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Searching for Sectoral Patterns of Innovation in European Manufacturing Industry

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SEARCHING FOR SECTORAL PATTERNS OF INNOVATION IN EUROPEAN MANUFACTURING INDUSTRY[1,2]

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ABSTRACT

The present paper is conducted under the research project "Enterprise of the Future: Trends and Scenarios towards Competitiveness" which attempts to disclosure determinants of future enterprise competitiveness. Innovation is not only a must today but also an imperative in future competitiveness scenarios. In modern evolutionary economics it is argued that sector-specific factors are one of the key factors explaining innovative behaviour and performance of firms. Several contributions have pointed that industries largely differ in terms of knowledge base and technological sources, opportunities and appropriation of innovative activities, technological trajectories and firms' strategies. Using as background Pavitt's taxonomy, this paper explores the nature, extent and sources of variety of innovation in the manufacturing industry, aiming at identifying common patterns across industries, and sectoral patterns across countries. This paper presents evidence based on the aggregated results of the last IV Community Innovation Survey released by EUROSTAT (CIS4), for which data is available for a number of industries and countries.

Keywords: innovation, manufacturing industry, Community Innovation survey CIS
JEL: L6 - Industry Studies: Manufacturing; O3 - Technological Change

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1. Introduction

The question as to 'why and how innovation differs across industries' has been central in modern evolutionary economics. Based on earlier contributions from Nelson and Winter (1977, 1982), Pavitt (1984) and Winter (1984), and subsequent empirical studies (Malerba and Orsenigo, 1993; Breschi et al., 2000; Evangelista, 1999 and 2000; Marsili, 2001; Marsili and Verspagen, 2002). These sets of contributions have made a great deal in improving our understanding of the most relevant dimensions that may explain sectoral differences. Indeed, it is possible to find many stylised facts in relation to sectoral patterns of innovation. Based on these previous studies, the paper investigates sectoral differences in innovative activity by considering sector-specific factors pointed out by recent research. The analysis is based on the recent data from CIS 4.

The empirical literature drawing upon the evidence provided by the Community Innovation Survey and exploring the nature and characteristics of technological innovation across firms and sectors is now large and consolidated. Most of these focuses either on one country, or on differences in firms' characteristics that may affect certain innovation dimensions. Exceptions to this are, for example, Castellacci, 2004, and Evangelista (2006). This paper adds to this literature providing the most recent evidence and uses aggregate data at sectoral level for 20 countries.

The paper is organised as follows. In the next section we construct the main dimensions of innovative activity that have been advanced in the literature to explain sectoral patterns of innovation accordingly to five subsets of indicators measuring respectively, innovation performance, technological trajectories, technological regime, learning regime, and firms' innovation strategy. After the methodological section, in part 4 we explore if these facts maintain in face of empirical evidence. In section 5, the several variables are reduced to six factors through a factor analysis. Then we use the different factors to explain innovation performance at industry level in Europe.

2. Taxonomies of industries and patterns of innovation

The paper is routed within the evolutionary and neo-Schumpeterian traditions and draws mainly on previous contributions from Pavitt (1984), Tidd et al., (1997), Kristensen (1998) and Kristensen (1999). The sectoral taxonomy used is Pavitt's (1984) original taxonomy[3]. The methodology and specific indicators are built on recent work, mainly by Catellacci (2003, 2004), Evangelista (2006) and Kristensen (1999). This literature suggests that there are a number of features of innovation that are sector/ industry specific. We group these features into five dimensions, namely, innovation performance, technological trajectories, technological regime, learning regime and firms' innovation strategy.

Innovation performance is probably the most basic dimension to analyse sectoral differences in innovation patterns. The indicators used to measure this dimension are either the percentage of innovating firms (Kristensen, 1999; Evangelista, 2006) or the innovative rents coming from new products as used by Catellacci (2003). Based on the findings of Kristensen (1999) and Castellacci (2003), we expect to find significant differences in innovative performance across sectors, and our expectation here is that science based and specialised suppliers sectors show higher innovation performance than scale intensive and supplier dominated sectors. In the second part of the paper we explore what contributes to difference in innovation performance at industry level.

Technological trajectories was considered by Pavitt (1984) one of the main dimension in constructing his taxonomy of sectoral patterns of innovation. The technological trajectory in each sector indicates the direction in which firms concentrate their innovative efforts. Following Pavitt (1984), and later Evangelista (1999), and Castelacci (2003), the strategies followed by firms in the innovative process are fundamentally different in the case that the objective is the development of a product innovation, or rather the improvement in the productive processes. The literature suggests process type of innovation to dominate in scale intensive and supplier dominated sectors. Science based and specialised suppliers appear with higher predominance of product-type innovation. However, Kristensen (1999) results seem to indicate quite common patterns across sectors, with predominance of mixed type of innovation for all sectors. The predominate and type of predominant innovation type (product or process) is bound to impact on the innovation performance of the industry. Castellacci (2003) found that the

[3] Posterior adaptations to the Pavitt's (1984) taxonomy (Tidd et al., 1997, and Kristensen, 1999, for example who expanded the taxonomy to include services) were not considered in this case as our main focus in manufacturing.

creation of new products was significant and positively related to innovation performance.

