
No diploma	–0.953	–95.4
CEP, CAP, BEP, BEPC	–0.789	–87.4
Bac, BS, BE or equivalent	–0.472	–44.9
Bac + 2 years (DEUG, DUT, BTS, etc.)	–0.350	–24.3
Date × Qualification (ref.: Date × strictly above Bac + 2 years)		
Date × (no diploma)	0.025	23.2
Date × (CEP, CAP, BEP, BEPC)	0.017	17.0
Date × (Bac, BS, BE or equivalent)	0.008	6.9
Date × (Bac + 2 years: DEUG, BTS, etc.)	0.013	8.3
R^2	0.503	
Number of observations	48 546	
Number of parameters	24	

Note: The table presents the results of a simple OLS regression.

1. "Experience" is the length of the individual's work (estimated from the date of the survey minus the date of completion of study) and "Date" is put for the year of the survey (1970, 1977, 1985 or 1993). These two variables are moreover centred on their mean value in the sample. In this sample, for example, the mean duration of work experience is 21.2 years. Other variables (which are not reported in the table) have been included, namely nationality, place of residence and industry. The Mills' ratio has been calculated from a probit regression similar to that used in Table 4.

Field: Men in full-time paid employment during the year preceding the survey.

Source: FQP Surveys 1970, 1977, 1985 and 1993, INSEE.

The earnings of short-course graduates (*Baccalauréat* + 2 years) are the most resilient: the *Baccalauréat* loses ground, but it is increasingly profitable for holders of the *Baccalauréat* to take a short post-*Baccalauréat* course.

- A slight declining trend can be noted for differences in earnings based on work experience. However, it is not so much average differences that are changing as the profile of wages based on work experience: as time goes by, the differentials between starting wages are narrowing and there is a parallel widening of the differentials between final wages.

By making use of the longitudinal dimension of the recent annual Labour Force Surveys we have been able to update and confirm the earlier diagnosis for the period 1990-95. By tracing the patterns of earnings over two or three years,

Table 6. **Earnings, qualification and work experience**

Men

Independent variables	Dependent variable Log (wage, in constant francs)
Intercept	0.000 (0.001)
Mills' ratio	–0.012 (0.021)
Seniority in the enterprise	0.003 (0.002)
(Seniority in the enterprise)	–9.105 (5.105)

Experience	Qualification						
	1a	1b	1c	2a	2b, 2c	3a	3b
1 year	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
2 years	0.36	0.31	0.34	0.08	0.20	0.09	0.15
	(0.02)	(0.03)	(0.02)	(0.03)	(0.04)	(0.03)	(0.02)
3 years	0.59	0.43	0.48	0.23	0.28	0.25	0.22
	(0.02)	(0.04)	(0.02)	(0.03)	(0.05)	(0.03)	(0.03)
4 years	0.68	0.52	0.57	0.33	0.29	0.31	0.30
	(0.03)	(0.04)	(0.02)	(0.04)	(0.05)	(0.03)	(0.03)
5 years	0.75	0.57	0.63	0.39	0.31	0.36	0.35
	(0.03)	(0.05)	(0.02)	(0.04)	(0.05)	(0.03)	(0.03)
6 years	0.75	0.65	0.67	0.44	0.40	0.41	0.41
	(0.03)	(0.05)	(0.02)	(0.04)	(0.06)	(0.03)	(0.03)
7 years	0.79	0.67	0.69	0.45	0.44	0.43	0.47
	(0.03)	(0.05)	(0.02)	(0.04)	(0.06)	(0.03)	(0.03)
8 years	0.82	0.80	0.72	0.53	0.51	0.47	0.52
	(0.04)	(0.06)	(0.03)	(0.04)	(0.06)	(0.04)	(0.04)
9 years	0.83	0.83	0.74	0.62	0.51	0.51	0.54
	(0.04)	(0.06)	(0.03)	(0.04)	(0.07)	(0.04)	(0.04)
10 years	0.88	0.94	0.77	0.67	0.57	0.52	0.56
	(0.04)	(0.06)	(0.03)	(0.05)	(0.07)	(0.04)	(0.04)
R^2				0.097			
Number of observations				21 619			

Abbreviations:

1a = No diploma or CEP (primary school-leaving diploma, now abolished).
1b = BEPC or BE, lower secondary school-leaving diploma.
1c = Vocational training diploma (CAP, BEP,...).
2a = Technical or profession-oriented *Baccalauréat* (advanced high school-leaving diploma).
2b, 2c = General *Baccalauréat.*
3a = Post secondary degrees, corresponding to 2 years' further education after the *Baccalauréat* (BTS, DUT, DEUG,...).
3b = Higher post secondary degrees, corresponding to strictly more than 2 years' further education after the *Baccalauréat* (thesis, PhD, engineering qualifications, Bachelor's degree 1, etc.).

Note: The coefficients correspond to the estimation of the following annual earnings equation (where dummy variables are represented by I):

$$Log\,(w_{i,t}) = X_i\beta + \sum_s \gamma_s I_s\,(i,t) + \alpha_1 Sen_{i,t} + \alpha_2\, Sen^2_{i,t} + \sum_{e=1}^{10} \sum_{d=1a}^{3b} \delta_{e,d} I_{e,d}\,(i,t) + \eta Mills_{i,t} + u_i + \varepsilon_{i,t}$$

where $w_{i,t}$ represents the annual wage of the individual i at the date t, *Sen* is seniority in the enterprise (years), *Mills* is Heckman's ratio assumed to allow for the selectivity bias linked to unemployment, e indicates experience in the labour market (in years), d is the level of qualification, s is the activity sector of the enterprise, and X_i represents the other individual variables that are constant over time.

Field: Wage-earning men with ten or less years experience in the labour market.

Source: Labour Force Surveys, 1990 to 1995, INSEE.

this source allows a breakdown of individual earnings into a variable component (reflecting career effects) and a fixed component (permanent human capital effect):

- As regards the variable component, analysis shows that today there is very little difference in the progression of earnings dependent on educational qualifications. The only noteworthy exception is that the less well educated have particularly large wage increases during the first few years of their working life. These results are as applicable to women as they are to men (Tables 6 and 7).

Table 7. **Earnings, qualification and work experience**

Women

Independent variables				Dependent variable Log (wage, in constant francs)			
Intercept				0.000 (0.001)			
Mills' ratio				0.080 (0.032)			
Seniority in the enterprise				–0.001 (0.002)			
(Seniority in the enterprise)				–7.106 (7.105)			
Experience	Qualification						
	1a	1b	1c	2a	2b, 2c	3a	3b
1 year	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
2 years	0.42	0.15	0.19	0.08	0.05	0.04	0.13
	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)	(0.02)	(0.03)
3 years	0.53	0.24	0.29	0.18	0.19	0.10	0.23
	(0.04)	(0.05)	(0.02)	(0.03)	(0.04)	(0.03)	(0.03)
4 years	0.60	0.33	0.40	0.18	0.20	0.14	0.22
	(0.04)	(0.05)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)
5 years	0.70	0.40	0.45	0.25	0.26	0.19	0.26
	(0.05)	(0.06)	(0.03)	(0.04)	(0.05)	(0.03)	(0.04)
6 years	0.76	0.45	0.50	0.27	0.31	0.22	0.29
	(0.05)	(0.06)	(0.03)	(0.05)	(0.05)	(0.03)	(0.04)
7 years	0.74	0.48	0.51	0.38	0.35	0.25	0.33
	(0.06)	(0.06)	(0.03)	(0.05)	(0.06)	(0.04)	(0.04)
8 years	0.77	0.55	0.54	0.40	0.39	0.26	0.36
	(0.06)	(0.07)	(0.03)	(0.05)	(0.06)	(0.04)	(0.05)
9 years	0.75	0.62	0.55	0.39	0.40	0.31	0.42
	(0.06)	(0.07)	(0.04)	(0.06)	(0.06)	(0.04)	(0.05)
10 years	0.74	0.67	0.58	0.42	0.39	0.31	0.42
	(0.07)	(0.07)	(0.04)	(0.06)	(0.06)	(0.04)	(0.05)
R^2				0.041			
Number of observations				19 988			

Note: The model and variables are the same as those presented in Table 6.
Field: Wage-earning women with ten or less years experience in the labour market.
Source: Labour Force Surveys, 1990 to 1995, INSEE.

– As regards the fixed component of earnings (fixed effect), its impact is, of course, greater in proportion to the length of the course of study pursued, but the earning differentials between employees with different education levels have tended to be weaker in the younger generations than in the older ones.[12]

IV. SHIFTS IN EMPLOYMENT BETWEEN SECTORS AND OCCUPATIONS

From these preliminary analyses it would appear that the inequalities confronting France and the United States are not of the same kind. In France they are mostly inequalities in employment, while in the United States they are inequalities in wages. It would appear that in two different institutional contexts the same technological and social developments may give rise to very different inequalities and imbalances: the French labour market appears to be dominated by supply shifts related to the development of the educational system, whereas the problems in the United States seem to arise above all from technical change and shifts in labour demand.

In order to understand the reasons for this divergence, we shall now attempt to identify more precisely the (many) mechanisms that govern the distribution of jobs among the various worker categories. The reduction in job opportunities for the least well qualified individuals may have two direct origins:

- Firstly, the progressive disappearance of sectors and occupations that do not require lengthy training of the workforce. Here, the reduced share of manufacturing industries and unskilled occupations in total employment naturally springs to mind. These shifts in activity are a response to the evolution of demand for goods and services, which is increasingly towards activities embodying more and more skilled labour. These shifts could equally reflect the fact that the pace of technical change is faster in those sectors and occupations that have the least well qualified workforce.
- Secondly, substitution *within* each occupation and each sector of activity of highly skilled for less-skilled staff. This phenomenon of substitution within sectors and within occupations may stem from the increasing abundance of educationally qualified individuals and the reduction in their relative cost. It may equally be a reflection of the fact that the spread of new technologies is increasing (decreasing) the educational level required of workers in the various types of occupations.

A very simple statistical decomposition may be used to analyse the respective contribution of these two basic processes.[13] If we adopt the convention of denoting by $q_{i,t}$ (resp. $q_{i,s,t}$) the share of workers corresponding to qualifications i in the economy as a whole (resp. in microsector *s* at date *t*),[14] and by $p_{s,t}$ the share of microsector *s* in total employment at date *t*, we may write:

$$q_{i,t} = \sum_s q_{i,s,t}\, p_{s,t},$$

from which

$$dq_{i,t} = \sum_s q_{i,s,t}\, dp_{s,t} + \sum_s p_{s,t}\, dq_{i,s,t} = inter_{i,t} + intra_{i,t}.$$

This is a highly standard decomposition: the first term reflects what the evolution in the share of educationally qualified individuals of type *i* owes to *inter-sectoral* redistributions of activity. The second term expresses what the evolution in the share of educationally qualified individuals of type *i* in total employment owes to the rise in educational levels *within* the different occupations and industries (*intra-sectoral* redistributions).

Whatever the education level considered, neither term completely dominates the other throughout the period 1975-93 (Table 8). Employment and activity shift towards those occupations and sectors that, by virtue of their structure, employ many educationally qualified individuals and few unqualified workers, but these *inter-sectoral* movements are far from sufficient in themselves to explain the shift in the demand for labour by educational level in its entirety. The rise in the level of education within sectors and occupations (*intra-sectoral* substitutions) makes just as significant a contribution to the scarcity of jobs on offer for the less well educated workers, especially during the recent period.

This first result is important: even if we assume that the reduction in manufacturing employment and blue-collar occupations may be ascribed in its entirety to a lack of symmetry in technical progress and to the development of international trade, it may be seen that these phenomena can scarcely, by themselves, account for more than half of the observed shifts in the composition of labour demand. Furthermore, according to our estimations, the inter-occupational and inter-sectoral shifts in activity may perhaps be due solely to changes in domestic demand: the "natural" changes that occur as the standard of living of households rises.

The role of international trade

As the standard of living rises, health expenditure grows, leisure time increases and the equipping of households reaches completion, it is clear that *domestic* demand is developing in the direction of the services sector, which in France employs a far better qualified workforce than do the manufacturing industries.[15] This natural evolution of industrial societies undoubtedly weighs quite

Table 8. **Evolution in numbers of workers with educational qualifications: the role played by inter-sectoral-occupational and intra-sectoral-occupational reorganisations**

Percentages

Period	Educational level	Share in employment at start of period	ΔD[1]	Evolution intra	Evolution inter
1975-81	(1) Above Bac + 2 years	4.58	+0.88	3.1	96.9
	(2) Bac + 2 years (DEUG, DUT, etc.)	3.65	+1.82	58.1	41.9
	(3) Bac or equivalent	8.60	+0.59	8.3	91.7
	(4) CAP, BEP or equivalent	23.27	+3.00	92.6	7.4
	(5) BEPC alone	7.20	+0.26	–21.7	121.7
	(6) CEP or no diploma	52.70	–6.55	58.8	41.2
	(1) + (3)	8.23	+2.70	40.1	59.9
	(1) + (3) + (4)	16.83	+3.29	34.4	65.6
1982-87	(1) Above Bac + 2 years	6.21	+1.35	23.1	76.9
	(2) Bac + 2 years (DEUG, DUT, etc.)	6.19	+1.68	53.6	46.4
	(3) Bac or equivalent	9.82	+1.51	66.7	33.3
	(4) CAP, BEP or equivalent	24.71	+3.24	118.7	–18.7
	(5) BEPC alone	7.19	+0.34	39.3	60.7
	(6) CEP or no diploma	45.88	–8.12	76.4	23.6
	(1) + (3)	12.40	+3.03	40.0	60.0
	(1) + (3) + (4)	22.22	+4.54	48.9	51.1
1987-93	(1) Above Bac + 2 years	7.56	+2.46	40.8	59.2
	(2) Bac + 2 years (DEUG, DUT, etc.)	7.87	+2.19	71.1	28.9
	(3) Bac or equivalent	11.33	+0.25	–102.0	202.0
	(4) CAP, BEP or equivalent	27.95	+2.18	118.1	–18.1
	(5) BEPC alone	7.53	+0.23	64.1	35.9
	(6) CEP or no diploma	37.76	–7.31	68.8	31.2
	(1) + (3)	15.43	+4.65	55.0	45.0
	(1) + (3) + (4)	26.76	+4.90	47.0	53.0

Note: In 1987, 7.87 per cent of jobs were held by workers with post secondary degrees (DEUG, DUT, BTS, etc.). Between 1987 and 1993, the share of these workers in total employment increased by 2.19 points (or 10.06 per cent) in 1993. 28.9 per cent of this increase is due to the redistribution of jobs among sectors and professions (inter-sectoral change) while 71.1 per cent are due to an increase in the weight of *Baccalauréat* + 2 years *within* each microsector (intra-sectoral change).

1. ΔD is the evolution in percentage points of the share of individuals with educational qualifications in total employment (*e.g.*

$$\Delta D_{Bac+2\ years} = \frac{\text{job Bac + 2 years}_t}{\text{jobs total}_t} - \frac{\text{job Bac + 2 years}_{t-n}}{\text{jobs total}_{t-n}}).$$

Source: Micro-sectoral Sample group (NAP40 * skill in 8 categories), Labour Force Surveys 1975-93, INSEE.

heavily in the distortion of national productive structures. There is, however, an additional hypothesis that is often placed at the heart of the debate: the emergence of the countries of the South in international trade is said to be at the origin of an important proportion of the job redistributions affecting the economies of the North.

Where distortion of the sectoral and occupational structures of employment is concerned, international trade may have two important direct effects:

- Firstly, the *evolution* of international trade leads to displacements in employment and activity, to the abandoning of sectors that face foreign competition in favour of those activities that are acquiring market share. In this way international trade makes an indirect contribution to the modification of national occupational structures. A strong increase in export demand in sectors that require relatively large numbers of engineers and technicians contributes in a mechanical way to the rise in the demand for labour affecting these occupations.
- Secondly, the *sectoral structure* of international trade may amplify the reorganisations taking place in the national economy. When a country is a large exporter in sectors in which technology and work organisation are constantly evolving, shifts in its job structure tend to occur more rapidly than when its market share is in sectors in which production processes and the organisation of labour are stable. Generally speaking, the specialisation of an economy is one of the factors explaining the rapidity with which some types of occupations replace others.

In order to assess these different effects we followed the same empirical strategy as Berman, Bound and Griliches (1994), which allow direct comparisons to be made between France and the United States [see Murphy and Welch (1992) or Goux and Maurin (1995*b*) for a simple theoretical validation of this strategy]. Assessing the first effect simply involves estimating the volume of employment of managers, supervisors and technicians (as a share of total employment) specifically created each year by sectoral shifts in domestic demand,[16] namely:

$$inter_t^c = \sum_s dp_{s,t}^c (q_{s,t} - \overline{q_t^c}),$$

where $p_{s,t}^c$ represents the share of employment of sector s devoted to domestic demand, and:

$\overline{q_t^c} = \dfrac{\sum_s p_{s,t}^c q_{s,t}}{\sum_s p_{s,t}^c}$ represents the average qualification level of jobs involved in this domestic production.

If we adopt the notation $inter_t^x$ for the impact of foreign trade on the intersectoral redistributions of the labour factor, we obtain:

$$inter_t^x = inter_t - inter_t^c = \sum_s dp_{s,t}^e (q_{s,t} - \overline{q_t^c}) - \sum_s dp_{s,t}^i (q_{s,t} - \overline{q_t^c}),$$

where $p^e_{s,t}$ represents the share of total employment used to produce exports of good *s*, while $p^i_{s,t}$ represents the share of total employment that would be needed to produce imports of good *s*. This decomposition of $inter^x_t$ may be used to distinguish the impact of the evolution of imports, on the one hand, and exports, on the other.

The second major type of effect (*intra*) may be assessed in the same way. It is possible to estimate the volume of employment of managers, supervisors and technicians (as a share of total employment) specifically created by internal reorganisations in that sector of the economy producing to meet domestic demand, namely:

$$intra^c_t = \sum_s (dq_{s,t} - \overline{dq^c_t})\, p^c_{s,t},$$

where $\overline{dq^c_t} = \dfrac{\sum_s p^c_{s,t}\, dq_{s,t}}{\sum_s p^c_{s,t}}$ represents the average evolution of qualifications in the domestic economy.

If we now agree to use the notation $intra^x_t$ for the impact of foreign trade on the intra-sectoral distributions of the labour factor, we obtain:

$$intra^x_t = intra_t - intra^c_t = \sum_s p^e_{s,t}\ (dq_{s,t} - \overline{dq^c_t}) + \sum_s p^i_{s,t}\,(dq_{s,t} - \overline{dq^c_t}),$$

Once again, this decomposition enables us to distinguish the specific role of exports, on the one hand, and imports, on the other.

The various *intra* and *inter* indicators were calculated using the annual sectoral sample set (1975-93) from the Labour Force Surveys and from national accounts. The results of this type of assessment are quite clear:

- In the first place, whatever the sub-period considered, the structure of international trade and its development have only marginal effects on shifts in labour demand by occupation (Tables 9*a* and 9*b*). The share of managerial and supervisory staff and technicians in total employment increases, while jobs for the unqualified decrease. However, more than 95 per cent of these developments may be interpreted as responses to shifts in domestic demand and to reorganisations extending through the sectors responding to domestic demand.
- Paradoxically, the dynamics (and the structure) of imports tends rather to restrain the development of supervisory jobs, and to slow down the decline in unskilled occupations. In the period 1987-92, if the increased demand met by imports had been met by the domestic economy, the share of skilled occupations would have increased 7 per cent more rapidly than was the case. There is a tendency to focus on the fact that the Western economies import increasing quantities of industrial goods with a high unskilled labour content (typically clothing and textiles). This overlooks the fact that the Western economies trade primarily among themselves, and

Table 9*a*. **Increase in the share of executives, managers, technicians, supervisors and professionals in employment: the role played by the development of international trade (inter component) and its structure (intra component)**[1]

	Evolution of the share of executives, managers, technicians, etc. (in points)		Decomposition of evolution (total = 100 per cent)	
	Inter	Intra	Inter	Intra
1975-81				
Imports	–0.023	0.065	–0.76	2.16
Exports	–0.002	–0.050	–0.08	–1.66
Domestic consumption	1.527	1.504	50.57	49.77
	1.502	1.519	49.73	50.27
Total		3.021		100
1982-87				
Imports	–0.023	–0.116	–0.74	–3.79
Exports	–0.090	0.121	–2.96	3.95
Domestic consumption	1.352	1.811	44.26	59.28
	1.239	1.816	40.56	59.44
Total		3.055		100
1987-93				
Imports	–0.046	–0.096	–1.31	–2.73
Exports	0.065	0.095	1.85	2.71
Domestic consumption	1.466	2.018	41.86	57.62
	1.485	2.017	42.40	57.60
Total		3.502		100

Note: Between 1975 and 1981 the proportion of executives, managers, technicians, supervisors and professionals in total employment increased by 3.021 points, of which 1.502 points came from the redistribution of employment between the different sectos (inter) and 1.519 from the internal evolution of each sector (intra). By itself the transformation in the structure of domestic consumption would have led to an increase of 1.527 points of the inter component, and the changes in the structure of imports and exports have operated in the sense of a decline of respectively 0.023 et 0.002 points in the share of highly qualified jobs.

1. Decomposition of the share of executives, managers, technicians, supervisors and professionals in total employment.

Source: Labour Force Surveys, 1975 to 1993, INSEE; national accounts.

thus increasingly import goods and services with a high skilled labour content (*inter* effect): in France, imports in the sphere of financial and information services, for example, are growing strongly. Basically, what is being overlooked is that imports mainly concern manufacturing goods, and that substitution of skilled for unskilled occupations is on average far more intense in manufacturing industries than in services and trade; were it necessary to produce domestically what is imported, the French economy would sustain a higher rate of reorganisation and intra-sectoral transformations (*intra* effect).

