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Innovation dynamics and employment effects

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Abstract

The paper reviews the state of the art on the employment impact of innovation and develops a dynamic model where changes in industry-level employment are explained by changes in demand, wages, by the diffusion of innovation and its market impact. The empirical test uses data from two EU innovation surveys - CIS 2 (1994-96) and CIS 3 (1998-2000) - on 11 industrial sectors and ten European countries. The results of the model show the importance to discriminate between different strategies for innovation (product vs. process), between high and low innovation industries, and between short-term labour market effects and the longer-term impact of structural change.

Key words: *Innovation, Consequences of technological change; Employment determination, Industries*
JEL classifications: *J20, J23, O30, O33*

1. Introducing innovation[1]

The classical Schumpeterian definition of innovation in products, processes, organisations, markets and sources of supply (Schumpeter, 1934) is a useful starting point for an analysis of the dynamics and variety of innovative efforts, and of their effects on employment. Using Schumpeter's terminology, we have an "*innovation*" when a firm first markets a new product or introduces a new process; the road open to "*the cluster of 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

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industries (and/or countries). The latter two lead to the diffusion of innovations throughout the economy, in both production and consumption.

While such different types of innovation have a distinct nature, economic significance and employment effect, in empirical studies of technological change they are generally lumped together, due to the difficulty to identify them, and the limitations of indicators such as R&D and patents. The differences in nature and effects of product and process innovations are well known (Pianta, 2005; Edquist, Hommen and McKelvey, 2001). The former - based on R&D, design and engineering - may lead to greater production and jobs when they meet an adequate demand, and when they are not confined to replacing old goods. Process innovations, on the other hand, tend to replace labour with capital, often leading to productivity growth and job losses. The mix between the two types of innovation is affected by the technological regime that in each industry shapes the opportunities for innovation (Breschi, Malerba, Orsenigo 2000, Malerba 2002, 2005), and by the specific strategy characterising industries and firms. Two basic models can be identified here: a strategy of *active price competitiveness* (relying on process innovations) and a strategy of *technological competitiveness* (rooted in product innovations) (Pianta, 2001).

The innovation dynamics, however, is not the sole determinant of the economic and employment impact. Structural and demand factors play an equally important role, including the growth of demand and the cost and wage dynamics. Such an approach makes is possible to conceptualise innovation as a deliberate process of *endogenous* change, highly specific to firms and industries.[2] A perspective combining neo-Schumpeterian insights, structural change and economic evolution, provides - in our view - the most appropriate tools for understanding the dynamics of innovation and analysing its employment impact[3]. While this paper will focus on the industry level, key works on the innovation-employment issue at the aggregate level include Freeman, Clark, and Soete (1982); Freeman and Soete (1987,1994); Freeman and Louçã (2001); Vivarelli (1995); Vivarelli and Pianta (2000), Simonetti and Tancioni (2002).

The paper is organized as follows: in the next section previous works are discussed; in Section 3 the data source is presented; in Section 4 a testable model is provided; in Section 5 econometric results are discussed, while conclusive remarks are listed in the final Section 6.

2. The state of the art

A large number of studies has investigated the employment impact of innovation at the firm and industry levels.[4]

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[2] 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.

[3] For a theoretical discussion on the employment impact of innovation see Petit, 1995; on concepts and empirical studies see Pianta (2005), where macroeconomic level studies and the impact on skills and wages are also reviewed; section 2 of this article summarises and expands the evidence provided there.

[4] Literature reviews are in Chennells and Van Reenen 2002, and Spiezia and Vivarelli 2002. It may be noted that measuring employment with the *number of jobs* becomes questionable as the relevance of part time work increases in several countries; the appropriate indicator would

Firms

Firm-level studies have shown that innovations in products *and* in processes generally lead to a positive *direct* employment effect in the firms that introduce them. Innovative firms tend to increase jobs faster than non-innovative ones, regardless of industry, size or other factors. Such a positive impact on jobs has been documented 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. Adopting a similar approach, Piva and Vivarelli (2003) found a positive and significant – although small in size – relationship between innovation and employment in a microeconometric study based on a panel of Italian firms. For German firms, Entorf and Pohlmeir (1990) 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.

An interesting research development is the combined analysis of technological and organisational innovations. 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.[5]

Two main problems emerge from such analyses. The first is that firm-level studies cannot identify whether the gains of innovating firms are made at the expense of competitors (the so-called "business stealing effect"), 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 when the analysis was carried out on the same data at the industry level, where product innovation alone was associated to job creation. Firm level studies may show that innovative firms are winners in the job creation game, and non-innovators tend to be losers, but they tell us nothing about the relative importance of the two, and on the overall employment effects on an industry.[6]

The second problem of the literature on the employment impact of innovation in firms is that, with few exceptions, most of the above studies have used annual surveys of firms in panels that usually are *not representative* of the whole manufacturing industry. The sample selection bias may lead to panels where the presence of innovators is distorted, and this makes comparisons of different studies difficult, and prevents us from drawing conclusions on what may happen to industry as a whole. Their results, in other words, cannot be easily generalised. Such a problem is starting to be solved with the use of innovation surveys where data are drawn from large samples of firms and the results are reported to the universe, and therefore

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be employment in full time equivalent units or, better, the number of hours worked. Unfortunately, firms and industry level data for such variables are not always available.

