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"INNOVATION AND EMPLOYMENT IN ECONOMIC CYCLES"

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Innovation and employment in economic cycles

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Abstract

This article explores the way economic cycles influence the relationship between innovation and employment in manufacturing industries. We investigate whether the ups and downs of cycles alter the possibility of exploiting technological opportunities and affecting patterns of job creation. A model that explains industries' employment change by combining technology and demand is proposed; the empirical test is based on data on 21 manufacturing sectors from 1995 to 2007 for Germany, France, Italy, the UK, the Netherlands and Spain. Results show that, in upswings, employment change is affected by new products, exports and wage growth, while during downswings new processes contribute to restructuring and job losses.

Keywords: *Innovation, Cycles, Employment, Demand*

JEL classification: *L6, J20, O30,E32*

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1. Introduction[1]

Employment dynamics have always followed a cyclical pattern; expansions of production bring new jobs, recessions lead to job losses. Economic analysis has long viewed this dynamic from an aggregate perspective, focusing, within a Keynesian framework, on the role of demand fluctuations. In this article we want to integrate this perspective with the consideration of changes in supply structures, exploring how the evolution of industries and the diversity of technological change affect employment in the different phases of economic cycles. We argue that the relationship between specific innovative strategies and their employment outcomes, taking into account changes in demand and wages, are radically different in upswings, when new products may open up new markets and offer new jobs, and in downswings, when new processes may come to dominate technological change, leading to restructuring and job losses.

In order to investigate these issues, different streams of literature are wowen together in section 2, a model is developed in section 3, an econometric test is carried out in section 4 and conclusions are discussed in section 5. The findings support the view that innovation-based growth and job creation may operate in drastically different ways during different phases of the cycle, suggesting the need to move beyond the assumption that employment dynamics are affected by the same factors and in the

[1] A preliminary version of this paper was presented at the international workshop "Crises, Institutions and Labour Market Performance: Comparing Evidence and Policies" organised by EACES, EAEPE, AIEL, AISSEC and the University of Perugia, held in Perugia on 10 November, 2011. We thank the participants, Josef Brada and Marcello Signorelli for their comments.

same way in upswings and downswings. In particular, the key role of demand in shaping job creation has to be integrated with new attention to industry-specific innovative strategies, which have contrasting employment effects over the cycle.

2. Literature and approach

Demand and wages matter

A large macroeconomic literature, generally with a Keynesian perspective, has investigated employment dynamics in their relationship to the cyclical patterns of economic growth. The ups and downs of aggregate demand have been shown to affect changes in production and demand for labour. Along the cycle, however, the same production function is generally assumed to operate and the relationship between output and labour demand has rarely been questioned. Distinctions have been made between the determinants of employment in short-term business cycles and in long-term growth, with the consideration of specific capital-labour complementarities, the evolution of labour supply and, more recently, the diversity of labour skills. Labour economics perspectives, on the other hand, have focused on the role of wages in affecting employment outcomes, and the relevance of cycles is usually considered in order to account for lower wage claims by workers and unions in periods of high cyclical unemployment (Layard, Nickell and Jackman, 1991; Davis, Haltiwanger and Schuh, 1996; Pissarides, 2009).

While these perspectives are essential in order to explain employment changes over the cycle, their aggregate nature represents a major limitation. In order to provide a more comprehensive explanation of the evolution of employment, we argue that the supply structures need be explored, considering the way industries and innovative activities affect job creation and destruction.

Industries and technologies matter

Neo-Schumpeterian approaches have explored the diversity of technological trajectories of sectors. The characteristics of knowledge and competencies differentiate them in modes through which innovation occurs (Pavitt, 1984, Malerba and Orsenigo, 1997, Breschi, Malerba and Orsenigo 2000). This representation introduces heterogeneity in the process of technological change. Sectoral patterns appear to be the appropriate level of analysis for considering such a variety in an effective way. Industry-specific patterns of technological change account for the systemic nature of innovation and for its impact on economic performances. The diversity of technological trajectories shapes the dynamics of industries and the overall process of structural change (Pasinetti, 1981). Moreover, sectoral specificities are related to country-specific institutions and policies, shaping the national system of innovation (Freeman, 1995).

