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Chapter 22

Innovation and Employment

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Introduction

The relationship between innovation and employment is a complex one and has long been a topical issue in economic theory[1]. The classical question "does technology creates or destroys jobs?" has to be asked in well defined contexts. Considering the disequilibrating nature of technological change, neo-Schumpeterian, Evolutionary and Structural perspectives have asked "what type of innovation are we considering?" and "what are the structural, demand and institutional factors which help create or destroy jobs?". Besides the *quantity* of employment change, *quality* aspects have received increasing attention, with the question on "what type of jobs are created or destroyed by innovation?". This line of research, often associated to an equilibrium view of the functioning of markets, has taken two main directions: "how does the composition of skills change" and "how does the wage structure change", leading to a large literature on skill biased technical change and on wage polarisation.

This chapter examines the evidence from empirical studies. First the perspectives, scope and types of innovations are considered, identifying the different employment effects they may have. Second, the effects on the *quantity* of employment are reviewed at the firm, industry and macroeconomic level. Third, changes in the *quality* of employment are examined, considering the effects on skills and wages, and the impact of organisational innovation, again at different levels of analysis. A summary of stylised facts concludes the chapter with a discussion of future research and policy issues.

1. Perspectives and scope of innovations

The literature on innovation and employment has addressed different research questions rooted in several streams of research. Table 22.1 summarises the main perspectives in terms of assumptions on the economic system, methodologies and levels of empirical analysis (for a review of theoretical approaches see Petit, 1995).

The mainstream approach looks at innovation as a change in technology across the economy, leading to economic growth and employment. Early growth theory in a Keynesian perspective had assumed that an (exogenous) new technology opens up investment opportunities, and that

[1] For their comments and suggestions I wish to thank the editors, Charles Edquist, Bengt-Ake Lundvall, Marco Vivarelli and several contributors to this volume.

investment increases output, income and employment.[2] A new technology may have the effect of saving on capital (as well as on labour), leading to a lower capital-output ratio and to a faster potential rate of growth. The argument that new technology creates investment opportunities and increases the marginal efficiency of capital, leading to steadily higher rates of growth, is parallel to the view of Schumpeter and has returned fashionable in the 1990s in the debates on the 'new economy'. The lack of an explicit conceptualisation of technology, either in the decisions of private agents, or in the tools of public policy and its exogenous nature remain, however, a limitation of Keynesian growth theories, including Solow's growth model (see the chapter by Verspagen and Louca in this volume).

Modern theories have approached the question of the employment impact of technology from two perspectives. On the one hand, growth theories have moved from an exogenous view of technological change to efforts, in the *new growth theory,* to conceptualise innovation – proxied by technology, learning, and educational variables - as an engine of endogenous growth. Labour economists, on the other hand, have explained changes in employment (and wages) with job demography, macroeconomic factors, wage costs, bargaining modes and flexibility of labour markets, then moving to consider competitiveness and technology factors (see table 22.1).

However, the fundamentally *disequilibrating* nature of technological change is usually treated in a context which still assumes a general (or partial) equilibrium of markets, that is, all output finds its demand, and all workers ready to accept the current wage find employment. Technological change is often reduced to new production processes (and new production functions) and models rarely envisage the emergence of product innovation. When employment losses appear in such studies, they rarely lead to permanent (or structural) unemployment; they lead to downward adjustments in wages so that the additional jobless are returned to work. If this cannot be found in the real world, then the responsibility is attached to the lack of flexibility of labour markets, with excessive union power or institutional rigidities such as the minimum wage.

A more convincing approach to the study of innovation and its consequences is one that addresses from the start the *disequilibrium* nature of economic change. This view has been developed by neo-Schumpeterian perspectives, by Kaldorian, Structural and Evolutionary approaches (see table 22.1).

Table 22.1 here

Neo-Schumpeterians have argued that advanced economies are witnessing the emergence of a new techno-economic paradigm based on Information and Communication Technologies (ICTs) (see the

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[2] Hansen (1964, ch.35) used the standard Harrod-Domar model - where $g = s / c$, the rate of growth g is equal to the ratio of the share of savings s and the capital-output ratio c - to show that a low propensity to save (i.e. a high multiplier) and a high capital-output ratio (i.e. a high accelerator and large investment opportunities for a given ouput) increase the *level of income* in the short term, with makets in a better position to reach full employment. A high *rate of growth*, on the other hand, may require the opposite conditions. A high flow of savings and a small capital-output ratio (i.e. a greater efficiency of capital, but lower investment opportunities) make higher growth possible and the economy more efficient, assuming that full employment (and high income) is reached through an active public policy that fills the gaps in demand. Hansen wondered whether the higher rates of growth in Western Europe compared to the US in the 1950s and 1960s could be explained by the higher European savings rate and the lower capital requirement (in countries characterised by high human capital and extensive state intervention to stimulate demand in the economy). I thank Richard Nelson for drawing attention to this work.

chapter by Fagerberg in this volume). A cluster of radical innovations in computers and telecommunications has led to rapid improvements in technologies which have a widespread application and diffusion potential and rapidly diminishing prices. Such a radical change in the nature and trajectories of innovations, and their widespread adoption is reshaping the economic structure and international hierarchies, but is also affecting the way (and the place where) most economic (and social) activities are carried out. Such powerful technological changes do *create and destroy a large amount of jobs*. The question of how many (and where) are created and destroyed depends from the highly dynamic process which shapes at the same time the content of specific technological innovations, the speed of adoption, the economic activities which are based on them, and the social relations which develop around them. Moreover, jobs lost and new jobs offered may take place in different areas or require different skills, leading to mismatches. The speed of adjustment is therefore crucial and makes the difference between frictional unemployment, easily absorbed by well functioning labour markets, and technological unemployment.

Sustained and sustainable growth can be expected only once the mismatches between the new technologies and the old economic and social structures and institutions are overcome, with a two-way adjustment. Innovation has to be adapted to social needs and economic demands; economic and social structures evolve under pressure from new technologies. Moreover, new technologies need to be matched by organizational changes, new institutions and rules, learning processes, emergence of new industries and markets, and expansion of new demand. Several studies on the emergence of technological paradigms and key technologies in the past have pointed out the long time required by the combination of all these elements before their impact on economic growth and employment could become evident (Freeman, Clark and Soete, 1982; Freeman and Soete, 1987; 1994). While extremely powerful in its explanation of long term economic changes and historical evolution, this approach has yet to be "operationalised" with more specific questions on the type of innovation and on the interaction with economic and employment variables.

Box 1

Technology and unemployment: a Classical debate

Since the emergence of the industrial revolution, the extensive substitution of labour by machinery incorporating the new technology of the time has led economists and policy makers to debate the economic and social consequences. At the end of the XVIII century James Steuart drew attention to the difficulty of reabsorbing the unemployment caused by sudden mechanisation, in spite of the positive effects from the construction of new machines and price reductions, and already envisioned a role for the government. Adam Smith linked the invention of machines to the division of labour and emphasised its labour saving effects. Jean Baptiste Say had less doubts on the ability of markets to adjust, while Thomas Malthus emphasised that the positive effects resulted from the strong demand dynamics experienced by England at the time. The optimism of Classical economists in the early XIX century contrasted with the dramatic impoverishment of the English working classes – industrial workers, small artisans and displaced peasants – who had started to organise trade unions and to launch Luddite struggles against the job losses and deskilling brought about by mechanisation. David Ricardo was convinced that the economy could compensate the negative employment effects, but in a famous passage in the chapter "On machinery" added in the third edition of his *Principles of Political Economy and Taxation* argued that "The opinion, entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy" (Ricardo, 1951:392).

The most articulated criticism of compensation theory was developed by Karl Marx who emphasised the losses for workers in terms of jobs, skills, wages and control over their work resulting from the way mechanisation was proceding at the time. Arguing that unemployment grows as technical change displaces labour faster that the accumulation of capital demands new workers, Marx developed important insights on the functioning of capitalism. The drive to capital accumulation leads to a constant search for new production techniques and new products (a key starting point in Joseph Schumpeter's theory of innovation). High unemployment assures lower wages and greater control over workers, but capital accumulation ultimately encounters the problems of finding adequate markets and demand, and making adequate profits (for a reconstruction of the debate see Heertje, 1973; Vivarelli, 1995).