The notion of technological trajectories is related to the development path within a technological field, and, according to Nelson and Winter (1982) are determined by the technological regime. Malerba e Orsenigo (1993) proposed that the technological regime is determined by the opportunity conditions, by appropriability conditions and by cumulativeness, as also by the nature of the underlying knowledge base.

Several contributions in the past decades have shown that industries largely differ in terms of the opportunities offered by scientific and technological advances. The level of technological opportunities refers in specific to the 'likelihood of innovating for any given amount of money invested in search' (Breschi and Malerba, 1997; Malerba 2004). Such definition focuses on the relationships between inputs and outputs of the innovation process in different sectors in the economy. In this line, Castellacci (2003) uses as indicator for technological opportunity the share of turnover from new products in relation to total innovation expenditures. With respect to sectoral differences in this dimension, vonTunzelmann and Acha (2004) for example, argue that opportunities can be very high in some technological advanced sectors and rather low in more traditional industries.

The maintenance of competitive superiority over time depends on the ability of a firm to protect its innovations from imitation by its rivals. Innovative companies have various alternatives to do this, as exemplified from studies by Mansfield (1986), Cohen et al. (2000), Arundel (2001). Firms can use secrecy or a variety of property rights, such as patents, trademarks and copyrights. *Appropriability conditions*, that is the possibility and forms of appropriating the rents from the innovative activities, are determined by characteristics of the companies but also by the knowledge of the technology. The higher the degree of codification of an item of knowledge, the more efficient the legal means of protecting it (Nieto and Pérez-Cano, 2004). Companies and sectors that use mostly explicit knowledge tend to choose patent system as protection mechanism. Patents are relatively unimportant compared to alternative appropriation methods in sectors that produce complex products that are costly to copy, or where high investment costs and expertise levels create entry barriers that limit competition from new entrants (Arundel and Kabla, 1998). Otherwise, in case of intangible commodities, as well as in the case of innovations and knowledge assets which cannot be codified, patents are not effective tools for protecting innovation. Evangelista (2006) shows that the propensity to patent is in fact much lower in the service sector than it is in the manufacturing sector.

Godinho and Rebelo (2006) survey notorious contributions of the literature with respect to appropriability of innovations and sectoral differences. The use of patents in particular seems to differ significantly across sectors. Godinho and Rebelo's (2006) major conclusion as regards patenting propensity is that in general sectors which spend more (less) on R&D obtain more (less) patents, but there are some important exceptions, of sectors with high R&D productivity and others yet, such as the aircraft sector, with very low R&D productivity. Along these lines, and following, Kristensen, (1999) we expect the science based sector to stress patents to a much higher extent than the other sectors.

At the outset we do not have any expectation regarding the effect of the appropriability conditions via patents on the innovation performance of industries.

Cumulativeness conditions, that is to what extent the current activities build upon experience, knowledge and results obtained in the past. According to Cohen and Levinthal (1989), firms' knowledge and competencies are cumulative over time. The cumulativeness conditions and characteristics differ across industries affecting direction and path of technological change in each industry. R&D is cumulative as it creates knowledge. One may expect sectors with higher R&D activity to reveal higher propensity for firms to be continuously engaged in innovation activities.

The learning regime is related to the dominant way in which learning takes place. The sources of innovation are main components of Pavitt's (1984) sectoral taxonomy. Sources can be either internal or external. In this regard, Kristensen did not find many sectoral differences in her study in Denamark.

Both variables appear significant and positively related to innovation performance in the study conducted by Castellacci.

Firms' innovation strategy depends to a great extent on the technological regime and on their specific objectives, in particular on the nature of the innovative processes (product vs. process innovation) and on the degree of novelty (Evangelista et alia, 1997; Marsili and Verspagen, 2002). Castelacci (2003) suggests that firms' innovative strategies may be defined by the intensity and type of innovative expenditures, by the use and type of partners of cooperation in innovation activities.

Intensity and type of innovative expenditures are two main characteristics of firms' innovative strategies. While expenditures in R&D are at most the focus of applied studies, firms rely also on a variety of expenditures directly connected to innovation. Acquisition of machinery and equipment, training of personnel, design-related expenditures, and acquisition of other external knowledge are types of expenditures that firms make to reach their objectives. Evangelista (1999) has focused on the distinction between two types of technological change: disembodied in the forms of R&D and design expenditures; and embodied that is expenditures in fixed capital and in the acquisition of new machineries.

Recent research as oriented towards the analysis of the type of interactions and cooperation that firms have with other actors. The interactions can be more towards the science-based actors (universities, research institutes), to the market (competitors and consultants), to suppliers or users. Otherwise, the sources can be mainly internal, as in the case of large and established innovative firms (Catellacci, 2003). Patterns of cooperation in innovative activities may well differ across sectors. Kristensen (1999) finds that the science based sector stresses to higher extent cooperation with partners. Scale intensive and supplier dominated stressed links to customers, and specialised supplier sector gives strong importance to suppliers.

Innovation intensity, disembodied expenditures, and the degree of systemicness were found significant and positive related to industrial innovation performance (Castellacci).