Innovation and employment

A large literature has explored the impact of innovation on employment at the firm and sectoral levels. Innovation is generally identified as a key factor shaping the dynamics of employment and an important distinction is usually made between the employment effects of product and process innovation: the first is able to lead to new jobs, while a negative employment impact is often found for the second.[2]

Starting from the distinction between product and process innovation in Schumpeter (1934), Pianta (2001) identifies two different types of strategies, technological and cost competitiveness: the former is associated with the search for product innovation

[2] For a review, see Pianta (2005). See Van Reenen (1997), Piva and Vivarelli (2005), Harrison et al. (2006), Hall et al. (2008), Bogliacino, Piva and Vivarelli (2012) for studies at the firm level; Greenan and Guellec (2000), Evangelista and Savona (2003), Mastrostefano and Pianta (2009), Bogliacino and Pianta (2010), Bogliacino, Lucchese and Pianta (2012) for the sectoral level of analysis.

or a better quality of products and a general orientation towards new markets; the latter is tied to the search for labour-saving process innovation, price competitiveness and flexibility in production. These categories characterize the main orientation of sectors in terms of the nature of innovative efforts and can be used in order to appreciate the impact of innovation on value added, employment and productivity. In Bogliacino and Pianta (2010), the differences in technological change are studied through the introduction of a Pavitt taxonomy extended to services. Different mechanisms of job creation are identified for each class, showing that technological competitiveness has a positive impact on employment in high technology industries, while employment losses prevail in traditional sectors, more oriented towards a cost competitiveness strategy. Evangelista and Savona (2003) found similar results on the role of innovation on employment in services in Italy, where job creation occurs in small, technology driven firms. Demand expansion emerges as a key factor for employment growth, while process innovation has mainly led to job losses.

The impact of economic cycles

Neoclassical perspectives, with their emphasis on equilibrium, have paid limited attention to the impact of business cycles on growth. Real business cycles approaches and endogenous growth theory have developed diverging explanations of the sources of fluctuations and growth, paying attention, in very different ways, to the role of technology (Galì, 1999; Gaggl and Steil, 2007). In endogenous growth studies, downswings can stimulate productivity and foster long-term growth through a process of restructuring and reorganization of activities where inefficient firms are crowded out, raising the rate of productivity growth of the whole economic system (Caballero and Hammour, 1991, Aghion and Saint-Paul, 1998). On the other hand, a short-term rise in output is able to increase long-run productivity and employment. By emphasizing the pro-cyclical character of technological change, business cycles can reinforce growth during an upswing, increasing the stock of capital devoted to training and learning (Blackburn and Pelloni, 2004). As described by Stiglitz (1993), upswings can overcome financial constraints that prevent firms from borrowing resources to innovate. In fact, when firms are credit constrained, they need to use their own profits to finance R&D and innovation. Others models describe a process of creative destruction where the continuous improvement of the quality of innovations generates growth by substituting old technologies and reinforcing the process of diffusion of innovation (Aghion and Howitt, 1992). In Aghion and Saint-Paul's model (1998), firms need to sacrifice a part of their production in order to increase productivity and this sacrifice is lower during expansions.

Evolutionary perspectives have developed a different view. Business cycles have been at the centre of the work of Schumpeter. A large body of literature has explored, building on his approach, the link between innovation, long economic cycles and employment. For Schumpeter, innovation activity is typically uncertain and discontinuous and the process of expansion is, in turn, uneven and unbalanced. This irregularity is transmitted to investments and employment, which expand in response to technological change (Schumpeter, 1934). While Schumpeter was interested in the unfolding of innovations and their impact on growth, the notion of long waves has fuelled a debate on the occurrence of clusters of radical innovations. For Mensch (1979), innovations bunch during depression phases: in upswings, firms do not have incentives to introduce new products because they can exploit rents from a higher demand for existing products; in a downswing, expected profits are lower and introducing innovations appears as a more attractive strategy. Kleinknecht (1982) emphasized the role of depressions in stimulating innovations, although the evidence is uncertain.

For Freeman (Freeman et al, 1982, Freeman and Louca, 2001), depressions can increase incentives to innovate, but strong demand with expanding markets creates high expectations of profits and important opportunities for the introduction of major innovations leading to the expansion of employment in emerging industries. In Freeman's approach the diffusion of major innovations throughout the economy is more relevant than their original introduction. In order to appreciate the real impact of technology on growth and jobs in the long term, it is necessary to identify the unfolding of technological revolutions, or techno-economic paradigms, defined as a cluster of radical innovations that shape the direction of technological change, building on particular scientific advances and offering wide opportunities for applications throughout the economy at rapidly decreasing costs. Although they recall the Schumpeterian idea of clustering of innovations, Freeman's techno-economic paradigms require the presence of favourable social and institutional conditions, including the presence of human and social capital. In this context, the possibility to identify clear regularities in the temporal distribution of innovations is reduced, as in each historical phase technological change and economic growth assume different forms (Perez, 1983, Freeman et al., 1982 and Freeman and Louca, 2001). In these studies the focus is on the ability of the techno-economic paradigm to support a wave of growth over several decades through the opportunities offered by scientific and technological discoveries, leading to a broad range of radically new products with a large potential demand offering large opportunity for job creation. This process leads to changes in production systems throughout the economy, with the adoption of superior technologies contributing new inputs, sources of energy, modes of organisation and control of production. Freeman also suggested that short term business cycles could have an impact on the type of innovations introduced in the economy; product innovation is associated to phases of strong growth, while process innovations seem to be “more attractive to entrepreneurs in periods of pressure on profit margin and during the downswing of long waves and even in depressions” (Freeman 1982, p. 4; Freeman and Louca, 2001).

