2010

# Innovation and employment: a reinvestigation using revised Pavitt classes

Mario Pianta
Francesco Bogliacino

Research Policy 39 (2010) 799–809

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

# Innovation and Employment: a Reinvestigation using Revised Pavitt classes

Francesco Bogliacino[a], Mario Pianta[b,*]

[a] Universidad EAFIT and RISE-group, Medellin, Colombia
[b] University of Urbino, Italy

ARTICLE INFO

*Article history:*
Received 27 August 2008
Received in revised form 30 June 2009
Accepted 23 February 2010
Available online 18 April 2010

*JEL classification:*
J20
J23
O30
O33

*Keywords:*
Innovation
Employment
Pavitt taxonomy

ABSTRACT

The relationship between innovation and employment is addressed in this article through a model and empirical test at industry level for eight European countries in 1994–2004. We investigate this relationship for manufacturing and services and propose a Revised Pavitt taxonomy (covering both of them) in order to identify specific patterns of technological change and job creation and loss. The contrasting effects of strategies of *technological* or *cost competitiveness* are investigated using innovation variables from CIS2 and CIS3. Together with demand, wages and industry dynamics, they account for changes in employees and hours worked. The diversity in these relations across industries is also explored; when the model is applied to each Revised Pavitt class, different mechanisms of technological change and effects on jobs emerge.



## 1. Introduction

Studies on the employment impact of technological change are in paradox. Advanced economies are deeply transformed by the diffusion of Information and Communication Technologies (ICTs) and yet little work is carried out that covers the *overall* consequences on the quantity of jobs. Conversely, a large literature has addressed the shifting *relative* composition of employment from blue to white collar workers, pointing out the *skill bias* effect of current technologies. Advanced economies are undergoing a major structural change – driven by changes in demand, technologies, organisations and international production – and yet a large economic literature leaves the explanation of job creation and loss mainly to labour market mechanisms.[1]

We believe that a careful understanding of the overall impact that technology has on employment is needed and that three problems – typical of the current literature – need to be considered in order to address it.

The first one stems from a conceptual issue – the view of technological change as an undifferentiated process. In much of the current literature, "technology" (often associated with ICTs) is expected to have a uniform impact on all firms, industries and economies. The complexity of the process of technological change and the variety of innovative activities carried out in firms are often lost and the contrasting effects that various patterns of technological change may have in different contexts are disregarded.

The second problem concerns the link between concepts and empirical work and the measures used as *proxies* of technological change in particular; R&D, patents or the adoption of ICTs are the most frequently used indicators but their limitations leave most innovative activities carried out in firms out of the analysis.[2]

* Corresponding author at: Facoltà di Economia, Università di Urbino, Via Saffi 42, 61029 Urbino, Italy. Tel.: +39 333 3396528; fax: +39 06 8841859.
*E-mail addresses:* francesco.bogliacino@gmail.com (F. Bogliacino), mario.pianta@uniurb.it (M. Pianta).

[1] Surveys of current literature on innovation and employment – with different conceptual perspectives and coverage – are in Addison and Teixeira (2001), Acemoglu (2002), Chennels and Van Reenen (2002), Spezia and Vivarelli (2002) and Pianta (2005). For a theoretical discussion, see Petit (1995). Previous work at the aggregate level on the overall employment impact of innovation include Freeman et al. (1982), Freeman and Soete (1987, 1994), Freeman and Louçã (2001), and Vivarelli (1995). Recent empirical studies are in Vivarelli and Pianta (2000).

[2] Firms carry out a wide range of innovative activities besides R&D including the acquisition of outside knowledge; internal design and engineering efforts; the acquisition of innovation-related machinery and equipment; efforts associated to the marketing of new products; all these aspects are measured for European countries by the Community Innovation Survey (Eurostat, 2008). Patenting is highly affected by the nature of the technology concerned and by firms' strategies on intellectual property leading to highly uneven patterns; moreover, in the whole service sector and the smaller manufacturing firms, little R&D and very little patenting is carried out. ICT adoption is often measured in *ad hoc* surveys with little comparability and may reflect very different patterns of innovation. A discussion on measures of innovation is in Smith (2005).

0048-7333/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.respol.2010.02.017

The third problem is of an empirical nature; the approach developed in many studies makes it difficult to draw general conclusions on the overall employment impact of technological change. Firm level studies are carried out on panels that are not representative of industries and they are unable to account for the *business stealing effect* where the job gains of innovative firms are obtained from the job losses of other firms in the same industry; moreover, the service sector, that represents the largest part of advanced economies, is usually left out of the analysis.[3]

In order to overcome such problems, we propose a view of technological change as a differentiated process and we argue that empirical studies are best carried out at industry level on both manufacturing and services with the use of the detailed indicators that can be drawn from innovation surveys. The relationship between technology and jobs is investigated in this article with a model and an empirical test where employment changes in European industries are explained by innovation, demand, wages and other factors; it provides three main contributions to the state of the art.

First, building on previous work,[4] it breaks down the view of an undifferentiated technology affecting employment and tests the contrasting employment effects of strategies of *technological competitiveness*, based on new products and new markets, and of *cost competitiveness*, relying on labour saving process innovations. We draw different indicators of such strategies from a rich database on 38 manufacturing and services industries for eight European countries with data from two waves of the Community Innovation Survey (CIS 2 and 3).[5] To our knowledge, this is the first investigation of innovation and employment that covers manufacturing and service data for a large number of countries and also includes a time dimension.

Second, we break down the idea that innovation and the other determinants of job creation and loss have the same impact across industries. In order to summarise the diversity across manufacturing and service industries, we propose a Revised Pavitt taxonomy that goes back to the original (Pavitt, 1984) groupings and extends them to include services. We argue that such taxonomy is an effective tool for identifying the variety of patterns of technological change and employment effects. The model for explaining changes in labour use is tested on each Revised Pavitt group, highlighting the diversity in the dynamics of job creation and loss. Again, this is the first time such an approach is developed.

Third, we investigate the impact of innovation and other economic factors on the number of work hours as well as on the number of employees (using data drawn from the KLEMS database). With the recent expansion of part-time work, the number of employees may be a less accurate measure of the actual amount of labour used in the economy.

The paper is organised as follows: Section 2 sets the conceptual framework, Section 3 describes data, model and econometric strategy, Section 4 presents the results and Section 5 provides a conclusion.

## 2. The diversity of innovation and the Revised Pavitt taxonomy

The conceptual framework we use in this article is based on two main building blocks. First, we rely on the Schumpeterian literature[6] that has argued that a clear conceptual distinction can be made between product and process innovations. Product innovations, either incremental or radical ones, developed through internal (and external) innovative activities, increase the quality and variety of goods and may open up opportunities for the growth of firms' output through larger quantities and/or prices. Conversely, process innovations lead to improvements in the efficiency of production of specific goods, lowering their prices, and are associated with investment embodying new technology. Although the two types of innovation are closely interlinked and in many innovative firms they often coexist, they are the results of separate innovative processes and pursue different objectives with different means.