The table 1. summarises many of the stylised facts of the sectors in Pavitt's taxonomy in relation to sectoral patterns of innovation. When applicable we also report the results from Kristensen (1999). In section 4 we explore if these facts maintain in face of empirical evidence. In section 5, these variables are reduced to six factor through a factor analysis. Then we use the different factor to explain innovation performance at industry level in Europe.

Table 1. Taxonomies of industries and patterns of innovation

Innovation Dimensions	**Science based**	**Specialised suppliers**	**Scale intensive**	**Supplier dominated**
1. Innovation performance	High	High	Medium	Low
2. Technological trajectories				
Product/ process type	Mixed	Product	Process	Process
Product/ process type*	Mixed	Mixed	Mixed	Mixed
3. Technological regime				
Technological Opportunity	High	Medium	Low	Low
Cumulativeness*	High	Medium	Medium	Low
Appropriability conditions	Patents and entry barriers	Tacit knowledge and reputation	Tacit knowledge entry barriers	Tacit knowledge
Use of patents*	High	Low	Medium	Low
4. Learning regime	Universities and research centres	Science based firms / customers	Production and specialised suppliers	Specialised suppliers
Sources of information*	Internal/ customers	Customers/ internal	Customers/ universities	Suppliers/ customers
5. Firms' innovation strategies				
Innovation intensity	High	Medium	Low	Low
Type of innovation expenditures	R&D Disembodied	R&D Disembodied	Embodied	Embodied
R&D Exp/ Total Innov. Exp	High	Medium	Low	Low
Use of Cooperation*	High	Medium	Medium	Low
Partners cooperation*	Universities/ Customers	Suppliers/ Customers	Customers	Technical centres

* results from Kristensen (1999)

3. Data and methodology

In this paper differences in innovation activities across sectors in Europe have been investigated by using the IV The Community Innovation Survey (CIS) database[4]. The CIS is based in a European (EUROSTAT) standardised questionnaire, with which each National Statistical Institute must conform, the aim being to gather data for comparative analysis of the innovative activity within the EU countries. The analysis in this paper covers industries from 20 countries. These were selected based upon substantial data availability on the selected indicators.

[4] The data were collected in April 2007, http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/science/inn/inn_cis4&language=en&product=EU_MAIN_TREE&root=EU_MAIN_TREE&scrollto=623.

Table 2. Countries covered in the dataset

Belgium	Finland	Italy	Portugal
Bulgaria	France	Lithuania	Romania
Cyprus	Germany	Netherlands	Slovakia
Czech Republic	Greece	Norway	Spain
Estonia	Hungary	Poland	Sweden

The CIS4 dataset includes data on 23 manufacturing sectors for a large number of European countries. For each of the 23 manufacturing sectors and each country, the CIS4 provides a wide variety of information on the innovative activity carried out by European firms in the period 2004-6, such us the nature and scope of innovation, the sources of information, patterns of cooperation, appropriation, innovation performance, obstacles to innovation and effects of innovation, type of investment in innovation. The original 34 variables have been used to build five subsets of indicators measuring respectively, innovation performance, technological trajectories, technological regime, learning regime, and firms' innovation strategy.

Table 4. Dimensions and variables

Innovation Dimensions	**Variables based on CIS 4.**
1. Innovation performance	
Innovative intensity	Percentage of innovative firms
Innovation performance	Turnover from innovations as percentage of total turnover
2. Technological trajectories	
Product-type innovators	Percentage of firms introducing product innovation
Process-type innovators	Percentage of firms introducing process innovation
Mixed-type	Percentage of firms introducing product and process innovation
Technological trajectories	(Nº firms with process innovation – nº firms with product innovation)/ (Nº firms with process + nº firms with product innovation)
3. Technological regime	
Technological opportunity	Ratio of turnover from innovations on total innovation expenditures
Cumulativeness/Continuous	Percentage of firms continuously engaged in innovative activities
Appropriability conditions	
Applied for patents	Percentage of innovative firms that applied for a patent
Registered trademarkes	Percentage of innovative firms that registered trademarks
Registered Ind. Design	Percentage of innovative firms that registered industrial designs
Copyright	Percentage of innovative firms that registered industrial designs
4. Learning regime	
Sources of information	
Internal sources	% Firms who reported own group as main source of information
Suppliers	% Firms who reported equipment suppliers as main source of information
Clients	% Firms who reported clients as main source of information
Competitors	% Firms who reported competitors as main source of information
Consultants	% Firms who reported consultants as main source of information

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(continued)

Universities	% Firms who reported universities as main source of information
Public institutions	% Firms who reported public insti. as main source of information
Conferences and fairs	% Firms who reported conferences and fairs as main source of information
Scientific journals	% Firms who reported scientific journals as main source of information
Professional institutions	% Firms who reported professional institutions as main source of information
5. Firms' innovation strategies	
Innovation intensity	Percentage of innovation expenditures on total turnover
	Percentage of innovation expenditures on employment
Type of innovation expenditures	
Disembodied	Percentage of expenditures on R&D on total innovation expenditures
Embodied	Percentage of expenditures on equipment on total innovation expenditures
Cooperation	
Use of cooperation	% Firms who used cooperation in innovative activities
Partners in innovation	
Own group/ internal	% Firms who used cooperation with own group in innovative activities
Suppliers	% Firms who used cooperation with suppliers of equipment in innovative activities
Clients	% Firms who used cooperation with clients in innovative activities
Competitors	% Firms who used cooperation with competitors in innovative activities
Consultants	% Firms who used cooperation with consultants in innovative activities
Universities	% Firms who used cooperation with universities in innovative activities
Public institutions	% Firms who used cooperation with public institutions in innovative activities

The analysis will be pursued on the level of industry applying the NACE classification. From the original data for manufacturing we eliminated three industries for which we had very limited data: *da16* Manufacture of tobacco products; *df23* Manufacture of coke, refined petroleum products and nuclear fuel; and *dn37* Recycling.