New products, processes and organisations

Schumpeter (1934) defined *product innovation* as "the introduction of a new good (...) or a new quality of a good" and *process innovation* as "the introduction of a new method of production (...) or a new way of handling a commodity commercially". He also analysed the emergence of new forms of organisation, the opening of new markets and of new sources of materials.

The development (or the adoption) of process innovations, introduced mainly through new investment, leads to greater efficiency of production, with savings in labour and/or capital, and with a potential for price reductions. The usual outcome is higher productivity and loss of employment; to the extent that process innovations increase product quality or reduce prices, a rise in demand (when elasticity is high) may result in more jobs.

The introduction of product innovations can be based on internal innovative activities as well as on the acquisition of new intermediate or capital goods. Products (or services) can be radical innovations (new to the world), incremental improvements on previous ones, or imitation of goods already produced in other countries or firms. Generally, product innovations increase the quality and variety of goods and may open up new markets, leading (when elasticity is high) to greater production and employment. But new products can simply replace old ones, with limited economic effects, or be designed in order to reduce costs, with an impact similar to the one of process innovations (Pianta, 2001).

New goods enter the economy as consumption goods, intermediate goods or investment goods, following the demands of consumers, firms and investors. Innovative investment goods have a dual nature; they start as new products in the industries producing them, but become process innovations in the industries acquiring them; their employment consequence are likely to be positive in the machinery producing sectors, and negative in the industries making new investments (Edquist, Hommen and McKelvey, 2001).

The distinction between process and product innovations should not be brought too far. Most innovative firms introduce both at the same time (see Box 2 below), but in most firms and industries (see the chapter by Malerba in this volume) it is possible to identify the dominant orientation of innovative efforts, associated to strategies of either price competitiveness (and mainly process innovations) or technological competitiveness (and mainly product innovations).

In addition to the *technological* changes in products and processes, *organisational* innovation is an equally important factor affecting the quantity and quality of employment, and is usually closely linked to the introduction of new technologies (Caroli, 2001). Sections 2 and 3 below will consider the impact on job creation and loss of each of these types of innovation.

Innovation, imitation, adoption and use

Looking at the emergence of new technologies from the perspective of the economic system, we have an *innovation* when a firm first markets a new product or introduces a new process; the road open to followers in the same industry (in other countries, too) is the *imitation* of new products (perhaps with incremental improvements, and adaptation to new users' needs); firms in all sectors may decide on the *adoption* of new processes or *use* of new (intermediate) products generated in other industries (and/or countries) The latter two lead to the diffusion of innovations throughout the economy, in both production and consumption (see Hall in this volume).

For empirical analyses, this distinction can be captured either by studies on the emergence of particular technologies, following their evolution through all the previous steps, or by studies on firms (or industries) based on surveys which identify product innovations novel to the market (original innovators), those new to the firm only (imitators), and the introduction of new processes (adopters). Traditional indicators such as R&D and patents fail to capture a large part of the latter two modes of technological development.

An important strength of this perspective is that innovation is conceptualised from the start as a deliberate process of change sustained by firms' efforts (learning, managing and spending) to develop knowledge, accumulate capital and access sources of innovation. In this perspective, innovation is therefore a thoroughly *endogenous* process, highly specific to firms and industries, affecting changes in both processes and products. This contrasts with the traditional view of *exogenous* technological change in neoclassical growth models, with the reliance on knowledge spillovers and with the efforts of new growth theories to endogenise innovation through measures of R&D, learning or human capital. Such approaches tend to view innovation as the emergence of a new production technology changing capital/labour ratios and productivity, concentrating therefore on process innovations, while the introduction of product innovations is rarely addressed in these models (see Verspagen and Louca in this volume).

Box 2
Evidence on innovation and employment

Conceptual and empirical difficulties have long led economists to adopt a rather homogeneous view of innovation, described either by R&D expenditure (one of its inputs), or proxied by patenting activity (one of its output). In the last decade the spread of innovation surveys in Europe and of surveys on panels of firms in the US has provided important new evidence on the variety of innovative activities and on their economic and employment effect (see the chapter by Smith in this volume).

Table 22.2 shows the key findings of the second Community Innovation Survey carried out in Europe (CIS 2, see European Commission-Eurostat, 2001), where large samples of firms (representative of the universe) have been asked whether they have introduced an innovation (either in products or in processes) in the period 1994-1996. The results are that 51 per cent of manufacturing firms and 40 per cent of service firms are innovative, with higher shares found in Ireland, Denmark, Germany and Austria, and the lowest ones in Spain, Portugal, Belgium and Finland. Considering manufacturing industry only, product innovations were introduced by 44 per cent of all European firms and process innovations by 39 per cent (the majority of innovative firms has introduced both); a stronger orientation towards product innovation is found in Austria, Germany, Ireland, Sweden and the UK, while in Spain, Portugal and Italy process innovators are more frequent than product ones.

An important novelty of innovation surveys is the possibility to discriminate the relevance of innovations. Table 22.2 shows that 21 per cent of European firms have introduced products that are new to the firm's market (not necessarily to the world market), showing that less than half of all product innovations are important; the Netherlands, Denmark and Ireland were the countries with above average shares. Finally, European firms reported that 12 per cent of their turnover in 1996 was due to products new to the firms, a key indicator of the economic impact of innovations; Germany, Ireland, Sweden and Austria have the highest values.

This selection of indicators offers an original perspective on the variety of innovative strategies carried out by firms and on their market outcome. The key results are that innovation is present in services almost as much as in manufacturing; one fifth of manufacturing firms introduces products new to their market, and another fifth develops minor product improvements, while almost as many firms change their production processes; the impact of new products on sales, on the other hand is limited to 12 per cent. In all indicators important differences are found across countries, associated to the nature of their industrial structure and national innovation system (see the chapters by Smith and Edquist in this volume).

Table 22.2 here

The latter variable offers the most accurate description of the economic relevance of innovations, and is related, in Figure 22.1, to the employment performance (average annual rate of change) of 20 manufacturing industries in four EU countries (France, Italy, the Netherlands and the UK). Looking at industry data for the share of new products in sales (drawn from the CIS 2-SIEPI database which provides data at the two digit industry level for major countries), a very strong variability is evident, from more than 20 per cent in office computing and telecommunications, to close to zero in more traditional industries (again with important cross country differences due to national specialisations). Looking at overall employment change, we first see that between 1994 and 2000 the majority of industries has had job losses. The relationship between innovation and employment experienced in European industries looks like a positively oriented curve, but a closer look at the distribution of cases is important.

ICT industries (computing, telecommunications, precision instruments and other transport, including aerospace) are generally in the top right quadrant, where new products in sales have a share higher than the average value for the EU (found in Table 22.1), and where no dramatic job losses are found. As expected, industries characterised by the new technology (and by a high concentration of product innovations) show the highest impact of new products in their turnover and better employment performances. In a few cases, however, moderate job losses are found even in this group, as strong international competition may lead to the decline of some ICT industries in some countries.

Traditional industries (textiles, wearing apparel, leather and a few others) tend to concentrate in the bottom left quadrant, where a below average innovativeness (and a strong dominance of process innovations) is matched by dramatic job losses.

The remaining sectors, in the top left quadrant, combine a low or intermediate impact of innovation with modest job losses or substantial gains, showing again a positive association. While several factors alongside innovation affect employment change (macroecomic conditions, competitiveness, etc., see Pianta, 2000) the distribution of Figure 22.1 highlights on the one hand the generally positive link we can expect between innovation and jobs; on the other hand, it shows the presence of winners and losers in all industries, reflecing the importance of national specialisations, of economic structures and the intensity of international competition in open economies.

Figure 22.1 here

2. The effects on the *quantity* of employment

The relationship between innovation and jobs is investigated in this section looking at the impact on the *quantity* of employment, defined in terms of the number of existing jobs, or, in more accurate analyses, in terms of the total hours of work. This link can be examined at different levels of analysis: firms, industries and the aggregate economy. Table 22.3 summarises the most relevant empirical evidence emerging from the literature.

Direct effects at the firm level

Firms are the place where innovations are introduced and where they show their immediate direct effects on employment. A growing literature has explored the issue with a variety of models, national studies and panels of firms (for reviews, see Petit, 1995; Chennells and Van Reenen, 1999; Spiezia and Vivarelli, 2002). Empirical work in this field has generally used annual surveys of firms in panel data; however, panels are usually not representative of the whole manufacturing industry, and in most cases leave out services altogether; therefore it is difficult to generalise their conclusions.