The approach

Our approach combines strands of literature reviewed above. Besides the macroeconomic and demand dimensions, the evolution of business cycles affects employment dynamics also through the nature of technological change and the diversity of industrial structures. We can expect that during upswings the potential for Schumpeterian profits from major innovations is greater, and this would favour the introduction of new products. On the other hand, in industries where radical innovations are less important, we may find that the expansion of demand lowers the competitive pressure and the need to innovate through technological advantages; in fact, during upswings even less efficient firms may survive and profit.

Conversely, during downswings, the lack of demand may discourage the introduction of new products and may increase competition based on costs and prices, leading industries to focus on new processes that allow labour saving and cost cutting in the context of restructuring and exit of less-efficient firms. But in some industries the very increase in price competition may lead to pressure to achieve technological advantages and introduce new products.

Focusing on industry level patterns, we allow for the possibility of either effect to emerge; however, we expect that, across sectors, upswings will be characterized by a greater role for new products in sustaining growth, and during downswings new processes will play a dominant role leading to the restructuring of production and job losses. Changes in demand play a key role in shaping employment outcomes. With rising demand, new products may lead to the expansion of new markets, and major investments in new processes may also be introduced to expand production capacity. With stagnant or falling demand, the introduction of new products may not be profitable, and a strategy based on process innovation may lead to restructuring, productivity improvements at the cost of job losses.

Our approach emphasizes the role of demand as an essential condition for the exploitation of industries' technological opportunities, a complementary factor to the unfolding of technological change. A coordination between technological and demand factors is required if growth is to be achieved, and only when new products find new markets does innovation contribute to economic development. In this perspective, our approach combines Schumpeterian insights with a post-Keynesian view of demand-led growth (Pasinetti, 1981, Kaldor, 1966).

In this analysis we focus on the industry level as it allows us to combine insights on micro behaviour, taking into account the profit incentives and innovation mechanisms in firms, without having to deal with the heterogeneity of firms. The industry level accounts for the diversity of industries and their technological regimes; industry aggregates are able to reflect the dominant pattern of technological change that characterise each sector, with its mix of new products and processes. Moreover, at the industry level we can fully consider the demand constraint that is typical of cycles; while individual firms can always find new demand by stealing markets from competitors, for industries demand is given by the combination of macroeconomic growth and the sectoral distribution of different demand components, shaping the pattern of structural change.

3. Empirical analysis

Data

In order to identify the role of innovation on employment during the economic cycle, we use industry-level data from the Urbino Sectoral Database (USD) developed at the University of Urbino. It combines data on innovation, drawn from the fourth (2002-2004), the third (1998-2000) and the second (1994-1996) Eurostat Community Innovation Survey (CIS) with other international sources of data at the sectoral level of analysis. The result is a comprehensive dataset that is able to highlight the role of innovation and the dynamics of structural change in major European economies from 1995 to 2007.

The specific dataset used for this work is based on the match of Eurostat CIS data and the 2010 OECD Structural Analysis (STAN) database. Due to the structural nature of the relationships we study and to the different sources of data, countries have been selected in terms of the greatest available coverage of sectors and data reliability. Countries included in the analysis are Germany, France, Italy, the Netherlands, Spain and the United Kingdom. The dataset covers 21 manufacturing sectors, from 15 to 37 NACE REV.1 subsections. The sectors included in the analysis and the relative NACE Rev.1 codes are presented in Table 1.

CIS data are able to describe the various patterns of technological change through a wide range of measures on the innovative activities of sectors that overcome the role of traditional indicators such as R&D and patenting. CIS variables considered in this paper include: the share of turnover due to a new or improved products, the share of firms for which the sources of innovation come from suppliers of equipment and materials; real expenditures per employee, which is associated with the acquisition of innovative machinery or equipment.[3] The quality and reliability of these data have been checked through quality controls on micro data that are described in Pianta, Lucchese and Supino (2012). An analysis of the consistency and stability of the dataset has been provided by Bogliacino and Pianta (2009), where an overall test on the stability of the distributions across waves, industries and countries is offered.