5 The relevance of organisational innovations is outside the scope of this paper. See Brynjolfsson and Hitt 2000, Brynjolfsson, Hitt and Yang 2002, Caroli 2001.

6 This simple consideration may help explain the "puzzle" pointed out by several chapters of Greenan, L'Horty and Mairesse (2002) concerning the related question of the innovation-productivity link. In the same way as for employment changes, positive effects at the firm level were found, that contrasted with the lack of effects at the macroeconomic level.

account for total economic activities in the industries concerned. Moreover, the rich set of variables made available by innovation surveys accounts in a more satisfactory way for the complexity of the innovation process and its economic and employment impacts (see European Commission-Eurostat 2001,2004).

A stream of firm level studies based on innovation surveys has investigated the relationships between inputs and outputs in the innovation process and the productivity effects of innovation, showing the importance of both structural factors and of innovativeness, finding strong cross country differences.[7]

Another line of research has used innovation surveys to investigate the dynamics of the size distribution of firms as one of the factors - alongside innovative efforts and technological regimes - affecting growth and employment change in industries. Studies have suggested that successful firms may experience sustained growth and that small firms can be strong job creators. The conceptual link to innovation, however, is not straightforward and the resulting evidence is mixed.[8] Neither stream of research directly addresses the innovation-employment relationship.

Although firm level analyses are crucial to understand the mechanisms for the development and introduction of innovations and their economic consequences, the combination of these two problems makes them hardly adequate to provide a full answer to the age-old question on whether innovation creates or destroys jobs.

Industries

Industry level studies can identify the overall effect of technological change within a sector, accounting for both its direct impact on innovating firms, and for the indirect effects that operate within the industry, including business stealing effect, product substitution or differentiation, price-elastic market expansion, change in market shares, entry and exit of firms, competition patterns, vertical integration/disintegration, etc.

Studies on industries have suggested that structural change (Pasinetti 1981) is the driving force behind the impact that the evolution of technology has on output and jobs. 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.

While traditional studies have relied on R&D or patents to estimate the technological activities at industry level,[9] of particular interest are the studies based on innovation surveys that better reflect the specificity of industries' technological regimes and innovative strategies. The evidence over almost two decades, first on selected countries pioneering innovation surveys in the 1980s, and then on Europe-wide comparisons based on the first two Community innovation surveys, shows that European manufacturing employment has experienced periods of poor growth or job losses, generally as a result of weak demand

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[7] On this theme a large literature is developing. See Crépon Duguet and Mairesse 1998, Mairesse and Mohnen 2001, 2002, Mohnen, Mairesse and Dagenais 2004, Van Leeuwen 2002.

[8] 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.

[9] The industry dynamics in output and employment were investigated in the OECD Jobs Study (OECD 1994) and in the related literature (see also Pianta, Evangelista and Perani 1996) mainly using R&D as an indicator of the different technological intensities of industries. A different stream of research has carried out studies at the sectoral level based on input-output models, often with a simulation perspective, that are not considered here (for reviews see Spiezia and Vivarelli 2002, Pianta 2005).

expansion, high wage dynamics, and weak product innovation; a higher intensity of innovative expenditure contributed to job losses due to the prevalence of labour saving process innovations.
Vivarelli, Evangelista and Pianta (1996) have studied Italian manufacturing industry in the 1980s, finding a negative employment effect of total innovation expenditure and an opposing impact of innovation in products and processes. Pianta (2000, 2001) has considered data from the first Community innovation survey concerning 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, using data from the second Community innovation survey. The same negative effect has emerged also in studies by Evangelista and Savona (2003) on service industries in Italy, based on the same data; 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.
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 generally result in job losses. In open economies, countries with an economic structure marked by a strong presence of industries with high innovation and rapidly growing markets 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 evolution of domestic and foreign demand.
From this review, it appears that the industry level is the most appropriate and viable one for the study of the employment impact of innovation, and that innovation surveys provide adequate empirical evidence on its nature and impact. In particular, they make it possible to identify the relevance of industry strategies based on product innovation (with job creating effects) or on process innovation (usually with negative employment effects).

Two other problems, however, emerge in such studies. The first is their reliance on cross sectional analyses over industries and countries, and the lack of a dynamic evidence on the evolution of innovative activities. The (static) sectoral differences in technological regimes and innovative strategies do account for the contrasting patterns of employment change in industries, but the question is still open whether a fully dynamic investigation of the changing pace of innovation over time may yield the same results.
The second one is the simultaneous structure of the relations often tested, with a lack of longer time lags that may be required to allow for the full emergence of the employment effects of innovation in industries. Such a model of the innovation-employment link may have endogeneity problems.
The availability of the third Community innovation survey on the years 1998-2000, that is comparable to the previous one, makes it possible to develop in this paper a fully dynamic analysis and to test the effects of longer lags, thus avoiding such two problems. In the next section the variables used to investigate innovation and its impact are described.