The evidence on the overall employment impact of innovation at the level of firms tends to be positive; firms which innovate in products, but also in processes, grow faster and are more likely to expand their employment than non-innovative ones, regardless of industry, size or other characteristics.[3] The variety of innovative strategies and job creation and destruction patterns has been highlighted in such studies, together with the firms' characteristics (structural factors, flexibility, competences, etc.) which tend to be associated to better performances.

A reverse relationship can also be considered. In the long run development of firms, phases of rapid growth of employment may be seen as determinants of innovations as firms have to cope with the rigidity of production processes and increasing wages, while trying to capture, through greater productivity and quality, the opportunities of expanding markets.[4]

Technological innovation is closely linked to organisational changes. A study on a large and representative sample of French firms, has found that firms that have introduced both in the adoption of advanced manufacturing systems in the period 1988-93 have had a greater employment growth than others, regardless of size or sector, and this positive effect was

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[3] Generally positive effects of indicators of innovation on the number of jobs (once the characteristics of firms have been controlled for) have been found in the studies of UK firms by Van Reenen (1997), who related a large panel of manufacturing firms to the SPRU database of British innovations, and by Machin and Wadhwani (1991), Blanchflower, Millward and Oswald (1991), Blanchflower and Burgess (1999) using the British workplace industrial relations survey on the adoption of ICTs; the latter also found weaker similar evidence for Australia. For German firms, Entorf and Pohlmeir (1991) have related innovation, export and employment in a cross section of firms, finding a positive effect of product innovation and no effect of process innovations. Smolny (1998) has found similar results with a panel of firms. Dutch firms investigated by Brouwer, Kleinknecht and Reijnen (1993) have shown an overall negative link between innovation and jobs, but where product innovations were dominant better employment outcome have been found. In Norway, Klette and Forre (1998) have found a negative association between R&D and employment at the plant level (including small units).

[4] This view is proposed by Antonelli (2001:173) in a study on the Italian car maker Fiat over the time series 1900-1970, which shows that employment growth Granger-caused patent growth with different time lags. In turn, patent growth led to productivity growth.

greater than in firms that introduced organisational innovation only (Greenan, 2003, see section 3 below).
However, firm level studies on the innovation-employment link are unable to point out whether the output and job gains of innovating firms are made at the expense of competitors, or whether there is a net effect on aggregate industry.[5] It is often difficult to generalise beyond the groups of firms investigated and to compare results across countries. When panels are used, a large part of the jobs created or lost may be accounted by the entry or exit of firms left outside the panel. In order to address these issues we need to turn to industry level studies.

Table 22.3 here

Direct (and a part of indirect) effects at the industry level

The evolution of sectoral value added and employment may show whether the gains of innovative firms have been greater or smaller than the losses of non innovative ones. An analysis at the industry level therefore addresses not only the direct employment effects of innovation within firms, but also the part of the indirect effects which operate within the industry. Such an impact includes first the competitive redistribution of output and jobs from low to high innovation intensive firms, and second, the evolution of demand (and therefore output and jobs) resulting from the lower prices due to innovation, given the price elasticities of the industry's goods.
Studies on industries (see Table 22.3) have shown that the sources and opportunities for both technological change and job creation are specific in individual manufacturing and service industries, and such factors are key determinants of employment performances. The empirical evidence shows that the employment impact is positive in industries (both in manufacturing and services) characterised by high demand growth and an orientation towards product (or service) innovation, while process innovation leads to job losses. The overall effect of innovative efforts depends on the countries and periods considered, but in general is more positive the higher is demand growth, the importance in the economy of highly innovative industries (both in manufacturing and services), and the orientation toward product innovation. In open economies, countries with an economic structure of this type are likely to receive a disproportionate part of the employment benefits of innovation; countries with stagnant economies and less innovative industries are likely to experience serious job losses due to technological change. Theories with roots in Schumpeter, Kaldor and Pasinetti focusing on structural change appear to explain effectively these empirical developments.
The industry level may be the most satisfactory level of analysis as it is able on the one hand to differentiate between the variety of technological regimes and firms' strategies and, on the other hand, to bring in the demand dynamics of specific sectors, taking into account country differences in economic structures.
Demand factors are important because, differently from the case of firms, an industry's demand is constrained by the composition and dynamics of domestic and foreign demand. High demand growth leaves room for a variety of firms' strategies and for better employment

[5] In France, Greenan and Guellec (2000) have found a positive relationship between both product and process innovation and employment at the firm level, but at the industry level only the former played a positive role. Using data from the French household survey, Entorf, Gollac and Kramarz (1999) found that computer use reduces the risk of unemployment in the short term, but not in the long term.

outcomes, while stagnant demand deepens the selection process among firms and emphasises the role of technological competition (Pianta, 2001).[6]

The empirical investigations of the employment impact of innovation at the industry level include studies using R&D or patenting as innovation proxies[7], input-output models,[8] and more recent works based on innovation surveys (unfortunately, available only for Europe). Set in the context of the European debate on 'jobless growth' in the 1990s, the evidence points to an extensive process of restructuring in many manufacturing sectors where the growth of value added is not matched anymore by increases in jobs (see Pianta, Evangelista and Perani, 1996; Fagerberg, Guerrieri and Verspagen, 1999).

Studies using innovation survey data matched to industry performances[9] show that in Europe employment change (in most cases a decrease) is affected by the dynamics of demand, of structural change, and the orientation of innovation towards new products, while a higher intensity of innovative expenditure *per se* has a negative impact on jobs. Once structural change and the nature of technological change are considered, a greater innovation (or R&D and design) expenditure is associated to worse employment outcomes, suggesting a prevailing pattern of labour-replacing technological change.

Similar findings come from a model where employment is affected by demand dynamics, labour costs and innovation variables associated with strategies of technological or price competitiveness; in the context of the modest aggregate growth of the 1990s, European industries (in eight countries) were dominated by the latter strategy, with a prevalence of process innovations, and generally negative effects on jobs (Antonucci and Pianta, 2002).

The findings for service industries do not differ substantially from those of manufacturing. Studies on Italy have found an overall negative effect, concentrated among the largest firms, on low skilled workers, on capital intensive and finance-related sectors, and where the impact of ICTs has been most widespread. Smaller firms and technology-oriented activities show, on the other hand, net employment gains (Evangelista, 2000; Evangelista and Savona, 2002, 2003; see also the chapter by Miles in this volume).

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[6] High demand is a necessary, but not sufficient condition for employment growth. In order to expand jobs, demand and output have to grow faster than productivity, a condition which has often been found in the US, but less in Europe. Since the 1980s, the relation between productivity growth and employment across industries has became negative (Appelbaum and Schettkat, 1995, Johnson, 1995).

[7] Typical of the former approach is the OECD Jobs Study (OECD, 1994) which investigated the high and persisting unemployment in advanced countries and downplayed the role of technological change. The report emphasised the positive role of new technologies associated to structural change, and showed employment decline in several R&D intensive industries, and even greater job losses in low-technology sectors.

[8] Meyer Kramer (1992) has used a model of the whole German economy to assess the impact of ICTs, proxied by direct and indirect R&D in 51 sectors; the findings suggest a generally negative employment impact, with some positive effects in higher technology industries.

[9] An early use of these data for Italian manufacturing industry is in Vivarelli, Evangelista and Pianta (1996) who have found a generally negative employment impact of technological change and the expected contrasting consequences of product and process innovations. Pianta (2000, 2001) has investigated the relationship between technological change and employment in five European countries (Denmark, Germany, Italy, the Netherlands and Norway) in 1989-93 across 21 manufacturing industries with variables accounting for changes in demand and industrial structure, for innovation intensity, and for the prevalence of product innovations.

The evidence at the sectoral level, especially for European countries, suggests a less optimistic view on the employment impact of innovation. The slow growth of the last decade has represented a substantial constraint on the demand side, which has limited the potential employment benefits of technological change. While product innovation has confirmed its positive effects on output and jobs, the increased international competition has pushed firms towards restructuring, and process innovations have dominated several industries in many European countries, leading to a prevalence of labour saving effects.

