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Introduction[1]

Unemployment, skill polarisation and growing wage inequality are major problems in advanced countries. Technological change - in particular the emergence of Information and Communication Technologies (ICTs) - has often been called into question as a factor in such labour market developments. This article investigates the impact innovation has on jobs, skills and wages, discussing the concepts for analysis, reviewing the evidence of major studies and providing recent empirical evidence for European countries.

1. The analysis of innovation and its impact

In investigating the employment impact of innovation, a useful starting point is the classical Schumpeterian definition of innovation in products, processes, organisations, markets and sources of supply (Schumpeter, 1934).
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.
These types of innovation greatly differ in their nature, economic relevance and labour market impact, and have to be addressed separately. However, such a variety is usually neglected in studies of innovation's impact, due to the difficulty to document them empirically, and to the

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frequent reliance on traditional indicators such as R&D and patents that fail to account for the relevance of process innovations, imitation and adoption strategies.

Product innovations (in both manufacturing and service industries) can be based on internal innovative activities as well as on the acquisition of new intermediate or capital goods. They may replace old products or may be designed in order to reduce costs, with little or no net effect on employment, skills and wages. On the other hand, new products meeting a demand with high elasticity may expand output, leading to job creation; may increase variety and quality, leading to skill upgrading; both developments may turn a part of the productivity increases into higher wages.

Process innovations (including those in the delivery of services) usually replace labour with capital (often with new investment based on information and communication technologies), leading to efficiency gains and job losses. Skills can either be upgraded or downgraded depending on the nature of technology, firm strategies, and the related organisational innovation. Wages may change accordingly (Pianta, 2001).

When the new products are investment goods, they represent a product innovation in the industries producing them, and process innovations in the industries acquiring them, with contrasting effects on jobs and skills in the different sectors (Edquist, Hommen and McKelvey, 2001).

The orientation of innovative efforts in firms and industries is heavily affected by the technological regime, shaping the opportunities for innovation, and by firm strategies concentrating either on price competitiveness (and mainly process innovations) or on technological competitiveness (and mainly product innovations).

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 view of technology as information and the reliance on knowledge spillovers. More recently, new growth theories have made efforts to endogenise innovation considering R&D activities, learning or human capital as factors contributing to growth, while differentiating between innovating and non innovating firms. 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. Moreover, the interaction between technological change and labour market developments - changes in employment, institutions and regulation systems - is not addressed in the new growth theory framework.

Neo-Schumpeterian insights, in a perspective considering structural change and economic evolution, provide the most appropriate tools for understanding innovation and its impact on jobs, skills and wages[2]. The next section addresses the impact of innovation on job creation and loss with a review of recent literature. Section 3 is devoted to the impact on skills, section 4 to effects on wages, followed by a section with empirical evidence on the link between innovation, jobs and wage polarisation in Europe. Section 6 concludes and discusses some policy issues.

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[2] For a broad discussion on theories see Petit, 1995; on concepts and empirical studies see Pianta (2004); sections 2-4 of this article summarise and expand the evidence provided there. Key works on innovation-employment issues include Heertje (1973); Freeman, Clark, and Soete (1982); Freeman and Soete (1987,1994); Freeman and Louçã (2001); Vivarelli (1995); Vivarelli and Pianta (2000).

2. The impact on jobs

The impact of innovation on the *quantity* of employment, defined in terms of the number of jobs created or lost, is reviewed in this section considering studies at the firm and industry levels.[3]

The most direct employment impact of innovation is found in the firms that introduce them, and the evidence available suggests that firms innovating 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.[4] Using a variety of measures of innovation, a positive impact on jobs has emerged in the studies by Machin and Wadhwani (1991), Blanchflower, Millward and Oswald (1991), Blanchflower and Burgess (1999) that used the British workplace industrial relations survey on the adoption of ICTs; the latter also found weaker similar evidence for Australia. Similar findings emerged in Van Reenen (1997), on a large panel of UK manufacturing firms related to the SPRU database of British innovations. 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. A generally negative impact of innovation on jobs has been found for Dutch firms by Brouwer, Kleinknecht and Reijnen (1993), although product innovations had a better effect on jobs. In Norway, Klette and Forre (1998) have found a negative association between R&D and employment at the plant level.

However, firm level studies cannot identify whether the gains of innovating firms are made at the expense of competitors, or whether there is a net effect on aggregate industry. In the study on France by Greenan and Guellec (2000), the positive relationship between both product and process innovation and employment at the firm level disappeared at the industry level (where only product innovation was associated to job creation). Entorf, Gollac and Kramarz (1999), in their study based on the household survey in France, found that computer use reduces the risk of unemployment only in the short term. Moreover, new technologies are often linked to innovations in organisations; Greenan (2003) has considered a large and representative sample of French firms that introduced advanced manufacturing systems in 1988-93, finding that firms innovating in both technologies and organisations have created more jobs than firms introducing only the latter and than non innovators.