3. Data

Building on the lessons emerged from the review of the literature in section 2, the innovation-employment relationship is investigated in this section at the industry level, as the sources and the patterns of innovation tend to be highly sector-specific and the sectoral composition of national economies has a key role in explaining differences in national employment performances. The analysis is carried out on 11 industrial sectors and 10 European countries - Austria, Finland, France, Germany, Italy, Norway, Spain, Sweden, the Netherlands, the United Kingdom – over the 1994-2001 period (the dataset and the methodology used are fully explained in the Appendix).

The innovation indicators used are drawn from two European innovation surveys, CIS 2 (1994-1996) and CIS 3 (1998-2000). Different variables are considered in order to assess the consistency over time of specific innovation patterns, the diversity of innovation strategies, and their different relationships with employment performances.
The two main technological indicators selected for the analysis are:
- *the percentage of innovating firms on total firms* (i.e. firms that have introduced either a product or a process innovation over a three year period), used as a proxy of the overall diffusion of innovation in European industries;
- *the share of turnover from new or improved products*, that describes the market impact of product innovations.
The employment dynamics is measured by the average annual *rate of change in total employment*.[10] Other two economic variables will be used in the empirical analysis of the next sections, calculated over the same periods; they include:
- the average annual rate of change (in real terms) of *value added* (a proxy for the evolution of demand in each industry);
- the average annual rate of change (in real terms) of *labour compensation per employee*, including social contributions, showing the dynamics of wage costs.

A preliminary question to be addressed is the presence of different innovative strategies (and their stability over time), following from the discussion in section 2. Comparing the patterns shown by several variables, the presence of a strategy based on product innovation appears to be well represented by our indicator of the market impact of product innovations.[11] A broader analysis of the heterogeneity of innovation patterns in different sectors has shown that

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[10] The indicator has been built for the 11 industrial sectors and 10 European countries over the two periods 1994-1997 and 1998-2001. The periods considered include a year after the end of the innovation surveys, in order to allow for a modest lag in the employment effects of innovation. It has also been calculated over the whole 1994-2001 period (see the Appendix).

[11] In order to test the variety of such patterns, using data from the second innovation survey, our indicator of the market impact of product innovations has been correlated to other variables that may identify a strategy based on product innovations. The share of turnover due to new products is positively (but weakly) correlated to the share of firms that introduced product innovations (coefficient of 0.3 at the significance level of 95%) and to the share of R&D in total innovation expenditure (coefficient of 0.2 at the significance level of 90%). The innovative behaviour of product innovation oriented industries is also confirmed by the strong correlation of the percentage of product innovators with the share of total innovation expenditures devoted to R&D (the coefficient is 0.5), that is a major source for the development of new products, and by the high and negative link to the share of expedintures devoted to investments (-0.57, both at the significance level of 99%), that, on the other hand, is the key source for the introduction of process innovations. Strong evidence of the consistency of results based on different indicators of strategies based either on product or on process innovation, drawn from the second innovation survey, can be found also in Antonucci and Pianta 2002.

industries differ in their innovative behaviours, strategies and performances, and this has a specific impact on their growth and employment performances.[12]

Such distinct patterns of innovation show a strong stability over time. The distributions of the percentage of innovative firms in 1994-1996 and in 1998-2000 show a close association, and an even stronger correlation emerges for the turnover from new or improved products measured over the two periods.[13] Our indicators therefore capture persistent patterns across sectors and countries in the diffusion and market impact of innovation.

4. The model

In this section a model is proposed aiming to test the impact of innovation on employment in a dynamic perspective. The key relationship to be tested is the influence on employment change of changes in demand (value added), of changes in labour costs per employee and of the diffusion and impact of innovative efforts. The general specification of the dynamic model is the following (estimates will be based on different versions of this extended model):

$$\dot{E}_{ijt} = k + a\dot{D}_{ijt} + b\dot{W}_{ijt} + c\dot{F}_{ijt} + d\dot{M}_{ijt} + e_{ijt}$$

where, for sector i, country j and time t:

E is the annual rate of change of employment,

k is a constant,

D is the annual rate of change of total demand (proxied by value added),

W is the annual rate of change of real labour compensation per employee (including social contributions),

F is the change in the general indicator of the diffusion of innovation in firms (measured by the share of innovative firms - either in products or in processes - over the two surveys),

M is the change in the importance of market-oriented product innovations (measured in terms of share of new or improved products in sales, over the two surveys),

e is the error term.

Fixed effects for countries and sectors are considered when appropriate.

We expect demand growth and the importance of product innovation to have a positive impact on employment. The effects of changes in labour costs are expected to be negative, while the overall innovation diffusion will reflect the dominant effect of technological change.

