2009

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Economics of Innovation and New Technology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713641545

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Online publication date: 24 November 2009

To cite this Article Mastrostefano, Valeria and Pianta, Mario(2009) 'Technology and jobs', Economics of Innovation and New Technology, 18: 8, 729 — 741
To link to this Article: DOI: 10.1080/10438590802469552
URL: http://dx.doi.org/10.1080/10438590802469552

Economics of Innovation and New Technology
Vol. 18, No. 8, November 2009, 729–741

Technology and jobs

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(*Received 18 May 2007; final version received 23 August 2008*)

The article investigates the employment effects of technology. A set of models is developed 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 (Community Innovation Survey) 2 (1994–1996) and CIS 3 (1998–2000) – on 10 industrial sectors and 10 European countries. The results of the models show the importance to discriminate between different strategies for innovation, between high- and low-innovation industries, and between short-term labour market effects and the long-term impact of structural change.

Keywords: innovation; employment; industries

JEL Classification: J20; J23; O30; O33

1. Introduction

Job creation and destruction in advanced economies are the result of complex changes in the markets for labour, goods, knowledge and capital. Technological change plays a major role in shaping the quantity and quality of employment. However, little attention has been paid to its differentiated nature – first pointed out by Schumpeter (1934) – and to the contrasting effects that new products or new processes may have on employment. The former – based on research and development (R&D), design and engineering – may lead to greater production and new 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 (Edquist, Hommen, and McKelvey 2001; Pianta 2005). The mix between the two types of innovation is affected by the technological regime, shaping the opportunities for innovation in each industry (Breschi, Malerba, and Orsenigo 2000; Malerba 2002), and by the specific strategy characterising industries and firms.

Few models and little detailed empirical evidence are available for assessing the effects on jobs that may result from different types of innovation, labour market factors and demand dynamics. In this article insights from neo-Schumpeterian and structural change

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ISSN 1043-8599 print/ISSN 1476-8364 online

DOI: 10.1080/10438590802469552
http://www.informaworld.com

perspectives are combined in order to investigate the evolution of employment. Our model aims to explain employment changes in manufacturing industries in Europe as a result of (1) cost and wage dynamics, (2) demand factors and (3) the orientation of innovation towards either a diffusion strategy or the development of new markets. Several versions of the model are tested in order to address different questions and test lagged effects.

The empirical test uses data from CIS (Community Innovation Survey) and in particular from two consecutive survey rounds – CIS 2 (1994–1996) and CIS 3 (1998–2000) – on 10 industrial sectors and 10 European countries. The determinants of employment change are investigated taking into account the complexity of the relationships involved, the need to discriminate between different strategies for innovation, between high- and low-innovation industries, and between short-term labour market effects and the long-term impact of structural change.

The article is organised as follows: in the next section previous works are discussed; in Section 3 the data source is presented; in Section 4 a model is proposed; in Section 5 econometric results are discussed; in Section 6 the main conclusions are drawn.

2. Innovation and employment

Studies on the employment impact of innovation have been mainly carried out at the firm and industry levels.[1]

Firm-level studies have shown that innovations in products *and* in processes generally lead to a positive *direct* employment effect on 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 – among others – by Machin and Wadhwani (1991), Blanchflower, Millward and Oswald (1991), Blanchflower and Burgess (1999), Van Reenen (1997), Entorf and Pohlmeir (1990), and Smolny (1998). A generally negative impact of innovation on jobs has been found for Dutch firms by Brouwer, Kleinknecht and Reijnen (1993), although product innovations have a less negative impact.[2] 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 the industry.* A French study carried out by Greenan and Guellec (2000) showed that the positive relationship between innovation and employment emerging at the firm level disappeared when the analysis was carried out on the same data at the industry level, where product innovation was alone associated to job creation. Firm-level studies show that innovative firms are winners in the job creation game and non-innovators tend to be losers, but they do not tell us much about the relative importance of the two and on the net employment effects at the industry or national level.

The second problem of this literature is that it is based on panel data that usually are *not representative* of the whole manufacturing industry. The sample selection bias may produce some distortion in the presence of innovators, making comparisons of different studies difficult, and preventing us from drawing conclusions on the outcomes for industries. Such a problem has recently been tackled with the use of innovation surveys that are highly representative of all economic activities. Moreover, the rich set of variables made available by innovation surveys accounts for the complexity of the innovation process (see European Commission-Eurostat 2001, 2004).

The problems typical of firm-level analyses emerge in the US studies on job flows (see in particular Davis, Haltiwanger, and Schuh 1998), where little attention is given to the role of innovative activities in the dynamics of job creation and loss.

Industry-level studies can identify the overall effect of technological change, accounting for both its direct impact on innovating firms and the indirect effects that operate within the industry, including 'business stealing', 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. Moreover, the sources and opportunities for technological change and job creation are specific to individual industries (Malerba 2002).

