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"Cycles and innovation"

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Cycles and innovation

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Abstract

This paper explores the way economic cycles influence the relationship between innovation and growth. A large literature has investigated this link in the long waves of development, focusing on the emergence of radical innovations and new technological paradigms; a parallel stream of research has examined differences in sectoral patterns of innovation and in industries' technological regimes, emphasising their stability and persistence over time. We build on these approaches and we investigate whether the ups and downs of cycles, with changes in demand dynamics, alter the possibility to exploit the technological opportunities of sectors. Within industries' innovative efforts, we identify on the one hand efforts based on R&D expenditure, focusing on new products and aiming at technological competitiveness and, on the other hand, investment in innovative machinery focusing on new processes and aiming at cost competitiveness.

A model that explains sectoral growth in value added by combining technological and demand factors is proposed. The empirical test is based on data for six major European countries – Germany, France, Italy, the UK, the Netherlands and Spain - at the level of 20 manufacturing sectors. Two upswings are considered - 1996-2000 and 2003-2007 – and their patterns are contrasted with that emerging from the downswing of 2000-2003. Results show that in upswings faster economic (and productivity) growth in industries is sustained by efforts to develop new products, while in downswings, due to a shortage of demand, process innovations aiming at restructuring result more relevant in supporting the increase in value added (or in containing its fall).

Keywords: *Innovation, Cycles, Growth, Demand*

JEL classification: *L6, L8, O31, O33, O52*

1. Introduction

Technological change has long been considered – and rightly so - as a long term process, characterised by the slow accumulation of knowledge, production competences, labour skills and capital equipment, and linked to structural aspects of industries and national economies that change slowly over time. The question on how technology affects growth has therefore been mainly addressed in the context of long term growth trajectories, with studies on long waves of development (Schumpeter, 1939,1955; Freeman, Clark and Soete, 1982; Freeman and Louca, 2001). A second stream of neo-Schumpeterian research has investigated differences in sectoral patterns of innovation and in industries' technological regimes, emphasising their stability and persistence over time, resulting from different types of cumulative knowledge and specific technological opportunities (Pavitt, 1984; Breschi, Malerba, Orsenigo 2001; Malerba, 2004).

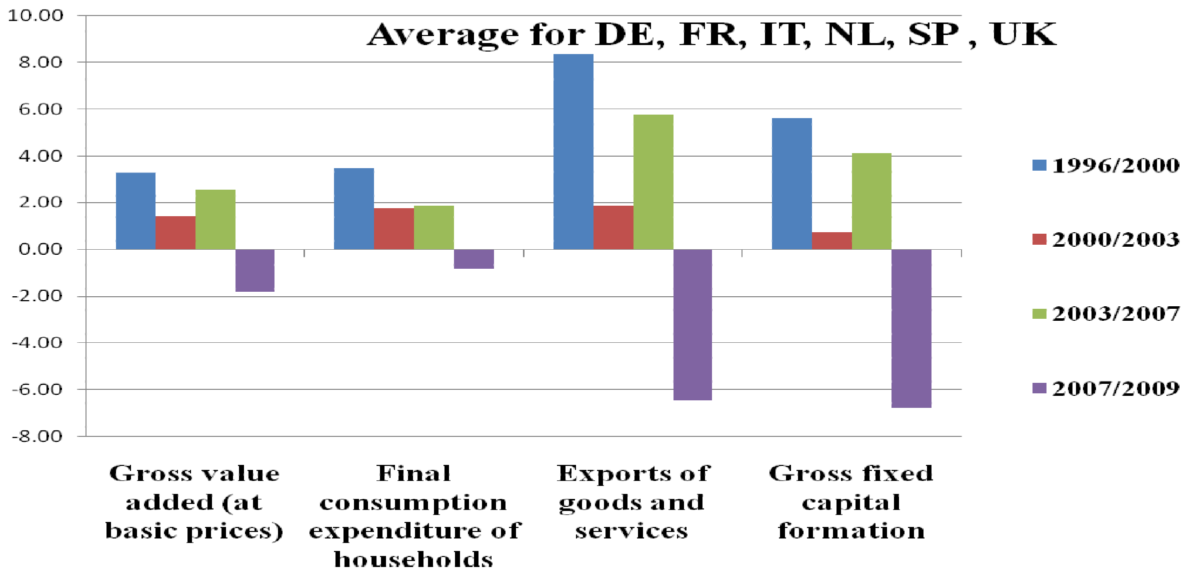
Both approaches disregard the impact of short term economic cycles on the relationship between innovation and growth; in particular, little attention has been devoted to the importance of demand and its specific influence on innovation and growth in the different phases of cycles. In this paper we explore whether the ups and downs of cycles, with changes in demand dynamics, alter the way different innovation activities may support economic growth at the industry level. Within industries' innovative efforts, we identify on the one hand efforts based on R&D expenditure, focusing on new products and aiming at technological competitiveness and, on the other hand, investment in innovative machinery focusing on new processes and aiming at cost competitiveness (Pianta, 2001). Data from European Community Innovation Surveys (CIS) make it possible to document this variety of innovative efforts and have been widely used in order to investigate the effects of these two strategies on productivity and employment (Crespi and Pianta 2008, Bogliacino and Pianta 2010a, 2010b); however, the influence of economic cycles on these relationships has not yet been considered.