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[12] An empirical study of the nature and sources of variety of innovation in industry across Europe has been carried out by Evangelista and Mastrostefano (2004), using the SIEPI database drawn by the second Community Innovation Survey for 10 countries, 22 manufacturing sectors and three firm size classes. The analysis has shown that the type of activity undertaken by firms to innovate is largely sector specific. This result confirms the existence of sector specific technological regimes (Malerba 2002,2005) that hold across countries and are only marginally affected by the size of firms. In particular, the analysis has shown that the greatest influence of sectors is found for indicators such as the percentage of turnover due to new products, the percentage of personnel involved in R&D activities, the importance of either R&D or new investment in total innovation expenditures.

[13] The correlation coefficients between the distributions in the first and in the second periods are 0.50 (at the significance level of 99%) for the share of innovative firms and 0.60 (at the same significance level) for the share of turnover due to new products.

The main aim of the model is to investigate the dynamic nature of the relationships in the short and longer terms, and the sectoral and country specificities that emerge. A sequence of different specifications will be tested.

1. First, the two periods of innovation survey data will be analysed together, in order to examine the overall simultaneous relationships between changes in economic variables and innovation intensities;
2. second, the model will highlight the constrasting effects emerging for high and low-innovation industries;
3. third, a fully dynamic specification with rates of change of innovation indicators from one to the other innovation surveys will be investigated, considering the longer term effects on employment changes from 1994 to 2001;
4. fourth, the independent variables of period 1 will be related to employment changes in period 2, in order to avoid the potential problems of endogeneity.

Tables 1 to 4 show the results of the empirical tests of the model. The Appendix provides further information on the variables and data used.

5. The results

1. Table 1 presents the results of a basic version of the model where innovation variables are calculated as intensities rather than as rates of change.[14] The two periods 1994-96 and 1998-2000 of the CIS innovation surveys are analysed together, with the rates of change of employment, value added and wages calculated as annual rates of change for 1994-1997 and 1998-2001. The econometric method used is a GLS fixed effects panel. In the first specification (column 1), the results considering the variable on innovation diffusion are shown; in the second one (column 2) the variable on the market impact of innovation is included.

In both cases employment change is explained by positive changes in demand (proxied with value added), negative changes in wages, and by positive effects of both innovative variables. All variables are highly significant. The coefficients for value added (about 0.50) show that a one per cent increase of value added leads on average to a half percentage point of job growth, while the negative impact on employment changes of increases in labour costs per employee is lower. The lower coefficients of the innovation variables are due to the different unit of measure used (percentages). The fixed effects show a strong variety of country patterns, with Spain showing a more positive effect and the highest negative ones in Austria, Germany, the UK and France.

The basic picture that emerges is that job creation is higher in the industries and countries where demands grows faster, labour costs increase more slowly, and innovation - of all types - is higher. These results represent the basic set of general relationships upon which the next regressions will be developed.

Table 1- The determinants of employment changes in European industries

Dependent variables: rates of change of employment

Method: Generalised Least Squares (Cross Section Weights) with fixed effects

Pool of 11 industries in AU, DE, ES, FI, FR, IT, NL, NO, SW, UK, 1994-97 and 1998-2001

	1	2

[14] The models in this case are:

$$\dot{E}_{ijt} = k_j + a\dot{D}_{ijt} + b\dot{W}_{ijt} + cF_{ijt} + e_{ijt}$$

$$\dot{E}_{ijt} = k_j + a\dot{D}_{ijt} + b\dot{W}_{ijt} + dM_{ijt} + e_{ijt}$$

Change of value added	0.51 (11.97)***	0.51 (11.12)***
Change in labour costs per employee	-0.40 (-8.43)***	-0.46 (-9.00)***
Percentage of innovative firms	0.03 (3.03)***	
Share of turnover from new products		0.02 (2.20)**
Fixed effects		
Austria	-3.85	-2.67
Germany	-3.01	-1.48
Spain	0.13	0.69
Finland	-0.68	0.50
France	-2.50	-1.30
Italy	-2.10	-1.06
Netherland	-2.21	-0.64
Norway	-1.46	-0.81
Sweden	-1.32	-0.11
United Kingdom	-2.69	-1.50
Adjusted R-squared	0.60	0.58
F-statistic	24.90***	21.70***
Number of cases	193	181

T-statistics between brackets. Significance levels: *90%, **95%, ***99%

2. Table 2 presents the results for the same data, but with a separate estimation of the coefficients for the set of high innovative industries (chemicals and drugs; machinery; electronics; transport equipment) and that of low innovative ones (all the remaining sectors, based on the values of the share of innovating firms; see the Appendix), concentrating on the role of the market impact of innovation[15]. The method is a GLS heterogeneous panel with fixed sectoral effects.
While the signs and high significance of the two economic variables are confirmed, this evidence provides a major qualification of the employment impact of innovation, demand and wages. In low innovation industries the coefficient of value added is much higher than in high innovation ones (0.83 vs. 0.37), as opportunities for job growth directly depend on an expansion of demand. Conversely, the negative effect of wages in low innovation industries is higher than in high innovation sectors (-0.44 vs. -0.30), where the wage dynamics may be higher and consistent with some job growth.