Industry level studies are particularly important as they can identify the overall effect of technological change within a sector, accounting for both the direct impact in innovating firms and the part of the indirect effects that operate within the industry. Studies on industries have shown that the sources and opportunities for technological change and job creation are specific in individual manufacturing and service industries, and such factors are key determinants of employment performances.

Of particular interest are the studies based on innovation surveys (available for Europe only), that account in a more satisfactory way for the complexity of the innovation process and its impacts. The evidence shows that in European industries in the 1990s employment generally decreased as a result of weak demand expansion, high wage dynamics, and weak product

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[3] Measuring employment with the number of jobs becomes questionable as the relevance of part time work increases in several countries; the appropriate indicator would be employment in full time equivalent units. For reviews see Chennells and Van Reenen (1999); Spiezia and Vivarelli (2002).

[4] A methodological note should be made here. Most studies have used annual surveys of firms in panels that usually are not representative of the whole manufacturing industry (services are rarely considered) and therefore the results cannot be easily generalised.

innovation; a higher intensity of innovative expenditure contributed to job losses due to the prevalence of labour saving process innovations. Weak growth and the pressure towards cost-based competition in most industries has resulted in the emergence of technological unemployment in Europe.[5]

Innovation appears to have a net job creating effect in those manufacturing and service industries showing high demand growth and an orientation towards product innovation, while new processes result in job losses. The overall effect of innovative efforts depends on the countries and periods considered, but in general is more positive the higher demand growth, the importance 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. Differently from the analysis of firms, whose demand is expected to be highly elastic, an industry's demand is constrained by the (relatively slow) evolution of domestic and foreign demand.
A major lesson for research and policy from firm and industry level studies is that a clear distinction is needed between product innovation (with job creating effects) and process innovation (usually with negative employment effects).[6]

3. The impact on skills

The impact innovation has on the *quality* of jobs has recently attracted widespread attention with studies on the skill biased nature of current technological change. Such studies, mainly relative to the United States, move from a view of labour markets in equilibrium, disregard the overall effects of innovation on the amount of jobs created and lost, and focus on the

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[5] Vivarelli, Evangelista and Pianta (1996) have studied Italian manufacturing industry in the 1980s, finding a negative employment effect of innovation and an opposing impact of changes in products and processes. Pianta (2000, 2001) has investigated five European countries in 1989-93 across 21 manufacturing industries, finding a positive employment effect of changes in demand and products, and an overall negative impact of innovation intensity. Antonucci and Pianta (2002) have found similar results on eight EU countries and ten industries in the latter half of the 1990s. The same negative effect has emerged also in studies by Evangelista and Savona (2002, 2003) on service industries in Italy; heavy job losses were found in the largest firms, among low skilled workers, in sectors heavy users of ICTs, in capital intensive and finance-related ones; net job creation emerged in smaller firms and in technology-oriented activities.
[6] The issues and the evidence reviewed so far do not include the size distribution of firms as one of the factors - alongside innovative efforts and technological regimes - affecting growth and employment change in industries. This literature has suggested on the one hand that successful firms may experience sustained growth and, on the other hand, that small firms can be strong job creators. The conceptual link to innovation, however, is not straightforward and the resulting evidence is mixed (see Acs and Audretsch, 1990; Geroski, 2000). For instance, Bottazzi, Cefis and Dosi (2001) investigated a panel of several thousands Italian manufacturing firms from 1989 to 1996 and found strong heterogeneity in production efficiency, but this did not lead to systematic differences in growth rates across firms.

relative importance of skilled and unskilled jobs. Studies on wage polarisation (reviewed in the next section) follow closely from such an approach.

The impact of technology on skills has long been at the centre of disputes. The industrial revolution (as Marx pointed out) was based on a process of mechanisation that led to the deskilling of artisans; such a model - machines incorporating human knowledge and making it possible to use cheaper and less qualified labour - has dominated the production system for over a century (Braverman, 1974), and it may still be found in parts of manufacturing and in low skill services. The technologies of the late XX century, on the other hand, have increasingly required the employment of workers with greater skills, matching the increasing supply of highly educated labour.

Skill levels - usually (crudely) measured with educational levels or blue/white collar occupations - experience a general increase, according to a large number of recent studies that have pointed to the skill biased nature of current technological change. 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 wage polarisation (Chennells and Van Reenen, 1999; other reviews are in Sanders and ter Weel, 2000 and Acemoglu, 2002).