Economic variables from OECD STAN include industry-level measures on performance, employment, competitiveness from 1970 to 2007. In order to explore industry-level dynamics of employment we select industry data on the number of employees (thousands), the monetary value for the labour compensation of employees and export of goods.[4]

Descriptive analysis

In order to summarize the diversity of industry patterns in innovation and employment over the cycle, we rely on the well-known Pavitt taxonomy (Pavitt, 1984). It provides a relevant conceptualization of the differences in the process of technological change by classifying firms and industries on the basis of their dominant sources of innovation, the forms of appropriation of technology and market structure.[5] In his taxonomy, Pavitt identifies four groups that describe the level of technological opportunities of each industry:

(a) Science-Based industries include sectors based on advancements in science, where R&D is the main source of innovation such as chemicals and

[3] In order to allow comparability among years and countries, we have deflated the expenditure variables and scaled them by using employment in sectors.

[4] Monetary variables have been expressed at constant prices using sectoral deflators. In order to limit the distortion introduced by the use of OECD industry-level hedonic prices, sector 30 (Office computing) has been deflated using the price index of the aggregate of the electrical and optical sector (30-33 sectors). All monetary variables have been previously expressed in Euro. For the United Kingdom, the original figures provided in GBP millions have been transformed using the exchange rate expressed in PPP (Prices and purchasing power parities, Statistics in Focus 53, 2004).

[5] A number of studies has used the Pavitt taxonomy to analyze the variety of technological trajectories (for a review, see Archibugi, 2001).

pharmaceuticals, office machinery. High technological opportunities are associated with a strong internal innovative effort. Together with specialized supplier sectors, they represent the most innovative sectors and a source of innovation for the whole economic system.

(b) Specialized supplier industries create specific products for users-industries, and these typically include machinery and equipment, with an active role for human capital. High levels of Research & Development expenditure (R&D) and a tacit transferring of knowledge among workers characterize a strong internal innovation process;

(c) Scale intensive industries include sectors characterized by large economies of scale, high capital intensity and strong relevance of organizational improvements such as motor vehicles, rubber and plastic products;

(d) Supplier dominated industries include traditional sectors including food, textiles, clothing); they typically direct efforts towards the mechanization of productive processes; innovation principally sources from suppliers of equipment and materials.

The list of sectors and the relative Pavitt groups are shown in Table 1.

[Table 1]

The diversity in the patterns of employment in the manufacturing sector is documented in Figure 1, where the dynamics of employment from 1995 to 2007 is shown. Figure 1 plots the annual rates of change of the number of employees classified by Pavitt groups as the first evidence of the diversity in the relationship between innovation and employment during the economic cycle.[6]

[Figure 1]

Considering the whole period, cycles affect the employment patterns of all industry-groups. In particular, Figure 1 identifies three key periods:

- a first phase from 1996 to 2000 is characterized by a some growth of employment, especially in specialized supplier industries;
- a second phase from 2000 to 2003 is marked by a deep slowdown of economic activity and a sharp fall in jobs creation in all sectors;
- a third phase from 2003 to 2007 shows decreasing job losses and modest job creation in high-technology industries.

These cycles represent the macroeconomic context of our analysis of the impact of innovation on employment. High technology sectors, especially science-based industries, are affected by the ups and downs of the economy, although they traditionally devote more resources to innovation and new products. In the context of demand shortage, an increase of the quality and variety of goods cannot be associated with value added growth, while productivity growth and a higher competitiveness can be obtained through lower employment. High technology sectors are thus particularly vulnerable to cycles, as shown by the heavy job losses in the 2000-2003 recession. Conversely, scale-intensive industries show a less rapid decline in employment; these sectors are characterized by a higher degree of market power that can explain the greater stability in their employment patterns over the cycle. Traditional industries

[6] The rates of changes of each group are calculated as average values among sectors and countries. Data for Office, Accounting and Computing machinery industry (30, Nace Rev. 1) have not been considered in the descriptive analysis. This sector is characterized in different countries by strong fluctuations that distort the overall pattern; in terms of the number of employees, it represents about the 1% of total employment only.

such as supplier dominated sectors, are characterized by a long-term decline in employment associated with the broader patterns of structural change and demand dynamics; with an industrial structure that relies less on technology and that is characterized by smaller firms, this group is highly vulnerable to economic downturns.

This pattern is highlighted in Figure 2, where Pavitt groups are mapped in a graph relating their employment performance with the share of innovative turnover due to new products, for each class and period.[7] During upswings, science-based and specialized supplier sectors appear to have the highest innovative turnover, the best available proxy of the impact on new products, and the best performance in employment. Conversely, during downswings, the performance of high technology industries worsens dramatically. These different patterns of job evolution over the cycle are rooted, as seen in section 1, not just in demand dynamics, but also in the different technological orientation of industries. In upswings in 1996-2000 and 2003-2007, the performance in terms of employment growth is clearly related, in Figure 2, to the relevance of innovative turnover although with lower job creation in the second period. During the 2000-2003 recession, this relationship disappears and both new products and new jobs fall to very low levels.