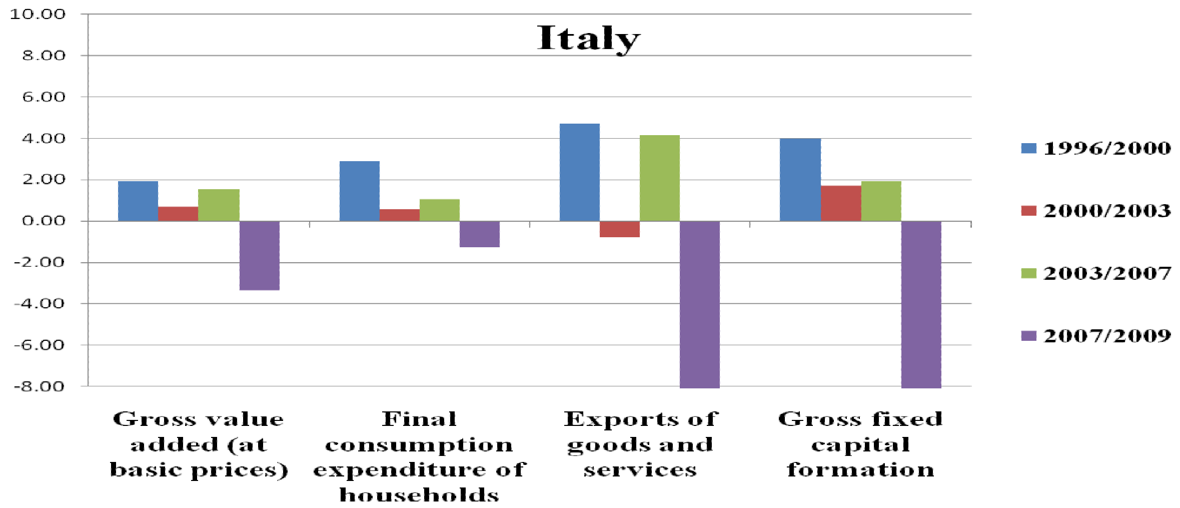
In a phase of upswing, the technological intensity of sectors, their ability to offer new products and the dynamics of demand are expected to drive industries' growth (and productivity) performances (Pasinetti, 1981). Conversely, in a downswing, the relationship between innovation and growth is uncertain; innovative efforts directed at new products may find no market outlets, while new processes may support the restructuring and increased efficiency of industries. During downswings, falling demand reduces the opportunities for new products and new markets, lowers the possibility to achieve increasing returns in production, increases competition and may lead to firms' exit and industries'consolidation.

After a decade when business cycles had come to be considered as almost irrelevant by mainstream economics, the crisis of 2008 and the lack of a rapid recovery in Europe has brought a new attention to the dynamics of economic cycles. Graph 1show the aggregate trends of major European economies and of Italy alone in the period 1996-2009, for major economic variables. The 1996-2009 period is divided in four different phases of the business cycle: the upswing of 1996-2000, the crisis of 2000-2003, the renewed growth of 2003-2007 and finally the 2007-2009 downswing. Value added trends show the severity of the current downswing, that is amplified in data for export and investment; Italy's performance is substantially worse of the European aggregate over the whole period in all variables.

As the detail of data at the sectoral level is not yet available for the 2007-2009 period, in this paper we consider the two upswings of 1996-2000 and 2003-2007, and their patterns are contrasted with that emerging from the downswing of 2000-2003. Six major European countries - Germany, France, Italy, the UK, the Netherlands and Spain, shown in the above

Graphs – are considered. Due to the higher availability of data, the empirical analysis focuses on 20 manufacturing industries.





Graph 1. Economic cycles in six major European economies and in Italy alone (source: Eurostat). DE (Germany), FR (France), IT (Italy), NL (the Netherlands), SP (Spain), UK (the United Kingdom).

The paper is organised as follows. Section 2 surveys the literature; section 3 presents the data used and a descriptive analysis on the relevance of cycles in innovative activities; section 4 introduces the model we propose for explaining the impact on economic growth of different technological activities and demand dynamics, and the econometric strategy used in the empirical test; section 5 shows the results obtained for the two periods of upswing and the period of downswing we investigate.

2. The literature and the approach

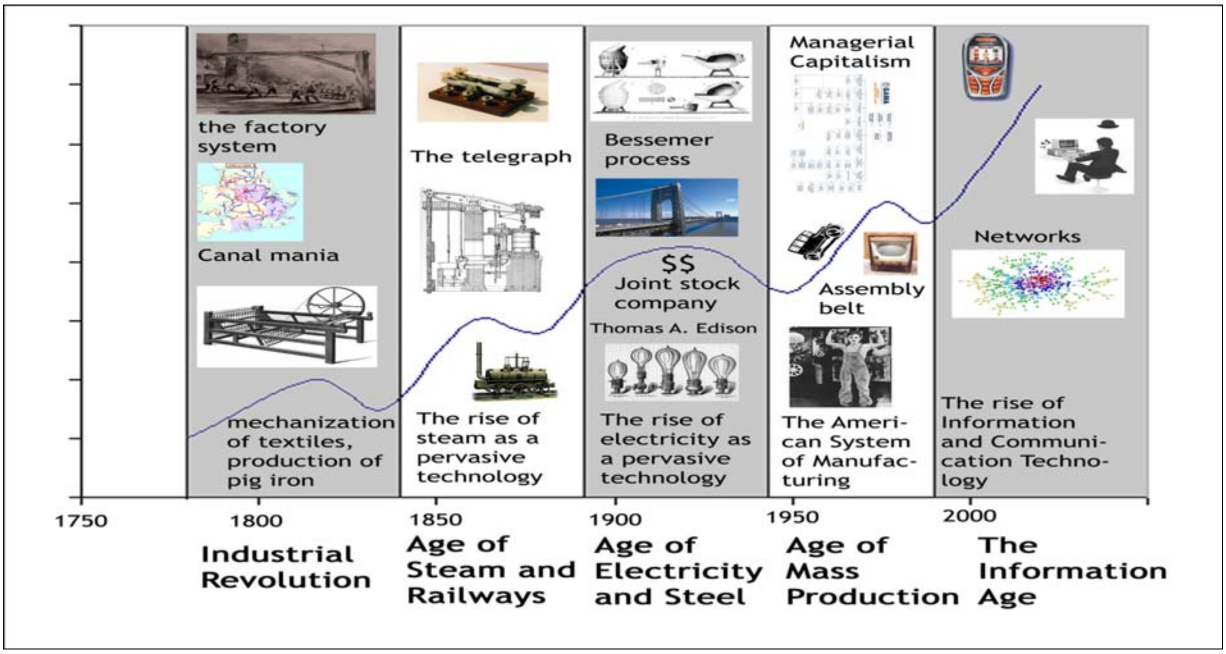
A large body of literature has linked technological change to the formation of long period economic cycles. Schumpeter (1939, 1955) – building on the work of Kondratief and other scholars - has investigated the "long waves" of sustained economic development, arguing that they are caused by the occurrence of clusters of radical innovations that spread in an irregular way in different sectors. As innovation activity is uncertain and discontinuous, the process of expansion, in turn, is uneven and unbalanced. This irregularity is transmitted to investments and employment, which expand in response to technological change.