In this wave of studies the diffusion of information and communication technology is considered as a key factor accelerating the upskilling process. Berman, Bound and Griliches (1994) and Autor, Katz and Krueger (1998) have opened the way for this literature, finding that, across US industries over long time periods, R&D and computers have been associated to faster upskilling of the workforce. Machin and van Reenen (1998) have extended the analysis to industries in 7 OECD countries, finding that R&D intensity was linked to the presence of higher skills. Studying panels of firms in the US, Doms, Dunne and Troske (1997) found that the use of computers was associated to higher skill levels (but no effects were found on wages). Bresnahan, Brynjolfsson and Hitt (2002) considered the IT stock and its use in another panel of US firms, finding a positive effect on skills when organisational change was also present.[7]

However, when skills are defined more carefully, the relationship with computerisation is more controversial. A study by Howell and Wolff (1992) has identified jobs characterised by cognitive skills (typical of technical staff), interactive skills (typical of supervisory staff) and motor competences (typical of manual workers) in US industries between 1970 and 1985. The main effect of industry level spending on computers and new investment has been a greater demand for high cognitive skill workers, leading to a more complex picture of the technology-skill relationship. Moreover, looking at aggregate US employment, Howell (1996) found that major shifts in the skill structure took place between 1973 and 1983, with little variation in the 1980s, when diffusion of ICTs accelerated. Computer-related investment per employee increased seven fold between 1982 and 1992, and in the late 1980s the heaviest falls in their employment shares were recorded by high skilled blue collars and low skilled white collars.

In fact, blue collar unskilled jobs have *grown slowly* in the United States (outpaced by the growth of high skilled white collar jobs) but they have actually *declined* in Europe, where in contrast the argument of skill biased technological change has received much less support. Furthermore, 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, p.34) point out. Evidence has been found on upskilling *within* the firms and the industries

[7] Another possible explanation for the decline of unskilled workers is the increase in international trade with countries specialised in low skill labour. Berman, Bound and Machin (1998) compared the effects of trade with that of technological change, finding that the latter accounted for most of the fall in demand for less skilled workers in the United States.

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). 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 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).

The impact of organisational innovation

Studies on skill change have often explored the relevance of organisational innovation associated to the introduction of new technologies. The opposing processes of deskilling and upskilling emerge again in research addressing organisational innovation. 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, 1984).
Organisational change has been investigated in a survey of US manufacturing plants, carried out in 1993 and 1996 by Black and Lynch (2000). The number of non managers using computers - an indicator of diffusion of new technologies - and the adoption of new work practices emerge with a strong association to productivity and wages. The same results were found by Appelbaum and Batt (1994) on manufacturing and service firms in the US.
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.[8]

[8] 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,

The increased productivity resulting from new technologies and organisations has often taken the form of the intensification of work, with firms pressuring workers to produce more effort in their activities. In studies on the UK and Australia, Green (2004) has found that computer usage is strongly associated to higher effort levels. Part of the explanation is the increased possibility to monitor work through ICTs, the weakening (or absence) of trade unions and overall changes in social relations and attitudes to work that may lead to greater commitment and effort.

Such processes, however, tend to be specific in different economic activities. Service industries and firms have been invested by particular combinations of changes in technologies and organisations and the introduction of ICTs has often been targeted to overcoming time and space constraints in the production and delivery of services. Several studies have identified here a growing polarisation of skills (and wages) as a result of changes inside firms and in its boundaries, with the greater importance assumed by networks, outsourcing and subcontracting (Petit and Soete, 2001b; Frey, 1997).

While the analysis of organisational innovation and its impact on the quality of employment may lead to several different directions, the available evidence suggests that innovations in technologies and in organisations can represent complementary factors, as firms pursue a strategy of change; conversely, when firms face downsizing and restructuring, they can become alternative paths for adjustment.

4. The impact on wages

As technological change reshapes the quantity and quality of jobs across firms, industries and countries, wages are bound to reflect such an evolution. As in the case of skills, research has largely investigated the *relative* dynamics of wages, focusing on the polarising effects of innovation. Surprisingly little research, on the other hand, has addressed the impact of innovation on the *absolute* levels of wages, on their relation to profits and rents, and on the associated changes in work hours and prices, addressing the broader *distribution* effects of technological change.

Studies on innovation and wage polarisation found that wages tend to be higher and grow faster in industries with higher technological opportunities, and for workers with higher education or using computers at work (for reviews see Chennells and Van Reenen, 1999; Sanders and ter Weel, 2000; Acemoglu, 2002).

Higher wages when computers are used are found for US firms by Krueger (1993) and by Black and Lynch (2000) who investigated computer use and organisational change in US firms. For US industries, Bartel and Lichtenberg (1991) and Bartel and Sicherman (1999) found similar results of technology based wage premia. Casavola, Gavosto and Sestito (1996) in a study on Italian firms found that the share of intangible capital, used as a proxy of technology levels, had a positive effect on skills and led to a limited wage dispersion. Higher wages when technology is used are found by Van Reenen (1996) who considered innovation counts and patent data for UK firms.

However, many of these results can identify a spurious correlation, as more competent and educated workers are likely to receive higher wages, and equally likely to make an above average use of computers and new technologies. As for the debate on skill bias, the idea that technology is a determinant of wage polarisation has been questioned by studies pointing out

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compentence building and problem solving (Leoni, 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 higher profits, high shares of blue collar workers, low hierarchies and greater management-worker interactions (Antonioli et al., 2003).

that the latter process has largely anticipated the diffusion of ICTs in the 1990s and did not accelerate as a result of it. Moreover, wages are more exposed than skill levels to competition from international trade and to changes in the sectoral composition of the economy (Mishel and Bernstein, 1996; Addison and Teixeira, 2001).