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15 The model here is:
$\dot{E}_{ijt} = k_i + a_i \dot{D}_{ijt} + b_i \dot{W}_{ijt} + d_i M_{ijt} + e_{ijt}$
with $i = 1$ for low innovation industries and $i = 2$ for high innovation industries.
Results for the variable on the share of innovative firms are not reported as they are not significant. The Wald test suggests that the two value added coefficients are significantly different; there is an 18 per cent probability that the two coefficients for wages are not different. For the innovation impact we find a simmetrical impact of the coefficients with a different sign.

The most relevant difference, however, is the negative (and significant) effect that emerges for the market relevance of innovation in low innovation industries, while high innovation sectors confirm the positive (and significant) contribution of new products in sales to employment growth.
This evidence suggests that in low technology industries job changes closely depend by the evolution of value added, the labour market operates in a more "neoclassical" way with negative effects of wages on employment changes, and innovation does not contribute to employment growth. In spite of the use of a variable associated to the market impact of innovation, the dominance of process innovation in these industries makes it evident that the overall effect of innovation is a negative one on employment.
Conversely, for the group of high innovation industries, job growth is slightly less demand driven and much more technology pushed, while wage increases have minor negative effects.[16]

Table 2 - The determinants of employment changes in European high innovation and low innovation industries.

Dependent variables: rates of change of employment.
Method: Generalised Least Squares (Cross Section Weights). Heterogeneous coefficients Fixed Effects model
Pool of 11 industries in AU, DE, ES, FI, FR, IT, NL, NO, SW, UK, 1994-97 and 1998-2001

Change of value added for low innovation industries	0.83 (11.87)***
Change of value added for high innovation industries	0.37 (6.42)***
Change in labour costs per employee for low innovation industries	-0.44 (-5.56)***
Change in labour costs per employee for high innovation industries	-0.30 (-3.84)***
Share of turnover from new products for low innovation industries	-0.05 (-2.05)**
Share of turnover from new products for high innovation industries	0.03 (2.04)**
Constant for low innovation industries	-0.23
Constant for high innovation industries	-0.95
Adjusted R-squared	0.58
F-statistic	33.75***

16 These results recall the two models of *active cost competitiveness* - associated to the dominance of process innovations - and of *technological competitiveness* - based on product innovations - discussed in Pianta 2001, Antonucci and Pianta 2002. The negative impact of innovation indicators on employment change was typical of the findings reported there from the first and second innovation surveys, concerning a period when European industry was marked by stagnation, widespread restructuring and job losses.

Number of cases	169

T-statistics between brackets. Significance levels: *90%, **95%, ***99%

3. In Table 3 a fully dynamic specification is tested, with the two innovation indicators calculated as rates of change from the first to the second period. Rather than pooling innovation and performance variables for the two available periods, the analysis is carried out with a cross section of industries and countries with data relative to a longer period, 1994-2001; all variables are calculated in rates of change.[17] The econometric method used is OLS with White correction for heteroskedasticity. The two innovation variables are included separately in columns 1 and 2, and together in columns 3 and 4.

The results for value added and wages show no difference with the previous ones. The percentage change of the share of innovative firms, an indicator of the general diffusion of innovation, in column 1, is not significant, while the positive impact of the growth of turnover due to new or improved products is confirmed to be positive and significant in column 2. When the two innovation variables are put together in column 3, the same outcome emerges. What brings a positive contribution to job growth over the last decade in European industries is the product innovation that has a market impact, rather than innovation *per se*, as process innovations heavily affect the strategies of several industries and countries, and lead to worst employment performances.

Column 4 includes industry fixed effects in order to test the impact of sectoral differences over the relationship. The size, sign and significance of all coefficients confirm the results of column 3. The specificity of the distribution of industries shows that only two sectors - textile and leather; rubber, plastic and non metallic minerals - are significantly different, the former with higher than expected job losses, and the latter with a better employment performance. These results show that the model properly captures the heterogeneity of sectors in terms of innovative patterns and employment outcomes.

The availability of CIS 3 data and the possibility to express also innovation indicators as growth rates has made it possible a fully dynamic specification of the model, whose results continue to confirm the results obtained in cross sectional analyses in the previous tables as well as in previous studies based on CIS 1 or CIS 2 only (Pianta 2000,2001, Antonucci and Pianta 2002).

Table 3 - The determinants of employment changes in European industries in 1994-2001

Dependent variable: rate of change of employment, 1994-2001

Method: Ordinary Least Squares - White correction for the heteroskedasticity consistency

Pool of 10 industries in AU, DE, ES, FI, FR, IT, NL, NO, SW, UK

	1	2	3	4
Changes in value added 1994-2001	0.54 (6.84)***	0.47 (4.23)***	0.53 (4.56)***	0.38 (3.15)***
Change in labour costs per employee 1994-2001	-0.30	-0.26	-0.28	-0.27

[17] The model used in column 3 is: $\dot{E}_{ij} = k + a\dot{D}_{ij} + b\dot{W}_{ij} + c\dot{F}_{ij} + d\dot{M}_{ij} + e_{ij}$

The model used in column 4 is: $\dot{E}_{ij} = k_i + a\dot{D}_{ij} + b\dot{W}_{ij} + c\dot{F}_{ij} + d\dot{M}_{ij} + e_{ij}$

In this analysis the sector Electricity, gas and water supply has not been included.