Studies based on innovation surveys can document the specificity of industries' technological strategies more effectively than traditional works relying on R&D or patent data. The evidence detected over two decades, first on selected countries pioneering innovation surveys in the 1980s and then on Europe-wide comparisons based on CIS, shows that the periods of poor employment growth or job losses in European manufacturing have generally been associated to a weak demand expansion, high wage dynamics and weak product innovation; the prevalence of labour saving process innovations is usually associated to job losses. Such evidence strongly emerges from the early studies by Vivarelli, Evangelista and Pianta (1996), Pianta (2000, 2001), Antonucci and Pianta (2002). The same negative effect has emerged in a study by Evangelista and Savona (2003) on CIS data on Italian service industries; heavy job losses were found in the largest firms and among low-skilled workers, in Information and Communication Technologies' (ICT's) heavy users sectors, as well as in capital intensive and finance-related ones, whereas net job creation occurred 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, whereas new processes generally result in job losses. In open economies, countries with an economic structure marked by a strong presence of highly innovative industries 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 more likely to experience serious job losses due to technological change.

The use of innovation surveys at the industry level appears as the most promising approach to the study of the employment impact of innovation. However, previous work based on CIS data was constrained by the limited availability of cross-section data and time series. This led to empirical tests of static relationships with a potential endogeneity in the innovation–employment links. In this article, the combined use of the second and third CIS makes it possible to overcome such problems and to test dynamic effects and lagged relationships. In the next section, the variables used to investigate innovation and its impact are described.

3. Data

The determinants of employment changes are investigated in this article at the industry level, considering 10 manufacturing sectors and 10 European countries – Austria, Finland, France, Germany, Italy, Norway, Spain, Sweden, the Netherlands, the United Kingdom – over the 1994–2001 period. Dataset and methodology are explained in the Appendix.

The economic indicators are drawn from the OECD STAN database and include:

- the employment dynamics measured by the average annual *rate of change in total employment*;[3]

- 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.

The innovation indicators used are drawn from two European innovation surveys, CIS 2 (1994–1996) and CIS 3 (1998–2000) and include:

- *the percentage of innovating firms on total firms*,[4] used as a proxy of the overall diffusion of innovation in European industries (where process innovations are usually dominant);
- *the share of turnover from new or improved products* that describes the market impact of product innovations.

These two variables identify distinct patterns of innovation that have a strong stability over time.[5]

4. The model

In this section a model is proposed aiming to test the determinants of employment changes. The key relationships to be tested are the influence of (1) changes in demand, proxied with value added, (2) changes in labour costs per employee, (3) the diffusion of innovation and (4) the economic impact of new products. The general specification of the dynamic model is the following one (estimates are based on different versions of this 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:

$\dot{E}$ is the annual rate of change of employment,
k is a constant,
$\dot{D}$ is the annual rate of change of total demand (proxied by value added),
$\dot{W}$ is the annual rate of change of real labour compensation per employee (including social contributions),
$\dot{F}$ is the change in the diffusion of innovation in firms (measured by the share of innovative firms – either in products or in processes – over the two surveys),
$\dot{M}$ 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, whereas the overall innovation diffusion will reflect the dominant effect of technological change. The aim of the model is to investigate the relationships in the short and long terms, and the sectoral and country specificities that emerge. A sequence of different specifications will be tested:

(1) 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) a version of the model will highlight the contrasting effects emerging for high- and low-innovation industries;
(3) a specification with rates of change of innovation indicators – calculated from the first to the second innovation surveys considered here – will be related to employment changes from 1994 to 2001, in order to investigate the long-term effects of changes in technological performances;
(4) a final version of the model will relate the independent variables of period 1 to employment changes in period 2, so as to avoid any potential problem of endogeneity.

Table 1. The determinants of employment changes in European industries.

	1	2
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

Dependent variables: rates of change of employment.
Method: generalised least squares (cross section weights) with fixed effects.
Pool of 10 industries in AT, DE, ES, FI, FR, IT, NL, NO, SE, UK, 1994–1997 and 1998–2001.
T-statistics between brackets. Significance levels: *90%, **95%, ***99%.

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

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***
Number of cases	169

Dependent variables: rates of change of employment.
Method: generalised least squares (cross section weights). Heterogeneous coefficients fixed effects model.
Pool of 10 industries in AT, DE, ES, FI, FR, IT, NL, NO, SE, UK, 1994–1997 and 1998–2001.
T-statistics between brackets. Significance levels: *90%, **95%, ***99%.