The relationship between innovation and wages may run also in the opposite direction. Kleinknecht (1998) has suggested that low wages and high labour market flexibility eliminate a major incentive for introducing innovation in firms. The Dutch experience of wage moderation and extreme flexibility in labour market arrangements has indeed led to extensive job creation, especially in small and medium-sized firms, often in part time employment, but this was made possible by low productivity growth. According to Kleinknecht (2003), in the 1980s and 1990s the rate of increase of GDP per working hour in the Netherlands has been half that of the European average, raising questions on the viability of such a model in the longer run.

Considering the complexity of the issues, explanations of the changing wage structure have to consider, besides the role of technology, the growth of aggregate demand, the competitive pressures on firms and industries, the dynamics and quality of labour supply, in the context of specific labour market institutions and social relations. While technological change does have a major impact on absolute and relative wage levels, it has an even stronger influence on the distribution of the productivity gains made possible by new technologies. The relationship between innovation and wages has therefore to be investigated in the context of macroeconomic distributional patterns, of industry-level sharing of productivity gains, of broad changes in social relations and trade unions activity, of national wage and welfare policies.[9]

Europe and the US do represent opposite patterns in this regard. The Unites States has experienced faster growth of population, labour supply and GDP than Europe, 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. Conversely, in Europe greater competitive pressure and slower growth have favoured changes in process technologies and organisations that have reduced low skill employment while creating few new jobs; at the same time wage polarisation has been mitigated by the stronger European rules on wage setting and employment protection.

Developments in the US have been described as a ‘low road’ (Howell, 1996), as firms have searched for lower labour costs through cuts in wages and in permanent staff, use of part time and temporary workers, anti-union practices, relocation to low wage production locations and inflows of low wage foreign workers. Such strategies are now increasingly found in Europe too. In fact, the decline of the traditional model of full time, life time, waged (and unionised) employment is a major process of change in all advanced economies, with firm strategies and governments policies leading to a rapid growth of flexible, temporary, part time, subcontracted work.

At the same time, social dynamics is leading to new waves of labour militancy in many countries, with demands for higher wages, a reversal of the ‘precarisation’ of work, renewed welfare protection, shorter working time (in some European countries), greater training and life long learning, more meaningful jobs and the development of socially useful activities carried out in the ‘third sector’ of non profit organizations. The diffusion of new technologies

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[9] Many of these issues are addressed by the Labour Market Segmentation approach (Villa, 1986). Simonazzi (2003) links recent developments in employment and skills to such a view of labour markets, institutions and social relations.

and the combination of technological, organisational, institutional and social innovations will have to provide answers also to these broader social demands.

5. Evidence on jobs and wages from the third Community Innovation Survey

The above discussion on research results can now be updated with preliminary evidence drawn from the newly released data of the third European Community Innovation Survey, covering the 1998-2000 period. In this section the main patterns in innovation in Europe and their impact on jobs and wages are investigated in a descriptive way. Eight countries (Austria, Finland, France, Germany, Italy, the Netherlands, Sweden, the UK) and 19 sectors of both industry and services (listed in the Appendix) are considered.[10] An overview of innovative performances is first presented, followed by a mapping of the association innovation has with employment change and with wage growth, concluding with new evidence on wage polarisation in Europe.

A first important result of the third European Community Innovation Survey is the picture it provides of innovative efforts by European firms and industries. The share of firms which over that period have introduced either one product or one process innovation in manufacturing industry is 62 per cent in Germany, 52 in the Netherlands, 44 per cent in Austria and Finland, 41 per cent in France, 40 per cent in Sweden, 38 per cent in Italy and 32 per cent in the UK. In services, shares are generally lower, but the ranking of countries is similar. Such results show a broad stability when compared with the findings of previous European innovation surveys.[11]

A second important indicator of the economic relevance of innovations is the share of turnover of firms that is due to new or improved products. Data for 2000 show that in manufacturing Germany leads again with 32 per cent, followed by Finland, Austria, Italy and the Netherlands (20 per cent), France, Norway and the UK (10 per cent). In services ranks are reversed with the UK first with 24 per cent, followed by Italy (12 per cent), Germany, France, Austria, Finland and Norway.

Such substantial national differences are amplified when data for the 19 sectors of industry and services are considered. Higher-tech industries (machinery, electronics and transport) and higher-tech services (computers and R&D) emerge with the highest values in both innovation indicators in all countries. The lowest innovative activities are found in services that tend to be labour intensive such as wholesale trade, transport and storage, and in the utilities (electricity, gas and water).

Figure 1 provides an updated descriptive evidence of the relationship between innovation and employment growth in European industries, showing the share of innovating firms and the average annual growth rate of jobs, 1995-2001.[12] A major contrast between industry and services is visible here. Computer services cluster at the top of the graph, with exceptional growth performances and above average innovation even in the countries where the industry is weaker. R&D services, on the other hand, are the most innovative ones, but account for a

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[10] Data are drawn from large samples of firms over 10 employees; the results have been reported to the universe and therefore account for total economic activities in the industries concerned. Data used here are from a collection of national sources.