Table 9*b*. **Increase in the share of skilled jobs: the role played by the development of international trade and its structure**[1]

	Evolution of the share of skilled jobs (in points)		Decomposition of evolution (total = 100 per cent)	
	Inter	Intra	Inter	Intra
1975-81				
Imports	–0.114	0.009	–2.92	0.24
Exports	0.007	–0.011	0.17	–0.27
Domestic consumption	1.737	2.265	44.60	58.18
	1.630	2.263	41.85	58.15
Total		3.893		100
1982-87				
Imports	–0.022	–0.077	–1.02	–3.63
Exports	–0.243	0.101	–11.42	4.74
Domestic consumption	1.770	0.601	83.11	28.22
	1.505	0.625	70.67	29.33
Total		2.130		100
1987-93				
Imports	–0.106	–0.215	–2.27	–4.62
Exports	0.143	0.151	3.05	3.24
Domestic consumption	1.890	2.801	40.53	60.07
	1.927	2.737	41.31	58.69
Total		4.664		100

Note: Between 1987 and 1993, the proportion of skilled jobs (executives, managers, technicians, supervisors, high-level employes and skilled workers) increased by 4.664 points, of which 1.927 came from the redistribution of employment between the different sectors (inter) and 2.737 from the internal evolution of each sector (intra). By itself the transformation in the structure of domestic consumption would have led to an increase of 1.890 points of the inter component, and the changes in the structure of exports have operated in the sense of an increase of 0.143 points in the share of jobs requiring qualifications, and those of imports in the sense of a decline of 0.106 points.

1. Decomposition of the share of executives, managers, technicians, supervisors, high-level employes and skilled workers in total employment.

Source: Labour Force Surveys, 1975 to 1993, INSEE; national accounts.

– The dynamics (and the structure) of exports helps rather to accentuate the development of supervisory occupations to the detriment of jobs for unskilled workers. According to our calculations, had increased domestic growth been substituted for increased external demand between 1987 and 1992, the share of unskilled occupations would have decreased 7 per cent less rapidly than was in fact the case. The French exporting sectors are, in fact, concentrated in manufacturing industries, in which job substitution is more rapid than in the remainder of the economy (*intra* effect). Furthermore, the French economy increasingly exports services with high value added, especially in the areas of software and telecommunications, in which the level of qualifications is higher than in the rest of the economy (*inter* effect).

To complete the analysis, we made identical estimations for the industrial sector alone. Goods from the manufacturing industries make up two-thirds of all traded goods: international trade could have a far more direct effect on this sector of the economy. However, this does not appear to be the case (Tables 9*c* and 9*d*):

Table 9*c*. **Increase in the share of executives, managers, technicians, supervisors and professionals in employment in industry: the role played by the development of international trade and its structure**[1]

	Evolution of the share of executives, managers, technicians, supervisors and professionals (in points)		Decomposition of evolution (total = 100 per cent)	
	Inter	Intra	Inter	Intra
1975-81				
Imports	0.042	0.044	2.90	3.00
Exports	0.114	0.019	7.79	1.30
Domestic consumption	0.477	0.767	32.58	52.43
	0.633	0.830	43.27	56.73
Total		1.463		100
1982-87				
Imports	–0.016	–0.122	–0.41	–3.19
Exports	–0.010	0.154	–0.27	4.03
Domestic consumption	0.295	3.527	7.71	92.13
	0.269	3.559	7.03	92.97
Total		3.828		100
1987-93				
Imports	0.143	0.012	3.77	0.33
Exports	–0.169	0.089	–4.46	2.34
Domestic consumption	0.165	3.562	4.34	93.68
	0.139	3.663	3.65	96.35
Total		3.802		100

Note: Between 1975 and 1981 the proportion of executives, managers, technicians, supervisors and professionals in industry (in the strict sense, excluding agriculture and public works) increased by 1.463 points, of which 0.633 came from the redistribution of employment between the different sectors (inter) and 0.830 from the internal evolution of each sector (intra). By itself the transformation in the structure of domestic consumption would have led to an increase of 0.477 points of the inter component, and the changes in the structure of imports and exports have operated in the sense of a rise of respectively 0.042 and 0.114 points in the share of highly qualified jobs.

1. Decomposition of the share of executives, managers, technicians, supervisors and professionals in industrial employment.

Source: Labour Force Surveys, 1975 to 1993, INSEE; national accounts.

Table 9*d.* **Increase in the share of skilled workers and high-level employees in industry requiring qualifications: the role played by the development of international trade and its structure**[1]

	Evolution of the share of skilled jobs (in points)		Decomposition of evolution (total = 100 per cent)	
	Inter	Intra	Inter	Intra
1975-81				
Imports	0.284	–0.004	8.82	–0.13
Exports	0.132	0.014	4.10	0.45
Domestic consumption	0.073	2.716	2.28	84.48
	0.489	2.726	15.20	84.80
Total		3.215		100
1982-87				
Imports	0.237	–0.111	14.41	–6.74
Exports	–0.277	0.212	–16.85	12.94
Domestic consumption	0.014	1.566	0.87	95.36
	–0.026	1.667	–1.57	101.56
Total		1.641		100
1987-93				
Imports	0.153	–0.048	2.58	–0.81
Exports	–0.257	–0.049	–4.33	–0.83
Domestic consumption	0.282	5.841	4.75	98.64
	0.178	5.744	3.00	97.00
Total		5.922		100

1. Between 1975 and 1981 the proportion of skilled jobs (executives, managers, technicians, supervisors, high-level employees and skilled workers) increased by 5.922 points in industry, of which 0.178 came from the redistribution of employment between the different sectors (inter) and 5.744 from the internal evolution of each sector (intra). By itself the transformation in the structure of domestic consumption would have led to an increase of 0.282 points of the inter component, and the changes in the structure of exports have operated in the sense of a decrease of 0.257 points in the share of jobs requiring qualifications, and those of imports in the sense of a rise of 0.153 points.
Decomposition of the share of executives, managers, technicians, supervisors, high-level employees and skilled workers in industrial employment.
Source : Labour Force Surveys, 1975 to 1993, INSEE.

according to our estimations, international trade has only a marginal (direct) effect on the occupational structures of French manufacturing industry. The study of manufacturing industry does, however, yield some interesting additional results: when the analysis is confined to this part of the economy, it is noticeable that the sectors that are the most dynamic exporters make use of relatively low qualifications. This is true for the agricultural processing industry, but also, *inter alia*, for the timber, and the paper and cardboard industries. French achievements in aeronautics (in which qualification levels are high), which are often given as an example, are not the rule. Taken overall, the dynamism of French exports tends to slow down the decline of unskilled jobs in manufacturing industry employment.

Over the recent period this effect is amply sufficient to neutralise the effect of the country's increasing openness to imports of products from the countries of the South (textiles and clothing, for example).[17]

Similar calculations by Berman, Bound and Griliches (1994) lead to the same type of diagnosis: the substitution of "white-collar" jobs for production jobs in American manufacturing industry is only very marginally based on the development of international trade or on its structure.

The role of asymmetry in technical progress

If we accept that international trade does not, *a priori*, play a major role in the recent evolution of occupational structures, an important question remains to be answered: are the observed shifts in employment (between sectors and occupations) all attributable to changes in *domestic demand* for goods and services, or do they to some extent reflect certain modalities of *technical progress*? The hypothesis of "asymmetrical" technical progress as an explanation for the disappearance of relatively unskilled occupations is in fact quite current in the recent economic literature:[18] new technologies are allegedly conducive to the establishment of an organisation of labour based on the acceptance of larger measures of responsibility, and on greater autonomy in work. The new technologies should safeguard supervisory occupations and promote their substitution for jobs requiring the carrying out of simple, repetitive tasks (again, see Berman, Bound and Griliches, 1993 and 1994).

For an extremely simple verification of this hypothesis, let us assume that returns to scale remain constant in the various sectors of activity. Let us further assume that capital is a quasi fixed factor that can be similarly substituted for the various categories of work. According to such a hypothesis a given technology may be regarded as "biasing" the development of occupational structures in favour of highly qualified occupations if the sectors in which it is applied most rapidly are also those in which the share of highly qualified occupations in the wages bill is increasing most rapidly.[19]

In a more formal expression, if we agree to use the notation $nt_{s,t}$ for the rate of use of the new technology *nt* in sector *s* on date *t*, and $m_{s,t}$ for the share of occupations of type *m* in the wages bill of the same sector on the same date, we may conclude that technological bias did exist in favour of occupations of type *m* between dates *t* and *t'* if the difference $(nt_{s,t} - nt_{s,t})$ proves to be negatively correlated with $(m_{s,t'} - m_{s,t})$. When this type of test is applied to the diffusion of new technologies in France between 1987 and 1993, some interesting results are obtained (Table 10):

– White-collar occupations (managers, supervisors, executives, high- and low-level professionals and technicians, etc.) undoubtedly benefit from

Table 10. **Evolution in job qualifications and spread of new technologies over the period 1987-93**[1]

Evolution 1987-93 in share of wages fund devoted to:	Correlation with the increase in the spread of		
	Computerisation	"Industrial" technologies	All new technologies
(3) Executives, managers, high-level professionals	0.29	(–0.06)	0.25
(4) Technicians and low-level professionals	–0.26	–0.27	**–0.35**
(5) High-level employees	–0.25	**–0.41**	0.30
(6) Low-level employees	(0.04)	–0.26	(–0.04)
(7) Skilled manual workers	**–0.41**	(0.12)	(–0.16)
(8) Unskilled manual workers	(–0.16)	(–0.11)	(–0.17)
(3) + (4)	(0.04)	–0.25	(–0.06)
(3) + (4) + (5) + (7)	**–0.39**	–0.28	–0.30

1. The table gives the coefficients of correlation between evolution in the rate of spread of technologies of type *y* in the sector (NAP40) with evolution in the share of the wages fund devoted to the occupations *q*. The correlations indicated in bold type are significantly non-zero at a 5 per cent confidence level. Those in parentheses are zero at the 15 per cent level (n = 38).

Source: Labour Force Surveys and TOTTO Surveys, 1987, 1993, INSEE.

computerisation. The sectors in which computerisation is most widespread are also those in which the share of white-collar workers in the wages bill has increased the most. When Berman, Bound and Griliches (1994) carried out the same type of calculation for American manufacturing alone they found the same kind of result: a significant proportion of the contraction of jobs in American manufacturing industry could be due to asymmetrical technical progress connected with investment in hardware.

- At the same time, the spread of new technologies other than computerisation (especially new production technologies: robots, NC machine tools, but also video techniques and telemonitoring) has tended to favour low-skilled occupations employing manual and non-manual workers. The share of blue-collar workers in the wages bill has thus stood up significantly better where new technologies other than computerisation are most widely disseminated. Further analysis shows that the occupations of technicians, supervisors and low-level professionals have suffered most from the spread of these new technologies. There is a return to the idea that the new production technologies and videosurveillance are making possible a shortening of the line organisation in enterprises.
- Overall, in France, the various effects tend to cancel each other out. In any event, there is no detectable significant correlation between the diffusion of new technology *in its totality* (computerisation and other new technologies) and the changes in the structure of the wages bill.

In Goux and Maurin (1995) we present a more general analytical framework (based on the estimation of a translog cost function) that accounts better for the accumulation of fixed capital or the growth of the outlets of the various sectors of activity. Nevertheless, the underlying result remains the same: new technologies are a source of bias, with some tending to favour white-collar jobs and others blue-collar jobs, but overall the net effects are not very significant.

Overall, when it comes to explaining the *net* trend of an increase in the proportion of resources devoted to supervisory jobs, the most plausible hypothesis is still that of changes in *domestic* demand and the modifications constantly imposed by these changes on the orientation of production.

V. INCREASING EDUCATIONAL LEVELS WITHIN SECTORS AND OCCUPATIONS

We now have a fairly clear idea of the origin of shifts in activity between sectors and occupations: these shifts mainly reflect changes in domestic demand for goods and services. There is one question that remains unanswered: to what should we attribute everything that cannot be explained by shifts in domestic demand? Let us emphasize once again that the proportion of individuals with educational qualifications is increasing regularly at all levels of the occupational structure, in all categories of occupation, in all sectors of activity. These *intra-sectoral* and *intra-occupational* developments contribute at least as much to the tensions of the labour market as do the shifts stemming from domestic demand, and we ought therefore to have a clear understanding of their origin.

Two main hypotheses can be put forward:

- first hypothesis: the substitution of educationally qualified workers for less qualified workers in the different types of occupations and the different sectors is mainly fuelled by developments in the *supply* of graduates and the decline in their relative cost;
- second hypothesis: technical progress leads *within* sectors and occupations to the substitution of highly qualified for less qualified workers.

In the preceding section we analysed those elements of technical progress that may be favourable (or unfavourable) to certain types of occupation, irrespective of the educational level (human capital) of the individuals holding the corresponding jobs. What is necessary in this section is to understand clearly that we are turning our attention to another type of potential asymmetry of technical progress. We are seeking to understand what it is in the evolution of technologies that may be favourable not to a particular type of occupation, but to a particular type of human capital *within* the different occupations.

The model

In order to keep the framework very simple, let us assume that there are only two types of labour, one of which is strongly endowed with human capital (denoted by $f_{1,s,t}$ in sector s at date t), and the other less so ($f_{2,s,t}$). The elasticity of substitution between these two forms of labour is assumed to be constant and independent of the sector of activity. In the model, one part of technical progress (denoted by $a_{s,t}$) will relate specifically to $f_{2,s,t}$, while the other part ($p_{s,t}$) will be neutral, and will relate to both types of human capital (namely, 1 and 2). Basically, what has to be done in this section is to estimate ($a_{s,t}$) and, where appropriate, analyse its variance.

Let $y_{s,t}$ be the demand relating to sector s, in which case we can formulate the levels of demand relating to each of the forms of human capital in sector s:

$$f^d_{1,s,t} = C_1\left(\frac{w_{1,s,t}}{w_{2,s,t}}\right)\frac{y_{s,t}}{p_{s,t}}$$

and

$$f^d_{2,s,t} = C_2\left(\frac{w_{1,s,t}}{w_{2,s,t}}\right)\frac{y_{s,t}}{a_{s,t}\, p_{s,t}}$$

where C_1 and C_2 represent the unit demand functions corresponding to a production function with a constant elasticity of substitution.

The expression for the number of workers of type 1 relative to workers of type 2 in sector s follows from the preceding system, namely:

$$\frac{f^d_{1,s,t}}{f^d_{2,s,t}} = \frac{C_{1,s,t}}{C_{2,s,t}}a_t \propto \left(\frac{w_{1,s,t}}{w_{2,s,t}}\right)^{-\sigma}a_t$$

where σ is the elasticity of substitution between factor 1 and factor 2.

Lastly, assuming that $a_{s,t}$ increases at the uniform rate a_s in each sector, we may write:

$$d\left(\frac{f^d_{1,s,t}}{f^d_{2,s,t}}\right) = -\sigma d\left(\frac{w_{1,s,t}}{w_{2,s,t}}\right) + a_s + \varepsilon_{s,t}.$$

This relation enables the impact of possible asymmetric technical progress as to be clearly isolated within different microsectors of the economy.

In France, it may be assumed in a first approximation that the earnings of the less well qualified evolve exogenously, in line with the evolution of the minimum wage. On the other hand, everything that helps to increase the supply of qualified labour contributes simultaneouly to forcing down their equilibrium earnings. In order to neutralise the potential endogeneity of the dynamics of relative earnings we used the evolution in the earnings of the less well qualified as an instrumental variable.

The estimates

Estimates were made for the main sample group of 204 microsectors (6 types of occupation x 34 sectors of activity) from the 1982-93 series of Labour Force Surveys. Estimates were also made for the different 34 sector sub-samples of the main sample group corresponding to the different types of occupation.

In order to distinguish between qualified (f_1) and unqualified (f_2) labour, we chose a definition that varies in accordance with the occupation considered. For manual workers and employees, f_1 thus represents the volume of work of wage earners without an educational qualification (with the possible exception of the school-leaving certificate), whereas f_2 represents the volume of work of those who have at least one occupational diploma. For the occupations of low-level professionals, technicians and supervisors, f_1 corresponds to wage earners with the *Baccalauréat* (*i.e.* 12-13 years of theoretical schooling), and f_2 to those who have obtained an educational qualification higher than the *Baccalauréat.* For managers, executives and high-level professionals, f_2 represents the volume of work for long-course degrees (a minimum of 15-16 years of schooling), whereas f_1 will correspond to those who did not reach that level.[20]

With these clarifications in mind, let us stress the main results (Table 11):

- A strong elasticity of substitution exists between the different forms of human capital: the estimated elasticity is greater than one. In Goux and Maurin (1995), we estimated a more complete and sophisticated model that gave even higher elasticities. However slight the changes in relative costs, the possibility that they may have strong substitution effects at the microsectoral level cannot be ruled out.
- Analysis of the variance of $\hat{a}_s$ further suggests that the specific rate at which graduates are substituted for other employees is scarcely any faster in the microsectors in which computerisation has spread most rapidly. An analysis by broad categories of occupation even suggests that the diffusion of computerisation has instead tended to slow down the rise in the level of qualifications at the managerial and supervisory level and among engineers. This stems from the notion that the use of software permits the dissemination of knowledge and techniques that were previously exclusive to managerial staff.

Moreover, the correlations between the use of telemonitoring or new industrial technologies, on the one hand, and the rate of substitution of more qualified for less qualified staff, on the other, tend to be negative. The isolation of trends by occupation is difficult.

As regards the respective roles of supply and demand factors, our estimates suggest that supply mechanisms predominate: the increase in the supply of graduates, relayed by a strong elasticity of substitution between graduates and

Table 11. **An estimation of a labour demand equation and an analysis of specific rates of technical progress**

Sample groups used[1]	Estimated coefficient (standard deviation) — Model (1): elasticity of substitution $\hat{\sigma}$	Model (2): analysis of specific rate of technical progress $\hat{\alpha}$	$\hat{\beta}$
(3) Executives, managers, and high-level professionals	1.24	–0.0052	–0.0006
	(0.25)	(0.002)	(0.003)
(4) Technicians and low-level professionals	1.60	+0.0023	–0.0012
	(0.24)	(0.0008)	(0.001)
(5) High-level employees	0.82	+0.00008	–0.012
	(0.19)	(0.0009)	(0.007)
(6) Low-level employees	0.81	–0.012	–0.0064
	(0.24)	(0.007)	(0.016)
(7) Skilled manual workers	0.98	+0.00032	+0.0013
	(0.18)	(0.0015)	(0.0015)
(8) Unskilled manual workers	1.59	+0.019	–0.0007
	(0.22)	(0.0016)	(0.052)
Complete sample group	1.12	+0.0026	–0.0030
	(0.09)	(0.0010)	(0.0019)

Models estimated: $d\left(\frac{f^{d}_{1,s,t}}{f^{d}_{2,s,t}}\right) = -\sigma d\left(\frac{W_{1,s,t}}{W_{2,s,t}}\right) + a_s + \varepsilon_{s,t}$, instrumented by $dW_{2,s,t}$ and $d\left(\frac{f^{d}_{1,s,t}}{M_{s,t}}\right)$ [1]

$$\hat{a}_s = \alpha comp_s + \beta techno_s + \sum_{g=Exec}^{unskilled} \gamma_g I_g(s) + u_s \quad [2]$$

where:
- $w_{1,s,t}$ (*resp.* $w_{2,s,t}$) is the average wage in sector *s* of individuals strongly endowed (resp. weakly endowed) with human capital;
- $f^{d}_{1,s,t}$ (*resp.* $f^{d}_{2,s,t}$) is the volume of the labour in months of individuals strongly endowed (resp. weakly endowed) with human capital in sector *s*;
- $M_{s,t}$ is the total wages fund of sector *s*;
- dx_t is written for $Log(x_t) - Log(x_{t-1})$;
- $comp_s$ is the rate of diffusion of computerisation in sector *s*;
- $techno_s$ is the rate of diffusion of new technologies other than computerisation in sector *s*.

Note: The estimates were made on different sectoral sample groups in the time dimension. The complete sample group describes 204 microsectors (34 activity sectors × 6 skill levels). The various levels of human capital by type of occupation are defined in the text.

Source: Labour Force Surveys, 1982 to 1993, INSEE.

non-graduates and relative rigidity of relative earnings, appears to be the main mechanism explaining the substitution of the educationally well qualified for the educationally less well qualified at the various occupational and sectoral levels of the economy. On the other hand, there is no strong evidence that the spread of new technologies has been especially conducive to this process.

CONCLUSION

In conclusion, it may be helpful to summarise some of the results.

In France, two phenomena appear to be contributing in almost equal proportions to the increasing scarcity of jobs being offered to less qualified and less experienced workers:

- the first such phenomenon is shifts in domestic demand which favour those sectors and occupations in which human capital requirements weigh heavily;
- the second is the increase in the supply of graduates and the decline in their relative earnings, the combined effect of which is conducive to the *substitution of college-educated workers for non-college-educated workers* within the various sectors of activity and types of occupation.

As regards technical progress, some of its aspects have the effect of stepping up the pace of the substitution of managerial jobs for manual posts and consequently of strengthening the demand for the most highly qualified and experienced individuals. This is especially the case in microcomputing and office automation. The diffusion of these technologies is also tending to increase the pace at which the educationally qualified are being substituted for other wage earners at all levels in the occupational scale.

In other respects, new technologies tend to slow down the substitution of managers, professionals and technicians for manual and non-manual workers. The introduction of industrial robots and NC machine tools in industry seems, paradoxically, to have had this effect; these technologies appear to effect greater savings in the work of managerial staff than in that of the manual and non-manual workers who are the minders of the new machinery.

All things considered, the *net* effect of new technologies on the development of employment structures appears ultimately to have played a less important role in France than the increase in the supply of the educationally qualified and the *decline in their relative earnings*.

Similarly, the development of international trade has had only marginal effects on the evolution in the occupational demand for labour.

The analysis leaves several questions unanswered:

- The French labour market does not appear to be subject to the same laws as its American counterpart. Should we therefore conclude that the French labour market is atypical and constitutes an exception? Or, alternatively, should we consider that it provides an example of mechanisms that will be found in other European countries, typified by greater institutionalisation of wage-setting procedures and also, perhaps, by lesser dynamism in innovation and research? Only comparative studies (especially at the European level), making use of harmonised measures to assess the diffusion of new technologies, will enable progress to be made on this point.