Focusing on these differences, Pianta (2001) has identified a distinction between a strategy of *technological competitiveness* and a strategy of *cost* (*or price*) *competitiveness*. The former is associated with a dominance of product innovation, requires substantial internal innovative efforts (research, development, design, as well as new investment), a strong inventive activity reflected in patenting and a stream of new products with the objective of increasing market shares and open up new markets. A strategy of *cost competitiveness*, rooted in process innovation, focuses on increased efficiency achieved through a variety of technological efforts (design, engineering, etc.) concerning production processes and the introduction of new machinery, with a key relevance of the objective of reducing labour costs and increasing production flexibility; such efforts may lead to a decrease in price and, possibly, to larger market shares. The two strategies have contrasting effects on employment.[7]

The second conceptual building block is rooted in the effort of scholars to conceptualise the regularities of the innovation process and its diversity across industries. The most famous work is Pavitt (1984). Working on a database developed at the University of Sussex, Science Policy Research Unit (SPRU), on innovation in UK manufacturing firms, he classified industries in four groups on the basis of the nature of technological change, the features of production processes, market structures and other characteristics. A very large literature has adopted the Pavitt taxonomy in order to investigate several questions on innovation and economic performance (for a review, see Archibugi, 2001).

A recent challenge to this literature has been the extension of the taxonomy to services,[8] with various proposals to create new groups, include them in the low technology class of industries dominated by suppliers or develop a completely different taxonomy (see DTI, 2007 for a discussion). We chose a conservative strategy; we moved from the original Pavitt taxonomy and included service

[3] Examples of relevant firm level studies include Van Reenen (1997), Piva and Vivarelli (2005), Piva et al. (2005), Evangelista and Savona (2003), and Greenan and Guellec (2000) show that the positive employment impact of product and process innovation at the firm level disappears at industry level (where only new products lead to new jobs); see the survey and the discussion in Pianta (2005). We argue that an analysis at industry level can effectively summarise the heterogeneity in innovation strategies and performance, accounting for the overall employment dynamics in the industry; when manufacturing and service sectors are investigated, this leads to a comprehensive view of the patterns of structural change for the whole economy.

[4] See Pianta (2000, 2001), Antonucci and Pianta (2002), and Mastrostefano and Pianta (2009).

[5] CIS surveys still present some problems in the definition of variables and in the ability of respondent firms to answer correctly but a solid cross-country comparability has now been achieved. This represents a major advance compared with the previous use of R&D and patent data as proxies for innovation. See Smith (2005) and Eurostat (2008).

[6] See Schumpeter (1934), Cohen and Klepper (1994), Pianta (2001), and Edquist et al. (2001).

[7] This conceptual framework has been tested on data over a number of issues; Crespi and Pianta (2008) have reassessed the debate over demand pull versus technology push in innovation; Pianta and Tancioni (2008) have explored the effects of innovation on wages and profits; Antonucci and Pianta (2002) and Mastrostefano and Pianta (2009) have investigated the employment impact of innovation. We refer to these works for a detailed analysis of the innovation variables that can be used as *proxies* for the two strategies.

[8] In a later work (Tidd et al., 2005), Pavitt extended his taxonomy to services, mainly included in a new group of "ICT users, called Information Intensive industries. We found the original classification to be more robust and we included services in the different classes.

industries in the four classes on the basis of the evidence on their technological activities provided by innovation surveys.[9]

The result is a Revised Pavitt taxonomy (the list of sectors is in Table A3 in Appendix A) that can be summarised as follows:

(a) *Science-Based* industries (SB) include sectors where innovation is based on advances in science and R&D (such as the pharmaceuticals, electronics, computer services) where research laboratories are important, leading to intense product innovation and a high propensity to patent.
(b) *Specialised Supplier* industries (SS) include the sectors producing machinery and equipment; their products are new processes for other industries. R&D is present but an important innovative input comes from tacit knowledge and design skills embodied in the labour force. Average firm size is small and innovation is carried out in close relation with customers.
(c) *Scale and Information Intensive* industries (SI) include sectors (such as the automotive sector and financial services) characterised by large economies of scale and oligopolistic markets where technological change is usually incremental. New processes (often related to information technology) shape the organisation of production and coexist with new product development.
(d) *Supplier Dominated* industries (SD) include traditional sectors (such as food, textile, retail services) where internal innovative activities are less relevant, small firms are prevalent and technological change is mainly introduced through the inputs and machinery provided by suppliers from other industries.

We have assigned service industries to the four Revised Pavitt classes on the basis of conceptual and empirical considerations. On conceptual grounds, the role of R&D and knowledge in sectors such as Communications, Research and Development and Computers leave little doubt about the closeness of such industries to the Science-Based group. Second, real estate, renting of machinery and other business activities include specialised activities that support specific needs of clients, assimilating them to the Specialised Suppliers group. Third, financial and insurance services and auxiliary activities are characterised by large size of firms and an extensive adoption of ICT based machinery – a point that was already made by Pavitt in Tidd et al. (2005) – and can be included in the Scale and Information Intensive industries. Finally, wholesale and retail trade, hotels and catering and all transport services include very little internal innovative efforts and mainly rely on innovations provided by suppliers. They can therefore be included in the Supplier Dominated group.

On empirical grounds, such associations have been confirmed by an analysis of several innovation variables (for further details, see Bogliacino and Pianta, 2008); a summary of the evidence is discussed in the data section below.

The diversity in the patterns of technological change and employment outcomes among these classes is documented in the descriptive evidence offered in Section 3 and is tested with our econometric model in Section 4.

Alongside these conceptual building blocks on the diversity of technological change and heterogeneity of industries, our analysis of employment change relies on a consolidated stream of research that considers demand, wages and other economic and labour market factors as key factors.[10] The model presented in the next section will reflect this set of determinants of job creation and loss.

## 3. Data, model and econometric strategy

### 3.1. Data

In order to explore the research questions on the diversity of the trajectories of technological change and the impact of innovation on employment, we use a major database recently developed at the University of Urbino – the Sectoral Innovation Database (SID) that includes most variables of the three comparable waves of the Community Innovation Survey (CIS 2, 3 and 4) and a large amount of statistical information on economic performance and employment drawn from different sources. The country coverage includes eight major European countries – Germany, France, Italy, Norway, the Netherlands, Portugal, Spain and the United Kingdom. Data are available for the two-digit NACE classification of manufacturing and service industries. The full description of the sources and methodology followed for the construction of the database is provided in the SID Methodological Notes (University of Urbino, 2007).

In this article we consider innovation data from CIS 2 (1994–1996) and CIS3 (1998–2000) for the eight countries. Variables that are used include R&D expenditure, expenditure for innovation-related machinery (both divided by employees), the shares of turnover due to new products, the share of firms introducing innovations in order to reduce labour costs; these indicators provide evidence on the contrasting strategies of *technological* and *cost competitiveness* that characterise European industries.

Industry-level innovation data are matched – in the Sectoral Innovation Database – to economic performance indicators drawn from the University of Groeningen 60 industry and KLEMS databases and from the OECD STAN database. We mainly use variables based on KLEMS data for employees, hours worked, value added, labour productivity, labour compensation (including social contributions), all in constant prices.

We allow a lag between innovation and performance, in order to control for a potential endogeneity problem[11]: innovative activities carried out in 1994–1996 (CIS 2) are expected to affect employment in the 1996–2000 period; innovation in 1998–2000 (CIS 3) is related to labour use in 2000–2004. Details are provided in Appendix A.