[11] The results of the second EU survey are published in European Commission-Eurostat (2001).

[12] Unfortunately data for full time equivalent employment were not available for all countries; in the figures, lines representing the median of the distributions of both variables are shown.

small employment base and a modest expansion. A cluster of low innovation but labour intensive (and job creating) services (wholesale trade and transport in partucular) also emerges. Manufacturing industries appear to be polarised between the group of high innovation industries - machinery, electronics, transport and chemicals, with above average shares of firms introducing product or process innovations and stable or slowly growing employment - and the rest of manufacturing, lagging behind in terms of innovation and experiencing frequent job losses in the 1995-2001 period.

A simple way of drawing together the evidence on the dynamism of European industries is to consider four indicators of innovative and economic performance - the share of innovating firms, the share of turnover due to new products, the growth rates of value added and employment - and calculate for each sector the average of its ranks in the four indicators. The 15 industries that are best performers among the 19 sectors of the nine countries include: the manufacturing of machinery (in the Netherlands), the electronics industry (in Finland and France), the transport equipment industry (in Austria and Germany), computer services (in Austria, Germany, Finland, the Netherlands and the UK) and R&D services (in Austria, Germany, Finland and Norway) plus testing services in Austria.[13]

Wage levels closely reflect the innovation intensity of European industries. Looking at the mean across the eight countries of annual wages per employee[14] in 2001, we find at the top computer, R&D and financial services, followed by the high innovation manufacturing industries - electronics, transport and machinery - with chemicals in the lead position together with the utilities (where wages are raised by the presence of round the clock operations in highly capital intensive productions). The lowest average wages in Europe are found in the sectors with less innovation - wholesale trade, other manufacturing, textile and food industries.[15]

While such differentials in wage levels are hardly novel in the analysis of industrial structures, it may be interesting to look at the changes in wages in recent years. Figure 2 relates the shares of innovative firms in European industries to the rates of growth of wages (calculated as average annual growth rates, 1995-2001). While the specificity of industries and countries prevents a clear general association between innovation intensity and wage growth to emerge, the clusters outlined above can be identified again.

Computer and R&D services are the most innovative sectors with sustained wage growth, even in the countries with a weaker technological dynamism. High innovation manufacturing industries have wage increases mostly above the median, led by the exceptional performances of the electronics industry in Sweden and Finland.[16] Conversely, low innovation industries

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[13] In these sectors the share of innovating firms ranges from 50 to 100 per cent, the share of turnover from new products ranges from 14 to 84 per cent , value added growth ranges from 3 to 21 per cent per year, and job creation from 0,6 to 18 per cent per year. By contrast, the worst performers always fall in three industries: textile, apparel and leather; wood, paper and printing; and electricity, gas and water. All countries are represented here (with France, Norway and the UK present in all three sectors), with the only exceptions of Germany and the Netherlands. In these industries innovation is always below the national average, value added is stagnating or declines and employment generally has dramatic losses.

[14] Data for wages and salaries were not available in some countries and sectors; the data used is total labour compensation per employee, that includes taxes and social contributions, at current prices.

[15] The ratio of the highest to the lowest average European wage across industries is 2.

[16] These are clearly affected by the presence of firms such as Ericsson and Nokia. In Figure 2 again, lines representing the median of the distributions of both variables are shown.

tend to have a modest wage dynamics, with a wide spectrum of variation, similar to the low technology but labour intensive services.
As wage increases tend to be higher in industries with wage levels already above average, we can expect to find a growing wage polarisation in European industries, supporting the evidence reviewed in section 4 above. A simple measure of wage dispersion across industries - the coefficient of variation (standard deviation divided by the mean) - has been calculated for for each country for 2001 and in 1995. Very wide differences emerge in Europe: the most 'unequal' countries are Italy and the UK, while Finland and Sweden are those with the lowest dispersion of wages across industries, followed by the Netherlands, France and Germany.
Starting from such levels of wage dispersion, what have been the changes in recent years? The algebric differences in the coefficients of variation of 2001 and 1995 - showing the increase or decrease in wage dispersion - is mapped together with the shares of innovating firms in Figure 3. Industry wages have become more polarised in the countries that started from a more equal distribution and have higher innovative intensities. The UK and Italy, the laggards in innovation and the most 'unequal' countries, are the only ones reducing wage dispersion across industries.
The descriptive evidence provided in this section supports some of the research results on the impact of innovation on employment and wages reviewed above. Industries and countries do differ in their innovative intensity and in their ability to increase jobs and wages. The expected polarisation trends characterise most European countries, but they are reversed where wage dispersion is already very high, and innovation is lagging.