- The French labour market may not be atypical, but may perhaps "lag behind" its American counterpart. Is strong asymmetry of technical change to be the future of the French economy, and more generally of the European economies as a whole? If that is the case, the pressures on the employment of unqualified individuals will undoubtedly continue to increase. In order to answer this question it would be necessary to make a closer study than we have done here of the most recent trends in earnings and employment in France.

NOTES

1. See Levy and Murnane (1994) for a very comprehensive review of the literature.
2. If the person is unemployed, the stated occupation and branch are those of the last job held.
3. This classification is a consolidated version of the French classification of occupations and social categories (PCS): executives, managers and high-level professionals (3); technicians, supervisors and low-level professionals (4); skilled workers (7); unskilled workers (8); administrative and public service employees (5); employees in trade and in the services sector (6).
4. Long-course graduates (average age on completion of education in 1993: 24.4 years), short-course graduates (21.8 years), holders of the *Baccalauréat* (20 years), holders of the certificate of vocational competence (CAP), or of the BEPC or CEP certificate (16.7 years) and school leavers with no certificate (15 years).
5. We decided against using the Labour Force Surveys carried out before 1975 because they used a classification of activities that differed from NAP-1973.
6. The 1970, 1977 and 1985 surveys do not specify the precise number of hours per week worked by part-time workers; we treated them as having been employed half-time.
7. See Gollac (1993) or Kramarz and Entorf (1994) for an account of these surveys and the use made of them.
8. See INSEE (1993) for the main trends in employment in France.
9. A reduction in the return on experience from generation to generation is not incompatible with stable differentials in the remuneration of workers of different ages or even with an increase in these differentials over time. In fact, as regards France, Davis (1992) and Katz, Loveman and Blanchflower (1993), point to an increase in these differentials, especially over the period 1977-85. The data used in these two studies (DADS) are, however, somewhat incomplete; on the one hand, they do not include information on the educational levels of employees and cannot be used to verify shifts in the relative educational levels of different age brackets. Furthermore, they relate only to the private sector and do not therefore take into account the inflow of young graduates into the public service in recent decades. According to the data at our disposal, the wages differential between workers in the 40-44 year age group, on the one hand, and the 25-29 year age group, on the other, tended between 1970 and 1993 to increase for workers with fewer educational qualifications and to decrease for

workers with higher qualifications; as a weighted average, relative earnings 40-44/25-29 years are relatively stable, fluctuating around 1.3 (Table 3). The increase seen in the United States is not to be noted.

10. Let us recall the principle of this method (Heckman, 1979). Let X_i be the level of qualification of the individual *i*. It is assumed that wages can be expressed as ($w_i = X_i\, b + u_i$) where *b* is the return on the qualification level, and u_i is a normal, centred remainder representing the unobserved determinants of the wage. By construction, the observation covers only the wages of individuals avoiding unemployment, *i.e.* those who are enabled by their qualification level (X_i) or other unseen factors (u_i) to get a larger wage than the basic wage ($w_{r,i}$), which is dependent, *a priori*, on the minimum wage w_0, for qualification level X_i and also possibly on other factors Z_i, such that ($w_{r,i} = w_0 + X_i c + Z_i d$). Accepting the convention of denoting wages by s_i, this yields the complete expression: $E(s_i) = E(w_i/w_i > w_{i,r} = Xb + E(u_i/u_i > w_0 + X_i(c - b) + Z_i d)$. In order to estimate *b* without bias, taking only s_i as the starting point, one has to calculate $M_i = E(u_i/u_i > w_0 + X(c - b) + Zd)$. Heckman's idea is that ($c - b$) and *d* should be estimated initially using a model of probit type of the probability of being unemployed ($P(u_i < w_0 + X(c - b) + Zd)$), and on that basis to reconstitute, individual by individual, an estimate of M_i (inverse Mills ratio).

11. These authors use DADS data supplemented by data on education obtained from the population census. In that respect, their data is more complete than those of Davis (1992) or Katz, Loveman and Blanchflower (1993) in their international comparative analyses.

12. See Goux and Maurin (1996) for a detailed analysis of recent changes in earning patterns.

13. See Goux and Maurin (1995) for a theoretical validation of the indicators used in this section.

14. The term "microsector" as used here designates the coming together of an activity sector and an occupation. 204 microsectors were used in the estimates (34 activity sectors x 6 types of occupation).

15. Or it is developing in the direction of industrial products that, by virtue of their "quality" increasingly embody services: after-sales service, product information, user training, etc.

16. This, and the subsequent calculations are based on the hypothesis of the proportionality of employment and production: the share of employment in sector *s* destined for domestic demand is calculated on the basis of the share of the production of that sector devoted to domestic demand (taken from national accounts).

17. It should be stressed that the calculations do not take into account the *indirect* effects of international trade: when one of the domestic industry loses (gains) outlets in the face of foreign competition, it is not only its firms that lose (gain) jobs, but also, indirectly, all suppliers. Moreover, the methodology makes only imperfect allowance for the differentials in employment structures between the firms held back by international competition, on the one hand, and those that win export markets, on the other.

18. The asymmetries described in this section correspond to the aspects of technical progress that favour certain types of occupation in preference to others. In the following section we analyse another form of asymmetry which within each occupation may be conducive to the accumulation of one type of human capital rather than another.
19. See Goux and Maurin (1996) for a theoretical description of this type of analysis.
20. When other breakdowns were tested, the results remained qualitatively identical.

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ASYMMETRIC GROWTH EFFECTS, SKILL MISMATCH AND UNEMPLOYMENT PERSISTENCE

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SUMMARY

This article considers two alternative explanations of the persistence of high unemployment rates in EU countries. One explanation is based on insider-outsider effects and the disenfranchisement of long-term unemployed workers; *the other explanation emphasizes the combined effects of asymmetric growth and* relative wage rigidities which lead to skill mismatch. The issue is important because the two stories have quite different policy implications, although in both cases much emphasis will be given to the need for co-ordinated demand and supply policies.

The two points of view are not easily distinguished empirically. The article gives some evidence in favour of the skill mismatch story. A simple analytical framework is proposed to analyse the relationship between skill mismatch and aggregate equilibrium unemployment. This framework highlights the policy dilemma between income maintenance and economic efficiency.

Twenty years after the first oil shock and the beginning of the current slow growth-high unemployment period, there is still much debate about the causes of unemployment and the appropriate economic policy responses. The nature of the debate has progressively changed. The focus, which was initially on the consequences of demand *vs.* supply shocks and the relative importance of the two, has now shifted on the mechanism of unemployment persistence. On the policy side, the emphasis is now on the need for more flexibility and for active (training and mobility) rather than passive (income maintenance) labour market policies. From this standpoint, the role and relative importance of structural phenomena remain a critical issue. We emphasize in this article the asymmetric effects of growth on the demand for high- and low-skilled workers. This asymmetry may result from technological changes, output demand shifts (deindustrialisation) and/or the increasing importance of newly industrial countries. Asymmetric growth plus relative wage rigidities inevitably leads to structural maladjustment and may contribute to explain unemployment persistence in Europe. The fear is furthermore that, even with flexible real wages and full employment, the American and European economy could in the future be unable to provide sufficient "middle-class jobs" (jobs that can provide a decent standard of living to low-skilled full-time workers). Hence the policy dilemma discussed in Drèze and Sneessens (1994): income maintenance *vs.* economic efficiency.

We briefly review in Section I the different factors that may lead to asymmetric growth (biased technological change, deindustrialisation and competition from low-wage countries). Our main objective, however, is not to evaluate the relative importance of each of these factors, but rather to look at the aggregate consequences of asymmetric growth and analyse to what extent such an asymmetry might be held responsible for the current situation in Europe. Section II briefly compares and evaluates the relative merits of two competing explanations of unemployment persistence, structural (skill) mismatch *vs.* hysteresis via disenfranchisement of long-term unemployed workers. A simple analytical framework is proposed in Section III to analyse the relationship between skill mismatch and equilibrium unemployment; this section also summarises the empirical results obtained on French data over the period 1962-89. Economic policy implications are discussed in Section V.

I. SOURCES OF ASYMMETRIC GROWTH

The key statistics for employment and real wages by skill are summarised in Table 1 for the United States and Table 2 for France and Germany. They show that skilled employment has increased steadily relative to unskilled employment in the 1970s and 1980s. Various studies (especially in the United States), based on detailed micro-data by industry, age, education, sex, etc., have been carried out that try to disentangle the various factors that may have caused this evolution (demand and supply shifts, variables, purely cyclical phenomena, institutional features linked to minimum wage regulations, union power and industry-specific rents). Most studies conclude that supply and cyclical or institutional changes alone cannot explain the changes summarised in Table 1; labour demand shifts must have played a substantial role (see Levy and Murnane's survey in JEL, 1992).

Table 1. **Employment composition and hourly real wage growth in the United States**

Percentages

	Employment composition			Real wage growth	
	1973	1979	1988	1973-79	1979-88
High-skilled	31	38	45	–9.20	0.07
Less-skilled	69	62	55	–5.00	–3.10

Source: Computed from Bound and Johnson (1992), Table 1.

Table 2. **Ratio of less-skilled to high-skilled employment and wages in Germany and France**[1]

	Germany				France	
	Employment		Wage		Employment	
	Blue-collar	White-collar	Blue-collar	White-collar	White + blue	White + blue
1966	1.34	0.88	0.78	0.56	5.00	0.43
1970	1.42	0.75	0.78	0.57	4.11	0.44
1980	1.17	0.43	0.80	0.59	2.92	0.52
1990	1.02	0.38	0.82	0.58	2.25	0.51

1. Skills are defined by educational level in the United States and by occupation in Germany and France. In the United States, high-skilled = college graduates + some college; less-skilled = high school graduates + drop-outs. For Germany, the high-skilled groups correspond to Category I for blue-collar workers, Categories II + III for white-collar workers. For France, high-skilled workers include managerial, clerical and professional workers.

Source: Drèze and Sneessens (1994); Sneessens and Shadman-Mehta (1995).

The factors that may have produced a positive demand shift towards more skilled labour can usefully be grouped into three categories. We briefly consider each of them.

– *Biased technological change.* The implementation of computer-related and new communication technologies may have shifted the demand from low-skilled to high-skilled workers. This view is endorsed for example by the 1994 *OECD Jobs Study.* Bean and Pissarides (1990) and Machin (1994) provide some evidence for the United Kingdom. In many US studies, the test is based on the idea that in a competitive set-up a technology-induced downward shift in the demand for low-skilled workers implies a negative correlation between the amount invested in new technologies and the relative wage of low-skilled workers. One does indeed observe such a negative correlation at the aggregate level in the United States. Krueger (1993) reports evidence based on micro data that the premium for skills (*e.g.* workers who use computers) has risen. This view is challenged by Entorf and Kramarz (1994),[1] although they recognise that the introduction of new technologies improves the employment prospects of high-skilled workers relative to low-skilled ones. Other studies look at a direct correlation between the installation of new technologies and skilled employment and find evidence of a positive correlation, although the effect may vary by sector and occupation group (see for instance Berman *et al.*, 1993; Berndt and Morrison, 1991; Howell and Wolff, 1992) . Bound and Johnson (1992) explain most of the shift in the demand for skilled labour by a general technological change common to all industries. This non-neutral technological progress, already present in the 1970s, would have had an even larger impact during the 1980s.[2] Howell (1996) finds that skill restructuring in the US manufacturing sector was much more important between 1973 and 1983 than after. This finding is compatible with German and French observations (see Table 2). As a consequence, Howell explains the relative wage changes observed in the 1980s in the United States in terms of "shifting wage norms" (including aggressive anti-union practices) rather than technological change.

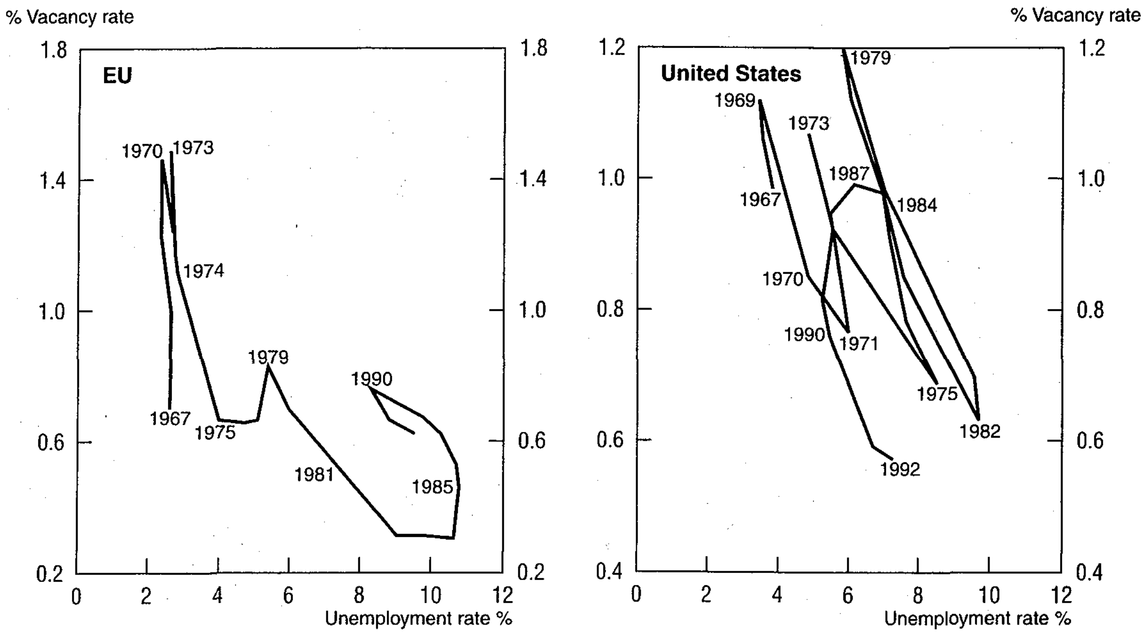
- *Deindustrialisation.* The rapidly decreasing relative importance of manufacturing employment (due to productivity gains and structural demand changes), especially after 1974, implied that many low-skilled workers had to leave the high paying manufacturing sector and find jobs in the service sectors, where wages are traditionally lower, in part as a result of stronger competition with women. Besides its effect on relative wages by increased competition between unskilled men and women, this structural change may also affect the skilled-unskilled labour demand mix if the non-manufacturing sectors utilise relatively more skilled labour. In 1979 (resp. 1987), the skilled to unskilled ratio was 0.30 (0.38) in the US manufacturing sector, compared to 0.56 (0.46) for the rest of the economy (see Levy and Murnane, 1992, Table 7).[3]
- *Globalisation and competition from low-wage countries.* Increased competition from low wage countries contributed to significantly worsen the situation of low-skilled workers in developed countries (see for instance Wood, 1994). Its impact may have been quite significant on some specific sectors. There seems to be a consensus though to consider that it cannot be the sole, nor even the major factor explaining employment losses in Europe and relative wage changes in the United States. As noted by Katz (1992), "the separate impacts of technological change and international trade are difficult to identify, since increased international competition could motivate firms to innovate, adopt new technologies, or change work organisations."

Our objective here is not to evaluate the separate effects of these three factors, but rather to look at the overall effects of these various sources of asymmetric growth. Estimates on French data (see Sneessens and Shadman-Mehta, 1995) suggest that the asymmetry has been quite large over the last 30 years. The trend rate of substitution of high-skilled for less-skilled workers at constant relative wages is estimated at around 5 per cent per year before 1973, about 2-3 per cent thereafter. While this asymmetry was compensated by changes in the composition of the labour force during the first sub-period, it was no longer true after 1973. In such circumstances, the effect of asymmetric growth on (un-)employment of course crucially depends on the way wages are determined. In particular, if there is perfect competition and wages are perfectly flexible, the impact on employment may be weak (although social consequences may not be); if on the other hand wages are sticky, asymmetric growth may lead to structural problems and unemployment persistence. Tables 1 and 2 show that the relative wage cost of less-skilled workers has evolved quite differently in France, Germany and the United States. From 1970 till 1990, the relative wage cost of less-skilled workers has increased in France, remained fairly stable in Germany, first increased and then decreased in the United States.

II. SKILL MISMATCH OR DISENFRANCHISEMENT?

Figure 1 reproduces the relationship observed over the last 25 years between unemployment and vacancies in the European Union countries (left panel) and in the United States (right panel). The figure suggests important shifts of the so-called Beveridge curve in the EU and the United States. There are differences, however. In the EU countries, there has been a progressive and continuing outward shift from 1975 till 1985; the Beveridge curve has since remained remarkably stable. In the United States, a similar outward shift is observed from 1972 till 1982; at variance with the EU countries, the curve has shifted backwards again

Figure 1. **Observed shifts in the Beveridge curve in the EU and the United States**



Source: Sneessens (1995).

and resumed its initial position during the second half of the 1980s. Any explanation of unemployment, and particularly of unemployment persistence in Europe, should be compatible with these facts.

Two explanations are *a priori* possible. Unemployment persistence and Beveridge curve shifts could be the consequence of relative wage rigidities and skill mismatch in the face of asymmetric growth of the type considered in Section I; it could also be the consequence of a hysteresis phenomenon coming from the progressive disenfranchisement of long-term unemployed workers, as insider-outsider theories may suggest (see, for instance, Layard and Bean, 1989). The two explanations are of course not mutually exclusive. The two phenomena may well interact and reinforce each other; skill mismatch is likely to increase the proportion of long-term unemployment and lead to the progressive disenfranchisement of unemployed low-skilled workers. Still the relative importance of the two phenomena is an important issue, because they may have quite different policy implications (see below).

Available observations clearly indicate that it is the least-skilled workers who are most vulnerable to unemployment. It is in these categories of workers that the rate of unemployment and the proportion of long-term unemployed are highest. This is illustrated by Table 3, which gives the unemployment rate by skill

Table 3. **Unemployment rates by level of educational attainment in 1991, and proportion of long-term unemployment in 1992**

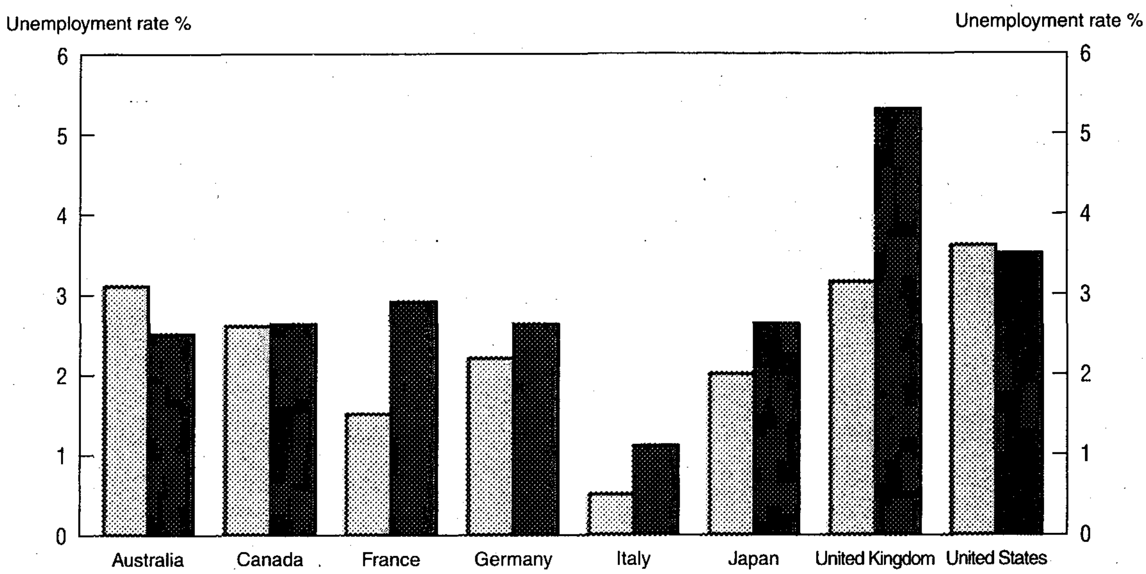
	Secondary education or less UR_l	Post-secondary education UR_h	Total UR	Proportion of long-term unemployment in total unemployment Π_{LTU}
Belgium	9.55	2.00	8.13	59.0
Denmark	11.53	4.95	10.39	27.0
France	8.95	3.73	8.17	36.1
Germany	7.50	4.55	6.85	33.5
Ireland	16.59	4.15	14.60	60.2
Italy	6.05	5.00	5.99	58.2
Netherlands	6.91	4.33	6.42	44.0
Portugal	3.88	1.55	3.78	30.9
Spain	13.50	9.30	13.08	47.4
United Kingdom	8.07	3.35	7.35	35.4
Austria	3.70	1.50	3.58	16.9
Finland	7.78	2.46	6.82	8.2
Sweden	2.43	1.10	2.12	8.0
United States	8.65	4.30	7.13	11.2

Source: OECD (1993, 1994).

(educational) level in 1991 in various OECD countries.[4] Figure 2 shows that the EU countries (not the United States) had in the early 1990s a higher relative unemployment rate of less-skilled workers than they had 20 years before, in the early 1970s. Figure 3, which describes the evolution of unemployment rates by skill level[5] in France from 1962 till 1989, suggests once again that most of the change took place from 1974 till 1984. Figure 4 shows for the same country that the proportion of long-term unemployed workers has more recently (after 1985) become highest among the least-skilled categories of workers (employees and blue-collar workers).