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

	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 (−3.56)***	−0.26 (−2.14)**	−0.28 (−2.29)**	−0.27 (−2.21)**
Percentage change in the share of innovative firms	0.005 (0.98)		0.0007 (0.10)	0.004 (0.49)
Percentage change in share of turnover from new products		0.01 (2.50)**	0.01 (2.12)**	0.01 (1.98)*
Constant	−0.35 (−1.74)*	−0.18 (−0.60)	−0.25 (−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

Dependent variable: rate of change of employment, 1994–2001.
Method: ordinary least squares – White correction for the heteroskedasticity consistency.
Pool of 10 industries in AT, DE, ES, FI, FR, IT, NL, NO, SE, UK
T-statistics between brackets. Significance levels: *90%, **95%, ***99%.

Table 4. The determinants of employment changes in European industries with one-period lag.

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

Dependent variable: rate of change of employment, 1998–2001.
Pool of 10 industries in AT, DE, ES, FI, FR, IT, NL, NO, SE, UK.
Method: ordinary least squares – White correction for the heteroskedasticity consistency.
T-statistics between brackets. Significance levels: *90%, **95%, ***99%.

Country dummies have been used in order to account for the macroeconomic, institutional and business cycle conditions of national economies; industry dummies are included for taking into account the specificities in terms of firm size, entry and exit patterns, market structure and labour market characteristics.

The simple econometric tests shown later are constrained by the limitations of data availability from innovation surveys and by the limited number of cases. Still, they shed new light on the dynamics of employment in European industries and on the role played by technological change. Tables 1–4 show the results of the empirical tests of the model. The Appendix provides further information on the variables and data used.

5. Results

(1) Table 1 presents the results of a basic version of the model where innovation variables are calculated as intensities.[6] The two periods 1994–1996 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 generalised least squares (GLS) fixed effects panel. In the first specification (column 1), the variable on innovation diffusion is considered, whereas 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 positive effects of both innovative variables. All variables are highly significant. The coefficients for value added (about 0.50) show that a 1% increase of value added leads on average to a half percentage point of job growth, whereas the negative impact of increases in labour costs per employee is lower.[7] The fixed effects show a strong variety of country patterns, with a more positive effect in Spain and the highest negative ones in Austria, Germany, the United Kingdom and France.

The basic picture that emerges is that job creation is higher in the industries and countries where demand 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.

(2) Table 2 presents the results for the same data obtained estimating separately the coefficients for high innovative industries and for low innovative ones[8] and concentrating on the role of the market impact of innovation.[9] 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 greater than in high-innovation sectors (−0.44 vs. −0.30), where the wage dynamics may be higher and consistent with job growth.

The most relevant difference, however, is the negative (and significant) effect that emerges for the market relevance of innovation in low-innovation industries, whereas 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 on 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.[10]

(3) In Table 3 a specification is tested with the two innovation indicators calculated as rates of change from the first to the second period. The analysis is carried out here with a cross section of industries and countries with data relative to a longer period, 1994–2001, and all variables are calculated in rates of change.[11] The econometric method used is ordinary least squares (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 in innovative firms (column 1) is not significant, whereas the impact of the growth of innovative turnover is confirmed to be positive and significant (column 2). When the two innovation variables are put together (column 3), the same outcome emerges. What brings a positive contribution to job growth in European industries is the product innovation that has a market impact, rather than innovation *per se*, as process innovations are dominant in several industries and countries.

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 job losses than expected and the latter with a better employment performance. Industry-fixed effect are therefore able to account for sectoral specificities, such as those associated to market structure and entry and exit of firms.[12] 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 has made it possible a specification of the model, where innovation indicators are also expressed as growth rates; the results continue to confirm those 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).

(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.[13] 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 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 emerges – employment may expand in sectors combining high innovation and growing wages. 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 stronger.

6. Conclusions

In spite of the limitations due to data availability, this sequence of simple econometric exercises opens the way to an explanation of changes in employment as a result of demand and wages dynamics and of different types of innovation. Among the determinants of job creation, the role of demand emerges as a key factor in all tests; high demand and value-added growth are necessary (although not sufficient) conditions for new employment.

Wage increases confirm the negative effect on job creation we can expect from the operation of labour markets; however, in the longer term (and in high-innovation industries) such a relationship disappears and fast-growing industries indicate a virtuous circle of growing demand and output, jobs and wages.

When innovation variables are considered, our results make it possible to overcome the limitations of previous studies investigating the static innovation–employment relationship with a cross section of countries and industries. The dynamic analysis and the lagged model confirm, however, previous findings on the diversity of innovative strategies characterising industries in particular countries. The general diffusion of innovation in firms appears to reflect a dominance of new processes with labour-saving effects; conversely, the market impact of product innovations has a job-creating impact.

Different mechanisms link technological change and employment in high- or low-innovation industries. The former are characterised by a greater importance of product innovation and lower constraints on wages. The latter shows an overall negative effect of innovation due to the dominance of process innovations in such sectors.