6. Policy directions

The amount of evidence discussed in this article has wide ranging policy implications. Here five key principles for policy will be discussed, focused on the specific ways innovation is supported and oriented by public action, and emerges as a force for change in industries and in the economy, leaving aside the broader labour market policies that greatly affect skill and wage dynamics (see also Vivarelli and Pianta, 2000). Such policies have to be developed at the appropriate level; actions by national governments need be integrated at the regional, European and global level, overcoming some of the limits of traditional national policies implemented in the past.

1. The first principle is the recognition that an *active, targeted innovation policy* is required in order to help shape the types of economic activities that a society would like to engage in, and the way they are organised on the basis of the opportunities offered by new technologies. Three perspectives could inform such policy.
First, policy should reconstruct a fertile relationship between *knowledge, research and innovation*. A recognition is needed that all innovative efforts are based on a wide pool of common, accessible knowledge, largely in the public domain, sustained by continued basic research and largely funded by public sources. In the past two decades policies for the privatisation of knowledge (such as stricter rules on intellectual property rights and incentives to universities and public research centres to market their inventions) have proven not to be appropriate and effective in speeding up the diffusion of knowledge and innovation, spreading more widely and evenly its benefits. The return of a major commitment of public funds to research and the recreation of large and accessible pools of knowledge, both basic and applied, are necessary conditions for a sustained innovative performance in the economy and for the successful development of new economic and social activities in leading edge technology fields.
Second, innovation policy should focus on *employment friendly innovations.* The distinction between product and process innovations - as we have seen in section 2 - plays an important role in shaping the economic and employment outcomes of technological change and 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 new products, rather than in labour-displacing new processes. Policies of indiscriminate financial support for supply-driven innovation by firms have led to major direct losses in employment. However, the discrimination in favour of the innovative activities likely to lead to product innovation can hardly be introduced at an early stage of the innovation process, where new generic knowledge is produced. The key for innovation policy is to focus on the applications of new technologies which can lead to new products. For instance, the relative incentives between carrying out R&D, design or trial production on the one hand and introducing innovation-related investment has to be tilted in favour of the former.

Third, greater attention should be paid to the *role of users* in sustaining and orienting the innovation process. So far, the evolution of most ICT activities has been driven by the design of suppliers rather than by the requirements of the users, resulting often in a limited expansion of new activites and in a unrealised potential of the new technologies. The “technology push” that in past decades has created countless innovations in ICTs appears now as a straitjacket for the expansion of economic activities based on ICTs, as what is lacking now are, on the one hand, the coordination and coherence of organisational, institutional and social innovations and, on the other hand, the operation of a “demand pull” able to launch the growth of new large markets for new goods and services (some of these issues are addressed in High level expert group, 1997). This “demand pull” should rely not so much on old-style public procurement, but rather on new schemes “empowering the users”, that might accelerate the development of markets for new goods and services, able to address existing specific social needs. In such a view, public procurement should abandon untargeted demand-led schemes and foster a selective public expenditure focused on ICT new products and systems (policies and rules supporting adoption of Linux based ICT systems in the public sector of several countries are examples).

2. The second principle for a new approach to innovation policy is the need for targeting industries and activities (often ICT-related) with the highest potential for growth and employment, for learning and ability to create new products and markets for unmet demands. Specific policy tools, operating both on the supply and demand sides, include a long-run strategy for repositioning the economy in the international division of labour; the provision of infrastructures and framework conditions for new sectors, new markets and new products; organizing private and public sector demand with incentives and procurement; action on regulatory and competition aspects, opening access for new producers; managing the contraction of declining industries, not just through income support policies, but with new activities.

3. A third principle is 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. Again, a large commitment of public funds is needed in this policy, as education is a major tool for spreading knowledge and supporting research activities, avoiding the simplistic request for an educational system closer to the short-term needs of firms. Incentives could be provided to firms and individuals (higher wages, tax deductions, etc.) to expand their competences and "human capital", in a comparable way to what happens with incentives to firms to expand their physical capital. Moreover, specific actions may be required for the problems of the low skilled and for assuring access to education to less favourite social groups, immigrant communities and less developed regions.

4. The fourth principle is the need for taking seriously the *systemic nature of innovation* and the role of *national innovation systems*. This implies a strong coherence between industrial, technology, labour market, learning and macroeconomic policies, that all too often are developed and implemented in isolation from one another, responding to very different pressures and constraints. The large literature on innovation systems has pointed out the key role played by close, effective, sustained and long term interactions between firms, universities and research centres, the financial sector, and government bodies. In such a perspective, a wave of institutional innovations, consistent with the new nature of technological change, may be required in order to reap all the benefits promised by the diffusion of ICTs.