Table 3. Aggregation the Industries in the Taxonomy

Science based	**Specialised suppliers**
Man. of office machinery and computers	Man. of machinery and equipment
Man. of electrical machinery and apparatus	Man of medical, precision and optical instruments, watches and clocks
Man. of radio, tv, communication equipment and apparatus	
Man. of chemicals and chemical products	
Scale intensive	**Supplier dominated**
Man. of food products and beverages	Man. of textiles
Man. of rubber and plastic products	Man. of wearing apparel, dressing; dyeing of fur
Man. of non-metallic mineral products	Man. of leather and leather products Tanning, dressing of leather; manufacture of luggage
Man. of basic metals	Man. of wood and wood products and cork
Man. of motor vehicles, trailers and semitrailers	Man. of pulp, paper and paper products
Man. of other transport equipment	Publishing , printing , reproduction of recorded media
Man. of fabricated metal products, except machinery and equipment	Man. of furniture

In table 3 we show the aggregation of the industries covered within the taxonomy. The aggregation is based on earlier studies and drawn from Kristensen (1999). Applying this aggregation in the remaining the paper, we will analyse the variables chosen as representatives to characterise each sector. The means of analysis will be a simple descriptive analysis of cross tabulations of the data within the sectors, a method followed by Pavitt (1984) and Kristensen (1999).

4. Exploratory analysis

In table 4 we report the main comparative findings. As expected Science based sector reports the highest innovative performance in terms of innovative firms and turnover from new products. In relation to technological trajectories, it is predominantly mixed, but essentially product-type oriented. Regarding the technological regime, it shows the highest technological opportunity, with the share of new products turnover over innovation expenditures reaching nearly the double of that for all the other sectors. It is also the sector where cumulativeness is strongest, and that stresses more patenting as mean of appropriability. Regarding the learning regime, and with exception to the use of conference fairs, it reports the highest percentage of firms attributing high importance to internal and external sources of information. Internal sources are paramount important. SB stresses clients and equipment suppliers external sources of information. Firms' innovation strategy in the SB sector is characterised by the highest innovation intensity, with innovation expenditures essentially of disembodied type. R&D expenditures represent over half of the innovation costs. Further, we find that firms in this sector cooperate considerably more than firms of other sectors. Equipment suppliers and clients, as well as universities are the principal partners in innovation activities.

The specialised supplier sector (SS) resembles in many aspects the science based sector. It has high innovation performance. We found a mixed innovation type, but where product -type innovation predominates. However, it shows a low level of technological opportunity, far below the SB sector. It reports medium level of cumulativeness and it also stresses the role of patents as appropriation mechanisms. The importance of sources of information is close to the SB picture. Own group is the main source of information, followed by clients and suppliers of equipment among external sources. Firms' innovation strategy in the SS sector is characterised by medium innovation intensity.

As for the SB sector, disembodied expenditures represent over an half of the innovation costs. Further, we found that it cooperates more than the SI and SD sectors, but less than the SB. The role of suppliers and customers as partners in innovation activities is paramount important.

Table 4. Sectoral differences in patterns of innovation: exploratory analysis (continues) (%)