[Figure 2]

The model and the econometric strategy

In order to investigate the impact of the economic cycle on the relationship between

[7] In Figure 2, innovative turnover from CIS 2 (1994-1996) is related to the rate of change of employment in 1996-2000; CIS 3 (1998-2000) to 2000-2003; CIS 4 (2002-2004) to 2003-2007. Rates of change of employment of each group are average values among sectors and countries.

innovation and employment, we propose the following model:

$$\Delta emp_{i,t} = \beta_1 \Delta tc_{i,t} + \beta_2 \Delta cc_{i,t} - \beta_3 \Delta w_{i,t} + \beta_4 \Delta exp_{i,t} + \Delta \varepsilon_{i,t}$$

where *emp* is the compounded annual rate of change of employment, *tc* and *cc* are proxies for the technological and the cost competitiveness strategy, *exp* are exports, a proxy for demand, *w* is the compound annual rate of change of labour compensation (changes in labour cost), ε is the error term, for industry i and period t. A simple indicator of the market structure of sectors, the average number of employees within each sector per firm, drawn from CIS, is also considered. The model introduces specific country effects in order to account for differences in country characteristics.

We estimate a model that allows coefficients to differ in upswings (1996-2000 and 2003-2007) and in the downswing (2000-2003), consistently with the phases defined in Section 3. The differences in β coefficients describe the impact of innovation on employment in the different phases of cycle. Table 2 reports the variables and the periods. Economic variables are related to the last year of reference of the relevant CIS wave.

[Table 2]

Building on the literature review, we expect that technological and cost competitiveness strategies have a contrasting effect on employment: employment growth emerges in product innovation oriented sectors, while new processes generally result employment losses.

However, the impact of these strategies is affected by the dynamics of the economic cycle. Technological competitiveness is expected to have a positive effect on employment during the upswing phases; but it could play a minor role in a downswing because of the lack of demand. Conversely, a labour-saving strategy is expected to have a significant and negative sign in the downswing due to the occurrence of a process of restructuring. Changes in demand growth (expressed as changes in exports) should reinforce employment growth during the upswings and may turn out not significant in a downswing. Wage growth, the labour compensation per employee, is expected to negatively affect employment through the neoclassical mechanism of labour demand, but its impact can be stronger when economic activity is reduced and cost constraints are higher for firms.

The baseline model can be estimated consistently with OLS. The model is adjusted for heteroschedasticity and intra-group correlation at the industry level, checking for intra-sectoral heterogeneity. In order to weigh observations, we use the average employment level in each sub-period with the aim to assure stability over time. The possibility of multicollinearity is checked through the VIF analysis (Variance Inflation Factors). The structure of lags in the innovation-employment link and the use of long differences should reduce endogeneity problems.

4. Results

In order to explore the relevance of cycles in the relationships between innovative strategies and employment dynamics, we have first tested the model on all our cases, both the upswings and downswings, with results reported in Table 3. Second, we estimated different coefficients for the upswings and downswings, showing that there are major differences in the way different innovative strategies, demand and wages affect overall changes in employment, and these results are reported in Table 4. Third, we add firm size to the determinants of job creation and consider the full set of country dummies in Table 5.

The general model is confirmed by our test, as shown in Table 3. When no consideration is taken of the presence of business cycles, employment change in manufacturing industries in six major European countries is explained by the importance of product innovation as proxied by the share of turnover due to new or improved products, and by the growth of exports that represent the most dynamic component of demand. Wage growth is negatively related to job creation. The only non-significant result is the negative effect of process innovation, proxied by the expenditure for innovative machinery per employee. Country dummies are included and always emerge as significant due to differences in labour market institutions across Europe.

[Table 3]

The way we can investigate the impact of business cycles on the above relationships is to test the model using separate coefficients for the two periods of upswing and the period of downswing. The results are shown in Table 4, with two versions of the model that use different variables as proxies of innovation. The findings of column (1) show that, for the two periods of upswing, the results are very similar to those of Table 3, with job creation supported by new products and exports and reduced by high wage growth. In the period of downswing, however, the results change. New products and exports are not significant, while job losses are associated with the relevance of process innovation as proxied by innovative machinery expenditure per worker, as well as with high wage dynamics. In the downswing the whole relationship is inverted; the recession leads to job losses that are associated with a restructuring of industries that is more dramatic where labour saving new processes are more relevant. Conversely, the job creating potential of new products is lost, and exports fall even faster than jobs. The negative relationship between employment change and wage increases becomes stronger ,with a coefficient of -1.06, twice as high as in upswings, suggesting that job losses in Europe have hit most severely those industries with above average wage growth.