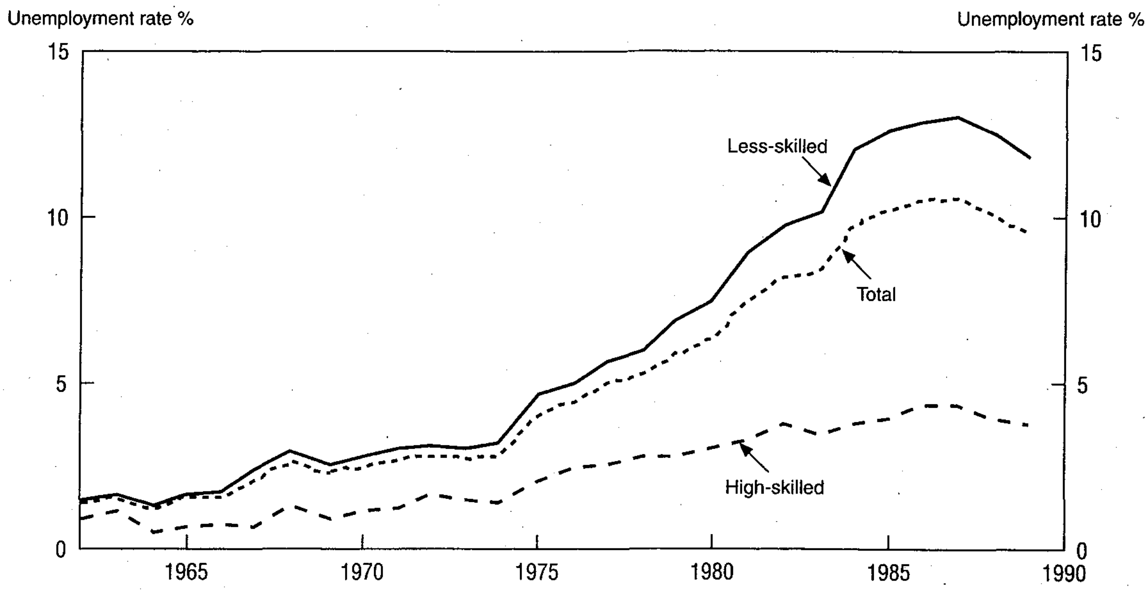
These simple observations do not prove that the skill mismatch story has to be preferred to the disenfranchisement one; the more unfavourable situation of least-skilled workers could result from a simple "ladder effect" (skilled workers taking the jobs of less-skilled ones) rather than from skill mismatch.[6] Still, the comparison between the EU countries and the United States and the timing of the changes make the skill mismatch story coherent and *a priori* appealing. As Figure 3 suggests, it is between 1975 and 1985 that most of the increase in the gap between skilled and unskilled unemployment rates has taken place (at least in France), at the same time as the shift in the Beveridge curve and the rapid change in the composition of employment (see previous section); the backward

Figure 2. **Relative unemployment rate of less-skilled workers in the early 1970s (light bars) and the early 1990s (dark bars)**



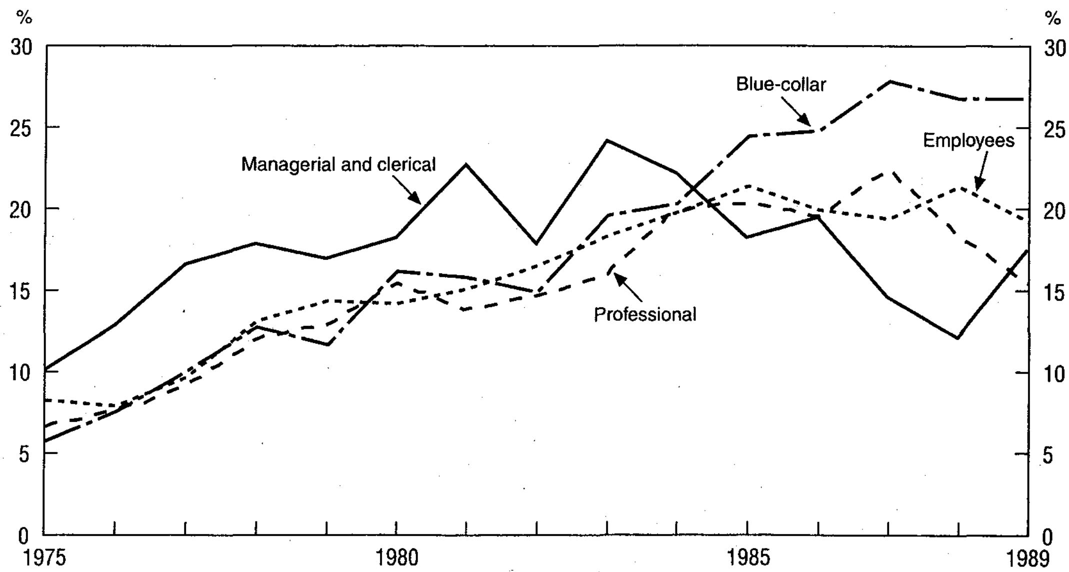
Source: OECD (1994), Figure 15.

Figure 3. **Unemployment rates by skill level in France**[1]



1. Same definitions as in Table 2.
Source: Sneessens and Shadman-Mehta (1995).

Figure 4. **Proportion of long-term unemployed workers (more than two years) in each occupation group in France**



Source: Maillard and Sneessens (1994).

shift in the US Beveridge curve next corresponds to the change in relative wages. In the disenfranchisement story, unemployment persistence comes from an unlucky succession of transitory negative demand or supply shocks, the effects of which are cumulated and consolidated by the disenfranchisement of the long-term unemployed (but otherwise identical) worker. This story is possible, although it may look somewhat *ad hoc*.

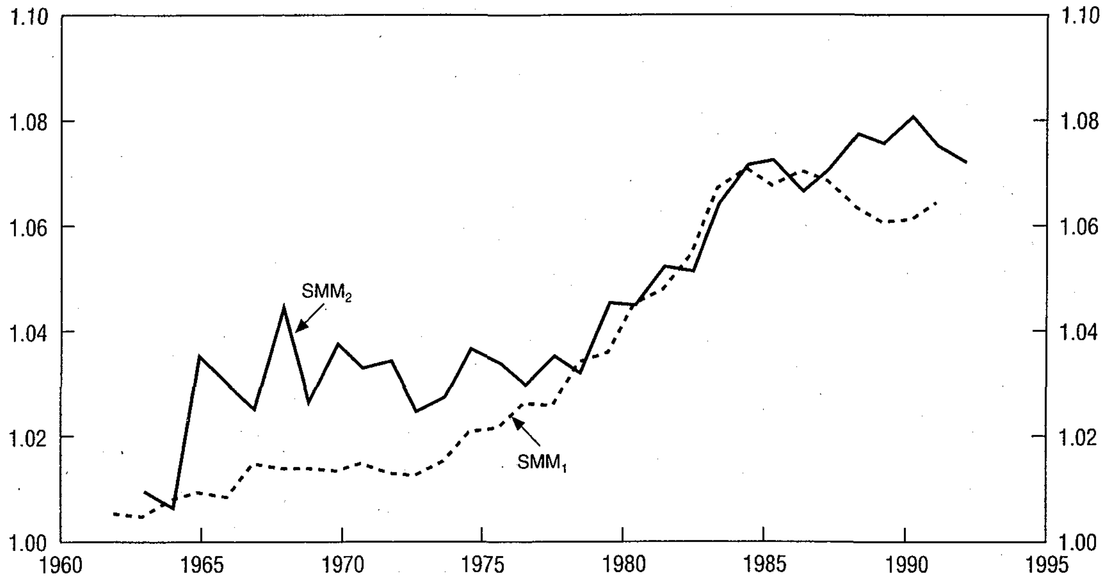
One way to try to disentangle the two phenomena (skill mismatch *vs.* disenfranchisement) is by constructing appropriate mismatch indicators. If the value of the mismatch indicator does not increase at the same time as the Beveridge curve shifts, the shift should then be explained by disenfranchisement rather than skill mismatch. Two types of indicators are usually considered; one is based on unemployment rate differences (SMM_1), the other on unemployment rate ratios (SMM_2). It is not clear whether one indicator has better theoretical foundations than the other. Layard *et al.* (1991), using a Nairu model with a segmented labour market, argue in favour of ratios; Sneessens and Shadman-Mehta (1995) obtain from a model with explicit skilled labour constraints and aggregation over micromarkets, an indicator based on differences. The two indicators, differences *vs.* ratios, may give quite different information, as Table 4 and Figure 5 illustrate.[7]

Table 4. **Total unemployment rates and skill mismatch indicators based on Table 3**

	Total UR	SMM_1% $\propto UR - UR_h$	SMM_2% $\propto (UR_l - UR_h)/UR$	Prop. long-term unemployment Π_{LTU}
Belgium	8.13	6.68	7.16	59.0
Denmark	10.39	6.07	3.14	27.0
France	8.17	4.83	2.64	36.1
Germany	6.85	2.47	1.60	33.5
Ireland	14.60	12.23	5.00	60.2
Italy	5.99	1.05	0.09	58.2
Netherlands	6.42	2.24	1.25	44.0
Portugal	3.78	2.32	0.73	30.9
Spain	13.08	4.35	0.47	47.4
United Kingdom	7.35	4.31	2.97	35.4
Austria	3.58	2.16	1.24	16.9
Finland	6.82	4.69	4.60	8.2
Sweden	2.12	1.05	3.53	8.0
United States	7.13	3.05	4.47	11.2

Source: Author.

Figure 5. **Values of the two mismatch indicators computed on French data**



Source: Sneessens (1994).

Sneessens and Shadman-Mehta (1995) show that the skill mismatch indicator based on differences (SMM_1) explains quite well the Beveridge curve shifts observed in France from 1962 till 1989. Table 5 reports the results of simple cross-section regressions based on the data reproduced in Table 4. The observed unemployment rate is the dependent variable, the two skill mismatch indicators and the proportion of long-term unemployment (PLTU as measure of the disenfranchisement effect) are the explanatory variables. Despite the simplicity of this exercise, there is one obvious and interesting result. If one focuses on unemployment ratios rather than differences (SMM_2% rather than SMM_1%; regression [3]), skill mismatch seems to play no role, while disenfranchisement is just significant (with the usual simple t-stat criterion). If one instead focuses on unemployment differences (SMM_1% rather than SMM_2%; regression [2]), the explanatory power of the equation is considerably increased (R^2=0.70 instead of 0.37) and skill mismatch becomes the dominant explanatory variable.[8] Figure 6 reproduces the relationship between observed unemployment and skill mismatch as measured by differences (SMM_1%). The figure shows that most countries lie along the regression line; that is observed unemployment is the sum of a skill mismatch effect plus an unexplained component roughly equal to 3.5 per cent in 1991. There are two main outliers, Spain (well above the curve) and Sweden (below).

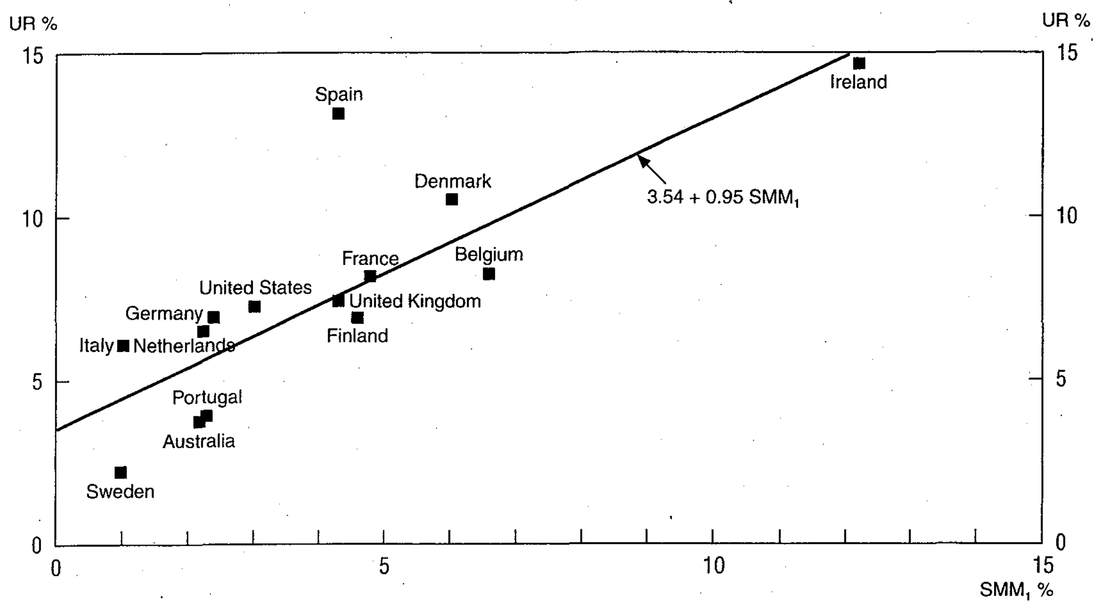
Table 5. **Cross-country OLS estimates of the relationship between observed unemployment rates on the one hand, and skill mismatch indicators and proportion of long-term unemployment on the other hand**[1]

Regression No.	Dependent variable: Unemployment rate UR				
	Constant	SMM_1%	SMM_2%	Π_{LTU}	R^2
(1)	3.62 (1.35)	1.13* (0.27)	–0.57 (0.35)	0.02 (0.03)	0.76
(2)	2.49 (1.23)	0.83* (0.22)		0.05 (0.03)	0.70
(3)	2.71 (2.08)		0.42 (0.40)	0.11* (0.04)	0.37
(4)	3.54 (1.00)	0.95* (0.20)			0.65
(5)	6.39 (1.61)		0.39 (0.47)		0.05
(6)	3.94 (1.70)			0.10* (0.04)	0.31

1. Standard errors between parentheses; a star indicates a t-statistic larger than the critical value at the 5 per cent significance level.

Source: Author.

Figure 6. **Relationship between skill mismatch (SMM_1 %, horizontal axis) and unemployment (UR, vertical axis) in 14 OECD countries, 1991**



Source: Author.

We should conclude, if anything, that: *i)* the type of mismatch indicator used matters; and *ii)* it is worthwhile investigating further the possibility of significant skill mismatch effects on equilibrium unemployment.

III. SKILL MISMATCH AND EQUILIBRIUM UNEMPLOYMENT

The objective of this section is to discuss how standard equilibrium unemployment (Nairu) models can be extended to have two types of labour (low- and high-skilled) and to examine the interactions between skill mismatch and equilibrium unemployment. We first present a simple, stylised version of the model, and then report some of the empirical results obtained on French data.

Structure of the model

The crucial part of the standard Nairu model can be summarised in two equations, respectively a price- and a wage-setting equation:

$$P = \pi_0 - \pi_1 \, UR + W, \qquad \pi_1 \geq 0, \qquad [1]$$

$$W = \omega_0 - \omega_1 \, UR + P, \qquad \omega_1 > 0, \qquad [2]$$

where the "constant terms" π_0 and ω_0 include all the relevant "push variables"; π_1 allows for mark-up variations. All variables except *UR* are in logs. These two equations can be recast in terms of real wages *(w)* and unemployment rate *(UR)*:

$$w = -\pi_0 + \pi_1 \, UR; \qquad [1']$$

$$w = \omega_0 - \omega_1 \, UR. \qquad [2']$$

Solving for UR gives the equilibrium unemployment rate as a function of the push variables π_0 and ω_0.[9] When two types of labour are distinguished, the model will include two additional equations, one determining the low- to high-skilled labour ratio, the other the difference between the low- and the high-skilled wage rates. The key elements of the model can thus be represented as follows:

$$\Delta_u = \lambda_0 + [(\phi_l - \phi_h) + (1 - \sigma)(\gamma_l - \gamma_h)] \,.\, \text{Trend} + \sigma(w_l - w_h); \qquad [3]$$

$$w_h = -\pi_0 + \pi_1 \, UR_h - \pi_2 \, w_l, \qquad \pi_1 \geq 0, \ \pi_2 > 0; \qquad [4]$$

$$w_h = \chi_0 - \chi_1 \, UR_h + \chi_2 \, w_l, \qquad \chi_1 \geq 0, \ \chi_2 \gtreqless 0; \qquad [5]$$

$$w_l = \nu_0 + \nu_1 \, smic. \qquad [6]$$

Equation [3] corresponds to the choice of the optimal (cost-minimising) low- to high-skilled labour ratio. It is obtained from a standard two-factor CES function with elasticity of substitution equal to σ and exogenous rates of productivity growth equal to γ_l and γ_h for low-skilled and high-skilled labour respectively. By subtracting the low- to high-skilled labour supply ratio, the equation can be given the form shown in [3], where Δ_u stands for the difference between the low- and the high-skilled unemployment rates ($\Delta_u = UR_l - UR_h$), and ϕ_l and ϕ_h stand for the rate of growth of the low- and high-skilled labour force respectively. The term $(\gamma_l - \gamma_h)$ is meant to represent the possible asymmetric effects of growth discussed in Section I. Equation [4] corresponds to the price-setting equation [1'], rearranged to distinguish the two types of labour. It is implicitly assumed that the supply of low-skilled labour is never binding, so that only the skilled unemployment rate enters the price equation to measure the effects of tensions on the mark-up. Equations [5] and [6] are the high-skilled and low-skilled wage equations. The two equations differ in that: *i)* the low-skilled unemployment rate is assumed to have no effect on the low-skilled wage rate, which is primarily determined by the minimum wage rate (*smic*); and *ii)* the high-skilled wage rate is assumed to have no effect on the low-skilled wage demand. The latter assumption is taken for convenience. The former reflects the (realistic) assumption that there is a huge excess supply of low-skilled labour, while firms may occasionally face high-skilled labour shortages and thus compete with other firms for this type of labour. The relevant push-variables (tax wedges, for instance) are again included in the pseudo-constant terms π_0, χ_0 and ν_0. It is worth emphasizing that the effect of the low-skilled wage rate on the high-skilled wage rate may *a priori* be positive (envy effect) or negative (profitability effect, via the effect of the low-skilled wage rate on the profitability of the firm and its ability to compete for high-skilled labour).[10]

The stylised structure of model [3]-[6] allows a simple presentation of its key features. Because the low-skilled wage is predetermined, the working of the model can easily be represented graphically. This is done in Figure 7. The left panel determines the equilibrium high-skilled real wage and unemployment rates, at given values of the push variables and the minimum wage *(smic)*; the right panel next determines the value of Δ_u, which, as mentioned in Section II, can be interpreted as a skill mismatch indicator.

The equilibrium values of the endogenous variables are given by the following reduced-form equations:

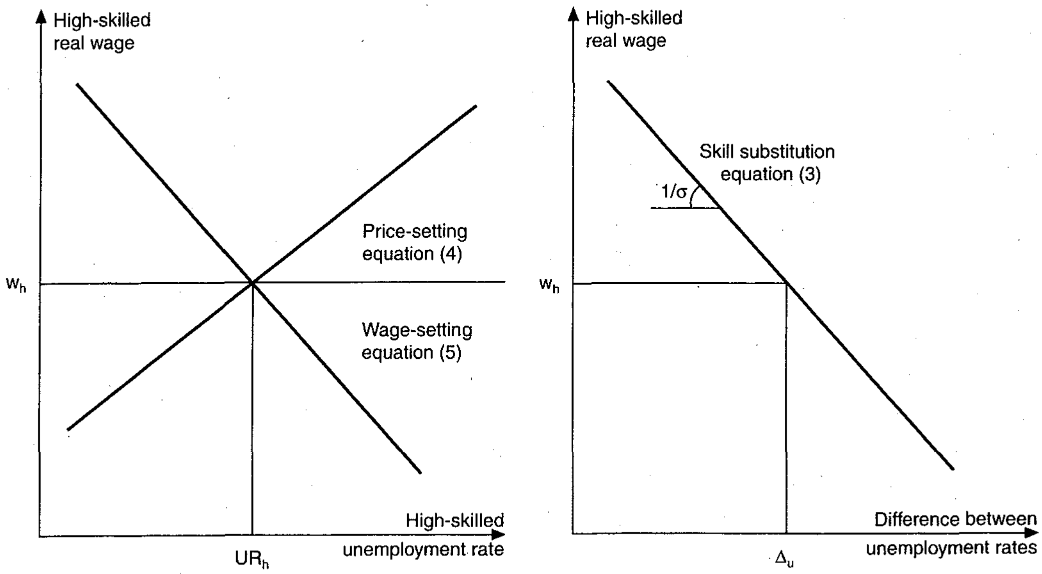
$$w_l = \nu_0 + \nu_1 \, smic; \qquad [6']$$

$$w_h = -\frac{\chi_1}{\chi_1 + \pi_1}\pi_0 + \frac{\pi_1}{\chi_1 + \pi_1}\chi_0 + \frac{\chi_2\pi_1 - \chi_1\pi_2}{\chi_1 + \pi_1} w_1; \qquad [7]$$

$$UR_h = \frac{1}{\chi + \pi_1}\pi_0 + \frac{1}{\chi_1 + \pi_1}\chi_0 + \frac{\chi_2 + \pi_2}{\chi_1 + \pi_1} w_1; \qquad [8]$$

$$\Delta_u = \lambda l_0 + [(\phi_l - \phi_h) + (1 - \sigma)(\gamma_l - \gamma_h)] \, . \, \text{Trend} \qquad [9]$$
$$+ \sigma \left\{\frac{\chi_1}{\chi_1 + \pi_1}\pi_0 - \frac{\pi_1}{\chi_1 + \pi_1}\chi_0 + \frac{(1 - \chi_2)\pi_1 + (1 + \pi_2)\chi_1}{\chi_1 + \pi_1} w_1\right\}.$$

Figure 7. **Determination of the equilibrium unemployment and wage rates**



Source: Author.