Innovation Dimensions	Science based	Specialised suppliers	Scale intensive	Supplier dominated
1. Innovation performance				
Innovative intensity	56,02	53,66	43,42	35,57
	(0,20)	(0,19)	(0,16)	(0,18)
Turnover new/ total turnover	29,97	29,55	20,36	19,68
	(0,22)	(0,11)	(0,14)	(0,14)
2. Technological trajectories				
Percent of product innovators	15,62	15,27	8,67	7,88
	(0,09)	(0,10)	(0,06)	(0,07)
Percent process innovators	9,46	10,38	11,96	11,23
	(0,08)	(0,12)	(0,09)	(0,08)
Percent mixed	29,23	25,81	20,61	15,32
	(0,14)	(0,13)	(0,09)	(0,10)
Technological Trajectories	-0,26	-0,21	0,12	0,20
	(0,40)	(0,52)	(0,51)	(0,49)
3. Technological regime				
Technological Opportunity	15,23	8,57	7,83	7,25
	(44,96)	(7,09)	(7,11)	(7,68)
Cumulativeness/ Continuous	52,27	45,93	29,85	24,14
	(0,21)	(0,17)	(0,17)	(0,17)
Appropriability conditions				
Applied for Patent	21,19	20,98	13,14	8,33
	(0,14)	(0,15)	(0,11)	(0,09)
Trade Marks	20,33	16,88	14,29	14,79
	(0,15)	(0,11)	(0,10)	(0,11)
Industrial Design	18,83	15,52	14,70	13,32
	(0,15)	(0,09)	(0,11)	(0,12)
Copyright	9,72	5,92	3,37	4,84
	(0,16)	(0,06)	(0,04)	(0,06)
4. Learning regime				
Source Own Group / internal	54,16	51,00	46,98	39,74
	(0,24)	(0,20)	(0,20)	(0,19)
Source Equipment Supplier	23,28	24,23	26,28	25,91
	(0,16)	(0,14)	(0,15)	(0,14)
Source Client	32,81	31,19	26,16	28,47
	(0,16)	(0,15)	(0,12)	(0,13)
Source Competitor	15,76	14,30	13,39	14,26
	(0,12)	(0,09)	(0,10)	(0,11)
Source Consultants	7,73	6,10	8,01	6,53
	(0,09)	(0,07)	(0,11)	(0,07)
Source University	8,17	6,57	7,11	3,79
	(0,10)	(0,07)	(0,10)	(0,07)
Source Gover. & Public Inst.	5,21	5,39	5,25	3,31
	(0,07)	(0,07)	(0,08)	(0,07)
Source Conference Fairs	16,12	18,67	17,14	20,06
	(0,13)	(0,16)	(0,13)	(0,16)
Source Scientific Journals	15,56	14,52	10,89	12,02
	(0,15)	(0,14)	(0,11)	(0,13)
Source Profess. Associations	8,35	8,80	7,79	7,41
	(0,11)	(0,11)	(0,10)	(0,10)

(Continued) Table 4. Sectoral differences in patterns of innovation: exploratory analysis

5. Firms' innovation strategies				
Innovation intensity				
Innov. Expend. on Turnover	4,69	4,81	3,97	4,50
	(0,03)	(0,03)	(0,03)	(0,05)
Innov. Exp on Employment	10,18	6,54	6,09	4,02
	(12,03)	(6,79)	(8,99)	(4,75)
Type of innovation expenditures				
Disembodied: R&D on Total	56,67	55,65	38,57	27,45
	(0,32)	(0,25)	(0,29)	(0,25)
Embodied: Equip on Total	41,93	43,08	60,26	70,68
	(0,32)	(0,26)	(0,30)	(0,26)
Cooperation				
AllCooperation	43,86	38,91	36,03	28,02
	(0,18)	(0,15)	(0,17)	(0,17)
Own Group	16,91	14,33	14,45	10,13
	(0,13)	(0,09)	(0,11)	(0,12)
Supplier Equipment	28,69	28,30	26,88	21,80
	(0,18)	(0,16)	(0,16)	(0,15)
Client	27,78	27,52	22,23	18,38
	(0,20)	(0,16)	(0,14)	(0,15)
Competitor	17,06	12,81	12,83	11,61
	(0,13)	(0,10)	(0,10)	(0,11)
Consultants & Labs	19,43	16,40	16,21	12,01
	(0,16)	(0,12)	(0,14)	(0,11)
University	20,81	18,02	15,03	8,65
	(0,16)	(0,12)	(0,12)	(0,10)
Government & Public Institutions	13,42	12,63	10,67	6,78
	(0,14)	(0,10)	(0,11)	(0,08)

Note: In brackets S.D. (p.p./100)

Scale intensive sector (SI) shows medium innovation performance. Regarding the technological regime it is essentially mixed, but it predominates slightly the process type of innovation, which contrasts to the finding for SB and SS sectors. With low technological opportunities and low cumulativeness characteristics, the technological regime resembles that for SD sector. Trademarks and registration of industrial design outpace patents as appropriation mechanisms, in contrast to the SB and SS sectors.

In general, compared to the SB and SS sectors, firms in this sector attribute less importance to both internal and external sources of information internal. Internal sources are important, being suppliers of equipment and clients the most valuable external sources. Notwithstanding clients are less stressed in this sector than in all the other sectors.

Firms' innovation strategy in the SI sector is characterised by medium innovation intensity. By contrast to SB and SS sectors, embodied (acquisition of equipment) expenditures represent over sixty percent of the innovation costs. With medium level of cooperation, we find that it cooperates clearly less than the SB, but more than the SD sector. The role of suppliers and customers as partners is innovation activities is also paramount important.

Finally, the supplier dominated (SD) sector, shows the lowest level of innovation performance, with mixed type of innovation. As for the SI sector, the technological trajectory is slightly process-oriented. Technological regime is closer to the SI sector, with low cumulativeness and low use of appropriability instruments. It shows the lowest use of patents. We found the lowest values for the importance of sources of information. Clients, sources of equipment are the most stressed sources of information (levels close to the SI sector). This sector gives very low importance to universities and scientific journals.

In the table 5 we summarize the results.