### 3.2. Descriptive results

The overall dynamics of labour use – in terms of work hours and jobs – in the two periods considered (1996–2000 and 2000–2004) leads us to identify four major patterns (see Table A1 in Appendix A).

The first one follows on from the downturn of European economies after 2001; all labour indicators in the second period are lower than in the first one; manufacturing jobs move from stability to a loss of 3% per year whereas in services, job creation is cut to one third of the previous period. Secondly, the structural shift from manufacture to services is not affected by the business cycle: the gap between labour use in services and manufacturing is stable in the two periods; employment in manufacture is constant in the first 4 years and decreasing in the following four whereas employment in services increases rapidly in the first period and slowly in the second one. The third interesting aspect is that in manufacturing, work hours decrease less than employees in both periods whereas

[9] We rely on the work by Evangelista (2000), Evangelista and Savona (2003) and Miozzo and Soete (2001), who provide a conceptual framework and empirical support to this approach. Detailed work to test the robustness of the Revised Pavitt taxonomy has been carried out in Bogliacino and Pianta (2008).

[10] Works with this approach include Vivarelli (1995), Vivarelli and Pianta (2000), Antonucci and Pianta (2002), and Mastrostefano and Pianta (2009).

[11] This is also consistent with the Schumpeterian approach where technology is deemed to play a role after an adjustment lag.

the opposite applies to services. The reduction of work hours per employee was a stylised fact for a very long period in Europe and this pattern is continuing in the service sector as a result of the spread of part-time service jobs. Conversely, in European manufacturing, the restructuring taking place has led to an increase in the effort per worker in the context of industrial decline, reversing a long term characteristic of employment in industry.

When we consider the innovation variables (see Table A2 in Appendix A), the strategies of *technological* and *cost competitiveness* can be summarised by two sets of variables – the expenditure per employee devoted to R&D or to innovation-related machinery; the relevance of new products in turnover or the share of firms innovating in order to reduce labour costs. The averages for manufacturing and services show some regularities: (1) manufacturing devotes more resources to R&D than services do but the outcomes in terms of share of turnover due to new products are similar; (2) manufacturing firms give greater priority to labour saving innovations than service firms do and in the second period, they invested much more in new machinery associated with (process) innovation.

The manufacturing/service dichotomy is, however, of little help in understanding the nature of innovation and a Revised Pavitt taxonomy (presented in Table A3 in Appendix A) is used in order to identify distinct patterns of technological change. Following up on the discussion of the previous section, in Table A4 in Appendix A we report the average values for the manufacturing and service industries included in each Revised Pavitt class for the same four major innovation variables used in Table A2. Again, we find important regularities for manufacturing and services. In the Science-Based class, the average values of R&D expenditure per employee and share of innovative turnover are the highest compared to the manufacturing and services subgroups in other Revised Pavitt classes. In the Specialised Suppliers class we find high shares of innovative turnover and low relevance of machinery expenditure relatively to manufacturing and services averages in other categories. In the Scale and Information Intensive industries we find the highest values of machinery expenditure per employee and a strong relevance of labour saving strategies. Finally, in the Supplier Dominated group, we find the lowest values of R&D expenditure per employee and share of innovative turnover for both manufacturing and services. This empirical evidence provides further support to the definition of the Revised Pavitt classes (see Appendix A and Bogliacino and Pianta, 2008) and we can use the taxonomy to map distinct patterns of technological change (in Fig. 1) and job creation and loss (in Fig. 2).

The four Revised Pavitt classes are mapped in the first graph along two key indicators of technological strategies, the share of new products in turnover and the share of firms innovating in order to reduce labour costs. Science-Based industries have the strongest focus on *technological competitiveness*, as well as labour cost reduction; Specialised Supplier industries follow the *technological competitiveness* trajectory with less cost-cutting efforts; in Scale and Information Intensive industries the search for *cost competitiveness* prevails with little relevance of new products; Supplier Dominated industries devote the least effort to innovation and are typically associated with a search for *cost competitiveness*.


**Fig. 1.** Innovative turnover and labour saving strategy in Revised Pavitt classes, averages of CIS 2 and 3.
*Source*: University of Urbino, Sectoral Innovation Database.

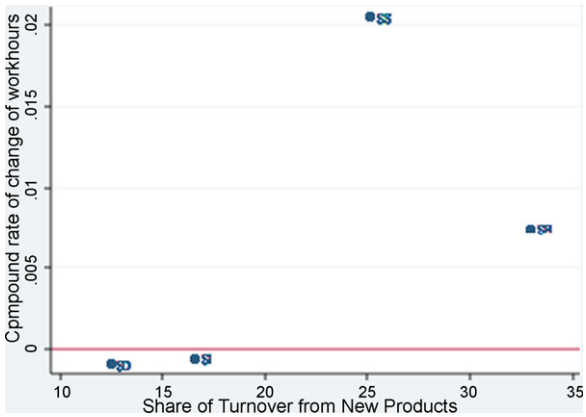


**Fig. 2.** Innovative turnover (averages of CIS 2 and 3) and average annual change in work hours in Revised Pavitt classes, 1998–2000 and 2000–2004.
*Source*: University of Urbino, Sectoral Innovation Database.

The effects on employment of such different trajectories are clearly seen in Fig. 2. A strategy of *cost competitiveness* is associated with (modest) reductions in work hours for the average of the manufacturing and service industries in the Scale and Information Intensive and in the Supplier Dominated groups. Work hours increase most in Specialised Suppliers where the search for labour saving innovation is less relevant and a significant increase is also found in Science-Based industries, driven by the development of new products.

The econometric analysis in the next section will investigate the relationships that underlie these general patterns in detail.

### 3.3. Model

The basic model we propose is based on the discussion above:

$$\Delta lab_{it} = \beta_0 + \beta_1 \cdot TC_{i,t-1} + \beta_2 \cdot CC_{i,t-1} + \beta_3 \cdot \Delta w_{it} + \beta_4 \cdot ID_{it} + \varepsilon_{it} \quad (1)$$

The rate of change of labour inputs is regressed over a variable capturing activities aiming at *technological competitiveness* (*TC*), a variable reflecting a *cost competitiveness* strategy (*CC*), the rate of change of labour compensation ($w$) and an indicator of industrial dynamism (*ID*) which we proxy through the rate of change of the number of firms in each sector. The last term is the error component; $i$ identifies industries, $t$ time.

In some specifications of the model, we include the average rate of growth of productivity (value added per hour or per employee). Country dummies are also added in order to account for the effects of national systems of innovation (Freeman, 1995).

As a dependent variable, we use both the number of employees and the total hours worked in each industry; we test the model first on all manufacturing and service sectors and then we run the regressions for each of the Revised Pavitt taxonomy groups; several controls and robustness checks are introduced.