5. The fifth principle is the need for policies on the *distribution of the productivity gains* resulting from technological change. Policies need to address not just the achievement of productivity gains, but also their distribution and the resulting economic and social effects. Over the past decades, innovation has mainly benefited firms and consumers, in the form of higher profits and lower prices, in a context of increasing pressure on firms from increasing international competition and from investors demanding high financial returns. Workers have seen job losses, increasing inequality, frequent reductions in real wages, more insecurity, work intensification, and often increased working time. The result has been an increasingly uneven distribution of incomes, made worse by the reduction of resources available for social redistribution through the tax system. If we want to reap 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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Appendix

In the Figures, country codes are the following:
AU Austria, FI Finland, FR France, DE Germany, IT Italy, NL the Netherlands, SW Sweden, UK United Kingdom
The listing of sectors for which both innovation data and employment and wage data are available is reported in the table below.
In Figure 1, 17 sectors are considered (for sectors 18 and 19 disaggregated data are not available). In Figure 2, 19 sectors are included (for sectors 18 and 19 the reported values of innovating firms are the same).
In Figure 3 the share of innovating firms for the whole countries is mapped with the differences in the coefficient of variation (standard deviation divided by the mean) of labour compensation per employee across 19 sectors in 2001 and in 1995.

Classification of economic activities

Code	NACE Rev. 1	Description of activity
1	15-16	Manufacture of food products, beverages and tobacco
2	17-19	Manufacture of textiles, textile and leather products
3	20-22	Manufacture of wood, wood products; pulp, paper and paper products; publishing a
4	23-24	Manufacture of coke, refined petroleum products and nuclear fuel; chemicals, chemical products and man-made fibres
5	25-26	Manufacture of rubber, plastic products and other non-metallic mineral products
6	27-28	Manufacture of basic metals and fabricated metal products
7	29	Manufacture of machinery and equipment
8	30-33	Manufacture of electrical and optical equipment
9	34-35	Manufacture of transport equipment
10	36-37	Manufacturing n.e.c.
11	40-41	Electricity, gas and water supply
12	51	Wholesale trade and commission trade, except of motor and motorcycles
13	60-63	Transport and storage
14	64	Post and telecommunications
15	65-67	Financial intermediation
16	72	Computer and related activities
17	73	Research and development
18	74.2	Architectural and engineering activities and related technical consultancy
19	74.3	Technical testing and analysis

Figure 1 - Annual rate of change of employment and innovating firms by country and sector