Direct and indirect compensation effects at the macroeconomic level

The full view of the employment impact of innovation has to come from a macroeconomic perspective that can account and integrate all the indirect effects through which technological change affects employment. This is the approach typical of the debate on "compensation mechanisms" which, since the times of Ricardo and Marx, has opposed those who argue that the economic system has in-built mechanisms which assure the recovery of jobs lost due to innovation, and the critics who have pointed out the limitations of their effects and the possibility of technological unemployment. It should be pointed out that most of this debate conceptualises technological change as the introduction of new capital goods, typical of XIX century mechanisation, therefore focusing on the impact that process innovations may have. Secondly, the equilibrium in product markets is generally assumed, i.e. no demand constraint is considered, following Say's law. Recent research in this direction has relied on Kaldorian approaches, on the work by Pasinetti (1981) and Boyer (1988a,b). A detailed treatment of this issue is in Vivarelli (1995), who has summarized the compensation mechanisms and the way they may (or may not) operate in the economy.

The compensation mechanism *via decrease in prices* is one of the most important ones: new technologies may make lower prices possible, increasing international competitiveness and leading to greater output and to the recovery of the job losses due to the original innovation. This outcome, however, is contingent on the lack of demand constraints, on the decision of firms to transfer in lower prices the productivity gains due to the innovation, and on the lack of oligopolistic power in the relevant markets (Sylos Labini, 1969).

The compensation mechanism *via new machines* may create new jobs in the industries where the new means of production are made, but the rationale for mechanisation is by definition saving on the use of labour, putting a limit to the relevance of this mechanism.

The compensation mechanism *via new investment* argues that the temporary extra profits available to the innovator may be turned into new investment; this however may expand production capacity and jobs, or may introduce additional labour saving effects.

The compensation mechanism *via decrease in wages* is typical of the neoclassical view of the labour market. As technological unemployment appears, wages would fall and firms would hire more workers. This mechanism however is based on strong assumptions on the feasibility of any combination of labour and capital, competitive markets, flexibility of wages and labour markets.

The compensation mechanism *via increase in incomes* operates in the opposite way, through the demand effects of the distribution of part of the gains from innovation to higher wages, as it has happened in large oligopolistic firms in mass production industries. However, wage increases can hardly be large enough to sustain additional aggregate demand.

Finally *new products* may lead – as discussed above - to new economic activities and new markets (*welfare effects*) or, on the other hand, they may simply replace existing goods (*substitution effect*, see Katsoulacos, 1986).

Aggregate empirical patterns for the US are examined in a descriptive way by Baumol and Wolff (1998). Considering five innovation indicators for the whole economy and their link to the structure and changes in unemployment in the US in the 1950-1995 period, they conclude that faster innovation leads to a higher 'natural rate of unemployment' and to longer frictional unemployment.[10]

Using aggregate models of simultaneous equations, a number of empirical test on the relevance of compensation mechanisms have been carried out. In a general equilibrium perspective, Layard and Nickell (1985), Nickell and Kong (1989) and Layard, Nickell and Jackman (1991; 1994) have found that the working of various compensation mechanisms ruled out the possibility of technological unemployment in the UK.

Building on Boyer (1988a,b) and on the Regulationist approach, Vivarelli (1995) has developed a model for testing the compensation mechanisms in the US and Italy. Considering total work hours in the economic system as the employment variable, he has found that the mechanism *via decrease in prices* is the most effective one, and that the positive effects of new products and labour markets operate in the US (where new jobs are created), but not in Italy, where net job losses have been found. This approach has been further developed by Simonetti, Taylor and Vivarelli (2000), who have considered four countries, and by Simonetti and Tancioni (2002) who have developed a model for an open economy in the case of the UK and Italy. All have found a differentiated impact of compensation mechanisms.

While this approach is the most comprehensive and satisfactory for explaining the overall impact of technological change on employment, the complexity of the construction of the model, the problems in specifying all relevant relationships and the lack of adequate data limit the feasibility of this approach. The evidence available points to a differentiated impact of innovation depending on countries' macroeconomic conditions and institutional factors; the employment impact generally is more positive the higher is the ability to generate new products and to invest in new economic activities, and the stronger is the effect of price reduction, leading to increased demand.

Simulation studies

The employment impact of innovation has also been studied with a simulation approach. Leontief and Duchin (1986) have estimated that the diffusion of computer technology and automation in the US economy would have negative employment effects; they used an input-output model where, however, high assumptions on productivity growth were made and no demand dynamics was allowed.[11]

A study on the impact of microelectronics in forty sectors of the UK economy in the 1980s showed the possibility of both net job gains and losses, depending on the assumptions on the speed of diffusion (Whitley and Wilson, 1982). For Germany, Matzner and Wagner (1990) carried out a complex study of the effects of technological change in all fields, finding a moderately negative impact on jobs, but a positive impact on international competitiveness which in turn protects employment.

A different approach - a general equilibrium model with a sectoral structure, which assumes full employment - has been used for simulating the employment impact of different scenarios of technology-based productivity growth and of composition of consumption, in a recent study by IPTS-ESTO (2002) on the European Union. The results show an overall positive impact on jobs, differentiated according to the alternative sectoral distributions of R&D and

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[10] They argue that "The evidence supports the conclusion that an increase in the pace of innovation (all else equal) will raise both the natural rate of unemployment and the average length of time during which an unemployed worker is 'between jobs'" (p.10).

[11] Their assumptions on productivity growth were based on the improvements in the engineering performance of robots; the long time lags in their adoption and their poor initial performance have meant that their actual economic effect on productivity has been much lower.

innovation efforts; the best outcomes result from the concentration of efforts in high technology industries.
While they are interesting as explorations of alternative futures, the weaknesses of such simulations are in their reliance on models which severely constrain from the start the possibility of identifying either technological unemployment (when general equilibrium is used) or most compensation effects (when input-output models are used), and on the arbitrariness of the assumptions made on the diffusion and productivity of new technologies.

Summarising the results of this section, both sectoral and aggregate studies generally point out the possibility of technological unemployment, which emerges when industries or countries see the prevalence of process innovations in contexts of weak demand. Firms innovating in both products and processes may be successful in expanding output and jobs regardless of the economic context, but often do so at the expense of non innovating firms. The specificities of industries, countries and macroeconomic conditions are crucial determinants of the results obtained in empirical studies.
All the analyses of this section refer to national economies, sometimes even assuming a closed economy. When we consider an open economy, the picture becomes more complex, as on the one hand innovation may lead to competitiveness and exports, thus weakening the demand constraint; on the other hand domestic demand may increase imports when foreign competitors are more innovative in terms of price or quality. Unfortunately, no empirical analysis has so far addressed the innovation-employment question in a truly global dimension; as several manufacturing sectors are highly internationalised, the introduction and diffusion of innovation leads to job creation and losses in a large number of different countries, with a complex distibution of the benefits and costs of technological change. The case of developing countries in this context is particularly interesting, as new technologies are at the centre of the structural changes and dynamic learning economies typical of catching up countries, which however face greater difficulties in capturing the employment benefits of technological change (see Karaomerlioglu and Ansal, 2000 and the chapter by Fagerberg and Godinho in this volume).

3. The effects on the *quality* of employment

Most approaches that assume equilibrium in labour markets (and therefore no technological unemployment, see Table 22.1) have disregarded the effects of innovation on the quantity of jobs, and have focused on the relative composition between skilled and unskilled workers and on wage polarisation. Moving away from an undifferentiated view of employment is a welcome development, although the conceptualisation and the empirical definitions in this field are often crude, based either on educational levels or on blue/white collar occupations, or on both. The importance of learning, competences and skills has also been emphasised by the evolutionary approaches to innovation, although few empirical investigations have been carried out.
A large (mainly) US literature on skill biased technical change (reviewed in Acemoglu, 2002:7) argues that technical change is biased towards skilled workers as it replaces unskilled labour and increases wage inequality. In fact, a strong complementarity between technology and skills has characterised most of the XX century, when innovation has probably always been skill biased, in contrast to the unskill bias typical of the XIX century, when mechanisation had led to the deskilling of artisans (see Braverman, 1974).[12]

[12] Petit (1995) suggests that techniques and human labour had a complementary relationship in pre-industrial times, following strong social norms; industrialisation has been characterised by the

This section considers the streams of research that have found evidence on the complementarity between ICTs and high skills, but also on the deskilling process associated to the greater control over production made possible by ICTs. The effects on the skill structure of employment usually lead to changes in the wage structure where a tendency to polarisation is generally found. Increasing attention is also devoted to the impact that organisational change – alone or combined with technological change - has on skills, wages and employment (for reviews see Chennells and Van Reenen, 1999; Sanders and ter Weel, 2000). Table 22.4 summarises the most relevant literature.