	(-3.56)***	(-2.14)**	(-2.29)**	(-2.21)**
Percentage change in the share of innovative firms	0.005		0.0007	0.004
	(0.98)		(0.10)	(0.49)
Percentage change in share of turnover from new products		0.01	0.01	0.01
		(2.50)**	(2.12)**	(1.98)*
Constant	-0.35	-0.18	-0.25	
	(-1.74)*	(-0.60)	(-0.75)	
Sector effects				
Food products, beverages and tobacco				0.18
				(0.40)
Textiles and leather				-1.73
				(-2.68)***
Wood, pulp and publishing				-0.23
				(-0.30)
Coke and chemicals				-0.24
				(-0.26)
Rubber and other non-metallic				0.85
				(2.12)**
Basic metals and fabricated metal products				0.73
				(1.47)
Machinery and equipment NEC				0.35
				(0.60)
Electrical and optical equipment				1.19
				(1.26)
Transport equipment				-0.40
				(-0.49)
Manufacturing NEC and recycling				0.37
				(0.65)
Adjusted R-squared	*0.51*	*0.39*	*0.42*	*0.49*
Log likelihood	*-162.63*	*-145.75*	*-141.88*	*-131.78*
Number of cases	*87*	*78*	*77*	*77*

T-statistics between brackets. Significance levels: *90%, **95%, ***99%

4. Finally, Table 4 shows the results of a long-difference version of the model that explicitly avoids any effect of endogeneity, by explaining the rate of change of employment in the second period, 1998-2001, as a result of variables calculated over the first period, 1994-1997[18]. They include the lagged employment rate of change, in order to account for the path dependency of industry and country job performances (this means that we have to drop from the equation value added, that is correlated to job changes), wage increases and the market

[18] The model here is: $\dot{E}_{ijt} = k + a\dot{E}_{ijt-1} + b\dot{W}_{ijt-1} + d\dot{M}_{ijt-1} + e_{ijt-1}$

impact of innovation. We have here fewer independent variables and no country dummies (they were never significant), resulting in a lower R square than usual. The estimator used is OLS with White correction for heteroskedasticity.
The results show that past employment changes have a positive and significant effect on current job dynamics, but the rather low coefficient suggests that from the mid 1990s to the second period employment growth in European industries has substantially moved across industries. Past wage increases, on the other hand, lose their negative effect on current job growth (the coefficient is not significant). When we look at structural changes with a substantial time lag between past wage dynamics and current job creation, the "neoclassical" negative effect disappears and the longer term structural change becomes clear, with the emergence of sectors with expanding employment, growing wages and high innovation. The market impact of innovation continues to have a positive and significant effect (and a higher than usual coefficient), suggesting than when longer lags are allowed, the impact of market oriented product innovation is more important.

Table 4 - The determinants of employment changes in European industries with one-period lag
Dependent variable: rate of change of employment, 1998-2001
Pool of 11 industries in AU, DE, ES, FI, FR, IT, NL, NO, SW, UK
Method: Ordinary Least Squares - White correction for the heteroskedasticity consistency

Rate of change of employment in 1994-1997	0.27 (2.64)***
Change in labour costs per employee in 1994-1997	0.06 (0.82)
Share of turnover from new products in 1994-1996	0.04 (1.81)**
Constant	-1.86 (-2.68)***
Adjusted R-squared	0.10
Log likelihood	-195.66
Number of cases	83

T-statistics between brackets. Significance levels: *90%, **95%, ***99%

6. Advancements on the state of the art

This sequence of econometric exercises shows that a dynamic analysis of the employment impact of innovation, controlling for demand and wages, provides important results. It adds on previous evidence on several aspects.

a. Innovation vs. R&D and patents
Compared to studies using R&D expenditure (an input indicator) or patent data (an indicator of inventive output with highly different sectoral propensities to patent), the use of innovation

survey data in this paper allows the use of indicators on the effective introduction of innovations in firms (the share of firms that introduced over three years a product or process innovation), and on their market impact (the share of turnover due to new or improved products). The measurement and assessment of innovation is therefore more accurate.

b. Universe vs. panels
Data used in this paper refer to *total* innovative and economic activities in the industries concerned. The results we have found are a description of patterns of the whole industry. This is a major advantage compared to panel studies on samples of firms that are not representative of the universe, and whose results therefore cannot be generalised.

c. Cross sections vs. time series
The dynamic analysis of this paper makes it possible to overcome the limitations of previous studies that were forced to investigate the innovation-employment relationship with a cross section of countries and industries using data for one innovation survey only. However, the fully dynamic analysis and the lagged model confirm the findings of those studies.

d. Product vs. process
A diversity of innovative strategies characterising industries in particular countries emerge from the results. The combined use of the two innovation indicators makes it possible to differentiate between the general diffusion of innovation in firms and the specific market impact of product innovations, confirming previous works emphasising the contrasting employment effects of strategies based on process or product innovations. The lesson for future research is that a generic innovation indicators is less and less adequate to capture the specific innovative strategies pursued by firms and industries.