From this stylised model we can draw the following conclusions:

- A positive value of the term $(1-\sigma)$ $(\gamma_l - \gamma_h)$ has, *ceteris paribus*, a positive effect on skill mismatch Δ_u. In other words, if the elasticity of substitution between the two types of labour is different from 1, asymmetric growth effects may lead to a dualisation[11] of the labour market.
- Equation [3] makes clear the dilemma between unemployment and income inequalities. Too large income inequalities among employed workers can be avoided by maintaining the low-skilled real wage above its competitive equilibrium value (either by union intervention or by legal minimum wage restrictions), but this will be at the cost of larger unemployment inequalities. Large unemployment compensations or minimum income guarantees may of course substantially reduce the personal cost of unemployment, but not the social loss due to economic inefficiency and the waste of human resources (see, for instance, de Kerchove *et al.*, 1995).
- Increasing the minimum wage (to reduce the gap between low and high wages) has a direct effect on unemployment rate differences (skill mismatch; see equation [9]). It may also affect the equilibrium unemployment rate of high-skilled workers (see equation [8]). *The structural and macroeconomic phenomena are thus interrelated.*

– The dualisation of the labour market induced by the asymmetric effects of growth generates asymmetric wage behaviours. For instance, a general increase in labour taxes (this means in our model $\Delta\chi_0 = \Delta\nu_0 = \Delta w_l > 0$ will in general have different effects on the two unemployment rates. If parameter χ_2 in the high-skilled wage equation [5] is negative (the profitability effect dominates the envy effect), the low-skilled unemployment rate will increase by more than the high-skilled one (see equation [9]). In other words, *the asymmetric effect of growth may well be reinforced by the asymmetric effects coming from the financing of social insurance expenditures.*

Empirical findings based on French data, 1962-89

The results are borrowed from Sneessens and Shadman-Mehta (1995). The estimated rate of exogenous "technical progress" is positive and large but decreasing for low-skilled workers (γ_l = 0.10 till 1974, 0.051 afterwards), nil for high-skilled workers ($\gamma_h = 0$). The elasticity of substitution between high- and low-skilled workers is estimated at around one-half ($\sigma = 0.52$). Despite the favourable changes observed in the composition of the labour force ($\phi_l - \phi_h < 0$), one obtains that the relative wage of low-skilled workers should have decreased by 14 per cent to compensate the asymmetric effects of growth, while it actually increased by 13 per cent. A 28 per cent cut would thus be necessary today to eliminate the difference in the unemployment rates (skill mismatch).

More details are given in Tables 6 and 7. Table 6 gives the long-term multipliers associated with the exogenous variables. These values have to be interpreted as the values of the coefficients of the reduced-form equations [6']–[9]; they incorporate the effects of wages on labour productivity not explicitly introduced in the equations (see note 7). The presentation focuses on the effects of asymmetric growth, labour force changes, minimum wage and labour taxes, with a distinction between low- and high-skilled labour taxes. The main conclusions from Table 6 can be summarised as follows:

- The exogenous productivity gains associated with low-skilled labour ($\gamma_l > 0$) lead to an almost proportional increase in *high-skilled* real wages and, at given minimum wage, imply a sharp reduction of the relative cost of low-skilled labour. This reduction dampens the effect of the "technological" bias on skill mismatch (Δ_u).
- When the change in the composition of the labour force compensates the "technological" bias (*i.e.* when $(\phi_l - \phi_h) + (1-\sigma)(\gamma_l - \gamma_h) = 0$), the net effect on unemployment is weak but favourable (taking all factor substitution effects into account).

Table 6. **Long-term multipliers (reduced-form coefficients), France, 1962-89**

Exogenous changes	Effect (× 100) on				
	w_h	$w_l - w_h$	UR_h	Δ_u	UR
$(1 - \sigma) \bullet \gamma_l$	0.901	–0.586	–0.042	0.644	0.466
$(\phi_l - \phi_h)$	0.00	0.00	0.00	1.00	0.788
Difference	**0.901**	**–0.586**	**–0.042**	**–0.356**	**–0.322**
Minimum wage	–0.685	1.095	0.030	0.527	0.446
Log $(1 + Tx_l)$	–1.053	1.685	0.046	0.811	0.685
Log $(1 + Tx_h)$	1.118	–1.077	0.175	–0.518	–0.234
$Tx_l + Tx_h$	**0.065**	**0.608**	**0.221**	**0.293**	**0.452**

Source: Sneessens and Shadman-Mehta (1995).

Table 7. **Long-term effects of changes in the exogenous variables France, 1962-89**

Percentages

Exogenous changes	Variation × 100 1962-89	Effect on				
		w_h	$w_l - w_h$	UR_h	Δ_u	UR
$(1 - \sigma)(\gamma_l - \gamma_h)$	92.78	83.59	–54.33	–3.88	59.74	43.22
Minimum wage	65.71	–44.99	71.96	1.97	34.64	29.28
1st sub-total		38.60	17.63	-1.91	94.38	72.50
$(\phi_l - \phi_h)$	–85.27	0.00	0.00	0.00	–85.27	–67.23
Sub-total		**38.60**	**17.63**	**–1.91**	**9.11**	**5.27**
Tx_l	15.03	–15.83	25.32	0.69	12.19	10.30
Tx_h	25.22	28.19	–27.15	4.41	–13.06	–5.89
Sub-total Tx		**12.36**	**–1.83**	**5.10**	**–0.87**	**4.41**
Other factors		3.39	–2.20	–0.76	–1.07	–1.59
Total		**54.35**	**13.60**	**2.43**	**7.17**	**8.09**
Observed variation		55.88	13.18	2.83	7.48	8.09

Source: Sneessens and Shadman-Mehta (1995).

– In our model (remember that we started from the assumption that the supply of low-skilled labour is never binding), a one percentage point increase in the minimum wage leads to a 0.69 per cent decrease in the high-skilled wage rate (*i.e.* the profitability effect dominates the envy effect and $\chi_2 < 0$) and increases the relative cost of low-skilled workers by 1 per cent, although the value of coefficient n is well below unity ($\nu = 0.66$). The unemployment rate of high-skilled workers is barely changed, skill mismatch is increased.

- Once all the indirect effects are taken into account, labour taxes (social insurance contributions) have quite different effects on low- and high-skilled wages, although the impact effect on wage costs was estimated to be identical and equal to 100 per cent for both types of wages. As discussed earlier, *this means that a generalised increase in social insurance contributions increases the relative cost of low-skilled workers; its estimated effect on unemployment rates is twice as large for low-skilled workers than it is for high-skilled ones.*

Table 7 uses the multipliers reported in Table 6 to calculate the total effects of observed exogenous changes on actual unemployment and wage rates. The main conclusions are:

- At a given minimum wage, the asymmetry of the growth process ($\gamma_l > \gamma_h = 0$) has a large positive effect on aggregate unemployment and skill mismatch, despite the change in relative wage costs. These effects are reinforced by minimum wage increases. Once the change in the labour force composition is taken into account, the total effect on aggregate unemployment is estimated at around five percentage points, and nine percentage points for skill mismatch.
- The large labour tax increases have added another four percentage points to aggregate unemployment, but have had little effect on mismatch. The larger labour tax increases observed for high-skilled workers have compensated the asymmetric labour tax effects mentioned above.
- Other variables such as union power, energy prices, real interest rates, capacity constraints, and frictions, when considered globally, have had little effect on unemployment and real wages. Individual effects may be important.

Another interesting feature of the model, mentioned earlier but not detailed here, is its ability to reproduce the observed shifts in the aggregate Beveridge curve. These shifts are mostly explained by skill mismatch, with a small contribution from increased frictions on the high-skilled labour market.

IV. POLICY IMPLICATIONS

We considered two alternative explanations of the persistence of high unemployment rates in the EU countries. One explanation is based on insider-outsider effects and the disenfranchisement of long-term unemployed workers; the other explanation emphasizes the combined effects of asymmetric growth and relative wage rigidities which may lead to skill mismatch. The two points of view are not easily distinguished, firstly because they are not exclusive of one another and may both have played a role in the persistence of unemployment in the EU countries; secondly because they have implications that are not easily distinguished and tested empirically (for instance the large proportion of low-skilled workers among long-term unemployed ones may be given different interpretations). I developed in the previous sections the reasons why I personally believe that skill mismatch plays a crucial role. The issue is important because the two stories have quite different policy implications, although in both cases much emphasis will be given to the need for co-ordinated demand and supply policies.

In the disenfranchisement story, the main problem is to reintroduce long-term unemployed workers on the labour market. As long as they remain "disenfranchised", any recovery will quickly lead to labour market tensions, even at high unemployment rates. To be successful, any policy towards economic expansion and full-employment should combine the following three ingredients:

- demand stimulation, because nominal rigidities may impede a spontaneous demand expansion even when there is no supply constraint;
- wage moderation, to prevent the starting of a wage-price spiral that would choke off the recovery;
- active labour market policies aiming at reintroducing disenfranchised (long-term unemployed) workers on the labour market, to permit job creation without inflationary pressures.

It must be emphasized that in this scenario, active labour market policies are needed only to help restart the job creation process. Once new jobs have been created and previously disenfranchised workers are enfranchised again, the policies are no longer needed. *Transitory* hiring subsidies, retraining programmes, etc., only are needed. If instead the skill mismatch story is correct, transitory subsidies or labour tax exemptions will be of little help. As soon as the subsidy is cancelled, the low-skilled worker will lose his job and unemployment will persist. In the skill mismatch explanation, what is needed is a *permanent* subsidy or labour tax cut or any other measure aiming at changing the relative cost of low-skilled workers.

There are different ways to bring about a permanent change in relative wage costs. These are further discussed in Drèze and Sneessens (1994). If there is agreement on the need to provide a decent standard of living to all and in particular to low-skilled workers, simply relying on competitive market mechanisms to change relative wages is unlikely to be a satisfactory solution and unlikely to work without social disruption. Rigidities at the low end of the wage spectrum (either via legal minimum wage requirements or via union behaviours) can be interpreted as a means to compensate for a lack of adequate transfer or insurance policies (see for instance Drèze and Gollier, 1993), in this case at the cost of unacceptably high unemployment rates. The main suggestion in Drèze and Sneessens (1994) is, where possible, to eliminate employer social insurance contributions on minimum or low wages (and scale the exemption so that it disappears around median or mean wages), with substitute resources allocated to Social Security from indirect taxation.[12] In most countries, this will allow a significant change in relative labour costs, without creating unacceptable relative income changes.

It is likely though that the effect of a change in relative wage costs on employment will be slow to come by if nothing else is done to stimulate the demand for low-skilled labour and help create (almost from scratch) a market for proximity services. Hence the need for additional initiatives (service vouchers is one example) to stimulate the demand for personal and "proximity services", a market which has become almost non-existent in Europe. It is worth noting that the proportion of personal services in total employment in 1985 was estimated at 12.4 per cent in the United States, compared with 7.7 per cent in France (see Effring, 1989).

NOTES

1. Entorf and Kramarz use a somewhat richer data set than Krueger. It is however worth keeping in mind that Entorf and Kramarz work on French data, while Kruger uses US data, and that the French and US labour markets behave quite differently.
2. One should add that specific case studies show that the installation of new technologies may in some cases have a de-skilling effect (see Howell, 1996).
3. These figures concern 24-35 year old full-time male workers. If one compares the 1979 and 1987 figures, one observes that the proportion of skilled workers increases in manufacturing industries and decreases in the rest of the economy (excluding agriculture, forestry, fisheries and self-employed). The latter decline is explained by the strong increase of low-skilled employment in the wholesale and retail trade sector.
4. Number of unemployed by level of educational attainment per 100 persons, 25 to 64 years of age in the labour force.
5. Skill groups are defined by occupation. Data by educational level (available since 1975 only and not reproduced here) give a picture similar to that of Figure 3.
6. A simple "ladder effect" cannot explain the shift in the Beveridge curve. In this story, high unemployment rates among low-skilled workers are essentially the consequence of a macroeconomic problem rather than a structural one.
7. The two indicators are defined as follows:

   $$SMM_1 = (1 - UR_h)/(1 - UR), \text{ and } SMM_2 = \exp[\mathrm{var}(UR_i/UR)/2],\ i = h, l.$$

   where UR_h is the high-skill unemployment rate. $SMM_1\%$ is defined as $(SMM_1 - 1)/100$.
8. It is worth noting that when Ireland (which appears at the extreme right on Figure 6) is dropped from the sample, the parameter estimates remain remarkably stable:

   $$\underset{(1.35)}{UR = 3.12} + \underset{(0.35)}{1.09}\ SMM_1, \text{ with } R^2 = 0.47.$$
9. For the sake of simplicity, we do not introduce explicitly the labour productivity equation. Thus, equations [1] and [2'] should be viewed as those obtained after eliminating the productivity variable by using the productivity equation.
10. For a more elaborate model along the same lines, see Sneessens and Shadman-Mehta (1995), where the consequences of high-skilled labour shortages (in particular on the determination of the high-skilled real wage rate) and the Beveridge curve phenomenon are explicitly introduced.

11. Although the term "dualisation" seems appropriate to describe the situation discussed here, it may be worth stressing that this situation is quite different from the one usually refer to by this term (*i.e.* segmentation of the labour market into a primary market with highly-paid jobs and search unemployment, and a secondary market with full employment and low-paid jobs).

12. See also Drèze, Malinvaud *et al.* (1994).

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TECHNICAL PROGRESS, INTERNATIONAL TRADE AND LOW-SKILLED LABOUR

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SUMMARY

The relative status of low-skilled workers has declined in the major industrialised countries, although the decline varies widely in extent from country to country and takes different forms depending on how the labour market functions. This article reviews the empirical literature on the causes of the decline: macroeconomic shocks, technical progress "bias", introduction into world trade of countries with low labour costs, the role of institutions and national policy.

Most attempts to assess the respective impacts of the different shocks are in fact based on a general equilibrium model, which the article seeks to clarify.

I. INTRODUCTION

Since the early 1970s, OECD economies have been experiencing a continuous slowdown in overall productivity gains. For the OECD area as a whole, the figure fell from 3 per cent per annum for the period 1960-73 to 0.7 per cent for 1973-92. This slowdown, which is paradoxical in that the pace of technical progress in the business sector does not appear to have slackened over the same period, has affected general wage trends. In the United States, where productivity gains have been particularly low since the early 1970s, the average real hourly wage rose by only 5 per cent between 1973 and 1991 (Lawrence and Slaughter, 1993).

This general slowdown has been accompanied, with some time-lag, by a widening of wage differentials, particularly in the United States and the United Kingdom. In spite of the remarkable rise in labour-force skill levels, the status of unskilled labour has declined. In continental Europe, where wage differentials have proved more stable, unemployment is overwhelmingly affecting the less-skilled segments of the labour force.

This dual trend – a slowdown in general wage growth since the early 1970s and a decline in the relative status of less-skilled workers since the early 1980s – has coincided with three major developments:

- Faster introduction into international trade of goods manufactured in countries with low labour costs. Developing countries raised their share of world exports of manufactured goods from 9.7 per cent in 1980 to 15.8 per cent in 1990. Yet international trade theory has it that, while international trade makes it possible for a country to reallocate its resources to the most efficient uses and achieve economies of scale, it simultaneously distorts the structure of returns to factors of production in that country. In particular, it can lead to lower returns to the factor that has grown scarcer as economies have grown more specialised, *i.e.* unskilled labour in OECD countries.

- *The large-scale diffusion of information technologies.* Miniaturisation – with microprocessors – and long-distance data transmission – through telecommunications networks – have profoundly altered the economic environment. The importance of learning processes in turning this development to best use may put less-skilled workers at a disadvantage.
- A general trend towards the liberalisation of goods and labour markets, together with a weakening of the institutions (centralised collective bargaining, trade unions) that traditionally work towards a narrowing of wage differentials.

There is a relatively broad consensus that these three developments are affecting the relative wages of less-skilled workers. However, their respective impacts are much debated. In the United States, where the increase in wage spread has been the most pronounced and the most fully documented, some economists (including Lawrence, Krugman and Bhagwati) tend to rule out international trade as a factor and stress instead the nature of contemporary technical progress, which is said to be intrinsically "biased" against unskilled labour.

The importance of this debate is not purely academic. While the influence of international trade does indeed predominate, the entry into world trade of very large countries with low labour costs, such as China and India, could be a sign that the trends observed since the early 1980s are accelerating. Such a prospect means that the debates on trade relations, customs tariffs and exchange-rate issues will be of growing importance in years to come.

Yet while most available research findings in the United States appear to promote the theory of a technical progress bias, these conclusions remain open to argument. Since the only available measurements of technical progress (R&D expenditure, patents, etc.) are far from perfect, there is very little direct proof that such a bias exists. Technology bias is usually an assumption put forward failing all else, when allowance for the other factors likely to affect the wage spread or low-skilled labour still leaves a large unexplained residual. More fundamentally, this bias theory raises a number of questions:

- How can technical progress be so violently biased against unskilled labour and yet have such a low impact on overall factor productivity?

– Can the technical progress bias be so strong as to drive down the pay of unskilled workers? Does the relative decline in wages, so far confined to unskilled workers in the United States, foreshadow a trend that might spread to all the other OECD countries, or does it reflect features specific to the United States (low productivity gains, de-unionisation, continuing high immigration, greater exposure to competition from emerging countries, etc.)?
– Is the bias, if any, determined exogenously by changes in technology or does it reflect a concern on the part of firms to increase their flexibility and range of skills to adapt to what has become a less stable and more competitive goods market?

The purpose of this brief overview is to see how much light the theoretical and empirical literature can throw on these issues, looking in turn at:

– the main stylised facts concerning the status of low-skilled workers, focusing more specifically on the United States, which is certainly the best documented case;
– a framework of analysis showing the role of factors liable to affect the relative status of low-skilled workers;
– all the arguments in the debate. After considering the increase in the relative supply of skilled labour in major OECD countries, we shall look at demand factors. The debate is polarising around the impact of international trade on the one hand and technical progress on the other. Other avenues are worth exploring, however, including the role of macroeconomic shocks, the disappearance of entrepreneurial rent and the weakening of labour-market institutions.

II. STYLISED FACTS: A SLOWDOWN IN OVERALL PRODUCTIVITY GAINS AND A DECLINE IN THE STATUS OF LOW-SKILLED WORKERS

There has been a slowdown in overall factor productivity gains throughout the OECD area since the early 1970s, a trend documented for instance by Maddison (1987). In Europe, this slowdown has put an end to three decades of exceptionally strong growth and marks the return to long-term productivity trends. In the United States, however, overall productivity gains, which did not accelerate during the "golden" period, have been well below their long-term trend since the early 1970s (an annual average of 0.5 per cent compared with 1.9 per cent from 1913 to 1973). The slowdown appears somewhat paradoxical in that technical change does not seem to have lost pace in the business sector. Solow was right when he said jestingly that computers show up everywhere but in productivity statistics.

Be that as it may, the productivity slowdown has reduced the surplus that can be distributed to workers and this has probably affected wage growth, which has decelerated sharply since the early 1970s. This deceleration all round makes the question of widening wage differentials and the declining status of low-skilled workers that much more sensitive.

In the United States, where relative wages are highly flexible, there has been a considerable increase in wage inequality since the early 1980s

The commonest indicator for measuring the increase in wage inequality is the log wage differential, which rose for male workers between the 90th and 10th percentiles from 1.23 to 1.40 between 1979 and 1990, *i.e.* a rise of 17 per cent (Katz, Loveman and Blanchflower, 1993). This increase in wage inequality reflects an erosion at the centre of the distribution: in 1990, the income earned by 35 per cent of young men (aged 25-34) fell into a 30 per cent band around the average income for their age group, compared with 41 per cent in 1980 (Freeman and Katz, 1994).

When the analysis is refined it can be seen that this widening of dispersion affects all social and demographic groups. The only differential to narrow was between male and female wages, by an average of 10 per cent during the 1980s (Blau and Kahn, 1994*a*).

a) The "college premium", *i.e.* the difference between the wages of workers with a college degree and those with only high-school education, which declined during the 1970s (from 48 per cent in 1971 to 38 per cent in 1979) rose during the 1980s to 58 per cent in 1989 (Murphy and Welch, 1992).

While the flood of baby-boom college graduates onto the labour market in the 1970s resulted in a narrower wage spread by skill level (Levy and Murnane, 1992), the 1980s were marked by a rise in returns to education. According to Bound and Johnson (1992), the average wage of college graduates rose by 15 per cent relative to that of high-school graduates between 1979 and 1988. Over the same period, the wages of white-collar workers in the manufacturing sector rose by 10 per cent against those of manual workers (Lawrence and Slaughter, 1993). The trend continued, but at a slower pace, in the early 1990s; the average annual growth rate in the relative wage of male college graduates fell from 1.8 per cent in 1979-1988 to 0.7 per cent in 1988-93 (Bound and Johnson, 1994).

b) The widening of the wage spread by skill level was accompanied by a fall in the purchasing power of low-skilled workers. From 1979 to 1989, the fall in the average real hourly wage of the last decile was between 11 and 20 per cent, depending on the statistical source (Freeman and Katz, 1994).

c) This improvement in the relative wage of skilled workers went hand in hand with a rise in the relative wage of more experienced workers. Between 1979 and 1987, the weekly wage of 40-50 year-old males rose by an average of 25 per cent relative to that of 20-30 year-old males, the improvement being more noticeable in the lesser-educated labour categories (Davis, 1992).

d) The wage-dispersion process is described by Krugman as "fractal", inasmuch as it is visible whatever the degree of refinement. As well as a widening of the wage spread between skills, there is also growing wage dispersion within each skill. The process, which began in the early 1970s (Juhn, Murphy and Pierce, 1993) is most pronounced at the higher skill levels. In a number of occupations (professional classes, entertainment industry), a few "superstars" receive most of the revenue on a "winner-takes-all" basis, their reputation spreading very rapidly thanks to information technology (Rosen, 1981). The most skilled segments of the labour market thus become a tournament and the winners can enjoy very high earnings (Krugman).

The deterioration in the conditions of employment of low-skilled workers, though not universal, is found in most other OECD countries

None of the other OECD countries appears to have recorded a drop in real wages in the low-skilled segments of its labour force. However, there was a very general upward trend in experience and education premia during the 1980s in countries for which data is available (United States, France, Germany, Australia, Netherlands, United Kingdom, etc., but not Sweden) (Davis, 1992).

a) Of the countries covered in research publications, only France, the Netherlands (Davis, 1992) and Germany (Abraham and Houseman, 1993) seem not to have seen a rise in the skill premium.