Table 22.4 here

Skill biased technical change

The relative importance of skilled work has increased in the past century, rooted in the changes in economic structures, technologies and in the growing availability of educated workers. Many studies – mainly on US firms and industries - argue that in the last two decades this process has accelerated as a result of the introduction of information technology and computers. The issue has generally been investigated using a factor substitution framework, showing that direct or indirect measures of technology are important explanatory factors for the relative increase of skilled labour (see Berman, Bound and Griliches, 1994; Autor, Katz and Krueger, 1998). One stream of work has compared the effects of technology with those of increased international trade, finding that the former accounted for most of the fall in demand for less skilled workers (see Berman, Bound and Machin, 1998). Other studies have found that new technologies are adopted more in plants with more skilled workers, but do not increase the demand for skills (Doms, Dunne and Trotske, 1997).

The dominant findings of the econometric literature on skill bias in industries, firms and individuals, using direct measures of technological change, is that the diffusion of technologies has a strong skill bias effect, while it has a less evident effect on wages (see the review in Chennells and Van Reenen, 1999).

However, little research has addressed the effects of different directions of technological change and types of innovation (e.g. product versus process) as Sanders and ter Weel (2000:34) point out. Evidence has been found on upskilling *within* the firms and the industries investigated, but also *between* firms and sectors, as the most dynamic ICT-related industries account in all countries for large (relative) increases of skilled employment.

In Europe such structural factors may be particularly strong. Machin (1996) for the UK and Piva and Vivarelli (2002) for Italy find some upskilling over the past decades, although in the latter case organisational innovation appears to be the most important factor, while technology and foreign direct investment play a secondary role. Indirect evidence on the limited pace of ICT diffusion and upskilling in European economies, and on the importance of organisational changes and work intensification has come from the third Survey on European Working Conditions (European Foundation for the improvement of living and working conditions, 2001).[13]

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substitution of machines for labour on the basis of profit seeking; post-war rapid growth has been associated to technologies designed to overcome labour shortages and increase productivity, while the current emergence of a new technological system based on ICTs is marked by uncertainties.

13 The survey has interviewed 21,500 workers in all EU countries and has found that the number of people working with computers (at least one quarter of the time) has increased only marginally from 39 per cent in 1995 to 41 per cent in 2000, while those using computers all the time are 19 per cent. Little change has taken place over that period also in the workers' perception of their skills: 8 per cent regard the demands of the job as too high for their skills

However, when more refined measures of skill are used, the evidence is more controversial. Moving from the simple measures of blue or white collar jobs, or of years of schooling, to more refined indicators of skills, including cognitive (typical of technical staff), interactive (typical of supervisory staff) and motor competences (typical of manual workers) in US industries between 1970 and 1985, Howell and Wolff (1992) have found that expenditures on computers and new investment were associated to raising demand for high cognitive skill workers, although with differences across occupations and industries. Using these indicators little support is found for the hypothesis of technology-skill complementarity.

The aggregate evidence for the US economy is also weak. Howell (1996) rejects the idea of a link between computerisation, upskilling and wage inequality and finds that major shifts in skill structure happened between 1973 and 1983, and little change took place afterwards, when diffusion of ICTs accelerated and computer-relate investment per employee increased dramatically.[14] In recent years the shares of high skilled blue collars and low skilled white collars have declined faster, and in services little change in the skill structure took place. The consequences of ICT investment since the mid 1980s therefore appear to have affected the low skilled white collars (mainly female) much more than the lowest blue collar skills.

Wage polarisation and the labour market

The effects of technological change on skills and wages are often treated together; more specific studies have investigated the evolution of wage differentials in three contexts: across industries with varying technological and capital intensities; among workers and firms using or not using computers or new technologies; among workers or social groups with different educational levels (see Sanders and ter Weel, 2000; Acemoglu, 2002). Evidence of polarisation is generally found, although the relationship to technological change is conceptually and statistically less robust, as computers are more likely to be used by more competent workers who already earn higher wages (Chennells and Van Reenen, 1999). On the other hand, the technology-wage polarisation link has been questioned by studies pointing out the lack of an acceleration in these effects in recent years, the importance of sectoral shifts and the effects of growing international trade on wages (Mishel and Bernstein, 1996; Addison and Teixeira, 2001).

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and 11 per cent as too low. However, work intensity has increased, as the share of workers reporting working at very high speed during at least one quarter of their time has increased from 48 per cent in 1990 to 56 per cent in 2000 (this is closely correlated to health problems and injuries at work). The share of workers which have control over their pace and methods of work has remained high and stable at about 70 per cent between 1995 and 2000, while only 44 per cent (including self-employed) have control over their working time (European Foundation for the improvement of living and working conditions, 2001).

[14] Computer-relate investment per employee rose from 150 US$ in 1982 to about 1000 US$ in 1992 for both manufacturing and services (id:292). The share of low skilled blue collar US workers in manufacturing declined from 45.1 per cent in 1978 to 39.7 per cent in 1982 and has then remained stable ending in 1990 with a 41 per cent share. In the late 1980s, when ICTs became important, the most serious reduction in the employment shares concerned the high skilled blue collars (who since 1978 had a stable share around 21.7 per cent and declined after 1985 to 19.7 per cent in 1990) and the low skilled white collars (who stayed stable around 12 per cent until 1985 and then declined to 10.6 per cent in 1990). At the opposite end, the share of high skilled white collars had an increase in the 1978-1983 period (from 19.5 to 24.1 per cent), then was stable until a raise in 1989-1990 to 25.8 per cent (id:299, tables 1 and 2).

In comparing US and European results a paradox emerges. Empirical patterns show that in the last two decades low skill and low wage jobs have *increased* much more in the US than in Europe, associated to a faster growth of the supply of labour, resulting from demographic trends, and to a greater polarisation of the wage structure. An alternative explanation of these patterns may be proposed, arguing that skill biased technical change is more a European than an American story. With a stagnant labour supply and more educated workers, with slower aggregate growth in the past two decades and greater competitive pressure, most European firms and industries appear to have taken the road of unskilled labour saving innovations. This has raised wage inequality, although the strong European labour market institutions have limited polarisation in comparison to the US.

In contrast, The Unites States has experienced faster growth of population, labour supply and GDP, with the expansion of new sectors based on product and service innovations, in more competitive labour markets where less regulation on minimum wages and union power are found. This has resulted in a faster growth of new jobs (compared to Europe) at the top and bottom end of the skill structure, and this polarisation has been amplified in terms of wage inequalities by the lower regulation of US labour markets.[15]

The effects of organisational innovation

Studies on organisational innovation associated to the introduction of new technologies have long identified opposing patterns of change. On the one hand there is evidence of *deskilling* of workers as machines incorporate human knowledge and make it possible to use cheaper and less qualified labour, a pattern that has emerged since the origins of modern industry and now frequently observed in manufacturing industries and low skill services (Braverman, 1974). On the other hand there is evidence of an upskilling of some occupations, resulting from the complementarities between new ICT technologies and skills (Bresnahan et al., 2002; see also the chapter by Lam in this volume).

Studies on several countries collected in Adler (1992) find that both processes take place as a result of different strategies of firms, suggesting that "the use of new technologies will in general be more profitable when entrusted in to more highly skilled employees" (id:3) with broader roles, greater competences and continued learning. However, it has been argued that "there is a fundamental contradiction between the potential of computerization to enrich working life and increase productivity and the development of the technology in the pursuit of authoritarian social goals" (Shaiken, 1984:5) as management has often introduced new technologies and shaped work organisation with the primary aim to increase control over workers (see also Noble, 1983, 1984).