The notion of long waves has fuelled a debate on the occurrence and role of the clusters of radical innovations (Kuznets, 1940). For Mensch (1979), innovations bunch during the depression phases: in upswings, firms do not have incentives to introduce new products because they can exploit the rents that derive them from growth; in a downswing, expected profits are lower and introducing innovations appears as a more attractive strategy. Also Kleinknecht (1982) emphasizes the role of depressions in stimulating innovations, although the evidence is uncertain.

A major contribution on this issue has come from Freeman (Freeman et al, 1982,; Freeman and Louca, 2001). While admitting the difficulty of finding a clear-cut pattern in historical data, he observes that radical innovations seem to be more uniform over time; while depressions can result in an incentive to innovate, a strong demand with expanding markets can create high expectations of profits and opportunities for the successful introduction of major innovations.

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 in the long period, it is necessary to identify the unfolding of particular technological revolutions - or *techno-economic paradigms* - in the economic system: they are groups of radical innovations that shape the direction of technological change, building on particular scientific advances and offerong wide opportunities for applications throughout the economy at rapidly decreasing costs. Although they recall the Schumpeterian idea of clustering of innovations, Freeman's approach stresses that the full emergence of a paradigm requires the adaption of social and institutional conditions and a parallel growth of appropriate 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 (Freeman, 1982, Perez, 1983, 2002 and Freeman and Louca, 2001). A summary of the sequence of *techno-economic paradigms* from the industrial revolution to the age of ICTs is offered in Graph 2, highlighting the succession of technologies that have supported different waves of growth over periods of about fifty years.

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, and to a widespread changes in production processes throughout the economy with the adoption of the superior technology - that may provide new key inputs, sources of energy or modes of organisation and control of production. However, 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, Freeman and Louca, 2001).



Graph 3. An overview of the succession of techno-economic paradigms (Verspagen, 2005)

This is the issue we address in the paper, developing a model at the industry level that explains the growth of value added as a result of efforts for introducing new products and new processes, and of changes in demand. We build on our previous work that has identified two major innovative strategies searching for either *technological* or *cost competitiveness* that characterise industries (Pianta, 2001). Based on the distinction between product and process innovation, the former is associated with the prevalence of internal R&D activities, supporting the search for new products and markets; the latter is rooted in efforts for increasing efficiency, mainly using external sources of technology and introducing process innovations. Considering the potential of such strategies during the different phases of business cycles, 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, however, 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 the competition based on costs and prices, leading industries to focus on new processes that allow labour saving and cost cutting, in a context of restructuring and exit of the 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.

In our model, focusing on industry level patterns, we allow for the possibility of either effect to emerge, considering also the role of market structure; however, we expect that, across sectors, upswings will be characterized by a greater role of new products in sustaining growth, and during downswings new processes will play a dominant role. Changes in demand are introduced in our model, as they play a key role in shaping 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 stimulate growth through restructuring and productivity improvements that are less affected by demand changes. The degree of market power as reflected by average firm size also contributes to explain the impact of specific innovations on growth.

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. The coordination between technological and demand factors is required if growth is to be achieved, and only when new products find new markets, innovation contributes to the economic development . In this perspective, our approach combines Schumpeterian insights with a post-Keynesian view of demand-led growth (Pasinetti, 1981, Kaldor, 1966; see also Saviotti and Pyka, 2010).

In this analysis we focus on the industry level as it allows to combine insights on micro behaviour – taking into account the profit incentives and innovation mechanisms in firms – without having to deal with the huge heterogenity 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. Data and descriptive analysis

The dataset used in this analysis integrates innovation data from EUROSTAT Community Innovation Survey with a great deal of measures on economic performance and demand variables from OECD's STAN 2010 database. The database covers 20 manufacturing sectors - NACE REV.1 subsections - for 6 European countries - Germany, France, Italy, The Netherlands, Spain e the UK from 1996 to 2007. The sectors included in the analysis and the relative NACE Rev.1 codes are presented in Appendix. Variables from STAN (Value Added, Labour Productivity, Exports and Gross Fixed Capital Formation) are expressed as compound rates of change at constant prices (2000) using sectoral deflators (from STAN) and GDP deflator (from OECD).[1]

On the technological side, three innovation variables are considered: In-house R&D expenditure per employee and the share of turnover due to a new or improved products (Innovative sales) are considered as proxies for the technological competitiveness strategy; on the other hand, the Expenditure on Innovative Machinery per employee is a proxy for cost competitiveness.