Table 5. Sectoral patterns of innovation in Europe: IV CIS

Innovation dimensions	Science based	Specialised suppliers	Scale intensive	Supplier dominated
1. Innovation performance	High	High	Medium	Low
2. Technological trajectories (Product/ Process)	Mixed/ Product	Mixed/ Product	Mixed/ Process	Mixed/ Process
3. Technological regime				
Technological Opportunity	High	Low	Low	Low
Cumulativeness*	High	Medium	Low	Low
Use of Appropriability instruments /patents	High/ Patents	High/ Patents	Low/ Trademark & Ind. Design	Low/ Trademark & Ind. Design
4. Learning regime (sources)				
Importance of sources of info.	High	Medium	Low	Low
Main Sources of information	Internal/ Clients	Internal/ Clients	Internal/ Equipment suppliers	Internal/ Clients
5. Firms' innovation strategies				
Innovation intensity	High	Medium	Medium	Low
Type of innovation expenditures	Disembodied	Disembodied	Embodied	Embodied
Use of Cooperation	High	Medium	Medium	Low
Partners in cooperation	Suppliers equipment/ Clients	Suppliers equipment/ clients	Suppliers equipment	Suppliers equipment

5. Differences and patterns of industrial performance?

In the exploratory analysis we verified a variety of aspects which according to the literature enable to characterise patterns of sectoral innovation. We also identified considerable asymmetry in innovation performance across sectors. In this section we conduct a first attempt to explore the factors which may lead to differences in innovation performance across industries in Europe[5].

Doing so, we followed Castellacci (2003) and used as measure of performance the percentage of turnover from new products. Seemingly, we reduced the wide set of indicators used in the previous parts of the paper to a smaller number of distinct dimensions. In order to reduce the number of explanatory variables used to identify sectoral differences in innovative activity, a principal component analysis has been performed, with the purpose of extracting a smaller number of factors that are able to explain most of the variance in the sample. In section 5.1 we conducted the principal components analysis and in section 5.2 we relate the factors to the industry performance.

5.1. Factor analysis of innovation dimensions

The results, presented in table 5, show that about 75% of the variance in our indicators may be explained by the six principal components that have been extracted. Each of these factors (linear combinations of some of the original indicators) is linearly independent on the others. Thus, the six principal components represent six main distinct aspects of the innovative process. Castellacci (2003) found 4 factors but has used less original indicators.

Factor 1: Degree of cooperation

This factor is a linear combination of the indicators measuring the intensity of cooperation that firms have in the innovative process. All cooperation variables are positively correlated, suggesting that cooperation is an attitude of innovative firms. However, as we have analysed in the previous sections, it is possible to distinguish

[5] Please do not quota as the results presented in part 5 are preliminary deserving further verifications.

between sectors, with some being more oriented to cooperate with the science system (SB) and others with suppliers.

Factor 2: Type of innovation expenditures, appropriability and cumulativeness

This factor has high factor loadings of four indicators, suggesting that the type of innovation expenditures is strictly linked to the appropriability and cumulativness conditions in each sector. The higher the share of R&D expenditures, the higher the degree of cumulativeness and the use of patents (appropriability). Recall that Castellacci (2003) found a similar factor, where type of expenditures and cumulativeness were present along with aspects of the technological regime.

Table 5. Results of the factor analysis: rotated component matrix and total variance explained

Variable	Factor 1: Cooperation	Factor 2: Type of innovation expenditures, cumulativeness and appropriability	Factor 3: Learning regime	Factor 4: Role of suppliers and innovation intensity	Factor 5: Technological opportunity and process innovations	Factor 6: Innovative intensity and product innovation	U
Use Cooperation	0,919	0,089	0,017	0,075	-0,111	-0,062	0,13
Cooperation with own group	0,792	0,297	-0,015	-0,024	0,038	-0,103	0,27
Cooperation with suppliers	0,940	-0,024	-0,039	-0,025	-0,051	0,026	0,11
Cooperation with clients	0,894	0,050	-0,011	-0,138	-0,169	-0,024	0,15
Cooperation with competitors	0,860	-0,038	0,035	0,071	-0,106	0,005	0,24
Cooperation with consultants	0,827	0,193	0,033	0,074	0,161	-0,051	0,24
Cooperation with universities	0,673	0,409	0,151	-0,110	-0,063	-0,235	0,29
Appropriability	0,056	0,789	-0,096	-0,068	-0,152	-0,255	0,27
Disembodied expenditures	0,142	0,942	0,018	0,005	-0,017	-0,090	0,08
Embodied expenditures	-0,057	-0,941	0,021	0,007	0,029	0,150	0,09
Cumulativeness	0,246	0,732	0,048	0,174	-0,088	-0,362	0,23
Learning from competitors	-0,016	-0,167	0,650	0,185	-0,378	-0,233	0,32
Learning from consultants	-0,024	-0,048	0,809	-0,002	0,318	0,056	0,24
Learning from universities	0,075	0,059	0,847	-0,241	-0,132	-0,082	0,19
Learning from equip. sup.	-0,140	-0,135	-0,057	0,854	0,052	0,022	0,23
Innovation intensity	0,119	-0,055	0,006	0,347	-0,267	-0,321	0,69
Process type innovators	-0,308	-0,136	0,092	0,221	0,604	-0,372	0,33
Learning from clients	0,121	0,324	-0,105	0,320	-0,515	-0,375	0,36
Technological opportunity	0,099	0,131	0,090	0,012	-0,765	-0,111	0,37
Innovative intensity	0,021	0,349	0,057	0,030	0,047	-0,920	0,02
Product type innovators	-0,008	0,498	-0,182	-0,289	-0,181	-0,600	0,24
Mixed type innovators	0,206	0,180	0,191	0,159	-0,100	-0,741	0,31
% of variance explained	30,5%	16,4%	9,3%	8,3%	6,4%	4,6%	
Cumulative % of variance explained	30,5%	46,9%	56,2%	64,5%	70,8%	75,4%	

Extraction method: Principal Component Analysis
Rotation method: Varimax with Kaiser Normalization.
Rotation converged in 8 iterations.