In an extensive survey of organisational change in US manufacturing and service firms, Appelbaum and Batt (1994) find a large diffusion of a variety of new management practices, often associated to the introduction of new technologies, resulting in improved productivity, quality and cost savings for firms, but no information is provided on the impact on employment levels. Similar findings have emerged from a study on a large number of US establishments, mainly in manufacturing, surveyed in 1993 and 1996, with both cross sectional and longitudinal analyses. Both technology adoption (such as the number of non

[15] This may amount to a shift in "wage norms": "in the face of mounting competition, employers reduced unit labour costs and increased flexibility in the production process by following the 'low road' – lower wages, little training, and fewer permanent employees" (Howell, 1996:301). Combined with a large use of part time and temporary workers, anti-union practices, relocation to low wage sites and inflows of low wage foreign workers, these developments have led to an increase in the supply of labour competing for low skill jobs, leading to a major fall in their wages, accompanied by a 25 per cent reduction in the real minimun wage over the 1980s (id:292).

managers using computers) and new workplace practices are closely associated to higher productivity and wages (Black and Lynch, 2000).

Several European studies (Caroli and Van Reenen, 2001 on France and Britain; Greenan, 2003 on France; Piva and Vivarelli, 2002 on Italy) have shown that organisational innovation is more important than technological innovation in shaping changes in occupational structure and skills. This is generally not associated to an increase in the number of employees, with the exception of management occupations.[16]

Organisational and technological changes in services, on the other hand, have reflected the opportunities offered by ICTs in order to overcome time and space constraints in the provision of services, leading to major flows of job creation and destruction, and to rapidly changing skill requirements. A variety of strategies of restructuring, emergence of networks, subcontracting and outsourcing, has resulted, leading to polarisation effects in terms of skills and wages (Petit and Soete, 2001b; Frey, 1997).

The rather fragmented evidence so far available on organisational innovation suggests that it plays a crucial role alongside technological innovation in shaping employment outcomes. The two can have a complementary relationship (especially when a virtuous circle of growth is in place), or represent alternative paths for adjustment (especially when restructuring and job losses are under way).

A broader view

While little doubt exists on the contribution of technological change to the long term improvement of the skills and wages of the more fortunate workers, the specific effects found in particular countries and periods are the result of economic structures, of the prevailing strategies of firms, of the operation of labour markets rules and institutions and of national policies. The link between innovation and employment has to be set in this broader context, bringing back a macroeconomic dimension which is missing in current literature. Little research has moved beyond the question of changing *relative* wages and addressed the broader *distribution* effects of technological change between profits, rents, wages, shorter work hours and lower prices.

So far attention has been devoted to the *demand* for labour only. New technologies interact with broader social changes leading to effects also on the *supply* of labour. Key processes affecting the quantity of supply include the slow demographic growth, immigration flows, an ageing population and the forms of women's presence in the labour force; the quality of labour supply results, on the other hand, from education and training, learning processes and accumulation of competences.

A major process of change has recently invested the forms of employment, with firms strategies and governments policies leading to the decline of the traditional model of full time, life time, waged (and unionised) employment and to the rapid growth of flexible, temporary, part time, subcontracted work.

On the other hand, social dynamics has led to demands for reducing the 'precarisation' of work, maintaining welfare protection, for shorter working time in Europe, greater training and life long learning, more meaningful jobs and to the development of socially useful activities

[16] A survey on Italian firms in the Bergamo district has found a limited diffusion of new work organisations and models of Human Relation Management, due to a general lack of skilled labour and to a failure by firms to use the potential of human resources in learning, compentence building and problem solving (Leoni et al., 2003). A survey of firms in the Reggio Emilia district has investigated the determinants of both technological and organisational innovation, finding that they are more likely to develop in firms having a higher profits, high shares of blue collar workers, low hierarchies and greater management-worker interactions (Antonioli et al., 2003).

carried out in the 'third sector' of non profit organizations. The diffusion of new technologies and the combination of technological, organisational, institutional and social innovations will have to provide answers also to these broader social demands.

4. A summary of stylised facts and research directions

This chapter has examined the relationship between innovation and employment and reviewed a large empirical literature addressing a variety of research questions at different levels of analysis. The complexity of the issues is such that no single approach can account for the direct and indirect consequences of technological change, for its effects on the quantity and quality of labour employed in the economy. Theories and empirical research have to proceed in parallel, with a close interaction between concepts and measures, hypotheses and tests, building links to related research areas. In this final section, a few stylised facts emerging from the empirical evidence are summarised, leading to possible directions for future research and policy.

A few stylised facts

The never ending race of innovation and employment. The evolution of (most) economies shows that when growth, structural change and demand dynamics take place together, in the long run the jobs lost to technological change are found elsewhere in the economy. If no innovation took place, economic activities facing competitive pressure would cut costs, wages and eventually jobs. The key question is how long does it take, and how the pace of innovation and diffusion eliminating old jobs compares to the pace of development of new economic activities creating new jobs. This makes the difference between the frictional unemployment of neoclassical economics and the technological unemployment of disequilibrium theories.

Technological unemployment can happen. On the basis of the available evidence current technological change may be a cause of unemployment. There is no automatic mechanism ensuring that a national economy is able to fully compensate for innovation-related job losses. This applies in particular to Europe in the 1990s.

The type of innovation is important. The evidence shows that it is essential to discriminate between *product* innovation (novel or imitative) which has a generally positive employment impact, and *process* innovation (adoption and use of new technologies) usually with negative effects; these findings emerge regardless of the theoretical approaches used.

Organisational innovation is closely linked to technological change. Changes in organisations reflect a variety of business strategies ranging from internal or external growth to restructuring and downsizing (leading to the job losses frequently documented by empirical studies); organisational innovation can play a complementary role to technological change, or can represent an alternative strategy in firms' restructuring.

The skill bias effect is relevant. Unskilled jobs have long been declining in absolute terms (in Europe) or growing slowly (in the US), while skilled jobs for educated workers are created at a faster pace in most countries, and are associated to greater innovative efforts. The discussion remains open on the specific effect of ICT-related innovation since the 1980s and on the role of the supply of more educated labour.

Wage polarisation is strong. Since the 1980s most countries have experienced a growing divide within wages (and more generally in incomes). This is the result of changes in economic structures, in firms' strategies and in government policies. Technological change is certainly part of the story, but the specific link between innovation and wage differentials has been questioned; a broader view of the evolution of labour markets, employment forms, social relations and national policies may explain in a more convincing way growing wage and income inequalities.

Aggregate demand and macroeconomic conditions are important. They play a key role in creating the conditions for a positive impact of technological change on employment, income and distribution. While the role of demand has generally been downplayed in the innovation literature, it may help explain the negative impact of innovation found in Europe in the low growth decade of the 1990s.

Innovation interacts with trade. In open economies trade is an important factor – alongside innovation – affecting employment and wages. The evidence available (mainly for the US) shows that job losses (especially for unskilled workers) and lower wages are explained by technological change more convincingly than by increased trade. But the interactions between innovation and trade shape competitiveness, the direction of technological change, the evolving division of labour and the employment outcomes.

The national innovation system is the source of change. A country's technological opportunities and ability to develop long term learning and innovating capabilities are rooted in the nature and characteristics of its national innovation system. Its strengths, orientation and priorities are likely to be reflected in the employment effects of a country's innovative efforts.

Labour market conditions and institutions matter. The employment outcomes of technological change depend on the way job creation and destruction takes place, wages are set, learning, flexibility and welfare protection are managed. On the other hand, labour market institutions influence the supply of labour, which should match the skill and competence requirements emerging with new technologies.

Directions for future research

The following research issues have emerged from this chapter as promising directions for future studies.

In terms of *method*, both theories and empirical studies should make efforts to develop explanations and predictions which are consistent at the levels of analysis of firms, industries and aggregate economy. Too often the findings at one level of analysis contradict the patterns at the more aggregate level. Ideally, this would require firm level data to be representative of whole sectors, and industry coverage to account for all the economy (i.e. including services). Innovation survey data, when accessible, could make this effort possible.

Studies on *firms* could address the innovation-employment question in the context of the evolution of firms and market structures through the processes of diversity generation (through innovation) and selection (in the marketplace, Nelson and Winter, 1982), as the potential for job creation depends of the dynamics of firms' growth and new firms generation.

An important challenge to innovation studies is to extend to *services* studies generally confined to manufacturing industry. From a theoretical perspective, an analysis linking structural and technological (and organisational) change is highly appropriate to account for the expansion of services in advanced economies. In empirical terms, the increasing availability of industry level data also for services (such as in European innovation surveys) makes this extension possible. As most new jobs are created in services, this is highly relevant also from a policy perspective.

The need to devote greater attention to *organisational innovations* and to link them to technological ones has already been pointed out; this appears as a major direction for future studies.