Following on from our conceptual framework, we expect proxies for *technological competitiveness* (R&D and new products) to

**Table 1**
The determinants of employment growth in European industries.

| | Work hours (1) | Work hours (2) | Employees (3) | Employees (4) |
|---|---|---|---|---|
| Share of turnover from new products | 0.0002 (0.0001)** | 0.0003 (0.0001)** | 0.0003 (0.0001)* | 0.0004 (0.0001)** |
| Share of firms innovating to reduce labour cost | −0.0002 (0.0001)* | −0.0002 (0.0001) | −0.0002 (0.0001)* | −0.0001 (0.0001) |
| Rate of change in the number of firms | 0.0290 (0.0177)* | 0.0303 (0.0183)* | 0.0298 (0.0180)* | 0.0322 (0.0190)* |
| Labour compensation per hour (rate of growth) | −0.2574 (0.0623)*** | −0.2197 (0.0630)*** | | |
| Labour compensation per employee (rate of growth) | | | −0.2501 (0.0739)*** | −0.1927 (0.0735)*** |
| Value added per hour (rate of growth) | | −0.0605 (0.0166)*** | | |
| Value added per employee (rate of growth) | | | | −0.1075 (0.0338)*** |
| Country dummies | | | | |
| DE | 0.0307 (0.0097)*** | 0.0268 (0.0099)*** | 0.0336 (0.0119)*** | 0.0287 (0.0116)** |
| ES | 0.0269 (0.0036)*** | 0.0263 (0.0037)*** | 0.0305 (0.0040)*** | 0.0297 (0.0040)*** |
| FR | 0.0367 (0.0052)*** | 0.0158 (0.0087)* | 0.0104 (0.0050)* | 0.0098 (0.0051)* |
| IT | 0.0219 (0.0042)*** | 0.0195 (0.0045)*** | 0.0231 (0.0046)*** | 0.0201 (0.0045)*** |
| NL | 0.0300 (0.0061)*** | 0.0281 (0.0062)*** | 0.0340 (0.0077)*** | 0.0316 (0.0074)*** |
| PT | 0.0242 (0.0064)*** | 0.0200 (0.0062)*** | 0.0192 (0.0056)*** | 0.0159 (0.0052)*** |
| UK | 0.0045 (0.0055) | 0.0031 (0.0057) | 0.0071 (0.0060) | 0.0057 (0.0060) |
| NO | 0.0133 (0.0042)*** | 0.0127 (0.0041)*** | 0.0089 (0.0049)* | 0.0089 (0.0047)* |
| Manufacturing | −0.0218 (0.0046)*** | −0.0223 (0.0047)*** | −0.0237 (0.0046)*** | −0.0245 (0.0046)*** |
| *N* obs | 327 | 305 | 327 | 305 |
| *R* squared | 0.45 | 0.47 | 0.45 | 0.50 |

Dependent variable: average annual rate of growth of work hours (1, 2). Average annual rate of growth of employees (3, 4). Pool of 38 industries in DE, ES, FR, IT, NL, PT, UK, NO, in 1996–2000 and 2000–2004. WLS with clustered (at industry level) and heteroskedasticity robust standard errors. Standard errors in brackets.

* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

have a positive effect on labour use and indicators of *cost competitiveness* (new machinery and labour cost reductions) to reduce labour inputs. In all regressions we include a wage variable – the rate of growth of labour compensation per employee or per hour worked – that we expect will have a negative effect on labour inputs. Finally, we control for the rate of change of the number of firms in each sector, an indicator of industrial dynamism and entry patterns (ID) that may also reflect the change in capital installed; we expect a positive effect for this variable.

When we test the model on the Revised Pavitt classes, we expect some diversity in results. In Science-Based industries *technological competitiveness* may play a dominant role in expanding labour use, wages and demand may have a minor effect. Specialised Suppliers industries again are expected to rely on *technological competitiveness*, with some influence of demand due to their specific user-producer interactions. The Scale and Information Intensive sectors may be close to the general model with a stronger role of demand associated with the presence of economies of scale. The Supplier Dominated group is characterised by a strategy of *cost competitiveness* and may be particularly affected by demand and wage growth.

### 3.4. Econometric strategy

As a baseline equation, we estimate the following labour demand curve:

$$y_{it} = x'_{it}\beta + u_i + v_{it} \tag{2}$$

where $y_{it}$ is the employment variable, $x_{it}$ the vector of regressors, $u_i$ the individual effect and $v_{it}$ the random disturbance, for industry $i$ and time $t$. Variables are assumed to be in log scale. As a standard procedure, we can assume the equation above to be the result of a cost minimisation programme by a firm with a translog cost function.

We eliminate the individual effect by taking the first difference of Eq. (2). The difference in log approximates the rate of change, thus we express both dependent variable and regressors in rate of variation (we take the annual compound rate instead of the long difference in order to better understand coefficients). Innovation variables are not expressed in rates; they are either shares of firms in the sector, shares of turnover or expenditure per employee (see Appendix A for details). However, innovative efforts are *intrinsically dynamic* and are deemed to capture the *change* in the technological opportunity set available to the industry.

Once expressed in differences, the model can be estimated consistently using OLS. Since we use industry-level data, we are dealing with data grouped in classes of different sizes and, for this reason, we use a Weighted Least Squares procedure using work hours as weights.[12] Since heteroskedasticity is pervasive, we use robust standard error. We also adjust standard errors for a potential correlation at industry level.

The robustness of our results is tested by running regressions for both work hours and employees, by using different proxies for *technological* and *cost competitiveness* and by testing the relationships on the Revised Pavitt classes and manufacturing industries only.

## 4. Results

Table 1 shows the results of the basic model; the first two columns use the rate of change of work hours as a dependent variable, the last two use the rate of change of employees in the same specifications of the regressions.[13] Turnover from new products is considered as a *proxy* for *technological competitiveness* and the share of firms aiming to reduce labour costs as a *proxy* for the alternative strategy. In order to explore the impact of greater production efficiency, we also test the model including the growth of labour productivity.

Expected results are strongly confirmed: in all versions, *technological competitiveness* has a significant positive effect on labour inputs and *cost competitiveness* has a negative impact. The negative effect of wages – a "neoclassical" labour market effect – and the positive effect of the growth in the number of firms – a "Schum-

[12] Employment-based data are usually more precise than value added; the use of the latter as a weight in our regression does not significantly affect the results.

[13] Obviously, the wage and productivity variables are related to work hours in the first two columns and to employees in the last two.

**Table 2**
The determinants of employment growth in European industries. Other innovation indicators.

| | Work hours (1) | Employees (2) |
|---|---|---|
| Log of R&D expenditure per employee | 0.0049 (0.0021)** | 0.0048 (0.0021)** |
| Log of expenditure on innovative machinery per employee | −0.0039 (0.0017)** | −0.0049 (0.0018)*** |
| Rate of change in the number of firms | 0.0733 (0.0123)*** | 0.0728 (0.0126)*** |
| Labour compensation per hour (rate of growth) | −0.2204 (0.0634)*** | |
| Labour compensation per employee (rate of growth) | | −0.2096 (0.0698)*** |
| Value added per hour (rate of growth) | −0.0964 (0.0297)*** | |
| Value added per employee (rate of growth) | | −0.0363 (0.0082)*** |
| Country dummies | | |
| DE | 0.0320 (0.0073)*** | 0.0364 (0.0075)*** |
| ES | 0.0486 (0.0083)*** | 0.0541 (0.0080)*** |
| FR | 0.03501 (0.0127)*** | 0.0242 (0.0080)*** |
| IT | 0.0334 (0.0068)*** | 0.0356 (0.0067)*** |
| NL | 0.0495 (0.0088)*** | 0.0531 (0.0080)*** |
| PT | 0.0401 (0.0113)*** | 0.0374 (0.0096)*** |
| UK | 0.0172 (0.0079)** | 0.0210 (0.0077)*** |
| NO | 0.0198 (0.0093)** | 0.0134 (0.0106) |
| Manufacturing | −0.0382 (0.0061)*** | −0.0405 (0.0059)*** |
| *N* obs | 316 | 316 |
| *R* squared | 0.51 | 0.55 |