Finally, when a longer lag is allowed for assessing the impact of innovation, the 'neoclassical' negative relationship between wage and job growth becomes less relevant and the 'Schumpeterian' job-creating effect of the market impact of innovation is stronger.

The results of this article show that a sustained demand dynamics and product innovations with a market impact are crucial for long-term employment growth. 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 greater *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 may be in danger of further erosion.

Notes

1. See Vivarelli and Pianta (2000). For a theoretical discussion see Petit (1995). Surveys are in Addison and Teixeira (2001), Acemoglu (2002), Chennels and Van Reenen (2002), Spezia and Vivarelli (2002) and Pianta (2005). The impact of innovation on the skill structure and wages is also addressed in some of these contributions. Older work carried out at the aggregate level include Freeman, Clark and Soete (1982); Freeman and Soete (1987, 1994); Freeman and Louçã (2001); Vivarelli (1995). A reverse relationship between employment growth and technological activity in the case study of a large firm is discussed in Antonelli (2001, 173).
2. The relationship between technological and organisational innovations is an important related issue, but it is outside the scope of this article; on this aspect see Greenan (2003) and Simonazzi (2004).
3. The indicator has been built for the 10 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).
4. The innovating firms are those firms that have introduced either a product or a process innovation over the reference period (three year) of the survey.
5. For the use of such data see also Mairesse and Mohnen (2002) and Mohnen, Mairesse and Dagenais (2006). 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.
6. The two models in this first version are:

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

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

7. The lower coefficients of the innovation variables are due to the different unit of measure used (percentages).
8. The distinction between high- and low-innovation industries is based on the values of the share of innovating firms, as described in Appendix. The high innovative industries include chemicals and drugs; machinery; electronics; transport equipment. All remaining industries are considered low innovative sectors.
9. The model here is:

$$\dot{E}_{ijt} = k_i + a_i\dot{D}_{ijt} + b_i\dot{W}_{ijt} + d_iM_{ijt} + e_{ijt}$$

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% probability that the two coefficients for wages are not different. For the innovation impact we find a symmetrical impact of the coefficients with a different sign.
10. 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) and Antonucci and Pianta (2002). A similar significance of the difference between high- and low-innovation industries has been found in the determinants of the growth of wages and profits (Pianta and Tancioni 2008) and in the innovation-productivity link (Crespi and Pianta 2008).
11. 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:

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

12. The role of firm size has also been considered in a version of this model, but no significant result has been obtained, while the remaining coefficients have retained their sign and significance.
13. The model here is:

$$\dot{E}_{ijt} = k + a\dot{E}_{ijt-1} + b\dot{W}_{ijt-1} + d\dot{M}_{ijt-1} + e_{ijt-1}$$

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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 CIS 2 (1994–1996), with economic and structural data, drawn for the OECD STAN database. It includes data for 10 industrial sectors – Nace Rev.1 subsections – and 10 European countries – Austria, Germany, France, Italy, Norway, Finland, Spain, Sweden, the Netherlands and the United Kingdom – over the period 1994–2001.

The sectors included (and the relevant codes) are the following:

(1) Food and beverages (Nace Rev.1 classes 15 and16)
(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 and 24)
(5) Rubber and plastics products and other non-metallic mineral products (25 and 26)
(6) Basic metals and fabricated metal products (27 and 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 and 35)
(10) Manufacturing NEC and recycling (36 and 37)

Four sectors – electronics, machinery, chemicals and transport industries – are considered as *High-innovation industries* due to their above-average performance in innovation. The remaining industries are included in the *Low-innovation industries* group.

The innovation indicators

The two main innovation indicators used for both descriptive and econometric analysis are

(1) 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;
(2) the share of turnover from new or improved products in 1996 and 2000, measuring the market impact of product innovation strategies.

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, whereas

in the CIS 3 the coverage of surveyed units was extended to all the enterprises with at least 10 employees. A better level of data harmonisation across countries at the micro-level was 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 CIS 3 questionnaire. The efforts made for reducing the methodological differences between countries from CIS 2 to CIS 3 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 a highly aggregated sectoral level – NACE sections), the CIS 3 indicators used here 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. A full description of the survey and the main findings of CIS 2 and CIS 3 are in European Commission-Eurostat (2001, 2004)

The economic indicators

The economic indicators are drawn from the OECD STAN database; they include:

- 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 measured as number engaged. These figures consider one job as one worker. Although they may overestimate the real number of hours worked, they are internationally comparable. Data on total employment in 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), whereas 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 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 over 10 employees and CIS 2 data to firms over 20 employees. The use of rates of change in the variables included in the models reduces the bias due to such different populations. 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.