Bringing the analysis of the innovation-employment link into the *macroeconomic context of an open economy* is also important, in order to highlight the interactions between technological developments on the supply side and growth potential on the demand side, as well as the interactions between innovation and trade in shaping growth and employment outcomes.

As *international production*, especially in manufacturing industries, becomes a key aspect of industrial structures, an additional level of analysis, looking at individual industries at the global level, may emerge. Data constraints are serious, but substantial evidence is now available on the international production networks of multinational corporations and the link to employment variables across the relevant countries may become possible.

The *appropriate labour market arrangements* for favouring a virtuous circle between innovation and a high quantity and quality of jobs and wages, through greater learning, competence building and improved working conditions is an additional area for future research.

Finally, as already suggested, research could address the *distribution* effects innovation throughout the economy, which are much deeper than their effects on wage polarisation and have a major policy relevance.

Policy considerations

Five key principles for policy emerge from the evidence gathered in this chapter (see Vivarelli and Pianta, 2000 and Lundvall and Borras in this volume).

The first is the need for a *pro-employment* policy, focusing on employment friendly innovation; the distinction between product and process innovations should inform policy in this field. Supply-side incentives and funds for innovation should introduce a clear focus on the type of innovative activities more likely to result in market-creating new products, rather than in labour-displacing new processes.

The second one is the need for *targeting* the industries with the greater potential for growth and employment, and for specific actions directed at the needs of individual industries, with policies relying less on the traditional supply push incentives, and stimulating more the demand pull effects of new potential markets and the active role of users.

The third one is the need to *expand education and learning* throughout the economy - in schools, universities, in continuing education and on the job - in order to accelerate social change and support the demand for higher skills coming from innovative economies, industries and firms.

The fourth one is the need for taking seriously *the systemic nature of innovation* and the role of national innovation systems (see the chapters by Edquist and by Lundvall and Borras in this book). This implies a strong *coherence* between industrial, technology, learning and macroeconomic policies.

The fifth one is the need for policies on the *distribution* of the productivity gains made possible by new technologies. So far innovation has mainly benefited firms and consumers, in the form of higher profits and lower prices. The result has been an increasingly uneven distribution of wages and incomes. If we want all to share in the benefits promised by the new technologies, it is vital that these negative trends be reversed through the pursuit of a new generation of policies.

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Table 22.1
A summary of approaches to Innovation and Employment

Main research questions *Does technology creates or destroys jobs?*	**General approach**	**Major streams of literature and key findings**	**Key assumptions and methodology**	**Main level of analysis**
Equilibrium of product and labour markets				
What is the amount of jobs created/lost What is the skill composition What is the structure of wages	Labour economics	Job demography and flexibility of labour markets Technical change favors more skilled workers, replaces the unskilled, exacerbates inequality Supply of educated workers shapes technical change Technological unemployment is irrelevant	Product and labour markets are in equilibrium The absolute level of job lost/gained is irrelevant Complementarity between ICTs and high skills	Firms, industries, macroeconomy
What are the returns from innovation	Growth	Technology, productivity, growth, employment: innovation may raise the natural rate of unemployment	Standard production function, focus on process innovation	Industries, macro
What is the innovation input to growth	New growth theory	Endogenous innovation, growth and employment: unemployment may happen	Innovating and non innovating firms, spillovers, focus on process innovation	Macroeconomy
Disequilibrium perspectives				
What is the type of innovation What is the amount/nature of unempl.	Evolutionary	Technological opportunities, variety, regimes: firms' strategies and industries' outcomes are different	Innovation brings disequilibrium in markets New product markets emerge	Firms, industries
What are the structural factors What are the demand factors	Neo-Schumpeterian	Techno-economic paradigms and long waves: mismatches can lead to unemployment	Radical innovations, pervasiveness, diffusion of new technology systems and ICTs	Industries, macro
What are the distribution effects What are the institutions	Structural	Sectoral composition of economies: specificity of innovation and demand, different job results	Innovation is differentiated: constrasting effects of new products and processes	Industries
	Regulationist	Macro models for testing indirect effects of innovation: compensation mechanisms may not work	Industries are different, demand is important Countries are different, institutions are important	Macroeconomy

Table 22.2
Presence, quality and impact of innovation in European countries
Technological innovations introduced by firms in 1994-1996
Percentage of all firms

	Innovating firms			**Manufacturing industry**		
	Manufacturing	**Services**	Firms introducing product innovations	Firms introducing process innovations	Firms introducing products new to the market	Percentage of turnover due to products new to the firm
European Union (14 countries)	51	40	44	39	21	12
Austria	67	55	60	49	24	13
Belgium	34	13	31	22	14	6
Denmark	71	30	58	51	27	7
Finland	36	24	30	25	18	9
France	43	31	38	31	20	9
Germany	69	46	65	53	24	17
Ireland	74	58	66	54	27	17
Italy	48	31	37	41	26	8
Luxembourg	42	49	32	29	21	na
The Netherlands	62	36	56	46	28	7
Portugal	26	28	15	23	7	9
Spain	29	na	24	25	11	10
Sweden	54	32	48	38	25	14
United Kingdom	59	40	52	37	19	8
Norway	48	22	35	40	14	10

Source: European Commission-Eurostat, Statistics on Innovation in Europe. Data 1996-1997, Luxembourg, 2001.
Data from Community Innovation Survey 2

Table 22.3
Effects of innovation on the quantity of employment
Selected empirical studies

Study	Countries	Years	Level of analysis	Innovation data sources	Results on employment
Firm level studies					
Entorf and Pohlmeier, 1990	Germany	1984	Cross firm, manuf.	Group of German firms	Positive with product innovation
Machin and Wadhwani, 1991	UK	1984	Cross firm, manuf.	British workplace industrial relations survey	Positive
Blanchflower, Millward and Oswald, 1991	UK	1984	Cross firm, manuf.	British workplace industrial relations survey	Positive
Brouwer, Kleinknecht and Reijnen, 1993	Netherlands	1983-1988	Cross firm, manuf.	Dutch survey	Negative Positive with product innovation
Meghir, Ryan and Van Reenen, 1996	UK	1976-1982	Panel of firms, manuf.	SPRU innovation database and patents	Positive more flexibility
Klette and Forre, 1998	Norway	1982-1992	Panel of manuf. firms	Norway universe of manuf.	Negative
Van Reenen, 1997	UK	1976-1982	Panel of manuf. firms	Survey on UK firms	Positive
Smolny, 1998	Germany	1980-92	Panel of manuf. firms	Survey on German firms	Positive
Greenan and Guellec, 2000	France	1986-1990	Cross firm, manuf. Cross sector	Innovation survey	Positive at the firm level Negative at the industry level for process innovations

Industry level studies					
Meyer Kramer, 1992	Germany	1980s	Input output model all economy		Negative, differentiated by sector
Pianta, Evangelista and Perani, 1996	G6 countries	1980-1992	Cross sector 36 manuf. industries	R&D and patents	Differentiated by country
Vivarelli, Evangelista and Pianta, 1996	Italy	1985	Cross sector 30 manuf. industries	Innovation survey	Negative of process innovation Positive of product innovation
Pianta, 2000, 2001	5 EU countries	1989-1993	Cross sector 21 manuf. industries	Innovation survey	Overall negative Positive of product innovation
Antonucci and Pianta, 2002	8 EU countries	1994-1999	Cross sector 10 manuf. industries	Innovation survey	Overall negative Positive of product innovation
Evangelista and Savona, 2002, 2003	Italy	1993-1995	Cross sector service industries	Innovation survey	Overall negative, differentiated by service industries and size

Macroeconomic level studies					
Sinclair, 1981	US	1946-1973	Macro model		Differentiated by compensation mechanism
Layard and Nickell, 1985	UK	1954-1983	Macro model		Neutral
Nickell and Kong, 1989	UK	1974-1985	Manuf. industry		Mostly positive
Vivarelli, 1995	US and Italy	1966-1986	Macro model	R&D linked to product and process innovations	Differentiated by compensation mechanism and country
Padalino and Vivarelli, 1997	G7	1960-1994	Macro model		Differentiated
Pini, 1998	G6 and Sweden	1960-1995	Macro model		Differentiated by country and periods
Simonetti, Taylor and Vivarelli, 2000	US, Italy, France, Japan	1965-1993	Macro model	R&D linked to product and process innovations	Differentiated by compensation mechanism
Simonetti and Tancioni, 2002	UK and Italy	1970-1998	Macro model quarterly data	R&D linked to product and process innovations	Differentiated by compensation mechanism
Simulation studies					
Leontief and Duchin	US	1980-2000	Input output model all economy	Assumptions on performance	Negative
Kalmbach and Kurz	Germany	2000	Input output model all economy	Assumptions	Negative
IPTS-ESTO, 2001	Europe	2000-2020	Gen. equil model all economy	Assumptions on productivity growth	Positive, differentiated by innovation policy