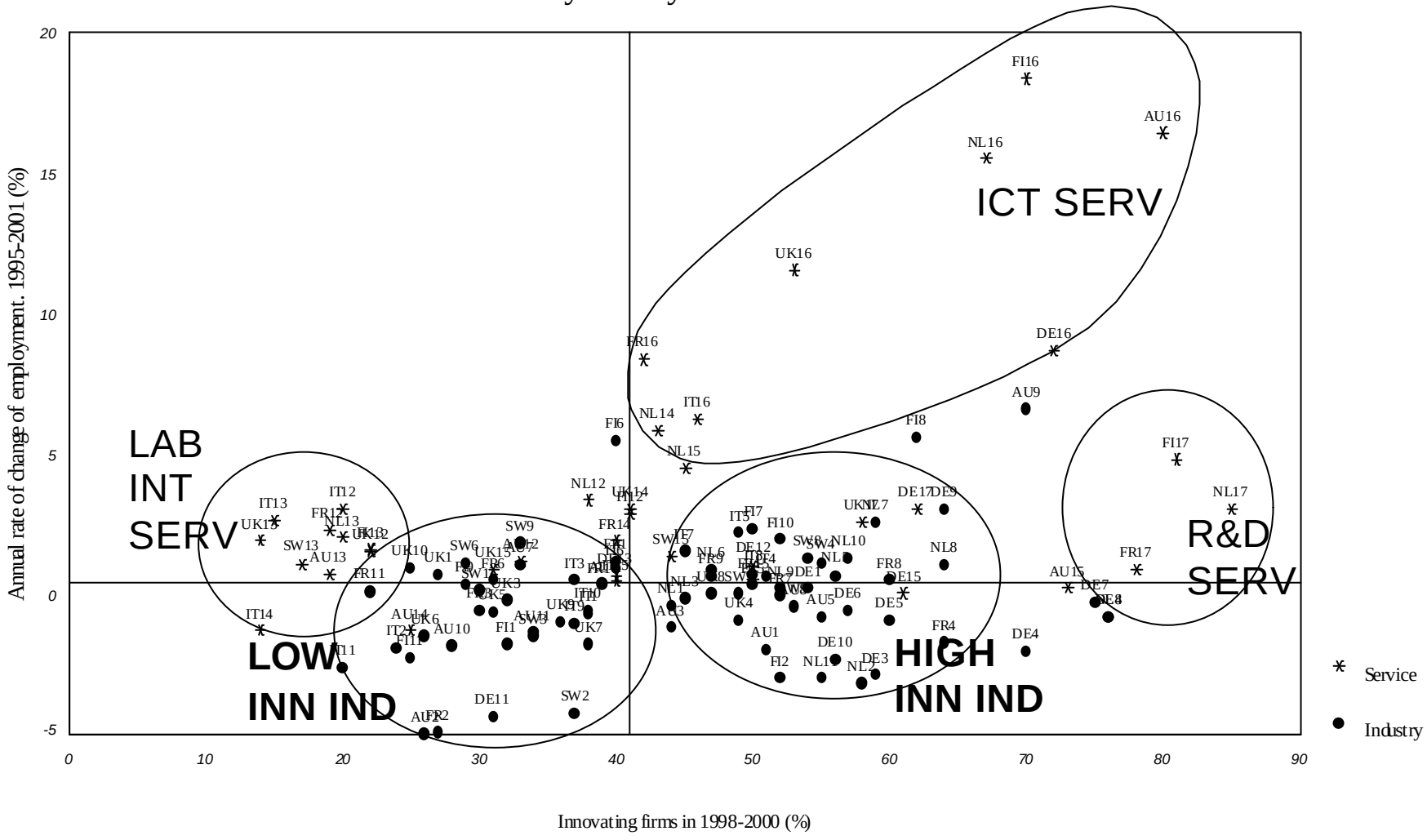

Figure 2 - Annual rate of change of labour costs per employee and innovating firms by country and sector

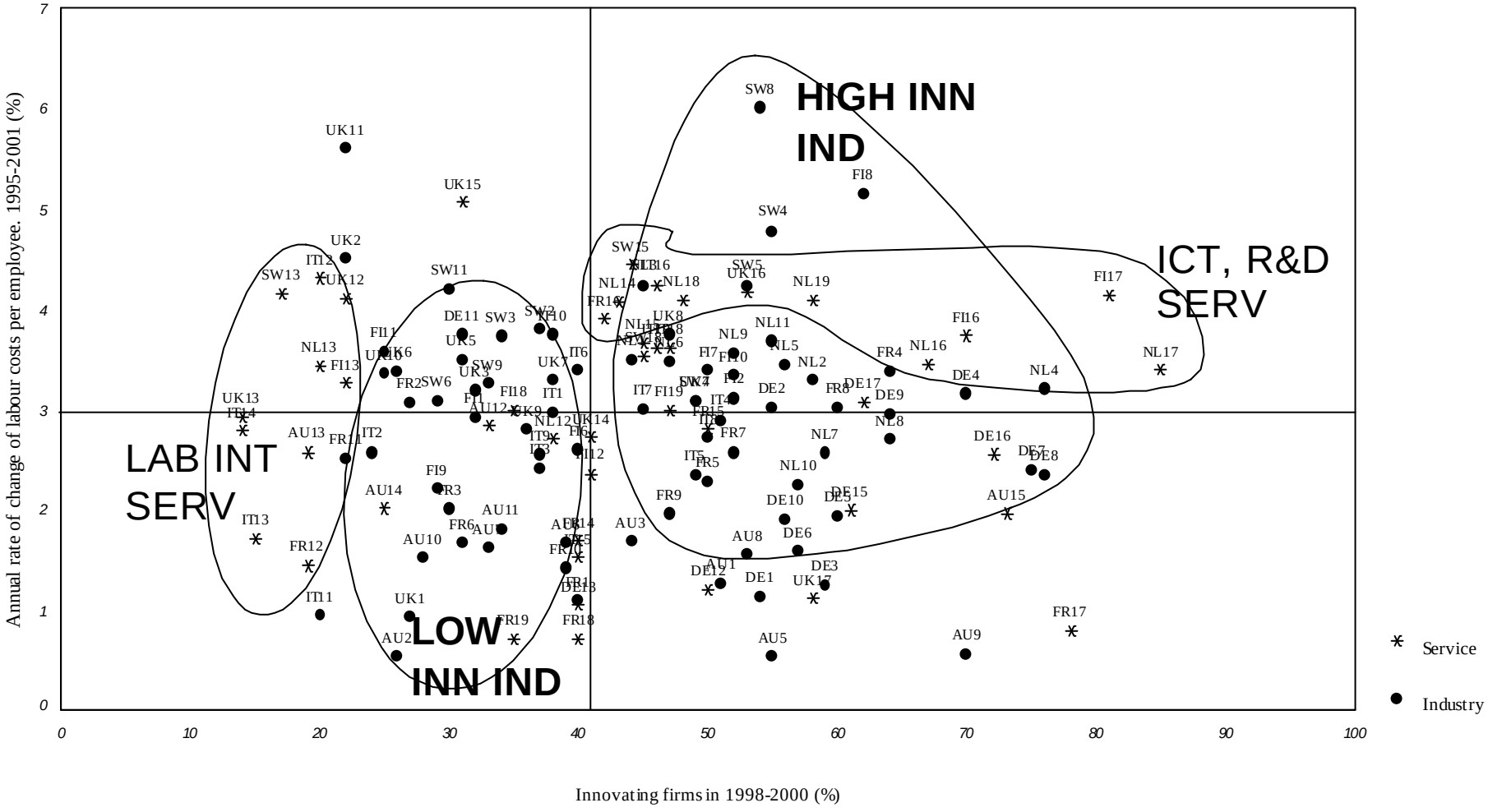

Figure 3 - Labour costs polarisation and innovating firms by country