In the United Kingdom, where the labour market has become more flexible, the wage spread has broadened considerably. However, low-skilled workers have seen their purchasing power stagnate but not fall as it has in the United States. From 1978 to 1992, the median real hourly wage for males rose by 27 per cent, while that of the last decile rose by 44 per cent and that of the first decile remained stable (Gosling, Machin and Meghir, 1994). The wage spread by skill level also widened during the 1980s in Italy (Erikson and Ichino, 1994), Canada, Sweden and Australia (Davis, 1992).

In continental Europe, the wage spread remained relatively stable (see Tables 1 and 2), particularly in Germany (Abraham and Houseman, 1993), France (Katz, Loveman and Blanchflower, 1993) and Scandinavia (OECD, 1993). In Japan too there was very little widening of the wage spread (Katz and Revenga, 1989; Katz, Loveman and Blanchflower, 1993).

Table 1. **Trends in earnings dispersion, 1980-91**

Ratio of the lower limit of the 10 per cent of highest earnings (9th decile) of male workers (both sexes totalled for some countries) to the upper limit of the 10 per cent of lowest earnings (1st decile)

	1980	1981	1983	1985	1986	1987	1988	1989	1990	1991
Australia	2.02	2.09		2.13	2.21	2.16	2.22	2.23	2.23	2.29
Austria	2.64					2.70	2.74	2.76		
Belgium (total)					2.48	2.51	2.54	2.36	2.30	
Canada		3.47			4.04		3.80		3.98	
Denmark (total)	2.13	2.16		2.17	2.20	2.20	2.18	2.17	2.16	
France	3.27			3.32	3.16	3.17	3.19	3.22	3.23	3.20
Germany			3.29	2.36	2.38	3.39	3.33	3.29	2.31	
Italy	2.10		2.14		2.06	2.08				
Japan						2.75			2.86	
Netherlands				2.17					2.29	
Norway (total)	2.06					2.16				1.97
Portugal (total)				2.58					2.64	
Sweden		2.14		1.97	1.97		2.06			2.14
United Kingdom	2.51	2.64		2.90	2.97	3.06	3.15	3.21	3.24	3.35
United States	4.81	4.86		5.58	5.55	5.69	5.59	5.63		

Source: For sources and definitions, OECD (1993), *Employment Outlook,* Chapter 5.

b) The wage spread by age increased in all the countries studied, including those with no trend towards general wage dispersion. This was the case for instance in Germany (Abraham and Houseman, 1993) and France (Katz, Loveman and Blanchflower, 1993). The only exception was Japan (Katz and Revenga, 1989).

c) It might be expected that the countries in which there was no significant change in relative wages would experience high unemployment in the low-skilled segments of the labour force. In fact the picture is more complex. *A priori,* the more flexible the labour market, the lower the unemployment rate among low-skilled workers. There are exceptions to the rule, however. In the United Kingdom, unemployment is high among the low-skilled, in spite of the wide and widening dispersion of wages. Conversely, Japan has experienced neither a significant change in wage spread nor a decline in relative unemployment among the low-skilled. In the United States, where the labour market is renowned for its flexibility, the ratio of unskilled to skilled unemployment is higher than in a country like France, with its more rigid labour market (see Table 3). Furthermore, the employment rate for unskilled male adults in the United States is lower than in the other major OECD countries (see Table 4).

Table 2. **Changes in earnings differentials by education among men, during the 1970s and 1980s**

	Educational groups	Initial year	Ratio value	Second year	Ratio value	Five-year change
1970s						
Australia	University/school leaving age 17-18	1968/69	1.89	1978/79	1.54	–0.17
Canada	University/high-school	1970	1.65	1980	1.39	–0.13
Japan	College/upper high school	1970	1.33	1979	1.26	–0.04
Sweden	University/post-secondary	1968	1.40	1981	1.16	–0.09
United Kingdom	University/no qualification	1974	1.64	1980	1.53	–0.06
United States	College/high school	1969	1.49	1978	1.36	–0.07
1980s						
Australia	University/high-school	1982		1990		0.03
Canada	University/high-school	1980	1.40	1985	1.42	0.03
Japan	College/upper high school	1979	1.26	1987	1.26	0.00
Sweden	University/post-secondary	1981	1.16	1986	1.19	0.03
Netherlands	College/high school	1983	1.43	1987	1.22	–0.35
United Kingdom	University/no qualification	1980	1.53	1988	1.65	0.08
United States	College/high school	1979	1.37	1987	1.51	0.09

Source: Davis (1992, and Addendum); Gottschalk and Joyce (1992).

Table 3. **Unemployment rates by educational attainment**

As a percentage of the labour force

Country and age grouping		Lower secondary or less	Upper secondary or higher	Ratio
Australia (25-54)				
Men	1982	5.8	2.3	2.50
	1990	7.1	3.2	2.26
Women	1982	6.7	5.8	1.16
	1990	6.9	5.5	1.26
Canada (25 and over)				
Men	1979	6.8	3.8	1.80
	1990	11.0	6.3	1.74
Women	1979	8.7	6.6	1.32
	1990	12.0	6.9	1.74
France (25-64)				
Men	1979	3.7	2.6	1.40
	1990	8.3	4.1	2.02
Women	1979	5.9	4.6	1.39
	1990	13.6	7.6	1.79
Germany (25-54)				
Men	1978	4.1	1.8	2.25
	1987	14.6	5.0	2.91
Women	1978	4.4	3.7	1.20
	1987	13.0	8.2	1.53
Italy (25-64)				
Men	1980	1.6	3.4	0.47
	1989	4.7	4.6	1.04
Women	1980	7.0	8.2	0.86
	1989	13.0	12.2	1.07
Japan (25-64)				
Men	1979	2.7	1.5	1.87
	1992	3.6	1.6	1.90
Women	1979	11.6	15.4	0.75
	1992	7.2	8.8	0.82
United Kingdom (25-55)				
Men	1979	5.4	2.2	2.49
	1990	8.7	3.3	2.68
Women	1979	5.8	4.1	1.43
	1990	6.8	4.2	1.64
United States (25-64)				
Men	1970	4.0	2.1	1.88
	1979	6.6	3.2	2.06
	1989	9.7	3.9	2.51
Women	1970	5.7	3.2	1.76
	1979	8.3	4.1	2.03
	1989	8.4	3.5	2.42

Source: OECD (1994), *The OECD Jobs Study.*

Table 4. **Employment rates for male adults by educational attainment, 1991**

	25-34	35-64	25-64
Canada			
Below upper secondary	65.5	64.6	64.8
Upper secondary and above	84.5	84.2	84.3
of which: Higher education	87.2	86.3	86.7
France			
Below upper secondary	83.2	67.9	71.1
Upper secondary and above	90.7	86.3	87.9
of which: Higher education	89.6	90.9	90.4
Germany			
Below upper secondary	83.5	69.3	72.5
Upper secondary and above	88.6	82.9	84.6
of which: Higher education	93.2	88.4	89.5
Italy			
Below upper secondary	88.6	75.9	78.9
Upper secondary and above	79.4	92.6	87.3
of which: Higher education	79.4	95.6	91.1
United Kingdom			
Below upper secondary	73.5	69.1	70.1
Upper secondary and above	90.2	85.9	87.4
of which: Higher education	94.0	90.3	91.6
United States			
Below upper secondary	70.0	63.0	65.0
Upper secondary and above	85.8	84.8	85.2
of which: Higher education	89.0	89.0	89.0

Source: OECD (1993), *Education at a Glance.*

III. WHY THE DECLINE IN THE RELATIVE STATUS OF LOW-SKILLED WORKERS? CLARIFYING THE CONCEPTS

Three different approaches, not mutually exclusive, can be used to attempt to explain the decline in the status of low-skilled workers

The first approach focuses on the role of major macroeconomic shocks affecting OECD economies and, more generally, on the more unstable nature of the economic environment. The second emphasises the relative importance of the factors of labour supply (rate of improvement in labour force skill levels, immigration, etc.) and labour demand (technical progress "bias", international competition, etc.). The third approach concentrates on the role of labour-market institutions, in particular the capacity of trade-union organisations to appropriate a share of rent and narrow the wage spread.

Whichever approach is used, the mechanisms linking changes in the economic environment to distortions in the wage and unemployment structure are complex. Competition from low-wage countries, for instance, drives down demand for low-skilled labour and the selling price of the goods concerned; in turn, these developments shift the balance of the economy as a whole, given that relative price movements alter the structure of demand; and the low-skilled labour surplus puts downward pressure on the wages of that category of workers.

Most attempts to assess the respective impacts of the different shocks are in fact based on a general equilibrium model entirely specific to this purpose. The use of such a framework for analysis should also make it possible to define formally and rigorously what is meant by technical progress bias

It should thus be possible to identify two different sources of bias: a general bias common to all industries, and sector-specific bias.

a) If bias is identical in every sector, technical progress leads to unskilled-labour savings and to increased complementarity between skilled labour and physical capital. The explanation for this enhanced complementarity would be that new technologies, in particular information technologies, are allocated first and foremost to skilled workers, whereas low-skilled workers have less easy access to them. In such a context, capital per worker increases for the skilled and tends to diminish for the unskilled. For a given rate of technical progress, the fall in the capital intensity of unskilled workers affects their marginal productivity and the demand for their labour.

When technical progress that generates unskilled-labour savings has the same effect on both the skilled and unskilled areas of activity, the share of skilled labour rises in each. Full employment of unskilled labour can only be maintained if there is a fall in the relative wage of unskilled workers to allow for a rise in the relative output of the unskilled-labour-intensive good.

b) Bias can also stem from technical progress that differs across sectors (Leamer, 1994, Baldwin, 1994). *A priori*, technical progress has two effects: it saves labour at a given level of output, and it boosts output and employment by way of a fall in relative prices. However, if technical progress is slanted towards mature manufacturing industries with an abundance of low-skilled labour, the substitution effect will tend to outweigh the income effect (more sales). The price-elasticity of demand will be too low to offset the labour savings generated by technical progress. In such a situation, the low-skilled labour surplus will shift into services. Since services are typically less capital-intensive, the marginal productivity of these workers will be affected.

Thus, the impact on employment of a technical progress bias depends not only on strictly technological factors but also on the substitutability of the various types of goods and labour. The methodological annex to this paper provides a more formal demonstration that there is no one-to-one relationship between technical progress "embodied in skilled labour" and the rise in the relative wage of skilled workers (for a given labour-supply structure). For instance, when there is low substitutability of goods or of labour categories, technical progress embodied in skilled labour may drive down the relative wage in that category.

Clearly, then, the relative status of unskilled workers may decline under the shock produced by a technical progress bias, with a rise in unemployment and a fall in relative wages. What happens to the real wage levels of unskilled workers? The overall effect is not clear but it can be shown, using certain strong assumptions, that the wages of the low-skilled may also fall in real terms. In terms of real income growth, it appears that the wider the productivity gap with skilled workers, the lower the substitutability of goods, the higher the degree of wage flexibility and the greater the presence of the skilled-labour intensive sector, the steeper the decline will be in the status of unskilled workers.

Formally, the impact on the economy of more open international trade can be analysed strictly as a technical progress shock confined to the unskilled-labour-intensive sector, assuming low substitutability of goods

Competition from low-wage countries is liable to affect low-skilled labour in OECD countries in three distinct ways:

- exposed sectors with an abundance of unskilled labour are crowded out by imports from low-wage countries or offshore production;
- a "contestable-market" effect occurs, whereby keener competition leads to a relative fall in prices of unskilled-labour-intensive goods. With wages unchanged, this pushes up real labour costs and erodes corporate profitability. Furthermore, the threat of seeing other competitors enter the market may encourage unskilled-labour-intensive firms to move upmarket and introduce more capital-intensive production techniques;
- rents fall on goods markets. In monopolistic sectors, firms are obliged, by competition, to improve their "X-efficiency".

Table 5. **Impact of main shocks on the labour market**

	Relative employment of unskilled workers	Relative wage of unskilled workers	Relative price of unskilled-labour-intensive goods	Real wage of unskilled workers	Real wage of skilled workers	Unemployment among unskilled workers
Technical progress bias	–	–	–	?	+	+
Exposure to trade	–	–	–	–	+	+
Rise in minimum wage	–	–	–	+	+	+
Rise in supply of skilled labour	+	+	+	+	–	–
Greater wage flexibility	+	–	–	–	+	–
Stylised facts (Europe)	**–**	**?**	**–**	**+**	**+**	**+**
Stylised facts (United States)	**–**	**–**	**–**	**–**	**+**	**0**

Source: Author.

These mechanisms can be analysed within the framework of the earlier-mentioned general equilibrium model (presented in annex). A developed (OECD) economy that opens up to trade with emerging countries will – given the respective factor endowments – export skilled-labour-intensive goods and import unskilled-labour-intensive goods. Thus more open trade with developing countries has a dual impact: the output of goods with a high unskilled-labour content will decline, as will the wages of unskilled workers. On the other hand, within each sector the fall in the relative cost of unskilled labour leads to some displacement of skilled labour, partly blunting the intersectoral impact.

A general equilibrium model makes it possible to identify the expected effects of the different types of shock and compare them with stylised facts

International trade leads to a fall in both the relative and real wages of low-skilled workers. Technical progress bias, on the other hand, drives down the relative wage of unskilled workers but its effect on their real wage has yet to be determined.

The opening-up of international trade and the increase in the relative supply of skilled labour have impacts that are diametrically opposed. The latter actually tends to boost the relative and real wages of low-skilled workers.

IV. TRENDS IN THE RELATIVE SUPPLY OF SKILLED LABOUR

In OECD countries there was an upward trend in the relative supply of skilled labour during the 1970s (Table 6), owing to a rise in educational enrolment ratios and the arrival on the market of the "baby-boom" generations. At the same time there was a narrowing of the wage spread. In the 1980s, however, growth of the skilled labour supply slowed, as shown by Blackburn, McKinley, Bloom and Freeman (1990) or Katz, Loveman and Blanchflower, (1993). Katz and Murphy (1992) estimate that growth in the supply of "college equivalent" relative to "high school equivalent" was halved, dropping from an average of 5 per cent a year in 1971-79 to 2.5 per cent a year in 1979-87.

An analysis based on fluctuations in the relative supply of skilled labour provides a simple, coherent picture of changes in education premia over the past two decades

In Katz and Murphy's model (1992), the relative wage in the two labour categories is contingent on the relative supply of workers by skill level and on a

Table 6. **Relative supply of college-educated workers in some OECD countries**

	Level	Annual average growth rate	
	Population or labour force		
France	1989	1970-80	1980-89
Population, males 15+			
Degree holders/total	11.8	4.6	4.0
Germany	1989	1976-82	1982-89
Working-age population			
(*Fachhochschule + Hochschule*)/total	9.4	3.6	3.5
Sweden	1990	1971-80	1980-90
Total labour force, both sexes			
University/total	23.1	8.3	3.4
United Kingdom	1989	1973-79	1979-89
Population, both sexes, 16-60			
University/total	18.3	7.0	4.3
United States	1989	1969-79	1979-89
Population, both sexes, 18-64			
College/total	21.5	4.4	2.6
	Employed labour force		
Australia	1989/90	1973/74-1981/82	1981/82-1989/90
Full-time, full-year males in the workforce			
Degree holders/total	13.4	9.2	5.0
Japan	1990	1970-79	1979-90
All employees, both sexes			
College/total	22.5	5.1	2.1

Source: OECD (1993), *Employment Outlook.*

trend over time showing the structural shift in the relative demand for skilled labour. This trend indicates that, for an unchanged relative labour supply, the relative wage for skilled labour has been rising by 3.3 per cent annually, or by over one-third in a decade. The following table shows the wage-spread trend in the United States since 1963, breaking down the contribution of supply and demand factors.

Variations in the supply of skilled labour appear to have made a decisive contribution to the extremely large increase in wage dispersion in the 1980s: changes in skilled-labour supply help to account for two-thirds (8.4/12.8) of the increase in wage inequality.

This slowdown in the relative supply of skilled labour during the 1980s can be put down to diminishing cohorts and the influx of immigrants. There was indeed a marked increase in immigration over two decades (the share of foreign-born

Table 7. **Contribution of the relative supply of skilled labour to wage inequality**

Ratio variation (skilled/unskilled wage)	1963-71	1971-79	1979-87
Observed net effect	7.7	–10.4	12.8
Estimated net effect	4.2	–2.5	8.4
Contribution of the increase in relative demand for skilled labour	26.4	26.4	26.4
Contribution of the increase in relative supply of skilled labour	–22.2	–28.9	–18.0

Source: Author.

workers in the employed labour force rose from 6.9 per cent in 1980 to 9.3 per cent in 1988), whereas immigrant skill levels showed a tendency to fall. Borjas, Freeman and Katz (1991) use this to account for one-third of the increase in wage differentials between educational attainment levels from 1980 to 1988. Topel (1994) also concludes that immigration helped to widen the wage spread. This finding is contested by many authors, including Card (1990), who have not observed any wage differential between areas with a dense immigrant population and those without. This is not a very relevant basis for argument, however, when there is high labour mobility, wages tend to level out across areas; furthermore, immigrants obviously tend to settle in the more prosperous areas.

While Katz and Murphy's research provides a plausible explanation, it does not prove that relative demand has grown steadily throughout the past two decades. Furthermore, this general model should be able to account for the extremely diverse situations across countries, in particular the contrast between Germany/Japan and the Anglo-Saxon countries

There are two possible explanations for this contrast:

- the decline in demand for low-skilled labour has not been as steep in countries like Germany or Japan;
- the decline in demand for low-skilled labour is general, but education and training performance varies considerably across countries.

A priori, demand factors differ little over the OECD area inasmuch as Member countries operate on the same markets and use similar technologies. Supply factors and labour market institutions, on the other hand, can differ considerably. Thus, greater relative efficiency of the education systems in Germany (Abraham and Houseman, 1994) and Japan would have reduced the supply of low-skilled labour as demand was falling. Conversely, low relative efficiency of the United Kingdom's training system would have prevented labour-force skill levels from rising sufficiently rapidly.

In theory, the institutional characteristics of national training systems should not play a major part in the adjustment of low-skilled labour supply to demand, which should be the spontaneous outcome of market forces. Thus a widening of wage spread would provide stronger incentives to acquire more skills and the surplus of unskilled labour would be absorbed. In practice, though, this kind of adjustment, suggested by human capital theory, is likely to be a very prolonged and even uncertain process.

- First, the capacity of education and training systems to react to a broadening of the wage spread is probably relatively low in the short term. For one thing, the training market has a number of weaknesses: credit-market imperfections may prevent low-paid workers from borrowing against higher future earnings (liquidity constraints); small firms bear higher training costs per worker than larger firms (economies of scale); and enterprises tend to use training schemes to select what are judged to be higher-ability workers (selection bias). For another, government intervention proves to be very costly in that public training systems take little account of differences in ability.
- Second, the high turnover of low-skilled labour, and high interest rates, dissuade firms from investing in training.
- Finally, externalities may create a "bad-job trap" (Snower, 1994): a relative shortage of skilled labour dissuades firms from raising their skill requirements; at the same time, a relative shortage in the demand for skilled labour dissuades the labour force from acquiring skills.

V. THE FALL IN RELATIVE DEMAND FOR UNSKILLED LABOUR: INTERNATIONAL TRADE OR TECHNICAL PROGRESS BIAS?

Empirical North-American research generally concludes that international trade only accounts in part for the declining status of low-skilled workers

Most studies, in particular those by Bound and Johnson (1992), Borjas, Freeman and Katz (1991), Krugman and Lawrence (1993), Katz and Murphy (1992), Lawrence and Slaughter (1993) and Berman, Bound and Griliches (1994), conclude that international trade plays a secondary role. According to them, the contribution of international trade to the relative decline in demand for unskilled labour ranges from 15 to 50 per cent. This relative scepticism as to the impact of competition from low-wage countries is based on four main arguments:

a) The decline in the share of US manufacturing in value terms is due to substantial productivity gains in the sector.

As Krugman and Lawrence (1993) point out, manufacturing output is equal to domestic demand plus net exports. But whereas the ratio of industrial output value to nominal GDP fell by 6.6 percentage points between 1970 and 1990, the ratio of the current manufacturing trade balance to nominal GDP fell by only 1.6 GDP points. The authors conclude from this that the decline of the manufacturing sector is mostly due to shrinking domestic demand for manufactured goods. Next they look at consumption of manufactured goods as a share of total consumption, and find that it has remained stable in volume terms over the past thirty years. The decline in value terms (40 per cent in 1991 compared with 46 per cent in 1973) is therefore due to a fall in the relative price of manufactured goods, reflecting higher productivity gains in industry than in the rest of the economy.

b) The fall in relative demand for unskilled labour has affected all sectors of the economy.

Changes in demand for unskilled labour can occur:

- within industry in response to a general shock, such as a change in relative factor prices or technical progress bias;
- between industries in response to a specific shock, such as a shift in consumer tastes, technical progress that is neutral (in the sense used by Hicks, *i.e.* without bias) but differentiated across sectors, or competition from low-wage countries.

According to Katz and Murphy (1992) and Berman, Bound and Griliches[1] (1994), however, changes in the employment content (skilled/unskilled) of production vary little across industries; this argues against international trade and in favour of technical progress as the predominant influence. According to Berman, Bound and Griliches (1994), 70 per cent of the annual 0.552 percentage point increase in the non-production-worker share of manufacturing employment can be attributed to within-industry changes, and the other 30 per cent to between-industry changes.

These findings have met with reservations on the part of several authors. In particular, wage flexibility may have helped to limit low-skilled job losses in sectors exposed to international competition. It may therefore be worthwhile looking at trends in the relative wages of unskilled workers by sector. However, as Revenga (1992) points out, relative wages in the different sectors are bound ultimately to level out if there is sufficiently high geographical and sectoral mobility of labour.

c) The skilled/unskilled employment content of foreign trade does not provide evidence that international trade has a significant impact.