Graphs 4 and 5 show the trend of value added and employment from 1996 to 2007 for manufacturing and services. Data are calculated as average values among the six countries: the

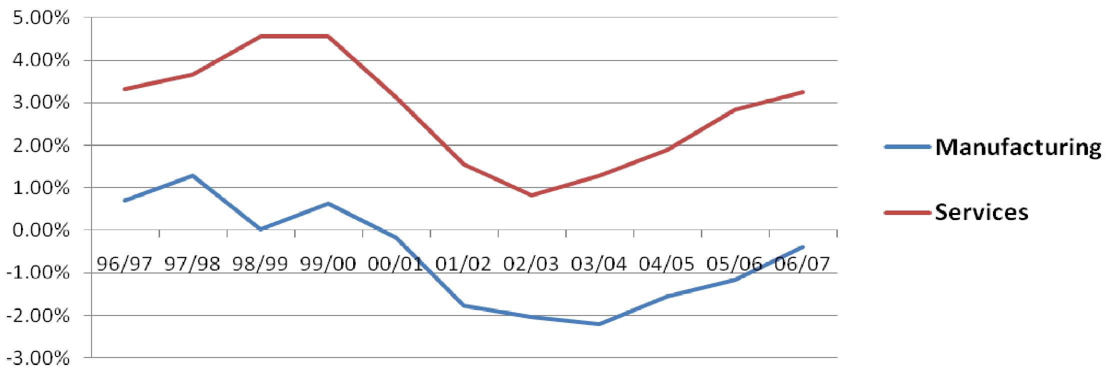
[1] The dataset for this paper is the last edition of the SID database (University of Urbino, 2011). Within manufacturing, sector 23 (Petroleum) has been dropped. Moreover, in order to avoid the huge distortion introduced by the use of OECD industry level hedonic prices, sector 30 (Office computing) has been deflated considering 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.

trend of economies is in fact similar, although the level of growth is different. Manufacturing always underperforms services and its growth is more affected by the ups and downs of the economy; for employment, the differential between job-losing manufacturing and job-creating services appears stable over time. Looking at Graph 4 and 5, we can identify three phases of development of manufacturing:

- a first phase from 1996 to 2000, characterized by a growth of value added and scarce growth of employment;
- a second phase from 2000 to 2003, marked by a deep slow down of economic activity and sharp reduction of employment
- a third phase from 2003 to 2007, with productivity recovery and decreasing job losses.

These cycles represent the macroeconomic context of our analysis of the impact of innovation on growth.

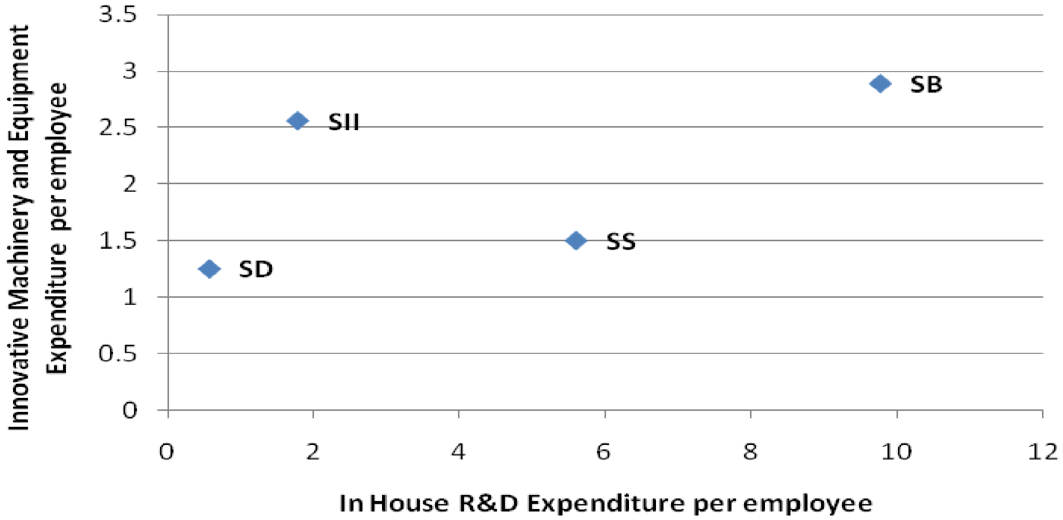
Graph 4. Annual Rates of Growth of Value Added. Averages values among countries.



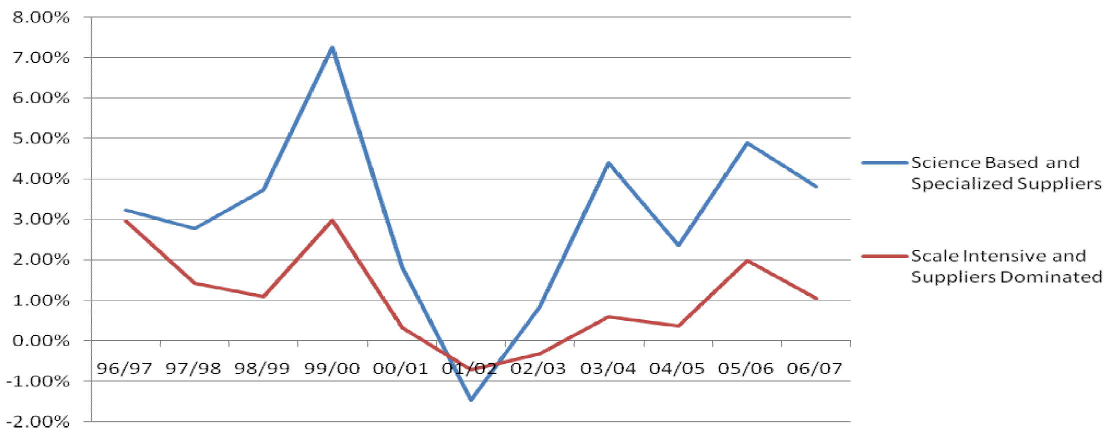
Graph 5. Annual Rates of Growth of Employment. Averages values among countries.

Once defined the structure of cycles, we need to investigate how sectors characterized by different technological opportunities act in different phases of cycles. A broad literature has shown that industry level studies make it possible to conceptualize the differences in innovative activities and to capture the heterogeneity of technological change (Breschi et al. 2000, Malerba, 2004, Pavitt, 1984). An important conceptualization of these differences is provided by Pavitt (1984) where firms (and industries) are grouped on the basis of dominant the sources of innovation and forms of appropriation of technological advantages. Pavitt

identified four patterns: Science Based industries, tied to product innovation and creation of technology; Specialized Suppliers sectors whose objective is the introduction of specific products for users industries; Scale Intensive sectors, where process and organizational innovation is required; Suppliers Dominated sectors in which the technological opportunities are lower and less creative effort is required.
The four Pavitt classes are dominated by different technological opportunities: Graph 6 shows the different values for In-house R&D and Innovative Machinery Expenditure of Pavitt classes.