Dependent variable: average annual rate of growth of work hours (1). Average annual rate of growth of employees (2). Pool of 38 industries in DE, ES, FR, IT, NL, PT, UK, NO, in 1996–2000 and 2000–2004. WLS with clustered (at industry level) and heteroskedasticity robust standard errors. Standard errors in brackets.
*Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

peterian" industrial dynamism effect – are found in all regressions. The latter clearly accounts for a "Schumpeter mark I" effect: the net entry of firms in industries suggests the presence of technological opportunities exploited by innovative firms that are able to create new jobs. Productivity has a negative impact on labour inputs, suggesting that improvements in efficiency are obtained mainly through labour saving rather than through demand and output expansion. The inclusion of the productivity variable reduces the significance of the labour saving variable, meaning that its effect has been partially captured by it. Finally, there is a negative effect of the manufacturing dummy variable that captures the structural change of European countries towards service-based economies[14]; country effects appear to affect employment growth positively, with the exception of the United Kingdom, where the dummy variable is not significant.

In order to test the robustness of our innovation variables, we run the basic regression using other *proxies* for the technological strategies; we use the log of R&D expenditure per employee and the log of machinery expenditure per employee as indicators, respectively, of *technological* and *cost competitiveness*. Results are shown in Table 2: the sign and magnitudes of all variables are confirmed. The relevance of national specificities is also confirmed; their analysis, however, is beyond the scope of this article.

The overall relationships between technology and employment highlighted by these results may, however, conceal diversities in the patterns that are present in subsets of industries. We therefore run the basic model on each group of the Revised Pavitt taxonomy and also introduce a variable on demand growth (proxied by the rate of change of value added) which is expected to play a role in industries where "demand pull" effects are important.

Results are reported in Table 3 where each column corresponds to a group (in Appendix A, we restrict the sample to manufacturing industries only in order to test robustness and the results are once again confirmed).

A substantial diversity in the significance of the determinants of work hours emerges through this breakdown of manufacturing and service industries. As expected, in Science-Based industries *technological competitiveness* – proxied by the relevance of new products – is a major factor in the increase of hours worked, together with industrial dynamism, while wage and demand growth play no significant role. The Schumpeterian nature of this group emerges in the clearest way: employment growth is sustained by the entry of new firms and by the introduction of new products that expand sales. The labour market here is not of the "neoclassical" type, wage growth does not discourage job creation and indeed much of the innovation expenditure (e.g. on R&D) consists of salaries to technicians who are the source of innovative success.

For the Specialised Supplier, the expected roles of *technological competitiveness* and *cost competitiveness* are confirmed with a positive (but not significant) and negative sign, respectively; we find the positive employment effect of demand – associated with the key role of interaction with clients – and the negative effect of wages, both significant, while industrial dynamism plays no role due to the small number of firms operating in these industries.[15]

Scale and Information Intensive sectors show a significantly negative employment impact of *both* innovation variables, no relevance of industrial dynamisms, a positive effect of demand and a negative one of wages. We have shown above that these industries experienced an overall loss of employment over this period, going through restructuring and extensive adoption of new processes; the dominance of a *cost competitiveness* strategy is confirmed and even the introduction of new products appears unable to expand employment.[16] Restructuring and job losses are more likely to hit industries with the highest wage dynamics whereas labour use still depends on demand growth due to the need to take advantage of economies of scale; furthermore, the oligopolistic nature of these industries creates barriers to entry that limit the job creation ability of new firms.

Supplier Dominated industries typically rely on *cost competitiveness* (the new products variable has a negative, not significant effect) and show the highest values of the coefficients for labour compensation (negative) and demand (positive) whereas the net entry of new firms has no significant impact. The expected results are once again confirmed with the traditional industries of this group showing negative employment effects of innovation (mainly new processes), a "neoclassical" labour market and a very high importance of demand, the only variable capable of increasing the number of hours worked.

Behind the (robust) relationships identified by our results for all manufacturing and service industries, shown in Tables 1 and 2, equally robust but *different* relationships emerge when we intro-

[14] An additional comment concerns the similarity of the results we have obtained for the variables on changes in employment and work hours; while cyclical changes could lead work hours to change more rapidly than the number of jobs, our analysis mainly concerns a cross-sectional perspective and cycles – by definition – affect most observations in the same direction. We can conclude that the mechanism rooted in technological change, labour markets and demand have a similar impact on the number of jobs and hours worked across European industries and countries.

[15] Some of these results may be affected by the small sample size of this group.

[16] These industries were most affected by the transfer of production and jobs outside Europe; if new products are the result of a new system of international production, no positive impact will emerge on domestic employment. The interaction between innovation and globalisation in shaping employment outcomes is examined in our current research.

**Table 3**
The determinants of employment growth in Revised Pavitt classes.

| | Science-Based work hours (1) | Specialised Suppliers work hours (3) | Scale and Information Intensive work hours (2) | Supplier Dominated work hours (4) |
|---|---|---|---|---|
| Share of turnover from new products | 0.0006 (0.0003)* | 0.0008 (0.0005) | 0.0004 (0.0002)* | −0.0004 (0.0002) |
| Share of firms innovating to reduce labour cost | −0.0003 (0.0003) | −0.0007 (0.0002)** | −0.0003 (0.0001)** | −0.0004 (0.0001)*** |
| Rate of change in the number of firms | 0.1587 (0.0686)*** | −0.0048 (0.0214) | 0.0104 (0.0196) | 0.0069 (0.0178) |
| Labour compensation per hour (rate of growth) | −0.0931 (0.0887) | −0.3279 (0.1466)** | −0.1767 (0.0681)** | −0.4722 (0.0668)*** |
| Value added (rate of growth) | −0.0419 (0.0442) | 0.4079 (0.1790)** | 0.4652 (0.0748)*** | 0.6442 (0.0971)*** |
| Constant | −0.0161 (0.0120) | 0.0042 (0.158) | −0.0038 (0.0046) | 0.0166 (0.0039)*** |
| *N* obs | 56 | 37 | 102 | 110 |
| *R* squared | 0.31 | 0.63 | 0.56 | 0.63 |

Dependent variable: average annual rate of growth of work hours. Pool of industries in DE, ES, FR, IT, NL, PT, UK, NO, in 1996–2000 and 2000–2004. WLS with clustered (at industry level) and heteroskedasticity robust standard errors. Standard errors in brackets.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

duce a breakdown of sectors based on Revised Pavitt classes. The role of technology is radically different in these groups as is the opportunity for industrial dynamism, the role of demand and the constraint emerging from wage increases. Interestingly, the diversity between manufacturing and services is of little relevance in these relationship; the results of our test on manufacturing industries only (see Table A5 in Appendix A) confirm the diversity among Pavitt classes in the determinants of hours worked.[17]

These results – made possible by the extensive use of innovation survey data – provide a major advancement in our understanding of the innovation-employment link. They confirm Pavitt's original idea that innovative strategies are differentiated across industries and show, as we claim, that different mechanisms shape the employment outcome of each group as a result of specific technological, demand and labour market dynamics.