In order to test the robustness of these results we have also used a different proxy for process innovation; in column (2) the share of firms identifying suppliers as the source of their innovation is used in place of machinery expenditure, and the same results, with similar coefficients, are obtained. These results show the radically different nature of the innovation-employment relationship in the different phases of the business cycle.

[Table 4]

In order to consider the relevance of firm size and market structure in shaping employment outcomes in European industries we tested an additional version of the model that includes all country dummies. The previous results are all confirmed; the average firm size of industries emerges as a positive and significant factor in job creation during upswings and is not significant during downswings, showing that major job losses are found both in traditional industries dominated by small businesses and in industries characterised by larger firms. Again, country dummies are always significant as they account for strong institutional diversities.

[Table 5]

5. Conclusions

Employment has always been affected by business cycles and the economic literature has long explored the macroeconomic and demand determinants of this relationship. The originality of our perspective and findings is that besides considering demand factors, proxied in our investigations by exports, we show that employment outcomes are affected by the nature of technological change. A clear difference emerges between new products that support job creation in times of growth, and new processes that are instrumental in job destruction in times of recession. These differences in the nature of innovation are visible in the diversity of industries, characterized either by a dominance of product-oriented efforts at technological competitiveness, or by a widespread use of new processes to achieve cost competitiveness, usually at the cost of large layoffs.

These results parallel a previous analysis (Lucchese and Pianta, 2011) of the relationships between innovation and growth (measured by the dynamics of industry value added) in the same periods of business cycles. During upswings aggregate industry growth, as well as productivity increases, appeared to be supported by both new products and new processes, as both technological and cost competitiveness may lead to output or efficiency improvements. During downswings new processes associated to restructuring appear significant in supporting the increase in value added or in containing its fall, while new products and export demand lose their relevance.

Our approach combines the lessons from the macroeconomic analysis of business cycles with an attention to the nature of technology and the patterns of structural change in manufacturing industry. By combining such perspectives, we have obtained new insights into the determinants of job creation and loss over the business cycle in

European manufacturing industries. However, the succession of phases of the cycle should not be considered in a mechanistic way, with a sequence of different relationships shaping economic performances. As shown is recent related research (Bogliacino and Pianta, 2012), there are major feedback loops in the "engines of growth" that relate technology to economic and employment results. R&D efforts lead to new products and better innovative performance that results in higher profits that, in turn, can finance the R&D effort and support the virtuous circle of innovation-based growth. This evolutionary view suggests that a weakening of this engine of growth can lead to inferior performance in all steps of the process. In this article we have shown that recessions disrupt the mechanisms of innovation-based growth and push firms toward a technological trajectory based on labour-saving new processes that increase efficiency but destroy jobs. Along with jobs, competences, skills and production capacity are lost during recessions, with the risk of setting the engine of growth on a lower path of development.

This view is particularly relevant in the context of the recession that has hit most of Europe in the aftermath of the financial crisis of 2008 and of the European debt crisis of 2011. The loss of jobs and production capacity may well set European manufacturing industries on a path of stagnation that could dramatically reduce the opportunities for innovation-based growth in Europe.

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Table 1. The list of sectors and the relative Pavitt groups.

Nace Rev.1	Sector name	Pavitt groups
15-16	FOOD PRODUCTS, BEVERAGES AND TOBACCO	Supplier Dominated
17	TEXTILES	Supplier Dominated
18	WEARING APPAREL, DRESSING AND DYEING OF FUR	Supplier Dominated
19	LEATHER AND LEATHER PRODUCTS AND FOOTWEAR	Supplier Dominated
20	WOOD AND PRODUCTS OF WOOD AND CORK	Supplier Dominated
21	PULP, PAPER AND PAPER PRODUCTS	Scale Intensive
22	PRINTING AND PUBLISHING	Scale Intensive
23	COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	Scale Intensive
24	CHEMICALS AND CHEMICAL PRODUCTS	Science-Based
25	RUBBER AND PLASTICS PRODUCTS	Scale Intensive
26	OTHER NON-METALLIC MINERAL PRODUCTS	Scale Intensive
27	BASIC METALS	Scale Intensive
28	FABRICATED METAL PRODUCTS, except machinery and equipment	Supplier Dominated
29	MACHINERY AND EQUIPMENT, N.E.C.	Specialized Supplier
30	OFFICE, ACCOUNTING AND COMPUTING MACHINERY	Science Based
31	ELECTRICAL MACHINERY AND APPARATUS, NEC	Specialized Supplier
32	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	Science-Based
33	MEDICAL, PRECISION AND OPTICAL INSTRUMENTS	Science-Based
34	MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	Scale Intensive
35	OTHER TRANSPORT EQUIPMENT	Specialized Supplier
36-37	MANUFACTURING NC AND RECYCLING	Supplier Dominated