Factor 3: Learning regime

This factor had high factor loadings on the variables measuring the interactions with external experts, be they from consultancies or from universities.

Factor 4: Suppliers and innovation intensity

This component is a linear combination of the indictor of interaction with suppliers and innovation intensity. Given that a significant part of the innovation expenditures indicator correspond to acquisition of equipment, this factor can therefore be considered as an overall measure of the role of suppliers of equipment in each sector.

Factor 5: Technological opportunity and process innovation

This principal component has high factor loadings for technological opportunity and process type innovations. The latter is positively correlated to the factor, while technological opportunity is negatively linked to it. On the whole, this factor can be considered as an overall measure of technological opportunity.

Factor 6: Innovative firms and product innovation

This factor has high loadings for innovative intensity (percentage of firms with innovation) and product type innovators. It can be considered as an overall measure of innovative intensity.

5.2. Performance and innovation factors

In the previous section we identified six aspects that are able to account for the variety of sectoral patterns of innovation. In this section we explore how these aspects can be used to explain differences in innovative performance across sectors in Europe using two simple models. In model a) we assume that the i^{th} sector's innovative performance is a positive linear function of the six factors, namely, degree of cooperation, innovation expenditures, cumulativeness and appropriability, learning regime, role of suppliers and innovation intensity , technological opportunity and process innovations, and innovative intensity and product innovation, U is the stochastic term of the equation:

$$PERF_t^i = \alpha COOP_t^i + \beta INNOEXP_t^i + \chi LER_t^i + \delta SUP_t^i + \eta TECOP_j^i + \sigma INNOINTE_j^i + \mu_j^i$$

In model b) differences in innovative performance across industries may be explained by six variables corresponding each to each factor: degree of cooperation, share of R&D and design expenditures on total innovation costs (disembodied forms of technical change), use of universities as sources of information (science based learning modes); innovation intensity, technological opportunity and innovative intensity:

$$PERF_t^i = \alpha COOP_t^i + \beta DISEM_t^i + \chi UNI_t^i + \delta INTEN_t^i + \eta TECHOP_j^i + \sigma INNOVATIVE_j^i + \mu_j^i$$

The model a) explains differences in industrial innovation performance in Europe in terms of type of innovation expenditures, cumulativeness and appropriability (Factor 2); role of suppliers and innovation intensity (Factor 4); Technological opportunity and process innovations (Factor 5), and innovative intensity and product innovation (Factor 6). In particular, model b) suggests that the innovative performance of industries is positively related to the share of disembodied innovation expenditures, to innovation intensity and to innovative intensity.

Table 6. Results of the regression analysis (model a and b)

	(a)		(b)	
Constant	7,3038	***	-6,3133	***
	(0,4123)		(1,0973)	
Factor 1: Cooperation	0,2331			
	(0,4125)			
Factor 2: Type of innovation expend., approp. and cumul.	3,2617	***		
	(0,4130)			
Factor 3: Learning regime	0,0887			
	(0,4125)			
Factor 4: Suppliers and innovation intensity	3,2080	***		
	(0,4123)			
Factor 5: Technological opportunity and prod. Innov.	1,1641	***		
	(0,4123)			
Factor 6: Innovative intensity and product innovation	3,6441	***		
	(0,4135)			
Cooperation			-0,0298	
			(0,0201)	
Disembodied			0,0884	***
			(0,0128)	
Source Universities			0,0354	
			(0,0391)	
Innovation intensity			1,1712	***
			(0,0952)	
Technological opportunity			0,0090	
			(0,0230)	
Innovative intensity			0,1099	***
			(0,0198)	
R-squared =	0,4443		0,4915	
Adj. R-squared =	0,4316		0,4823	

*** Significance at the 0,01 level
** Significance at the 0,05 level
* Significance at the 0,10 level

6. Conclusion

The paper investigates differences in innovative activity across sectors in Europe. Beforehand, we refer to the danger in attempting to synthesise taxonomies of sectoral patterns of innovation. First, within each sector it is possible to identify several technological trajectories and regimes. Hence, it is unlikely that the logic of the innovation is as clear-cut as presented in section 4. Nevertheless, it seems reasonable to argue that within each taxonomy there are dominant patterns that represent the majority of the industries within the taxonomy (Kristensen, 1999).

Section 2 has presented the main dimensions of innovative activity that have been advanced in the literature to explain sectoral patterns of innovation accordingly to five subsets of indicators measuring respectively, innovation performance, technological trajectories, technological regime, learning regime, and firms' innovation strategy. These broad set of characteristics are strictly related to each other and an investigation of sectoral differences in innovative activity requires a joint consideration of them.