## 5. Conclusions

The complex ways in which technological change affects employment have led much of current research to address general relationships with inadequate proxies for technology. In this article we have broken the "spell" that prevents a clear understanding of the *diversity* of the mechanisms of technological change and of its effects on the use of labour in two fundamental directions. First, the concepts of *technological* and *cost competitiveness* and the use of appropriate innovation variables able to account for the prevalence of such diverse strategies within European industries have made it possible to identify the contrasting effects of technology on jobs: efforts to develop new products and new markets may lead to new jobs whereas a search for labour saving process innovation leads to job losses.

Second, these mechanisms do not operate in the same way in all industries and the manufacturing/service distinction is of little relevance to understanding outcomes. We consider the Pavitt taxonomy to be an excellent tool for analysing and summarising differences in the patterns of technological change across industries. We built on the original groupings proposed by Pavitt (1984) and extended them to include services, developing a Revised Pavitt taxonomy that makes it possible to identify distinct groups of manufacturing and service industries characterised not only by specific patterns of technological change but also by specific relationships between innovation and economic variables shaping employment outcomes. The richness of the database we used allowed us to empirically test the differences in these relationships across Revised Pavitt classes.

This parallel breakdown of views – and empirical approaches – that treat innovation as an undifferentiated process and industry diversities as irrelevant, offers a major contribution to understanding the complex relationships between technological change and employment.

Innovation, however, does not shape employment outcomes alone. Building on substantial previous research, our model and empirical results show that changes in the use of labour – here estimated for the first time with a parallel analysis of employment and work hours – are generally affected by increases in demand and wages; we also identified a major role played by industrial dynamism, with the growth in the number of firms that plays a major role in job creation, reflecting the "Schumpeter mark I" nature of industries. Such relationships clearly emerged in our analysis across all manufacturing and service industries and over two periods of time.[18]

However, important differences across industry groups exist not only for innovation but also for the nature of demand, wages and industrial dynamism. When our model is applied to each of the classes of the Revised Pavitt taxonomy, we find clear support for the intuition of Keith Pavitt in proposing his original taxonomy. The (modest) expansion of hours worked in Science-Based industries over the period of study is driven by the relevance of new products – a *proxy* for *technological competitiveness* – and by the net entry of new firms while labour saving process innovation has no significant effect and demand and wage growth are equally irrelevant; this group has an obvious Schumpeterian nature in its patterns of technological change and in its employment dynamics. In Specialised Supplier industries, different mechanisms affecting jobs coexist with weaker positive effects of new products and stronger negative effects on new labour saving processes, with a positive impact of demand and a negative one of wages; this group of industries has the best job creation performance in the period we examined. Scale and Information Intensive sectors – that recorded a net loss of jobs – appear dominated by a labour saving

[17] Two main differences are found between the results in Table A5 (on manufacturing only) and Table 3 (on all industries); in Scale and Information Intensive industries, new products have a significantly positive effect on employment; in Supplier Dominated industries, the share of firms aiming to cut labour costs has a significantly positive effect on hours worked.

[18] The lags we introduced between innovation and employment change make sure that endogeneity is not a problem in our tests. In Mastrostefano and Pianta (2009) the same relationships are investigated for a smaller number of manufacturing industries, considering longer time lags, and innovation variables also expressed in rates of change; the results obtained there provide further support to the robustness of our findings.

use of technology and by a strategy of *cost competitiveness*, relying on the positive role of demand, with a negative effect of wages and no relevance of industrial dynamisms, given their oligopolistic market structure. Finally, Supplier Dominated industries – that also experienced a decline in employment – show that changes in hours worked are the result of the negative effect of new processes (reflecting a search for *cost competitiveness*) and wages while the increase in demand is the only factor supporting job creation in this group.

Building on our breakthroughs, three main directions for future research emerge.

(a) Besides innovation and industries, an additional break down is needed for employment variables. Total employees or work hours can be divided by professional groups and a similar model – integrated with information on educational level – can be applied in order to identify the different determinants of job creation and loss for managers, clerks, skilled and unskilled manual workers.[19]
(b) The different patterns of technological change are associated with specific patterns of organisational change that is also documented by Community Innovation Surveys. An investigation of the combined impact of new products, processes and organisations in industries can shed additional light on the employment dynamics.
(c) We found the job losses in Scale and Information Intensive and Supplier Dominated industries to be related to the labour saving use of technology and the reactivity to wage increases; these factors, however, may have their roots in the increase in competition and market penetration from foreign producers and in the international production systems of European firms. An investigation of the combined impact of technology and globalisation on employment may complete the picture of the determinants of job creation and loss in Europe.

## Acknowledgements

We would like to thank three referees and Nick Von Tunzelman for their comments. Work for this article was partly funded by the Italian Ministry of Research FIRB project RISC, "Ricerca e imprenditorialità nella società della conoscenza: effetti sulla competitività dell'Italia in Europa" (RBNE039XKA).

## Appendix A.

### A.1. Data

The database used for this article is the Sectoral Innovation Database developed at the University of Urbino that includes innovation data drawn from Community Innovation Surveys (CIS) and economic data drawn from a variety of sources. Data cover 21 manufacturing and 17 services industries – aggregated at 2 digit level using the NACE Rev. 1 classification – for eight European countries: Germany, Spain, France, Italy, The Netherlands, Portugal, Norway and the UK. The Sectoral Innovation Database has been developed through cooperation agreements with national data providers – either national statistical institutes or research groups with access to CIS data. All data are representative of the total population of firms (see University of Urbino, 2007 for details).

[19] This work is carried out in Nascia and Pianta (2008).

**Table A1**
Average annual rate of change in work hours and employees.

| | 1996–2000 | | 2000–2004 | |
|---|---|---|---|---|
| | Work hours | Employees | Work hours | Employees |
| Manufacturing | 0.02 | −0.04 | −2.38 | −2.85 |
| Services | 3.51 | 4.05 | 1.18 | 1.27 |

*Source*: University of Urbino, Sectoral Innovation Database.
Manufacturing and services, 1996–2000 and 2000–2004, percentages.

For this article we have used Community Innovation Survey data, wave 2 (reference years 1994–1996) and wave 3 (1998–2000) and economic indicators taken from OECD STAN and from the Groeningen Growth and Development Center (GGDC) 60 industry database and KLEMS. The list of the 38 industries considered is included in Table A3.

In order to investigate the effect of innovation, we introduce a lag in performance variables, calculated as rates of change over a 4-year period starting from the last year of the relevant CIS wave (CIS 2 data refer to 1994–1996 and are related to economic and employment data for the 1996–2000 period; CIS 3 data refer to 1998–2000 and are related to the 2000–2004 period). We calculate annual average compound rates of change since data are only available from 1996 to 2003 for some of the countries.