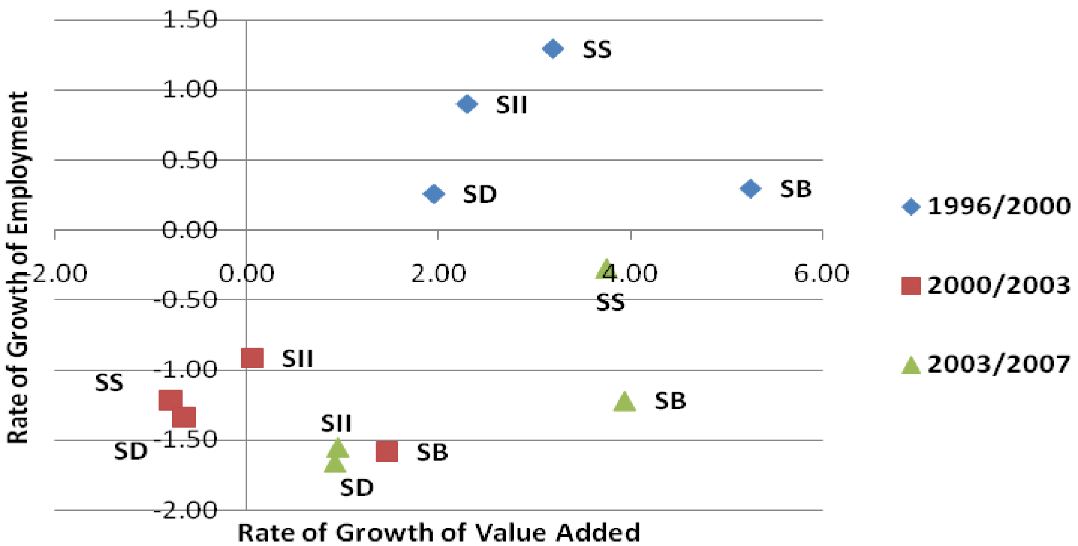
Graph 6. Different technological opportunities of Pavitt classes. Averages among 3 CIS waves.



Graph 7. Annual Rates of Growth of Value Added. A comparison between Science Based and Specialized Suppliers industries and Scale Intensive and Suppliers Dominated sectors.

The growth performances of the different industry groups, shown in Graph 7, documents that Science Based and Specialized Suppliers industries have much higher increases of value added and are much more affected by the economic cycle. This pattern is also evident in Graph 8

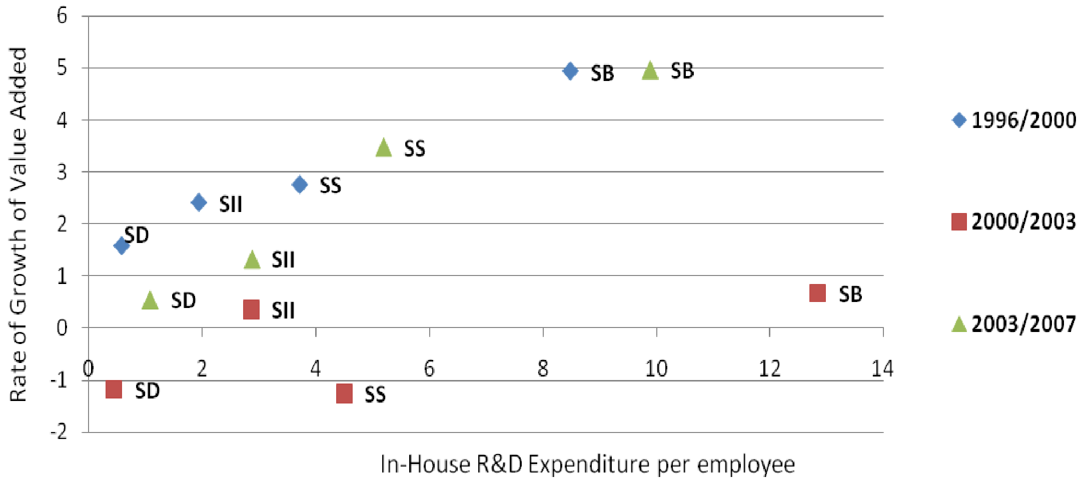
where the average values (among countries) of growth rates of the four Pavitt classes are represented in a value added–employment plot. First, we can interpret the Graph in a horizontal way, stressing the relationship between innovation and value added growth. In 1996/2000 and 2003/2007, the different technological opportunities reflect a different performance in terms of value added growth. Conversely, during the 2000-2003 downswing, the drop of Science Based and Specialized Suppliers sectors is accentuated. At the same time, Scale Intensive sectors are less affected by the occurrence of a negative economic cycle, although they have a reduced recovery in 2003-2007.
Interestingly, comparing Graph 6 and Graph 8, the position of sectors in the downswing reflects the different level of expenditure in Innovative Machinery. Conversely, R&D expenditure seems to be more able to characterize the performance of sectors during the upswing phases.



Graph 8. Compound Annual Rates of Growth of Value Added and Employment for Pavitt classes. Average among countries.