A country's foreign trade implicitly changes the volume of labour supply available to meet domestic demand: exports reduce the labour supply, while imports increase it. Assuming that one franc of imports in sector i has the same employment content as one franc of domestic output, it is easy to calculate the employment content of foreign trade. In formal terms, if T_i is the foreign trade flow of the industry *i*, L_i/Q_i the labour input per unit of output by the industry and L the amount of labour required to produce the traded output, we obtain the following equation:

$$L = \sum (L_i/Q_i)\ T_i = \sum L_i\ (T_i/Q_i)$$

L_i is positive for imports alone, but negative for exports alone. When T_i corresponds to net exports, L_i can be positive or negative.

To allocate the implicit labour supply resulting from exchanges between the different labour categories, the previous equation is changed to:

$$L_j = \sum a_{ij} L_i (T_i/Q_i)$$

where L_j is the implicit labour supply in labour category j and a_{ij} the average proportion of workers in industry i belonging to category j.

On this basis, the studies conclude that the impact of international trade was very small until the early 1980s though greater since, because of the widening trade gap and sectoral re-allocation, but that it accounts for no more than about one-third of the increase in wage spread.

d) Another approach is to examine trends in relative prices.

The Stolper-Samuelson theorem predicts that, when North-South trade increases, developed countries will see:

- a relative increase in the output of skilled-labour-intensive goods;
- a relative decrease in the price of unskilled-labour-intensive goods;
- a relative decrease in the wage of less-skilled workers;
- within each sector, an increase in the relative share of unskilled workers in response to the relative decrease in their wage (this going hand in hand with the decline in the unskilled-labour-intensive sectors and the rise in the skilled-labour-intensive sectors).

The magnitude of these effects will depend on the degree to which the traded goods are differentiated (Helpman and Krugman, 1985). In sectors where competition is essentially through product differentiation, an increase in exposure to foreign trade will have little impact on relative wages. Conversely, import penetration will be accompanied by a perceptible change in relative wages if firms are not in a dominant position and/or if the products are homogenous. If the products are homogenous, the greater the similarity between each trading partner's factor endowments, the lower the pressure will be on the wage spread. Oliveira-Martins (1994) has found that in several OECD countries import penetration puts downward pressure on relative wages in sectors with low entry costs manufacturing largely undifferentiated goods (textiles, etc.). However, in sectors where OECD countries have market power, relative wages are markedly higher.

According to Lawrence and Slaughter (1993) and Sachs and Schatz (1994), two points in the predictions of the Stolper-Samuelson theorem are not borne out:

- First, the relative share of skilled labour rose in the manufacturing industries during the 1980s, even though the relative wages of skilled workers were rising. In the US manufacturing industry, the wages of non-production workers rose by 10 per cent against those of production workers between 1979 and 1989 (Lawrence and Slaughter, 1993), while the ratio of non-production to production workers rose by 25 per cent over the same period (Katz and Murphy, 1992).
- Second, the relative price of unskilled-labour-intensive goods did not fall significantly.

The relevance of these findings should not be overestimated. They do not necessarily mean that international trade has had no impact at all. It is not inconceivable, for instance, that international trade has driven down the price of unskilled-labour-intensive goods, while technical progress has driven down the price of skilled-labour-intensive goods. Furthermore, the conclusions relating to the stability of relative prices are based solely on manufacturing prices. While the price of skilled-labour-intensive manufactures did not rise relative to that of unskilled-labour-intensive manufactures, the price of these products taken together did fall relative to the rest of the economy.

Current studies usually tend to underestimate the role of international trade, a fact acknowledged by several of the authors (*e.g.* Sachs and Schatz, 1994)

The main criticism that can be levelled at studies on the impact of international trade is that they probably reason too mechanically in terms of trade flows and make no allowance for contestable markets. Even if North-South trade flows are still light, the threat posed by new competitors may be real enough to incite producers in the North to move up-market and adopt more capital-intensive production techniques.

Apart from this fundamental problem, the studies suffer from a number of methodological defects. In particular, cross-sector analyses that find a predominance of changes "within", *i.e.* affecting all sectors, are of little relevance in that they have not been made at a sufficient level of disaggregation. When production trends are examined at a finer level, they show that each sector has both its bottom-of-the-range activities, seriously challenged by countries with low labour costs, and its top-of-the-range activities, based on high technology and product differentiation strategies. For instance, northern countries, continue to be major exporters of textile goods, while countries with low labour costs export computer products.

By the same token, analyses of the employment content of trade are also biased. Calculations are based on the average content in different sectors, whereas it is "bottom-of-the-range" production, with a larger unskilled labour input, that is being hit by competition from emerging countries.

Wood (1994) levels another criticism at the method used to calculate employment content. He points out that industries in the North no longer make many of the unskilled-labour-intensive goods they import from developing countries, leaving them to produce those goods. The goods being compared are non-competing and therefore not really comparable. The correct approach is to estimate production functions for the South and then calculate what the labour content would have been had the South been paying northern wages. On that basis, manufacturing industry in the OECD area has lost 9 million jobs (or 12 per cent of its labour force) in thirty years, not counting the impact of the preventive productivity gains sought to ward off future competition.

The prevailing approach across the Atlantic is that new technologies are intrinsically biased against unskilled labour

a) The nature of technical progress bias.

The assumption that technical progress contains an intrinsic bias towards skilled labour is relatively new. The classic image of technical progress was that it caused de-skilling (Taylorism ousting craftsmen). Even today, technical progress and organisational change are clearly still affecting semi-skilled (secretarial) or intermediate grades. However, many experts believe that new information technologies are changing the nature of technical progress. To simplify, the technologies are said to complement skilled labour and to displace unskilled labour.

Several arguments have been put forward to support this view:

- skilled workers are best fitted to introduce new technologies in a firm;
- information technologies can generate wide variations in individual performance, and learning costs will depend on the person concerned;
- information technologies also make it easier to assess individual performance. Their introduction therefore has the effect of increasing wage dispersion and breaking up the system of implicit subsidies that formerly benefited unskilled labour;
- new technologies eliminate unskilled jobs when production lines are robotised and automated;
- new technologies increase levels of responsibility, abstraction and interdependence;
- in a context of underemployment, employers may also use new technologies to screen lists of job applicants.

Technical progress and productivity

Some clarification is needed on what is meant by technical progress. A finer distinction should probably be made between:

- technical progress in the strictest sense, aimed at boosting overall factor productivity;
- technical progress aimed at widening the range of products offered. Yet a wider range of products may prevent firms from fully exploiting economies of scale on their existing products;
- changes in the capital intensity of production, in response to a change in relative factor costs or to competition from low-wage countries;
- organisational changes made to enhance corporate flexibility. In this context, new technologies are introduced because they improve the firm's capacity to react to its environment, which may have grown more unstable, without *a priori* affecting overall factor productivity.

While technical progress is specifically aimed at boosting overall factor productivity, the somewhat disappointing findings at aggregate level may stem from a problem of measurement – technical progress boosts "notional" productivity but does not improve measured productivity. It could well be that statistics do not fully reflect the improvement in quality of some (in particular data-processing) goods and therefore underestimate the output of certain services. However, if the slowdown in productivity gains is to be attributed to a problem of measurement, the assumption must be not only that productivity is hard to measure in services but also that such measurement is becoming increasingly difficult and that computer-related progress is trending upward.

Leaving aside possible statistical problems, the co-existence of low overall productivity gains and rapid technical progress may stem from:

- adjustment and organisational problems experienced by the firm and its workforce when new technologies are introduced (*e.g.* inadequate planning, organisational change lagging behind technical change);
- the transfer of organisational costs to suppliers and sub-contractors (just-in-time production);
- stronger consumer preference for product diversity. Here, firms will try economies of scope. Technical progress may then mean widening their product range rather than cutting unit output costs.

More generally, there is little doubt that the international environment has become much more unstable and volatile since the early 1970s, with movements in relative prices (oil prices, interest rates, exchange rates, etc.), rapidly shifting consumer tastes, and so on. In such a climate, firms are encouraged to become more flexible so as to be able to accommodate fluctuations in demand and react immediately to changes in their environment. Technical progress then becomes a means of enhancing the ability of firms to react, without necessarily raising productivity.

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This kind of structural instability puts corporate organisation in question. Firms tend to adopt a more flexible, decentralised structure. Grades are "flattened out" and more responsibility given to each individual. These changes extend to job content through job enrichment and new duties (*e.g.* control, management, maintenance). Broadly skilled workers are then in greater demand, possibly to the detriment of low-skilled workers.

b) While several studies show the theoretical possibility of a technical progress bias (see Cohen and Saint-Paul, 1994, Betts, 1994, Agenor and Aizenman, 1994), there is still relatively little direct, empirical evidence of such a bias.

Most North-American empirical studies, as we have seen, test the impact of international trade and immigration on relative demand for unskilled labour. Since that impact is considered to be low, technical progress is thought to be the most plausible explanation remaining (see Davis and Haltiwanger, 1991, Bound and Johnson, 1992, Berman, Bound and Griliches, 1994).

In the United States, a number of recent studies attempt a direct assessment of the impact of technical progress on the relative status of unskilled labour:

- Bartel and Lichtenberg (1987) show that when a new technology is adopted, relative demand for skilled labour increases because the new technology requires a certain capacity for problem-solving and broad general knowledge rather than highly specialised skills.
- Mincer (1991) shows that the trend in the wage differential between young college graduates and high-school graduates between 1963 and 1987 can largely be attributed to movements in R&D expenditure; there is a positive correlation between relative growth in skilled employment and investment in data-processing systems and R&D intensity (Berman, Bound and Griliches, 1994).
- Krueger (1993) finds evidence of a wage premium (17 per cent in 1984 and 19 per cent in 1989) linked to the use of computers. This finding is not wholly conclusive either. The relative improvement may in fact be due to higher intrinsic productivity or to an initial selection bias (the firm chose the most productive workers to use the new equipment). A French study based on individual data (Entorf and Kramartz, 1993) appears to validate the second assumption.

- Berndt, Morrisson and Rosenblum (1992) find a positive correlation between high technology and the demand for white-collar workers in manufacturing.
- Lawrence and Slaughter (1993) show that sectors with a high share of skilled labour have also achieved the best overall productivity gains, which may indicate that technical progress has a selective impact on sectors with the highest share of skilled labour.
- Machin (1994) finds that, in the United Kingdom, growth in the share of skilled employment (equated here with non-manual work) is more noticeable in R&D-intensive sectors and in firms that introduced microcomputing between 1984 and 1990.

VI. OTHER AVENUES TO EXPLORE ON THE DEMAND SIDE: THE ROLE OF MACROECONOMIC SHOCKS AND INSTITUTIONS

Role of macroeconomic shocks

OECD economies have suffered major shocks over the past twenty years, such as the oil shocks of the 1970s and the rise in real interest rates since the early 1980s. These macroeconomic shocks have hit the more fragile segments of the labour force hardest, for two reasons:

- Skill escalation. When there is unemployment, people apply for posts for which they are overqualified. Given the choice, employers screen long lists of applicants and select the more highly skilled, their qualifications being a "signal" of labour force efficiency.
- Skilled-labour hoarding. During a recession, firms prefer to keep their skilled workers, given the cost of recruiting and training them, and instead lay off unskilled or younger workers on a "last in, first out" basis.

Adverse shocks have a greater impact on the status of the low-skilled unemployed than beneficial shocks (such as the oil-price countershock, economic recovery in the 1980s, etc.). This stems from a combination of two factors. A long period of unemployment is detrimental to human capital and job-seekers are then less able to benefit from the recovery. At the same time "insiders", or those in jobs, operate a job-wage trade-off that varies with the cycle. Seeking to maximise their own well-being, they focus on job security during the troughs and on wage-rises during the peaks.

From a broader viewpoint, a more volatile and unstable economic environment may affect the relative demand for skilled labour. Bhagwati and Dehejia (1994), for instance, focus on the internationalisation of goods markets, which has reduced or made more volatile the comparative advantages of OECD countries. Hence a higher labour turnover between industries, enhancing the relative status of skilled workers who are more adaptable than the unskilled.

Furthermore, technical progress need not be biased to have a (temporary) impact on unskilled labour. Helpman and Trajtenterg (1994) have developed a model representing the introduction of major technologies, like electricity at the turn of the century and information technologies over the past two decades. Two findings emerge, revealing the coexistence of a productivity slowdown and technical progress, the introduction of which may be detrimental to unskilled labour:

- The benefits flowing from the diffusion of a new technology become apparent later on, once complementary inputs have been developed and introduced. In the meantime, skilled labour resources must be taken out of production and used to develop the new inputs, and the economy initially experiences a slowdown in productivity on the production side.
- During this development phase, skilled workers are taken out of production and moved to research and development. To the extent that skilled and unskilled labour are complementary in the production process, unskilled workers may see a decrease in their marginal productivity and pay.

Loss of rent and de-unionisation

In imperfect or regulated goods markets, firms can extract rent from consumers. Some of this rent can be shared with workers and is known as wage rent, which may be called a quasi-rent in that workers receive it essentially on a provisional basis. Ultimately the increase in the labour supply to the sector will affect wage formation, until the wage rent disappears.

Whether workers receive this rent depends, for instance, on trade-union power and factor substitutability (Lindbeck and Snower, 1988). Inasmuch as the unions try to narrow the wage spread, the pay of low-skilled workers is above the market wage (Blau and Kahn, 1994*b*). Wage rents may also stem from a deliberate policy on the part of the employer, who wants to encourage efficiency and motivate the workforce. This is the case when enthusiasm for work is not easy to monitor. However, efficiency wage models relate mainly to intellectual work, where output is hard to monitor; they are less relevant when used to characterise corporate wage policies towards low-skilled workers.

The 1980s were marked by the deregulation of goods markets and their exposure to international competition (*i.e.* lower rents), and by a decline in the leading manufacturing industries and the development of less unionised service sectors (*i.e.* a decline in the capacity of workers to earn rent). The unionisation rate fell sharply in the United States (*cf.* Table 8). The decline was steepest

Table 8. **Unionisation trends in G-7 countries**

Union members as a percentage of total employees

	1970	1990
Canada	31.0	35.8
France	22.3	9.8
Germany	30.0	32.9
Italy	36.3	38.8
Japan	35.1	25.4
United Kingdom	44.8	39.1
United States	23.2	15.6

Source: OECD.

among young manual workers (aged 25-34), with union membership falling from 43 to 25 per cent. Yet in this category, the unionisation premium (*i.e.* the differential between unionised and non-unionised pay) was around 25 per cent in 1978 (Freeman 1991). The impact of de-unionisation on young workers' pay is therefore some 5 per cent (18 per cent of young manual workers having lost a premium of 25 per cent).

Borjas and Ramey (1993) find a strong correlation between the US trade deficit in durable goods and the log wage differential between skilled and unskilled workers. Their explanation is as follows: industries that produce durable goods tend to be highly concentrated and earn high rents. This being so, the entry of foreign firms onto the durable goods market drives down the rents of domestic firms and hence the wage rents paid to workers. This decrease in entrepreneurial rents and wage rents should boost recruitment theoretically. However, foreign penetration tends to reduce employment in these industries, in particular unskilled employment. The surplus labour then shifts to other sectors of the economy, where it puts downward pressure on pay.

CONCLUSION

What then are the main lessons to be learnt from this review of the literature?

It is probably very hard to quantify with any accuracy the respective impacts of technical progress, international trade, immigration or de-unionisation, for all are interdependent. De-unionisation is linked to the decline in the leading manufacturing industries, itself brought about by international trade and technical progress; a country's international specialisation depends on its technology; conversely, international trade can push firms into choosing, from all the techniques available, those which make the most savings in unskilled labour.

The Borjas and Ramey model

1. In the Borjas and Ramey model, low-skilled workers in an oligopolistic sector earn a rent

Consider an oligopolistic sector producing an unskilled-labour-intensive good. More specifically, suppose that the sector has n firms producing a good x and behaving as Cournot oligopolists. Foreign firms also produce the good x, and they export an exogenous amount x_f to the domestic economy. Total demand for the good x is given by:

$$p = a - bx \quad [1]$$

The demand perceived by each domestic firm i is given by:

$$p = a - b(x_i + (n - 1)x_j + x_f \quad [2]$$

where x_i is the amount produced by firm i, x_j the amount produced by each other domestic firm and x_f the amount produced by foreign firms.

The production function for firm i is simply:

$$x_i = l_i$$

where l_i is low-skilled labour.

Each firm bargains with a union over wages. The firm and the union jointly maximise rents R, where rents are given by:

$$R_i = px_i - \overline{w}l_i \quad [3]$$

where $\overline{w}$ is the competitive wage. Workers receive the competitive wage plus a fraction of the rents.

2. Given maximisation of rents by each firm and its workers, equilibrium production and rents are given by:

$$x_h = \frac{a - \overline{w} - bx_f}{b(1 + n)} \quad [4]$$

and

$$R_i = \frac{(a - \overline{w} - bx_f)^2}{b(1 + n)^2} \quad [5]$$

Assuming symmetrical equilibrium, domestic industry output is simply nx_i. Thus total labour used in the industry is given by:

$$l = \frac{n}{1 + n} \cdot \frac{a - \overline{w} - bx_f}{b} \quad [6]$$

(continued on next page)

(continued)

3. **As equation [4] shows, an increase in imports leads to a decline in entrepreneurial and wage rents. The more competitive the industry (*i.e.* the larger the *n*), the lower the rent and therefore the smaller the decrease in wages.**

Similarly a rise in import volumes has an adverse effect on employment. A number of unskilled workers are thus driven out of the sector and find employment in the rest of the economy. The increase in the supply of low-skilled labour in the rest of the economy will tend to drive down the competitive wage.

Technical progress is a tempting explanation in that, unlike international trade, it encompasses all aspects of wage dispersion, in particular the rise in wage inequalities within each category (Davis and Haltiwanger, 1991). It is plausible to see the widening of wage-spread within each skill category as the outcome of higher capacity to use new technologies or of greater flexibility in production processes. Whereas Taylorism tended to iron out differences in individual productivity, new technologies are developing in line with individual ability.

At the same time, the view prevailing in the United States that the declining status of low-skilled workers stems from a technical progress bias appears to be a rather hasty conclusion, since there is very little concrete evidence of such a bias. Conversely, the role of international trade has probably been underestimated inasmuch as the research makes no allowance for the more contestable nature of the markets.

Three avenues are worth exploring in the future:

- Few studies seem to have taken a serious look at the reasons why low-skilled US workers have suffered a substantial fall in purchasing power over the past twenty years. It is therefore difficult to predict whether the trend will continue in the United States and spread to other OECD countries.
- It would be interesting to study the extent to which the differences observed in wage spread between countries reflect the impact of different shocks on the relative demand for unskilled labour or differences in education systems or labour markets.
- The assumption that technical progress, in particular the large-scale diffusion of technology and information, is endogenous to goods markets probably merits deeper study.

Annex

A TWO-SECTOR, TWO-SKILL GENERAL EQUILIBRIUM MODEL

Presentation of the model

The economy is divided into two sectors, one producing goods with a high-skilled-labour content (Sector 1) and the other specialising in unskilled-labour-intensive goods (Sector 2). The labour market comprises two segments, skilled *(S)* and unskilled *(U)*. Capital is assumed to complement the two forms of labour and will subsequently be omitted to simplify presentation.

Technical progress, embodied in labour, depends on both the skill and the sector. The productive process of the sector i is given by:

$$Y^i = F(A_s^i L_s^i, A_u^i L_u^i) \qquad [1]$$

where A_s^i (or A_u^i) is the efficiency factor of skilled (or unskilled) labour in the sector *i* and L_s^i (or L_u^i) is the skilled (or unskilled) labour employed in the sector *i*. The technical progress embodied in skilled labour in the sector *i* corresponds to the growth rate of A_s^i.

Assuming constant returns to scale, [1] can be expressed as:

$$Y^i = A_s^i F^i(L_s^i, (A_u^i / A_s^i) L_u^i) \qquad i = 1 \text{ to } 2 \qquad [2]$$

- The bias relating to skill is A_u^i / A_s^i. If the technical progress embodied in skilled labour rises faster than the technical progress embodied in unskilled labour (A_u^i / A_s^i decreases), the amount of skilled labour required per unit of output decreases faster than the amount of unskilled labour ("skilled labour saving").
- The sectoral bias is A_s^1 / A_s^2. When A_s^2 rises faster than A_s^1, technical progress makes faster (skilled and unskilled) labour savings in Sector 2 than in Sector 1. If demand for the corresponding goods fail to change at the same pace, employment in Sector 2 declines.

When goods markets are competitive, the labour demand of the typical Sector 1 firm depends on the demand for goods, the real wage and technical progress:

$$\begin{cases} l_s^i = y^i - \sigma^i(w_S - p^i) + (\sigma^i - 1)a_s^i \\ l_u^i = y^i - \sigma^i(w_u - p^i) + (\sigma^i - 1)a_u^i \end{cases} \qquad [3]$$

where the small letters are logs of the magnitudes defined above, w_s (or w_u) is the log skilled (or unskilled) pay and p_i the log selling price of the aggregate good of sector *i*. The assumption is that this is a CES-type technology; σ^i is the elasticity of substitution between the two forms of labour in the sector *i*; constants have been omitted to simplify presentation.

For a given demand (y^i) and real wage ($w_{u,s} - p^i$), technical progress affects demand for the corresponding factor in two opposite ways, via a "scale effect" and a "substitution effect". Consider a shock to skilled labour caused by technical progress in sector i. The technical progress leads to skilled-labour savings. At the same time, however, skilled labour becomes more productive: with no wage adjustment, it becomes advantageous to replace unskilled with skilled labour. From this standpoint, a 1 per cent rise in the efficiency of skilled workers has the same impact as a 1 per cent fall in their relative wage, namely a σ^i per cent rise in the demand for skilled labour. The total impact, $\sigma^i - 1$ per cent, therefore depends on the substitutability of the different forms of labour in the productive process.