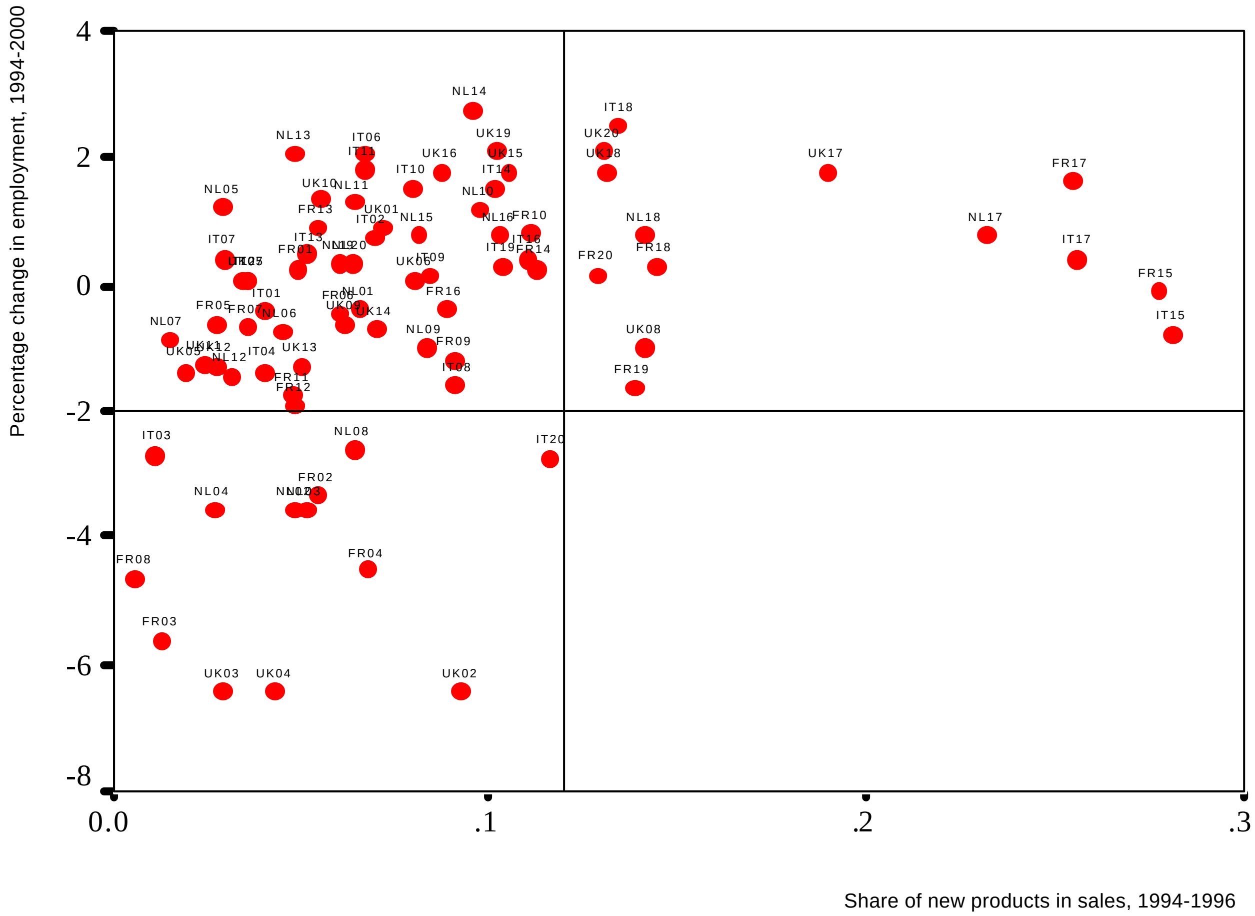
Table 22.4
Effects of innovation on the quality of employment: skills, wages and organisations
Selected empirical studies

Study	Countries	Years	Level of analysis	Innovation data sources	Results
Skill biased technical change					
Firm level studies					
Machin, 1996	UK	1984-1990	Cross firm, manuf. cross sectors	British workpl. ind. rel. surv. R&D, innov., computer use	Positive effect on high skill jobs Negative on least skilled ones
Doms, Dunne and Troske, 1997	US	1988, 1993	Panel and cross firm	Use of 5 manuf. technologies	Higher skill where technologies are used; in panel: only for computers Higher wages where technologies are used; in panel no effects
Caroli and Van Reenen, 2001	UK and France	1984-1990 1992-1996	Panel and cross firm	% or workers affected computer use	Positive effects on skills in the UK Weak in France Organ. innov. has stronger negative effects on low skill
Bresnahan, Brynjolfsson and Hitt, 2002	US	1987-1994	Panel and cross firm	IT stock and use	Positive effect on skill demand combined with organ. change

Industry level studies					
Howell and Wolff, 1992	US	1970-1985	Cross sector all private economy	Exp. on computers, new investment	Positive on cognitive skill jobs Negative on interactive and motor skills
Berman, Bound and Griliches, 1994	US	1979-89	Cross sector 4 digit manuf. industr.	R&D and computer invest.	Higher skill where technology is higher
Wolff, 1996	US	1970-1990	Cross sector all private economy	Exp. on computers, R&D	Positive effect on complexity of tasks Negative on motor skills
Autor, Katz and Krueger, 1998	US	1960-1995	Cross sector all economy	Computer use, R&D, TFP	Faster upskilling in high tech industries, and after 1970
Machin and Van Reenen, 1998	7 OECD countr.	1970-1989	Cross sector 2 digit manuf. industr.	R&D intensity	Higher skill where R&D is higher in all countries

Technology and wage dispersion					
Firm level studies					
Casavola, Gavosto and Sestito, 1996	Italy	1986-1990	Cross firms	% of intangible capital INPS wage data	Positive effect on skills Limited wage dispersion
Machin and Van Reenen, 1996	Italy, France, UK, Germany	1982-1990	Cross firms	Lagged R&D intensity	Positive effects on wages, stronger in UK and Germany
Van Reenen, 1996	UK	1976-1982	Panel and cross firm	Innov. counts and patents	Positive effects on wages
Black and Lynch, 2000	US	1993-1996	Panel and cross firm manuf.	Computer use, organ. changes	Higher wages and productiv. with tech. use and organ. change involving employees
Industry level studies					
Bartel and Lichtenberg, 1991	US	1960, 1970 1980	Cross sector manuf.	Computer invest., R&D	Wage premia with newer technologies
Bartel and Sicherman, 1999	US	1979-1993	Cross sector manuf.	Computer invest., TFP, etc Nat'l. Long. Survey of Youth	Wage premia in high tech industries
Organisational innovation					
Firm level studies					
Caroli and Van Reenen, 2001	UK and France	1984-1990 1992-1996	Panel and cross firm	% or workers affected Computer use	Negative effects on low skill in both countries
Piva and Vivarelli, 2002	Italy	1991-1997	Panel and cross firm	R&D, organ. change	Positive effects of organ. inn. on skills no effect of technology
Greenan, 2003	France	1988-1993	Panel and cross firm	Tech. invest, organ. change	Positive effects of organ. inn. on skills less effect of technology

Figure 22.1 Share of new products in sales and employment change



Industry codes
(2 digit nace rev.3)

01 Food products
02 Textiles
03 Apparel
04 Leather and footwear
05 Wood
06 Pulp and paper
07 Printing and publishing
08 Petroleum products
09 Chemicals
10 Rubber and plastic
11 Non metallic minerals
12 Basic metals
13 Fabricated metal products
14 Machinery and equipment
15 Office, computing machinery
16 Electrical machinery
17 Communication equipment
18 Precision instruments
19 Motor vehicles
20 Other transport equipment

Source: CIS 2-SIEPI Innovation Database, University of Urbino and OECD STAN data