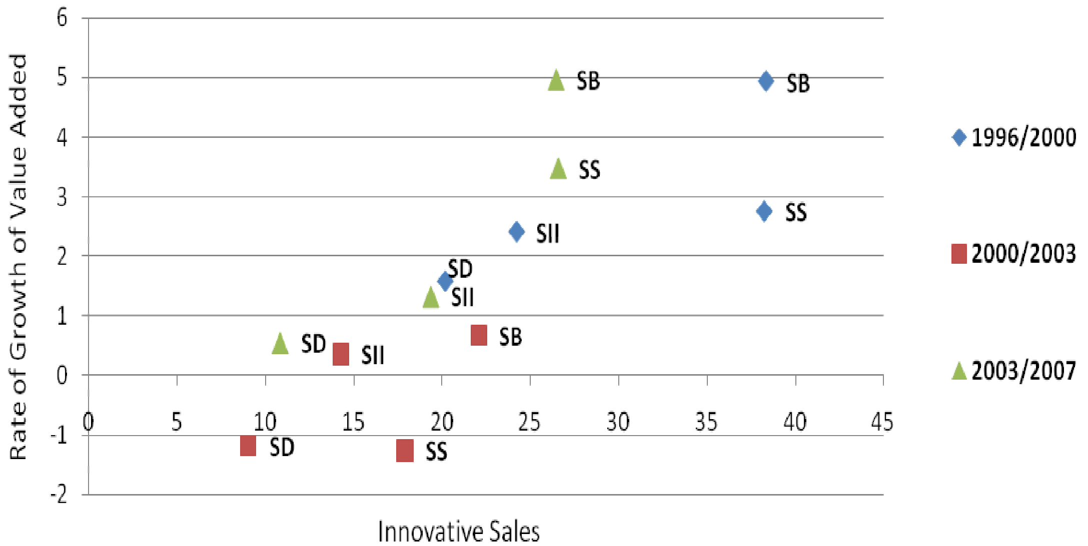
On the vertical axis, it is possible to study the dynamics of employment. In the upswings, only the Specialized Suppliers sectors stably create employment; in the downswing, Scale Intensive industries are instead characterized by a lower loss of employees.
Finally, Graph 8 also documents the patterns of growth for the whole manufacturing sector: the 1996-2000 period is characterized by a weak employment growth while the 2003-2007 is marked by job losses and a general productivity recovery.
A further test on the relationship between the technological trajectories of sectors and their performances is provided in Graph 9 where the value added growth rates of each class are compared with the level of expenditure in R&D per employee. In this case, value added growth for each period is associated with the average level of expenditure of the CIS wave:

	Innovation variables (technological flow)		
	Upswing	**Downswing**	**Upswing**
	CIS2 (1994-1996)	**CIS3 (1998-2000)**	**CIS4 (2002-2004)**
Value Added Growth	1996-2000	2000-2003	2003-2007



Graph 9. Weighted compound annual rates of growth for value added. Averages among countries and sectors.

Each point in the graph represents the average value among sectors, weighted with the relative employment level. While the relationship between innovation and growth is clear in the phases of upswing, it results weaker in the phase of downswing. In this case, the line that passes through the Pavitt classes is flatter. The same result is obtained when the innovative sales are considered on horizontal axis (Graph 10).
Moreover, it is important to mention that the period of reference of the CIS wave which is associated with the 2000-2003 is referred to the span1998-2000, a period of high expectations of growth. In this sense, the drop of performance is not imputable to a reduction of the innovative activity.



Graph 10. Weighted compound annual rates of growth for value added. Averages among countries and sectors.

A last point to deal with before the empirical tests is the stability of described patterns over countries. Concerning this, in Table 1, the rates of growth for Germany and Italy are compared.
As we can see, the performance of Science Based sectors in the downswing for Germany is lower than in other periods but its performance is higher than in other Pavitt classes: Science Base industries seem not to be strongly affected by the reduction of the economic activity. However, Specialized Suppliers are hit by the recession, while Scale Intensive sectors remain stable. For Italy, apart from the typical low dynamics of Science Based industries, the performances of sectors reflect the patterns described: technologically advanced sectors decrease more than other sectors.
Table 2 shows the values for exports growth during the three phases. It highlights a strong fall of international demand in 2000-2003. It is worth mentioning that the drop of exports is uniform over countries and over sectors and it does not reflect changes in national competitiveness.

	1996/2000	2000/2003	2003/2007
	Germany		
Science Based	5.41	5.28	12.71
Specialized Suppliers	2.99	-1.33	3.51
Scale Information Intensive	0.61	0.94	2.72
Suppliers Dominated	2.13	-2.72	1.31
	Italy		
Science Based	1.32	-1.52	1.32
Specialized Suppliers	2.30	-1.27	4.03
Scale Information Intensive	1.04	-1.20	-0.06
Suppliers Dominated	1.55	-1.50	1.17

Table 1. A comparison between Germany and Italy.

In 2000-2003 the foreign demand pull for value added growth was therefore limited. Changes in exports growth overestimate changes in demand conditions in a downswing, but exports represent the most dynamic part of final demand for the majority of sectors in the European manufacturing sector.
The same dynamics is verified for gross fixed capital investment of sectors. In this case, investment growth in 2000-2003 tends to reflect negative perspective of demand for sectors that can amplify the impact of cycle on growth.

	Exports Growth	Gross Fixed Capital Formation
1996-2000	**7.71**	**4.15**
2000-2003	**0.03**	**-5.44**
2003-2007	**5.8**	**2.44**

Table 2. Demand and Investment variables. Averages value among sectors and countries.

4. Models and econometric strategy

Building on the discussion of the previous sections, we propose a model where growth of industry value added is the results of the nature of technological change, market structure and demand dynamics. The model will then be separately tested in the phases of "upswing" (1996/2000 and 2003/2007) and in the phase of "downswing" (2000/2003) of economic activity.

We start from the baseline model

$$y_{i,t} = \beta_1 tc_{i,t} + \beta_2 cc_{i,t} + \beta_3 exp_{i,t} + \eta_i + \varepsilon_{i,t}$$

where y is the real value added variable, tc and cc are proxies for the technological and the cost competitiveness strategies, exp are the exports (a proxy of demand), η is the individual effect and ε is the error term, for industry i and time t. All the variables are supposed to be in log scale. By taking the difference, we eliminate the individual effect. The dependent and the regressors are expressed in annual compound rates of growth (the differences in log approximate the rates of variation):

$$\Delta y_{i,t} = \beta_1 \Delta tc_{i,t} + \beta_2 \Delta cc_{i,t} + \beta_3 \Delta exp_{i,t} + \Delta\varepsilon_{i,t}$$

An alternative version of model considers labour productivity growth as dependent variable.