#### A.1.1. The innovation variables

The CIS indicators used in this analysis are:

- Share of turnover from new or improved products.
- Share of firms aiming at reducing labour cost.
- (log of the) R&D expenditure per employee (thousands of euros at 1995 prices).
- (log of the) Expenditure on machinery and equipment linked to innovation per employee (thousands of euros at 1995 prices).
- Rate of change in the number of firms in each sector from one wave to the next.

#### A.1.2. The economic indicators

We collected data from the following sources:

- For work hours, employees and labour compensation we used KLEMS (except Norway where the source is STAN).
- For value added the source is OECD STAN for Norway, Italy and Germany (data are available up to 2004) and GGDC 60 industry database for the other countries (data are available only up to 2003).

All data are deflated using GDP deflators (base year 1995) and are expressed in euros, using PPPs for Norway and United Kingdom. Using these data we calculate the average annual compound rates of change for the following variables:

- Number of employees and hours worked.
- Value added.
- Value added per employee and per hour worked.
- Labour compensation per employee and per hour worked.

An overview of the main descriptive statistics is provided in the tables below (Tables A1 and A2).

### A.2. The Revised Pavitt taxonomy

The elaboration of a Revised Pavitt taxonomy has required detailed investigation at the conceptual and empirical level, that

**Table A2**
Key innovation variables.

| | 1994–1996 | | 1998–2000 | |
|---|---|---|---|---|
| | Technological competitiveness | Cost competitiveness | Technological competitiveness | Cost competitiveness |
| | In house R&D expenditure per employee | Expenditure on innovative machinery per employee | In house R&D expenditure per employee | Expenditure on innovative machinery per employee |
| Manufacturing | 2.41 | 1.96 | 2.88 | 3.20 |
| Services | 1.92 | 2.07 | 2.08 | 1.29 |
| | Share of turnover from new products | Share of firms innovating to cut labour cost | Share of turnover from new products | Share of firms innovating to cut labour cost |
| Manufacturing | 24.62 | 39.38 | 14.5 | 25.19 |
| Services | n.a. | 28.74 | 15.49 | 15.74 |

*Source*: University of Urbino, Sectoral Innovation Database.
Manufacturing and services, 1996–2000 and 2000–2004, thousands of euros at 1995 prices and percentages.

can be found in Bogliacino and Pianta (2008) and cannot be fully reported here for lack of space. The list of the industries, with NACE codes, in the Revised Pavitt classes is provided in the following Table A3.

A preliminary empirical evidence on the coherence between the manufacturing and service industries within each Revised Pavitt class is shown in Table A4. The four variables considered are the same as in Table A2. For each class, we show the average values of the manufacturing and services subgroups (considering data from all countries and all CIS waves available).

The evidence confirms the large role that R&D and innovative turnover play in Communications, Research and Development and Computers, the service industries that have been included in the Science-Based class. Real estate, renting of machinery and other business activities show considerable innovative turnover, non-negligible R&D and are less focused on machinery and labour cost reduction; such service industries appear close to the Specialised Suppliers group. Financial and insurance services and auxiliary activities have the highest values of expenditure in machinery per employee as well as a large firm size, and can be grouped in the Scale and Information Intensive class. Finally, wholesale and retail trade, hotels and catering and all transport services have the lowest internal R&D efforts and innovative turnover; they can be included in the Supplier Dominated group.

Additional evidence on the robustness of the Revised Pavitt taxonomy comes from the stability of the results when our models for the four classes are tested separately on the whole manufacturing and service database (in Table 3) and on manufacturing industries alone (in Table A5 below). The Revised Pavitt taxonomy appears to effectively capture the diversity of the relationships between innovation and employment in European manufacturing and service industries.

### A.3. Econometric analysis

In order to test the robustness of our model, we have tested the regressions for the Pavitt classes – shown in Table 3 – on Manufacturing industries only using the original Pavitt (1984) taxonomy. We wanted to check whether the inclusion of services in the Revised Pavitt taxonomy could lead to a distortion in the patterns of technological change and their performance effects. The results are shown in Table A4 below; the exclusion of services leads to lower sample size and reduced significance of some coefficients but the results obtained in Table 3 are broadly confirmed.

**Table A3**
The Revised Pavitt taxonomy for manufacturing and services.

| | NACE codes |
|---|---|
| Science-Based | |
| Chemicals | 24 |
| Office machinery | 30 |
| Manufacture of radio, television and communication equipment and apparatus | 32 |
| Manufacture of medical, precision and optical instruments, watches and clocks | 33 |
| Communications | 64 |
| Computer and related activities | 72 |
| Research and development | 73 |
| Specialised Suppliers | |
| Mechanical engineering | 29 |
| Manufacture of electrical machinery and apparatus n.e.c. | 31 |
| Manufacture of other transport equipment | 35 |
| Real estate activities | 70 |
| Renting of machinery and equipment | 71 |
| Other business activities | 74 |
| Scale intensive | |
| Pulp, paper and paper products | 21 |
| Printing and publishing | 22 |
| Mineral oil refining, coke and nuclear fuel | 23 |
| Rubber and plastics | 25 |
| Non-metallic mineral products | 26 |
| Basic metals | 27 |
| Motor vehicles | 34 |
| Financial intermediation, except insurance and pension funding | 65 |
| Insurance and pension funding, except compulsory social security | 66 |
| Activities auxiliary to financial intermediation | 67 |
| Supplier Dominated | |
| Food, drink and tobacco | 15–16 |
| Textiles | 17 |
| Clothing | 18 |
| Leather and footwear | 19 |
| Wood and products of wood and cork | 20 |
| Fabricated metal products | 28 |
| Furniture, miscellaneous manufacturing; recycling | 36–37 |
| Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel | 50 |
| Wholesale trade and commission trade, except of motor vehicles and motorcycles | 51 |
| Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods | 52 |
| Hotels and catering | 55 |
| Inland transport | 60 |
| Water transport | 61 |
| Air transport | 62 |
| Supporting and auxiliary transport activities; activities of travel agencies | 63 |

NACE two-digit industries.

**Table A4**
Innovation in manufacturing and service industries in the Revised Pavitt classes.

| Industry | In house R&D expenditure per employee | Share of turnover from new products | Expenditure on innovative machinery per employee | Share of firms innovating to cut labour cost |
|---|---|---|---|---|
| Science-Based | | | | |
| Average SB manufacturing | 9.03 | 33.83 | 2.51 | 33.67 |
| Average SB services | 2.82 | 28.31 | 1.05 | 19.65 |
| Specialised Suppliers | | | | |
| Average SS manufacturing | 4.47 | 19.89 | 1.26 | 27.83 |
| Average SS services | 0.18 | 9.09 | 0.32 | 15.00 |
| Scale and Information Intensive | | | | |
| Average SII manufacturing | 1.65 | 15.76 | 2.78 | 28.00 |
| Average SII services | 1.00 | 12.56 | 1.45 | 23.05 |
| Supplier Dominated | | | | |
| Average SD manufacturing | 0.50 | 12.84 | 1.11 | 24.09 |
| Average SD services | 0.24 | 7.44 | 1.25 | 14.16 |

*Source*: University of Urbino, Sectoral Innovation Database.
Average values for European industries over the three CIS waves.