Section 3 presents the indicators that have been used to construct the relevant dimensions of the innovative activity. It also explains that a factoral analysis has been done with the purpose of reducing the large number of variables to a smaller set of distinct dimensions in an attempt to explain differences in innovative performance across industries in Europe.

First, in section 4 we have conducted an analysis based on Pavitt taxonomy in order to see whether the theoretical propositions can be supported by empirical measures. We have found significant sectoral differences, and, on the whole, differences were as expected.

Science based and specialised suppliers' sectors do show better innovative performance as measured by the variables selected.

Technological trajectories prove to be an important aspect to characterize sectors. Science-based and specialised suppliers' sectors are more product oriented, while the others are process oriented. Nevertheless, mixed type of innovation (product and process) predominates for all sectors.

Technological regime, is another dimension to consider when analysing patterns of innovation across sectors. Opportunity and cumulativeness revealed to be stronger not only on the SB but also on the SS sector. Use of patents is markedly more important for SB and SS sectors.

Finally, firms' innovation strategy also seems to differ across sectors. Innovation intensity is positive related to innovative performance. As expected, disembodied type of expenditures are critical for innovation in SB and SS sectors, but not in SI and SD sectors. Firms in less innovative industries are characterised by focusing their innovation efforts on the acquisition of machinery and equipment. The importance of acquisition of machinery and new equipment reveal a passive approach to innovation relying upon the mere acquisition of technologies from suppliers.

In spite of the differences, some trends are general and hold across sectors.

The preference for patents is called into question by the empirical evidence. Firms in general give a low rating to patents to protect innovations. Our findings are in line with surveys consistently show that for most manufacturing firms patents are less effective than alternatives such as lead time, secrecy and complementary sales and service effort (Levin et al., 1987; Cohen et al., 1998; Arundel et al., 1995; Arundel, 2001; Galende, 2006; González-Álvarez and Nieto-Antolín, 2007). Levin et al. (1987) point out a range of reasons why in the majority of industries patents are not used as mechanisms to protect against imitators. In addition to the fact that it is often not easy to demonstrate the novelty of the innovation and the high costs involved in obtaining and defending it, and that imitators can legally copy around the patented technology, there are situations in which information included in the patent limits its effectiveness since it can reveal important information on the technology used by the company (Arundel, 2001). Unlike other transactions among firms, there are many critical interrelated factors that affect the choice of protection mechanisms.

Concerning the learning regime and degree of cooperation, the SB and SS sectors show significant higher level of interaction with external sources overall. But, the differences were not very great. Importance of internal resources within the group, as well as equipment suppliers and clients, competitors, conferences and fairs and even scientific journals ranked quite seemingly across sectors. The interactions between firms and the science system appears to be a much less relevant feature for many SB (technologically advanced) sectors than Pavitt suggested. Castellacci (2004) derives conclusions in the same line. Such flows and interactions are located 'up-stream in the knowledge-creating process and take place between he R&D departments of firms, universities and research institutes, conferences and scientific journals. The results reveal that other type of interactions need to be considered, namely with suppliers of technology and clients. These 'downstream' links and interactions are specifically oriented to answer specific need of the final users or costumers of services. This pattern reflects the central role of 'learning by doing' and learning by interacting processes in the innovation activities of many sectors. In this case knowledge and information flows are likely to be less codified than in the previous patterns and therefore more tacit in their nature (Evangelista, 2006). User-producer relationships –with clients, competitors and consultants, are not peculiar characteristics of the manufacturing industry but is a feature share with service sector (Evangelista, 2006).

Part 5 of the paper opens avenue for further research. I part 5 we inspired in the work by Castellacci (2004). We started by reducing the initial variables to 6 factors and then explored how these contributed to explain differences in innovation performance. Further research and tests are necessary.

Factor 2 reveals that type of innovation expenditures are related to the technological regime (appropriability and cumulativeness) and model a) it proves to be a key factor to discriminate between innovative performance across sectors in Europe. Factor 5 reveals that technological regime (technological opportunity) is also associated to technological trajectories, and accordingly to the results from table 6 it contributes to discriminate between innovative performance.

The importance of suppliers as sources of information is associated with innovation intensity (percentage of expenditures on innovation), revealing that investments in innovation go hand in hand with linkages with suppliers of equipment, and is also determinant to explain industrial differences in innovation performance.

Innovative intensity (percentage of firms introducing innovations) is related to adoption of new products and explains variability in innovative performance.

Otherwise, learning regime and degree of cooperation do not seem to discriminate across sectors.

The detailed analysis with individual variables reveals that disembodied type of innovation expenditures, innovation intensity and innovative intensity are the variables which individually explain variance in innovative performance. The amount of resources spent on innovation and the share of such costs devoted to R&D activities (disembodied) show a positive relationship. This in turn is positive related to innovative performance.

While we have observed, on the one hand, a technological dependence of SI and SD industries on the acquisition of technologies developed by other firms and sectors, in part 5, on the other hand, we realised the importance that endogenous technological efforts (disembodied expenditures) have for the overall innovative performance of all industries. Further analysis can be conducted. We may investigate if the models (a and b) prove to be stable to the inclusion of country and sectoral effects.

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