The following Table reports the temporal matching of models:

	Innovation variables (technological flow)		
	Upswing	**Downswing**	**Upswing**
	CIS2 (1994-1996)	**CIS3 (1998-2000)**	**CIS4 (2002-2004)**
Economic variables (rates of growth)	1996-2000	2000-2003	2003-2007
Average firm level (from CIS)	1996	2000	2004

In order to compare ups and downs phases, we consider a model for upswing periods and then we compare the results with a regression on the downswing phase. The differences in β coefficients are investigated.

Following the descriptive analysis, the innovative dynamics of sectors is explored considering the distinction between a In-house R&D expenditure (proxy for product innovation and search for technological competitiveness) and Innovative Machinery expenditure (proxy for a strategy based on process innovation and cost competitiveness). Although the innovative variables are defined in levels, they can be interpreted as the efforts that, over time, feeds the stock of technology of each industry. In this representation, the country dimension is introduced through dummy variables.

The baseline model can be estimated consistently with OLS. The model is adjusted for heteroschedasticity (robust estimation) and intra-group correlation at industry level, checking for intra-sectoral heterogeneity. In order to distort at minimum the real importance of sectors, we use weighted regressions. With the aim to assure a stability over time, employment levels for the starting year of each period are chosen.

The possibility of multicollinearity is checked through the VIF analysis (Variance Inflation Factors). In every regression, the VIF values of regressions do not exceed 5.
The use of long differences is related to the reduction of endogeneity problems. As the technology is supposed to affect the economic performances of sectors, the performance variable is associated with the last year of reference of the respective CIS wave (consistently with the phases of cycle). Moreover, the differencing has eliminated the individual effect.

5. Results

The results of the model are presented in Tables 3, 4 and 5. In each Table, two distinct phases are explored: results from the panel for the first and third periods are reported in column 1, while those of the phase of downswing (CIS3) are shown in column 2. In this way, we directly compare the impact of innovation and demand on the different phases of the economic cycle.
Table 4 explains the growth rate of value added through the role of technological and cost competitiveness strategies, market structure (proxied by average firm size) and demand growth (expressed by the growth rate of exports). Country dummies are inserted in order to control for national patterns.
In upswings, the model shows a significance for In-house R&D expenditure, stressing the positive impact of product innovation on sectoral growth. The expansion of new markets induces higher opportunity of growth for the sectors and broadens the possibility to introduce new goods. Innovative Machinery expenditure is also positive and its impact grasps the increase of productive capacity of sectors and the improvement in efficiency that can derive from the introduction of new machinery and economies of scale.
Conversely, during the downswing, product innovations lose their significance. While R&D expenditure creates the conditions for Schumpeterian profits, a context of weak demand can reduce the prospects of expansion. On the other hand, a strategy of process innovation-based restructuring can be effective in supporting value added growth (or in containing its fall), and the coefficient is significant.[2]
A key difference emerges in terms of role played by market structure, proxied by the average firm size. In upswings, value added growth is stronger in industries with a smaller firm size, suggesting a "Schumpeter Mark I" model of new emerging sectors leading overall expansion. In the downswing, a "Schumpeter Mark II" model appears, where sectoral growth is associated with a higher market concentration and larger dimension of firm. Growth, or at least a limitation in the fall of value added, is driven by industries where market power is greater and price competition lower. In both cases the coefficient for the firm size variable is significant.
Looking at the demand variable, the rate of growth of exports is crucial – positive, significant and with a high elasticity – during upswings; it is not significant during the downswing. While in upswings, exports play a role in pulling economic growth, a lower demand growth represents a direct and indirect (through the impact on innovation activity) constraint to the expansion of sectors.
Regressions shown in Table 4 introduce changes in gross fixed capital as an additional component of demand. Results for all the other variables do not change; in upswings capital

[2] These patterns reflect the dynamics of Graph 8, where Specialized Suppliers sectors strongly suffer the impact of demand fall and Science Based industries reduce more than proportionally their expansion, although they still experience higher levels of growth. The greater stability of Scale Intensive sectors can explain the significance of the cost competitiveness strategy. However, we assist to a general reduction of the impact of technology on sectoral growth; innovation activity reduces its capacity to discriminate among the performances of sectors.

investment do not appear significant in supporting value added growth; during the downswing the fall in investment is always deeper that that of value added and a positive and significant sign emerges, reflecting the role of the collapse of investment as a major driver of recessions.
In both models on value added, country dummies are rarely significant, mainly during recessions.

A parallel analysis can be carried out considering changes in labour productivity as the dependent variable; results are shown in Table 5. The distinction between the importance of product and process innovation in the phases of cycles is clearer and the contrasting effects of market structure are confirmed. On the demand side, the role of exports in upswings alone is confirmed, and capital formation emerges with a negative effect in upswings and no effect in downswings; during growth phases productivity increases are faster in industries that rely less on capital investment (and more on technological competitiveness, as we have seen); conversely, during recessions productivity gains are not associated to (generally falling) capital investment. Country dummies tend to be significant.

The effects of the economic cycle on the innovation-growth relationship at the sectoral level are studied in this paper by comparing the effectiveness of two innovative strategies based on technological and cost competitiveness in the context of industries' market structures and demand dynamics. During upswings, a technological competitiveness strategy is able to support growth though the introduction of new products and the emergence of new markets. Conversely, a cost competitiveness strategy is relevant for expanding production capacity in upswings and for containing losses in value added in the period of downswing, when demand is scarce and the possibilities of growth are tied to recovery of productivity. Market power as proxied by average firm size also plays a significant role, but with opposing effects; growth during upswings is led by emerging sectors with smaller firm size and greater competition; in recessions, the presence of a higher industry concentration allows to contain the fall in value added by limiting price-based competition. Finally, as expected, the role of demand (represented by exports growth) is crucial in upswings and disappears in a downswing phase.
While the influence of technology on growth has generally been examined considering long term patterns, our results show strong differences in the mechanisms that operate during upswings and downsings of short term economic cycles. The incentives for firms and the specificities of industries – in terms of nature of knowledge and innovation, competitiveness strategies and market structure – interact with demand patterns in different ways during expansions and recessions. These findings shed new light on the fundamental mechanisms of economic growth and on the policy steps that may be taken to address economic crises.