**Table A5**
The determinants of employment growth in Pavitt classes, manufacturing only.

| | Science-Based work hours (1) | Specialised Suppliers work hours (3) | Scale and Information Intensive work hours (2) | Supplier Dominated work hours (4) |
|---|---|---|---|---|
| Share of turnover from new products | −0.0002 (0.0006) | 0.0005 (0.0004) | 0.0006 (0.0002)*** | −0.0003 (0.0003) |
| Share of firms innovating to reduce labour cost | 0.0002 (0.0004) | −0.0003 (0.0001)** | −0.0003 (0.0001)*** | 0.0003 (0.0001)** |
| Rate of change in the number of firms | 0.2759 (0.1082)** | 0.0806 (0.0370)** | 0.0131 (0.0257) | 0.0149 (0.0234) |
| Labour Compensation per hour (rate of growth) | −0.0328 (0.1254) | −0.2098 (0.1409) | −0.2077 (0.0631)*** | −0.4361 (0.0880)*** |
| Value Added (rate of growth) | −0.0438 (0.0345) | 0.2713 (0.1017)** | 0.4790 (0.0800)*** | 0.6748 (0.1058)*** |
| constant | −0.0296 (0.0122)** | −0.0187 (0.0139) | −0.0079 (0.0045)* | 0.0060 (0.0060) |
| *N* obs | 40 | 33 | 85 | 87 |
| *R* squared | 0.42 | 0.61 | 0.65 | 0.67 |

Dependent variable: average annual rate of growth of work hours. Pool of industries in DE, ES, FR, IT, NL, PT, UK, NO, in 1996–2000 and 2000–2004. WLS with clustered (at industry level) and heteroskedasticity robust standard errors. Standard errors in brackets.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

## References


Acemoglu, D., 2002. Technical change, inequality and the labour market. Journal of Economic Literature 40 (1), 7–72.
Addison, J., Teixeira, P., 2001. Technology, employment and wages. Labour 15 (2), 191–219.
Antonucci, T., Pianta, M., 2002. The employment effects of product and process innovations in Europe. International Review of Applied Economics 16, 295–308.
Archibugi, D., 2001. Pavitt's taxonomy sixteen years on: a review article. Economics of Innovation and New Technology 10, 415–425.
Bogliacino, F., Pianta, M., 2008. The impact of R&D and innovation on economic performance and employment: a quantitative analysis based on innovation survey data. European Commission-Joint Research Centre, Institute for Prospective Technological Studies (IPTS-Seville) Report (J03/32/2007).
Chennels, L., Van Reenen, J., 2002. In: Greenan, L'Horty, Mairesse (Eds.), Technical Change and the Structure of Employment and Wages: A Survey of the Microeconometric Evidence, pp. 175–224.
Cohen, W.M., Klepper, S., 1994. Firm size and the nature of innovation within industries: the case of process and product R&D. Review of Economics and Statistics 788 (2), 232–243.
Crespi, F., Pianta, M., 2008. Demand and innovation in productivity growth. International Review of Applied Economics 22 (September), 5.
DTI, 2007. Innovation in Services. DTI Occasional Papers 9, June, 2007.
Edquist, C., Hommen, L., McKelvey, M., 2001. Innovation and Employment: Product Versus Process Innovation. Elgar, Cheltenham.
Eurostat, 2008. Science, Technology and Innovation in Europe, 2008 Edition. European Commission, Luxembourg.
Evangelista, R., 2000. Sectoral patterns of technological change in services. Economics of Innovation and New Technology 9, 183–221.
Evangelista, R., Savona, M., 2003. Innovation, employment and skills in services. Firm and sectoral evidence. Structural Change and Economic Dynamics 14, 449–474.
Freeman, C., Louçã, F., 2001. As Time Goes By. From the Industrial Revolution to the Information Revolution. Oxford University Press, Oxford.
Freeman, C., 1995. The National System of Innovation' in historical perspective. Cambridge Journal of Economics 19 (1), 5–24.
Freeman, C., Clark, J., Soete, L., 1982. Unemployment and Technical Innovation. Pinter, London.
Freeman, C., Soete, L. (Eds.), 1987. Technical Change and Full Employment. Blackwell, Oxford.
Freeman, C., Soete, L., 1994. Work for All or Mass Unemployment? Pinter, London.
Greenan, N., Guellec, D., 2000. Technological innovation and employment reallocation. Labour 14 (4), 547–590.
Greenan, N., L'Horty, Y., Mairesse, J. (Eds.), 2002. Productivity, Inequality and the Digital Economy—A Transatlantic Perspective. MIT Press, Cambridge.
Mastrostefano, V., Pianta, M., 2009. Technology and jobs. Economics of Innovation and New Technology 18 (7–8), 729–742.
Miozzo, M., Soete, L., 2001. Internationalisation of services: a technological perspective. Technological Forecasting and Social Change 67, 159–185.
Nascia, L., Pianta, M., 2008. Skill bias or polarisation? Innovation and job growth in Europe. In: Paper Presented at the EAEPE 2008 Annual Conference, Rome, 6–8 November.
Pavitt, K., 1984. Patterns of technical change: towards a taxonomy and a theory. Research Policy 13, 343–374.
Petit, P., 1995. Employment and technological change. In: Stoneman, P. (Ed.), Handbook of the Economics of Innovation and Technological Change. Amsterdam, North Holland, pp. 366–408.
Pianta, M., 2000. In: Vivarelli, Pianta (Eds.), The Employment Impact of Product and Process Innovation, pp. 77–95.
Pianta, M., 2001. Innovation, demand and employment. In: Petit, P., Soete, L. (Eds.), Technology and the Future of European Employment. Elgar, Cheltenham, pp. 142–165.
Pianta, M., 2005. In: Fagerberg, Mowery, Nelson (Eds.), Innovation and Employment, pp. 568–598.
Pianta, M., Tancioni, M., 2008. Innovations, wages and profits. Journal of Post Keynesian Economics 31 (1), 103–126.
Piva, M., Santarelli, E., Vivarelli, M., 2005. The skill bias effect of technological and organisational change: evidence and policy implications. Research Policy 34, 141–157.
Piva, M., Vivarelli, M., 2005. Innovation and employment, evidence from Italian microdata. Journal of Economics 86 (1), 65–83.

Schumpeter, J.A., 1934. Theory of Economic Development, 1st ed. Harvard University Press, Cambridge, MA, p. 1911.
Smith, K., 2005. In: Fagerberg, Mowery, Nelson (Eds.), Measuring Innovation, pp. 148–179.
Spezia, V., Vivarelli, M., 2002. In: Greenan, L'Horty, Mairesse (Eds.), Innovation and Employment: A Critical Survey, pp. 101–131.
Tidd, J., Bessant, J., Pavitt, K., 2005. Managing Innovation: Integrating Technological. Market and Organizational Change. Wiley, London.
University of Urbino, Faculty of Economics, 2007. Sectoral Innovation Database Methodological Notes. Urbino, Mimeo.
Van Reenen, J., 1997. Employment and technological innovation: evidence from U.K. manufacturing firms. Journal of Labor Economics 15, 255–284.
Vivarelli, M., 1995. The Economics of Technology and Employment: Theory and Empirical Evidence. Elgar, Aldershot.
Vivarelli, M., Pianta, M. (Eds.), 2000. The Employment Impact of Innovation: Evidence and Policy. Routledge, London.