e. High vs. low innovation industries
A diversity of mechanisms that link innovative strategies and employment outcomes emerges in the case of high or low-innovation industries. The former are characterised by a greater importance of product innovation, and lower constraints on wages. The latter show an overall negative effect of innovation, due to the dominance of process innovations in such sectors. Models and future empirical work may take this variety of relationships into account

f. Shorter vs. longer term
When a longer lag is allowed for the analysis of the impact of innovation, the "neoclassical" negative relation between wage and job growth is less relevant and the "Schumpeterian" job creating effect of the market impact of innovation is stronger. Structural change becomes critical in explaining the combination of changes in technologies, demand and wages.

g. Cycles v. structure
These results on employment change have shed some light on the possible interactions between the effects of macroeconomic cycles and the outcomes of industry-specific structural patterns of innovation. Further research may try to identify and compare the importance of the two effects on job creation and loss in particular periods.

Moreover, the above conclusions do not concern only studies on the employment effects of innovation, but are likely to to be relevant for wider studies on economic performance - growth of value added, productivity, export, etc. - associated to technological change.

The results of this paper show the importance for long term employment growth of a sustained demand dynamics and a concentration on product innovations with a strong market impact.

Such conditions are more likely to be found in high innovation industries characterised by rapid technological change and high growth of final demand. The industrial structure of Europe (and of several of its countries in particular) shows a limited presence of such industries, and a troubling prevalence of strategies aiming at cost competitiveness through labour saving process innovations and wage containment. Such structural factors and current strategies, combined with the continuing restraint on demand due to fiscal and monetary policies, suggest that Europe's industrial and employment base are in danger of further erosion, if no active macroeconomic, industrial and innovation policies are introduced.

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APPENDIX

The database used for addressing the impact of technological change on employment merges innovation indicators, provided by the CIS 3 (1998-2000) and the CIS2 (1994-1996), with economic and structural data, drawn for the OECD STAN database, for 11 industrial sectors

- Nace Rev.1 subsections – and for 10 European countries - Austria, Germany, France, Italy, Norway, Finland, Spain, Sweden, the Netherlands and the UK - over the period 1994-2001.

The sectors included, and the codes reported in the Figures are the following:
1. Food and Beverages (Nace Rev.1 classes 15-16);
2. Textiles, Dressing and Leather (17-19);
3. Wood, Pulp, Paper and Publishing-Printing (20-22);
4. Coke and Refined Petroleum products and Chemicals (23-24);
5. Rubber and Plastics products and Other Non-Metallic Mineral products (25-26);
6. Basic Metals and Fabricated Metal products (27-28);
7. Machinery and Equipment (29);
8. Office, Accounting and Computing Machinery, Electrical Machinery Telecommunications and Medical, Precision and Optical Instruments (30-33);
9. Motor Vehicles and Other Transport Equipment (34-35);
10. Manufacturing NEC and Recycling (36-37);
11. Electricity, gas and water supply (40-41).

The innovation indicators

The two main innovation indicators used for both descriptive and econometric analysis are:
- the percentage of innovative firms on total firms with reference to the periods 1994-1996 and 1998-2000. It is used as a proxy of the overall innovation intensity of European industries;
- the share of turnover from new or improved products in 1996 and 2000, measuring the market impact of product innovation strategies.

Some other indicators drawn from the CIS 2 have been used in order to consider the variety of ways in which firms and sectors innovate. They include the following ones:
- the share of firms introducing product innovations
- the share of R&D in total innovation expenditure
- the share of machinery and equipment in total innovation expenditure

The innovation variables in the two periods are based on the same definitions and are comparable. The most relevant difference between the second and the third round of CIS concerns the size of target population in manufacturing industries: in the CIS 2 the cut off point was 20 employees, while in the CIS 3 the coverage of surveyed units has been extended to all the enterprises with at least 10 employees. A better level of data harmonisation across countries at the micro level has been reached with the CIS 3. Participating countries have agreed to follow recommendations on target population, survey methodology, collection and processing methods and transmission of data in addition to use the same standard CIS3 questionnaire. The efforts made for reducing the methodological differences between countries from CIS2 to CIS3 consequently led to a better quality of the statistical results.
Due to the lack of official CIS 3 data at NACE division level (Eurostat has decided to disseminate data at highly aggregated sectoral - NACE section – level), the CIS 3 indicators here used come from a collection of national data made by Institute of Statistics of Norway and in particular by Frank Foyn, who kindly allowed us to use these data.

The economic indicators

The set of economic indicators calculated for each country and sector considered includes:
- the annual rate of change of total employment, measuring employment dynamics;
- the annual rate of change of real value added, used as proxy of demand dynamics;
- the annual rate of change of labour compensation per employee.