Assuming also that product demand i is determined by

$$y^i = y - \sigma(p^i - p) \qquad [4]$$

where y is the log aggregate output, and p a log price index. This is obtained when the typical consumer maximises a utility (CES-type), with σ as the elasticity of substitution between goods 1 and 2. Replacing in [3], this gives:

$$\begin{cases} l_S^i = y - \sigma(p^i - p) - \sigma^i(w_S - p^i) + (\sigma^i - 1)a_S^i \\ l_u^i = y - \sigma(p^i - p) - \sigma^i(w_u - p^i) + (\sigma^i - 1)a_u^i \end{cases} \qquad [5]$$

Assuming that aggregate output is constant, factor demand depends on the pace of technical progress, on the real wage of the labour category expressed in terms of selling price and on the relative price of the good produced by the sector.

We further assume, for simplification purposes, that elasticity of substitution is identical for factors of production and goods ($\sigma^1 = \sigma^2 = \sigma$). In this specific case, [5] becomes [5']:

$$\begin{cases} l_S^i = y - \sigma(w_S - p) + (\sigma - 1)a_S^i \\ l_u^i = y - \sigma(w_u - p) + (\sigma - 1)a_u^i \end{cases} \qquad [5']$$

Total employment of labour in each category is obtained, in the first order, by a linear combination of equations [5']:

$$\begin{cases} l_S = y - \sigma(w_S - p) + (\sigma - 1)a_S \\ l_U = y - \sigma(w_u - p) + (\sigma - 1)a_U \end{cases} \qquad [6]$$

where $a_S = \pi_S a_S^i\ (1 - \pi_S)a_S^i$ and $a_U = \pi_U a_U^i + (1 - \pi_U)a_U^i$, with the coefficient π_S (or π_U) being the share of skilled (or unskilled) labour hired in Sector 1. Note that system [6] could also be obtained by assuming either that the two sectors use only one form of labour ($Y^1 = A_s^1 L_s^1$ and $Y^2 = A_u^2 L_u^2$, "two specialised goods model"), or that there is a single aggregate good using both forms of labour ("one good, two labour-categories model").

The technical progress bias for the economy as a whole is $a_S - a_U$. This is a combination of sectoral bias ("inter bias") and skill bias ("intra bias").[2]

$$a_S - a_U = (\pi_S - \pi_u)(a_S^1 - a_S^2) + a_S^1 - a_U^1 \qquad [7]$$

There is a positive correlation between total bias and intersectoral bias ($a_S^1 - a_S^2$) since Sector 1 makes relatively intensive use of skilled labour (high π_s) and relatively unintensive use of unskilled labour (low π_u).

Impact of technical progress

a) If there are no obstacles to the adjustment of real wages, there will be full employment of labour. If $\bar{l}_S$ (or $\bar{l}_U$ is the supply of skilled (or unskilled) labour in a full-employment situation, we can obtain from [6] the relative equilibrium wage:

$$w_S - w_U = -1 / \sigma \{(\bar{l}_S - \bar{l}_U) + (1 - \sigma)(a_S - a_U)\} \quad [8]$$

It is clear that the impact of an asymmetrical productivity shock on the relative equilibrium wage depends on the elasticity of substitution between goods and between forms of labour, and on the direction of the technical progress bias. The different possibilities are summarised in Table A1.

Table A1. **Relative changes in the wages of unskilled workers under a technical progress shock**

	Strong technical progress embodied in	
Substitutability of goods or forms of labour	**Skilled** labour	**Unskilled** labour
High	Fall in relative wage of unskilled workers	Rise in relative wage of unskilled workers
Low	Rise in relative wage of unskilled workers	**Fall in relative wage of unskilled workers**

Source: Author.

As we can see, the fact that there is a technical progress bias, or greater technical progress embodied in skilled labour, does not automatically imply a rise in the relative wage of skilled workers. The outcome depends on the substitutability of labour categories on the one hand and the substitutability of goods on the other. If there is no substitutability, the wages of highly skilled workers may fall in spite of the productivity gains achieved, since these also make skilled labour relatively abundant. A return to full employment of skilled labour in this case exerts a downward pressure on the wages of highly skilled workers which outweighs the direct impact of the productivity rise.

Widening of the wage spread may therefore stem from one of two situations:

- either from technical progress that is embodied more in skilled labour with high substitutability of goods and/or labour categories;
- or from technical progress that is embodied more in unskilled labour, but with low substitutability of goods and labour categories.

In fact the two situations may coexist. In individual firms, as was suggested above, technical progress would be embodied more in skilled labour. Relatively large scope for substituting capital and skilled labour for unskilled labour would lead to greater use of skilled labour. The impact would be heightened by a sectoral bias, with the sectors that make intensive use of unskilled labour globally experiencing high productivity gains. Prices would then fall, but the reaction in demand would not be strong enough to offset the direct impact of the productivity rise.

b) Using [5] and [7] we can obtain

$$l_S^i - l_U^i = (\bar{l}_S - \bar{l}_U) + (\sigma - 1)(a_S^i - a_U^i - (a_S - a_U)) \quad [9]$$

It is the difference between intra-sectoral bias and total bias that determines the change in relative demand for each category of labour in each sector. When a technology shock occurs affecting the skilled-labour-intensive sector ($a_S - a_U > 0$) but with no intra-sectoral bias ($a_S^i - a_U^i = 0$), the second term on the right-hand side is negative if goods and labour categories are sufficiently substitutable ($\sigma > 1$). The increase in the relative wages of skilled workers results, in each sector, in a fall in demand for skilled labour.

There is no fall in the wages of skilled workers because the demand for Sector 1 goods (hence labour) increases: there is a global re-allocation of Sector 2 labour, now less productive, into Sector 1. This becomes apparent if the sectoral price differential is specified (assuming that firms maintain a constant profit ratio):

$$p_1 - p_2 + (\theta^1 - \theta^2)(w_S - w_U) - [(\theta^1 - \theta^2)(a_S^1 - a_S^2) + a_S^1 - a_U^1] \quad [10]$$

where θ^1 (or θ^2) is skilled pay as a share of total costs in Sector 1 (or Sector 2).

There are two opposing forces: more expensive skilled labour pushes up the price of goods in Sector 1, which uses that labour more intensively, but this is more than offset by the price cuts made possible by productivity gains. As Sector 1 uses more skilled labour, this offsets the fall in intra-sectoral demand for skilled labour.

Sectoral re-allocations depend solely on the presence of a sectoral bias. By replacing [7] in [9], we obtain:

$$l_S^i - l_U^i = (\bar{l}_S - \bar{l}_U) - (\sigma - 1)(\pi_S - \pi_U)(a_S^1 - a_S^2) \quad [11]$$

When the bias is intra-sectoral, the relative wage trend exactly offsets the direct impact of the shock caused by the technical progress bias and no sectoral re-allocation occurs.

c) The specification above is applicable to the situation in Anglo-Saxon countries, where extensive wage movements have been observed. A simple modification of the previous model makes it possible to integrate the rigidities that in continental Europe have hindered wage adjustment and thus made it harder for the unskilled to gain access to employment. (It is assumed that skilled workers there are in full employment.) Figure A1 below depicts equilibrium on the labour market. The relative wage $w_s - w_u$ ensures equilibrium between the relative demand for labour (*AD*) and the labour supply (*AS*). When relative wages are flexible, the supply curve (*AS**) is vertical. Wages adjust fully ($w_u^* - w_s^*$) to ensure full employment of unskilled labour $l_u = \bar{l}_u$. If the wages of unskilled workers adjust less than fully, there is a rise in unemployment. This apart, the analysis based on full wage adjustment still applies and its conclusions stand.

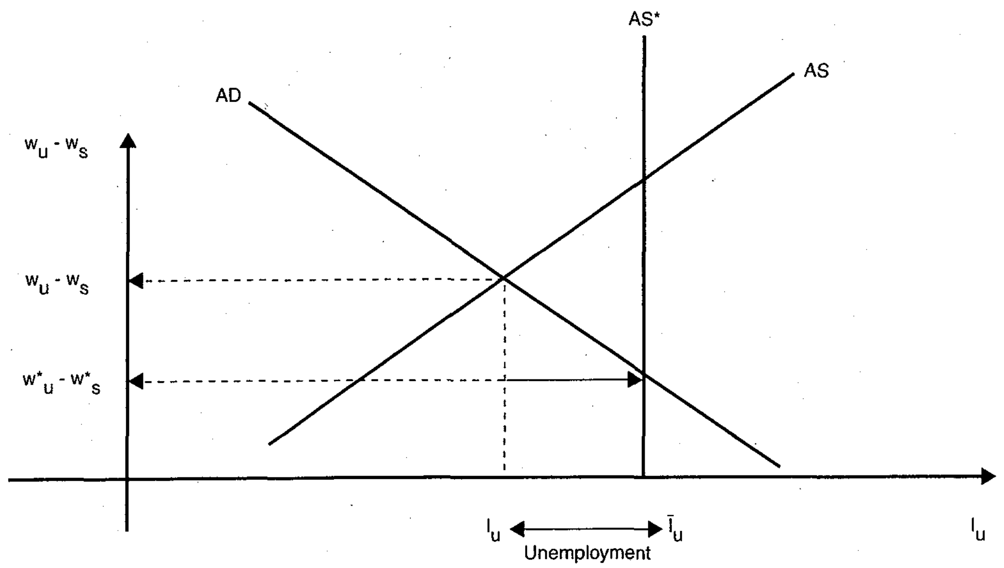
Figure A2 shows how the economy reacts to a shock brought about by technical progress. It depicts a case in which technical progress bias causes a fall in relative demand for unskilled labour. A comparison between the reaction of a flexible economy (AS* curve) and that of a more rigid economy illustrates what was said above, namely that wage rigidities limit the impact on wages [$\Delta(w_u - w_s)$ is lower than $\Delta(w^*_u\ w^*_s)$], but unemployment rises.

Table A2. **Sectoral effects of a biased technological shock**

	Technical progress bias	
Substitutability of goods or forms of labour	**Intra-sectoral** (stronger on skilled labour)	**Inter-sectoral** (stronger on goods with high skilled-labour content)
High	– Rise relative in wages of low-skilled labour – No labour re-allocation	– Rise relative in wages of low skilled-labour – Fall in low skilled-labour *employed in each sector* – Re-allocation to goods with low skilled-labour content
Low	– Fall in relative wages of low skilled-labour – No labour re-allocation	– Fall in relative wages of low skilled-labour – Rise in low skilled-labour employed in each sector – Re-allocation to goods with high skilled-labour content

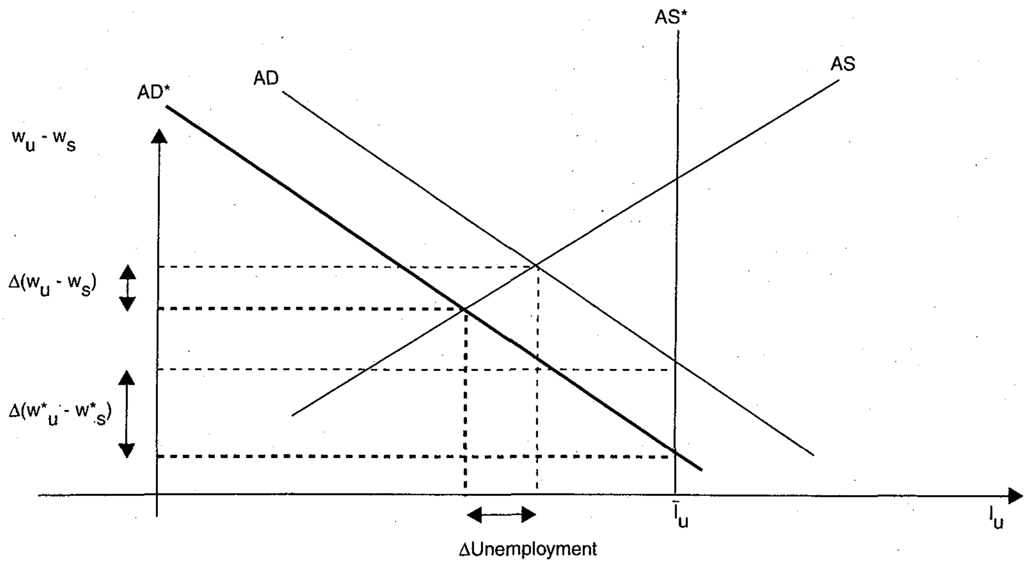
Source: Author.

Figure A1. **Equilibrium model**



Source: Author.

Figure A2. **Impact of an asymmetrical technical progress shock**



Source: Author.

When wage rigidities are taken into account, technical progress affects both relative wages and unemployment. Table A3 is the equivalent of Table A1 for a non-flexible economy.

d) How do these findings change in the case of an open economy? Free trade in goods leads to equality of goods prices expressed in a common currency, and in the previous model means the levelling-out of domestic $p_1 - p_2$ and foreign relative prices. In the case of a small country, the terms of trade cannot be modified. This corresponds to the case in which σ is infinite in the previous model: an increase in

Table A3. **Relative trends in the status of unskilled workers under a technical progress shock**

	Strong technical progress in the sector	
Substitutability of goods or forms of labour	With high **skilled**-labour content	With high **unskilled**-labour content
High	w ↓ L ↓ p ↑	w ↑ L ↑ p ↓
Low	w ↑ L ↑ p ↑	**w ↓ L ↓ p ↓**

Key: $w = w_u/w_s$, $p = p_1/p_2$, $L = l_u/l_s$.
Source: Author.

prices would generate such a fall in demand that it would dissuade firms from changing them. Thus, in a small open economy a change in technical progress affecting goods with a high unskilled labour content would result in an improvement in the status of unskilled workers (upper right-hand box in the previous table), whereas in a closed economy their status would decline (lower right-hand box). This can happen in an economy that is catching up and adopting the production techniques used in developed countries (economies in transition, for instance).

The case above, however, is unlikely to apply to the OECD area, where technical progress probably spreads rapidly. Technical progress conceivably produces the same shock in every OECD country. Relative prices are therefore altered on both the domestic and foreign markets. For OECD countries as a whole, the findings are probably relevant. But the implications for individual Member countries will not be the same, given that wage rigidities vary from one country to the next.

If foreign wages are more flexible, the fall in the relative prices of foreign goods with a high unskilled-labour content is steeper than the fall in domestic prices would have been in an autarky. Exposure to international trade brings relative prices into line with international prices (in the case of a small country); as wage rigidities prevent a similar adjustment in wages, unemployment rises more steeply than in an autarky. These mechanisms may have come into play between the United States, where wages are very flexible, and Europe. An analysis of US foreign trade with the European Union reveals a degree of specialisation in unskilled-labour-intensive goods that could be due to this.

Clearly, then, the relative status of unskilled workers may decline under the shock produced by a technical progress bias, with a rise in unemployment and a fall in relative wages. What happens to the real wage levels of unskilled workers? The overall effect is not clear but it can be shown, using certain strong assumptions, that the wages of the low-skilled may also fall in real terms. In terms of real income growth, it appears that the wider the productivity gap with skilled workers, the lower the substitutability of goods, the higher the degree of wage flexibility and the greater the presence of the skilled-labour intensive sector, the steeper the decline will be in the status of unskilled workers.

Finally, it should be noted that when there is dissymmetrical technical progress, relative wage rigidity causes a reduction not only in absolute wealth, but also in economic growth, owing to the decline in unskilled employment.

Table A4. **Absolute trends following a technical progress shock ($A_u > A_s$)**

	Technical progress		
	Fairly symmetrical	Dissymmetrical	Highly disymmetrical
Rigid relative wages	w_u ↑ UnU ↑	**w_u ↑ UnU ↑**	w_u ↓ UnU ↑
Flexible relative wages	w_u ↑ UnU →	**w_u ↓ UnU →**	w_u ↓ UnU →

Key: UNV = unemployment rate among the unskilled.
Source: Author.

Impact of exposure to international trade

The classic Heckser-Ohlin-Samuelson (HOS) trade model, in its strictest form, holds that if there is price equalisation for goods traded on the international market, the wages of the workers producing those goods will also tend to equalise. According to the Stolper-Samuelson theorem, those endowed with factors of production that are scarcer in one area than in the rest of the world will see a fall in real factor payments. Thus competition from countries with low labour costs may lead to a fall in the price of unskilled labour in the OECD area.

Even if transport costs, differing technology and trade barriers are taken into account, there is nevertheless a trend towards equalisation of goods and factor prices as trade develops (Helpman and Krugman, 1985). The mobility of factors, in particular capital, is encouraging the diffusion of production techniques, thereby strengthening the tendency towards equalisation. More specifically, competition from low-wage countries may affect low-skilled labour in OECD countries in three distinct ways:

- Exposed sectors with an abundance of unskilled labour are crowded out by imports from low-wage countries or offshore production.
- A "contestable-market" effect occurs, whereby keener competition leads to a relative fall in the price of unskilled-labour-intensive goods. With wages unchanged, this pushes up real labour costs and erodes corporate profitability. Furthermore, the threat of seeing other competitors enter the market may encourage unskilled-labour-intensive firms to move upmarket and introduce more capital-intensive production techniques.
- Rents fall on goods markets. In monopolistic sectors, firms are obliged, by competition, to improve their "X-efficiency".

How can these mechanisms be analysed within the framework of the model set out above? According to the HOS theorem, exposure of a developed (OECD) economy to trade with developing countries will, given their respective factor endowments, result in exports of skilled-labour-intensive goods (Sector 1) and imports of goods with a high unskilled-labour content (Sector 2). The demand for domestic goods 2 will then fall and the demand for domestic goods 1 will rise .

Exposure to foreign trade can be formulated by altering demand equation [4]:

$$y^i = y - \sigma(p^i - p) + d^i \qquad [4']$$

where d^i is a shock on demand in the sector i. Exposure to international trade causes a shock leading to a rise in d^1 and a fall in d^2, or overall a positive $d^1 - d^2$ shock (demand bias).

Replacing this in [3], we obtain:

$$\begin{cases} l_S^i = y - \sigma(w_S - p) + (\sigma - 1)a_S^i + d^i \\ l_u^i = y - \sigma(w_u - p) + (\sigma - 1)a_u^i + d^i \end{cases} \qquad [5'']$$

System [5"] is a good illustration of how hard it is to distinguish the effects of the sectoral technical-progress bias and of international trade, since $(\sigma - 1)a_S^i + d^i$ alone is used to determine factor demand. Without direct observation of the shocks, this magnitude is treated overall as a residual, and its components cannot be extracted from the information contained in quantity movements.

Formally, the impact on the economy of exposure to international trade is analysed strictly as a technical-progress shock located in the unskilled-labour-intensive sector, assuming low substitutability of goods. Thus exposure to trade with developing countries has a dual impact: the output of goods with a high unskilled-labour content will decline, and the resulting fall in the wages of unskilled workers, described earlier, will still occur; however, within each sector the fall in the relative cost of unskilled workers leads to some displacement of skilled labour, partly blunting the inter-sectoral impact.

There is nevertheless an important difference as regards relative price movements. Equation [10] does not change: the impact of exposure to international trade is entirely confined to wage movements.

Increased technical progress embodied in unskilled labour would have different effects. There would be a fall in overall labour demand in the unskilled-labour-intensive sector, for the reasons given earlier, coupled with a decline in the use of unskilled labour in each sector.

Impact of a change in the labour supply

A shock to the labour supply can be analysed immediately and, once again, long-run trends reveal similarities with the impact of technical progress and of international trade. Here too the outcome is neutral when the shock is symmetrical ($l_S - l_U = 0$).

An increase in the proportion of unskilled labour produces exactly the same effects as a progressive exposure to international trade. Thus the steep increase in low-skilled immigrant labour in the United States over the past few decades may have contributed to the widening of the earnings span.

The most striking feature of the period 1970-80, however, is the tremendous increase in the relative supply of skilled labour in all OECD countries which considerably limited the impact of declining relative demand for unskilled labour. Yet it is possible that some slowing of growth in the supply of skilled labour in the 1980s, particularly in the United States, made this process lose momentum.

Table A5. **Summary of findings**

	$l_u - l_s$	$w_u - w_s$	$p_2 - p_1$	$w_u - p$	$w_s - p$	Unemployment[1]
Technical progress bias	–	–	–	?	+	+
Exposure to trade	–	–	–	–	+	+
Rise in minimum wage	–	–	–	+	+	+
Increase in supply of skilled labour	+	+	+	+	–	–
Increase in wage flexibility	+	–	–	–	+	–
Stylised facts (Europe)	**–**	**?**	**–**	**+**	**+**	**+**
Stylised facts (United States)	**–**	**–**	**–**	**–**	**+**	**0**

1. Semi-elasticity, unskilled.
Source: Author.

Nevertheless, unlike the two previous shocks which are not directly observable, labour supply by skill can be measured from employment and unemployment statistics, making it possible to isolate this factor's contribution.

Summary of the findings

The above findings are summarised in the table below. Also shown is the impact of a rise in the minimum wage and increased wage flexibility (or a fall in rents), which is likewise easy to analyse with the previous model. A rise in the minimum salary wage obviously narrows the wage spread; on the other hand, an increase in the cost of unskilled labour drives down demand; relative rigidities do not enable adjustment via wages, hence a rise in unemployment. A decrease in wage rigidities and rents, when there is a surplus of unskilled workers, leads to a relative decline in their wages, previously set above the competitive equilibrium level; the resulting decrease in labour costs permits a rise in the demand for unskilled labour and a fall in unemployment among unskilled workers.

NOTES

1. Berman, Bound and Griliches divide workers into two categories, namely "non production workers" and "production workers", on the following basis:

$$\Delta P_n = \sum_i \Delta S_i \overline{P}_{ni} + \sum_i \Delta P_i \overline{S}_i$$

where:

$\overline{P}_{ni} = E_{ni}/E_i$, share of skilled labour E_n in sector i;

$\overline{S}_i = E_i/E$, share of employment in sector i in total employment.

The first term on the right of the equation reflects the changes in skilled employment ascribable to a re-allocation of employment between sectors. The second term reflects the change in the share of skilled employment within each sector. The authors use a similar method based on relative wage bills. The two employment and wage bill indicators allow them to conclude that intra-sectoral changes predominate over inter-sectoral changes.

2. It has been assumed that the intra bias does not depend on the sector, which implies $a_S^1 - a_S^2 = a_U^1 - a_U^2$.

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