Table 3. The determinants of value added growth in manufacturing

Manufacturing sector - Dependent variable: Compound Annual Rate of Growth of Value Added
Pool of industries in DE, FR, IT, NL, SP, UK
WLS rob s.e.
Standard Errors in brackets: * significant at 10%, ** and *** respectively at 5 and 1% level

	Upswing (1)		Downswing (2)	
	1996-2000, 2003-2007		2000-2003	
In-house R&D expenditure per employee	0.168	*	0.038	
	(0.088)		(0.093)	
Machinery and Equipment expenditure per employee	0.580	**	0.344	**
	(0.236)		(0.148)	
Average Firm Size	-3.755	*	5.780	***
	(1.980)		(0.884)	
Rate of Growth of Exports	0.472	***	0.318	
	(0.075)		(0.203)	
Time Dummy	-0.865	**		
	(0.309)			
Germany	-1.124	**	-1.780	
	(0.480)		(1.459)	
France	-0.775		dropped	
	(0.523)			
Italy	-0.669		1.532	
	(0.539)		(1.436)	
Netherlands	0.104		2.017	*
	(0.653)		(1.147)	
Spain	0.668		3.130	***
	(0.589)		(0.922)	
Constant	-0.685		-3.382	***
	(0.594)		(1.036)	
N obs	217		84	
R^2	0.58		0.43	

Table 4. The determinants of value added growth in manufacturing

Manufacturing sector - Dependent variable: Compound Annual Rate of Growth of Value Added
Pool of industries in DE, FR, IT, NL, SP, UK
WLS rob s.e.
Standard Errors in brackets: * significant at 10%, ** and *** respectively at 5 and 1% level

	Upswing (1)		**Downswing (2)**	
	1996-2000, 2003-2007		**2000-2003**	
In-house R&D expenditure per employee	0.184	*	0.070	
	(0.100)		(0.099)	
Machinery and Equipment expenditure per employee	0.544	**	0.537	**
	(0.238)		(0.213)	
Average Firm Size	-3.671	*	2.727	*
	(2.184)		(1.345)	
Gross Fixed Capital Formation	0.022		0.151	***
	(0.033)		(0.050)	
Rate of Growth of Exports	0.432	***	0.118	
	(0.085)		(0.148)	
Time Dummy	-0.775	**		
	(0.331)			
Germany	-1.056	*	-3.289	**
	(0.530)		(1.196)	
France	-1.125	**	dropped	
	(0.471)			
Italy	-0.664		-0.757	
	(0.548)		(0.935)	
Netherlands	0.158		1.466	
	(0.691)		(0.894)	
Spain	0.643		1.480	**
	(0.570)		(0.679)	
Constant	-0.548		-1.131	
	(0.598)		(0.695)	
N obs	201		80	
R^2	0.54		0.55	

Table 5. The determinants of labour productivity growth in manufacturing

Manufacturing sector - Dependent variable: Compound Annual Rate of Growth of Labour Productivity
Pool of industries in DE, FR, IT, NL, SP, UK
WLS rob s.e.
Standard Errors in brackets: * significant at 10%, ** and *** respectively at 5 and 1% level

	Upswing (1)		**Downswing (2)**	
	1996-2000, 2003-2007		**2000-2003**	
In-house R&D expenditure per employee	0.220	**	0.035	
	(0.101)		(0.085)	
Machinery and Equipment expenditure per employee	0.435		0.468	**
	(0.341)		(0.190)	
Average Firm Size	-6.455	***	4.228	**
	(2.155)		(1.480)	
Gross Fixed Capital Formation	-0.056	*	-0.006	
	(0.032)		(0.056)	
Rate of Growth of Exports	0.312	***	0.070	
	(0.096)		(0.125)	
Time Dummy	0.401			
	(0.350)			
Germany	-1.377	*	-5.605	***
	(0.791)		(0.956)	
France	-1.806	**	dropped	
	(0.825)			
Italy	-2.810	***	-4.992	***
	(0.611)		(0.696)	
Netherlands	-1.391		-1.112	
	(0.896)		(1.215)	
Spain	-3.049	***	-3.376	***
	(0.765)		(0.622)	
Constant	2.075	***	2.159	**
	(0.688)		(0.773)	
N obs	201		80	
R^2	0.44		0.66	

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Appendix

Table A. The list of sectors.

Nace Rev.1 / Isic Rev.3	*Sectors name*
15-16	FOOD PRODUCTS, BEVERAGES AND TOBACCO
17	TEXTILES
18	WEARING APPAREL, DRESSING AND DYEING OF FUR
19	LEATHER AND LEATHER PRODUCTS AND FOOTWEAR
20	WOOD AND PRODUCTS OF WOOD AND CORK
21	PULP, PAPER AND PAPER PRODUCTS
22	PRINTING AND PUBLISHING
24	CHEMICALS AND CHEMICAL PRODUCTS
25	RUBBER AND PLASTICS PRODUCTS
26	OTHER NON-METALLIC MINERAL PRODUCTS
27	BASIC METALS
28	FABRICATED METAL PRODUCTS, except machinery and equipment
29	MACHINERY AND EQUIPMENT, N.E.C.
30	OFFICE, ACCOUNTING AND COMPUTING MACHINERY
31	ELECTRICAL MACHINERY AND APPARATUS, NEC
32	RADIO, TELEVISION AND COMMUNICATION EQUIPMENT
33	MEDICAL, PRECISION AND OPTICAL INSTRUMENTS
34	MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS
35	OTHER TRANSPORT EQUIPMENT

36	MANUFACTURING NEC