Table 2. Key variables and periods

Variables	*Source*	*Period 1*	*Period 2*	*Period 3*
Compound Annual Rate of Growth of the number of employees	STAN	1996-2000	2000-2003	2003-2007
Share of total turnover due to new or improved products	CIS	1996	2000	2004
Innovative machinery expenditure per employee (thousands of euros)	CIS	1996	2000	2004
Share of firms identifying suppliers as innovation sources	CIS	1996	2000	2004
Average Firm size – Employees per firm	CIS	1996	2000	2004
Compound Annual Rate of Growth of Exports of goods	STAN	1996-2000	2000-2003	2003-2007
Compound Annual Rate of Growth of Labor compensation per employee	STAN	1996-2000	2000-2003	2003-2007

Table 3. The determinants of employment growth in European industries (all periods). Pool of manufacturing industries in 1996-2000, 2000-2003, 2003-2007 for DE, FR, IT, NL, SP, UK.

Dependent variable: Compound Annual Rate of Growth of Employees		
Share of turnover due to new or improved products	0.039 (0.016)	**
Innovative machinery expenditure per employee	-0.053 (0.123)	
Labour compensation per employee (rate of growth)	-0.337 (0.136)	**
Exports (rate of growth)	0.109 (0.035)	***
Constant and Country dummies	Yes	
N obs	264	
R^2	0.36	

Weighted Least Squares regression with robust standard errors.
Standard Errors in parentheses:
* significant at 10%
** significant at 5%
*** significant at 1% level

Table 4. The determinants of employment growth in European industries. Pool of manufacturing industries for DE, FR, IT, NL, SP, UK in Upswings: 1996-2000, 2003-2007 (UP) and Downswings: 2000-2003 (DOWN).

Dependent variable: Compound Annual Rate of Growth of Employees	*(1)*		*(2)*	
Share of turnover due to new or improved products (UP)	0.040 (0.014)	***	0.041 (0.014)	***
Share of turnover due to new or improved products (DOWN)	-0.048 (0.034)		-0.004 (0.032)	
Innovative machinery expenditure per employee (UP)	-0.050 (0.135)			
Innovative machinery expenditure per employee (DOWN)	-1.368 (0.507)	**		
Share of firms identifying suppliers as innovation sources (UP)			-0.012 (0.013)	
Share of firms identifying suppliers as innovation sources (DOWN)			-0.072 (0.040)	*
Labour compensation per employee (rate of growth) (UP)	-0.669 (0.121)	***	-0.478 (0.144)	***
Labour compensation per employee (rate of growth) (DOWN)	-1.062 (0.198)	***	-0.816 (0.213)	***
Exports (rate of growth) (UP)	0.089 (0.089)	**	0.067 (0.067)	*
Exports (rate of growth) (DOWN)	-0.071 (0.105)		-0.004 (0.093)	
Time dummy	2.830 (1.040)	***	1.938 (1.938)	*
Constant	-1.077 (0.434)	**	-1.060 (-1.060)	**
N obs	264		268	
R2	0.34		0.24	

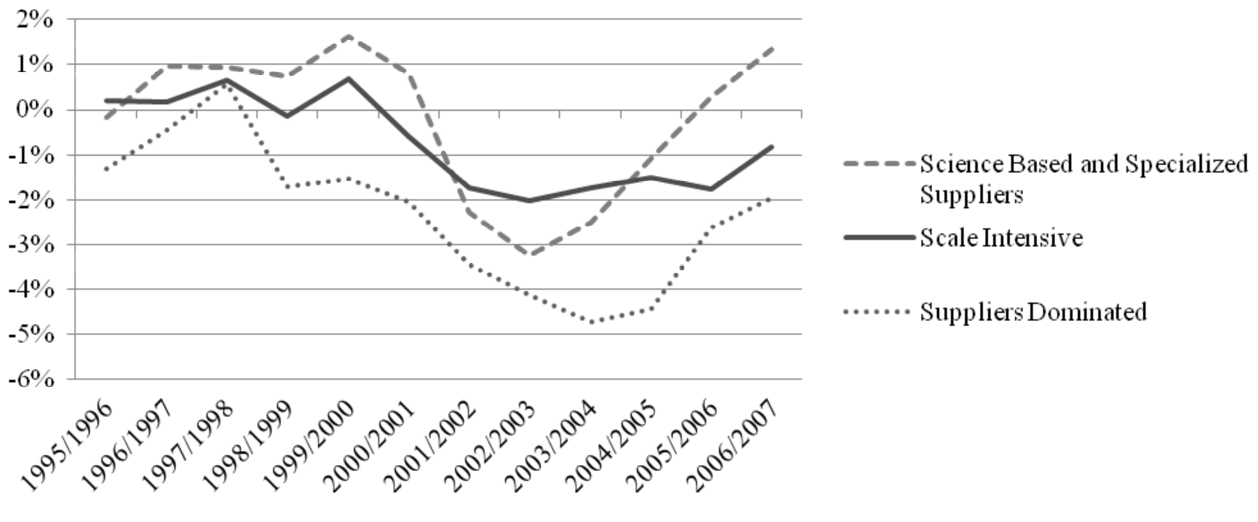
Weighted Least Squares regression with robust standard errors.
Standard Errors in parentheses:
* significant at 10%
** significant at 5%
*** significant at 1% level