Data on employment used in the analysis are expressed as Total employment, Number Engaged. These figures consider one job as one worker, and they may overestimate the real number of hours worked, but they are internationally comparable. Data on Total employment, Full-time equivalents which account for part-time jobs, on the contrary, are not always available across countries and often are not updated to 2001.
Data on labour compensation have been divided by employment to allow for comparisons among economies of different size. Data on labour compensation have been preferred to those on wage since the former also include social contributions paid by firms that represent an important part of total labour costs.
Value added data have been deflated with sectoral deflators (elaborated from the OECD STAN database), while GDP deflators have been used to deflate Labour Compensation of Employees data. Nominal figures have thus been transformed in constant values with base year 1995.
The rates of change have been computed for each variable for the 1994-1997 and 1998-2001 periods in order to analyse the average dynamics in two different periods, as well as and for the overall 1994-2001 period. Due to missing data, data on Value Added refer to 2000 in the case of Sweden; data on Labour Compensation per employee refer to 2000 in the case of the United Kingdom, Norway and Spain and to 1999 for Sweden.

The integration of economic and innovation data also deserves some attention. STAN data refers to the universe of all firms, CIS 3 data to all firms above 10 employees and CIS 2 data to firms over 20 employees. The use of rates of change in the variables used reduces the bias due to such differences in the definition of the universe. Moreover, such discrepancies are likely to be much more serious when other technology indicators, such as R&D or patents, are used, as the R&D or patenting activities of very small firms is generally negligible.

An overview of innovation and employment patterns, 1994-2001.
Table 1 shows the innovation, economic and employment performances of the aggregate industrial sector in European countries in the two periods considered. Comparing the 1994-1996 to the 1998-2000 innovation surveys, a general decrease in the shares of innovative firms is found in all countries (with the exception of Spain), and is largely due to the inclusion in CIS 3 of smaller firms (having 10 to 20 employees), that usually are less innovative. Differences are particularly marked in Norway, United Kingdom and Austria. In the share of turnover from new products this fall is less noticeable, except in the case of the United Kingdom, moving from 23% in 1996 to 9% in 2000, Austria and Norway.

The best innovation performers turn out to be Germany and Netherlands, that have the highest percentage of innovating firms in both periods (more than half of industrial firms innovate) and high shares of turnover from new products (in Germany more than one third of sales comes from product innovations). Looking at economic indicators, the United Kingdom and Norway show the worst employment and economic performances; in particular, Norway moves from positive change in employment and value added in 1994-97 (respectively 2.5% and 2.7%) to a negative one (-2.6% and –0.3%). A pick up of demand and employment is found in Germany, France and the Netherlands, while a positive dynamics in both periods is found in Sweden, Finland and Spain, although with a slight decrease over time.

Table 1- The evolution of innovation and economic performances of European industries over time.

Country	Innovating firms (%)		Share of turnover from new or improved products		Annual rate of change of value added		Annual rate of change of employment	
	1994-96	1998-2000	1996	2000	1994-1997	1998-2001	1994-1997	1998-2001
Austria	67	44	31.8	20.5	-1.2	-0.4	4.0	3.3
Germany	81	60	35.8	32.2	-2.2	-0.2	0.5	0.8
Spain	29	37	26.9	n.a.	2.4	2.4	3.8	3.2
Finland	n.a.	43	n.a.	27.3	2.5	1.4	6.1	5.5
France	43	40	20.5	13.8	-0.7	0.5	2.8	3.4
Italy	48	40	26.7	19.9	-0.4	-0.4	1.9	1.4
Netherland	64	51	22.6	19.8	-0.1	0.2	2.0	2.5
Norway	47	25	20.0	13.4	2.5	-2.6	2.7	-0.3
Sweden	54	40	30.8	n.a.	1.6	0.4	5.1	4.0
United Kingdom	58	32	23.2	9.5	1.0	-3.4	1.3	0.2

Sources: OECD STAN data; SIEPI CIS2 data; CIS 3 data collcted by Norway Statistics Institute.

Table 2 provides a picture of the sectoral differences in innovation intensity in four major European countries during the two periods considered. Electronics, machinery, chemicals and transport industries are the most innovative ones in most countries. At the other extreme of the distribution, food, textiles and other manufacturing industries usually show the lowest percentages of innovative firms in both periods. While country specificities are important, the distinction between the two groups appears persistent over time, in spite of the frequent reduction in CIS 3 data.

Table 2 - Industrial innovation in selected European countries in 1994-96 and 1998-2000

Economic activity	Innovative firms (% on total)							
	Germany		France		United Kingdom		Italy	
	1998-2000	1994-96	1998-2000	1994-96	1998-2000	1994-96	1998-2000	1994-96
High innovation industries								
Electronic	76	78	60	61	47	63	50	56
Machinery	75	84	52	63	38	56	45	61
Chemicals	70	75	64	68	49	51	51	61
Transport	64	72	47	49	36	76	37	47
Low innovation industries								
Rubber and plastic products	60	67	50	49	31	81	49	44
Wood, Pulp and Paper	59	59	30	32	32	56	37	45
Basic metals and metal products	57	59	31	31	26	53	40	54
Other manufacturing industries	56	69	39	38	25	63	38	53
Textiles	55	62	27	30	22	58	24	32
Food	54	68	40	45	27	58	38	59