Table 5. The determinants of employment growth in European industries. Pool of manufacturing industries for DE, FR, IT, NL, SP, UK in Upswings: 1996-2000, 2003-2007 (UP) and Downswings: 2000-2003 (DOWN).

Dependent variable: Compound Annual Rate of Growth of Employees (1996-2007)		
Share of turnover due to new or improved products (UP)	0.037 (0.015)	**
Share of turnover due to new or improved products (DOWN)	-0.031 (0.040)	
Innovative machinery per employee (UP)	-0.077 (0.199)	
Innovative machinery per employee (DOWN)	-0.982 (0.581)	*
Labour compensation per employee (rate of growth) (UP)	-0.438 (0.147)	***
Labour compensation per employee (rate of growth) (DOWN)	-0.635 (0.249)	***
Exports (rate of growth) (UP)	0.099 (0.040)	**
Exports (rate of growth) (DOWN)	0.033 (0.132)	
Average firm level (UP)	2.708 (1.472)	*
Average firm level (DOWN)	-9.099 (7.803)	
Country and Time Dummies	Yes	
N obs	264	
R2	0.43	

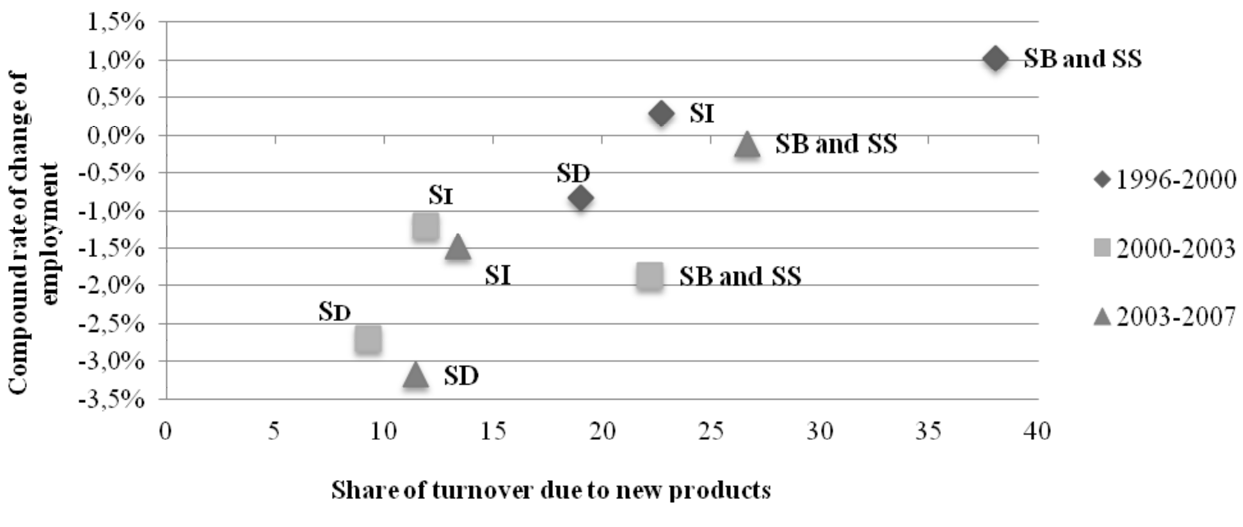
Weighted Least Squares regression with robust standard errors.
Standard Errors in parentheses:
* significant at 10%
** significant at 5%
*** significant at 1% level

Figure 1. Compound annual rate of change of employment from 1995-2007 by Pavitt classes.



Source: University of Urbino, Urbino Sectoral Database

Figure 2. Compound rate of change of employment and average innovative turnover by Pavitt classes (SB Science-Based, SS Specialized supplier, SI Scale Intensive, SD Supplier dominated industries).



Source: University of Urbino, Urbino Sectoral Database