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Structures Formed by Innovative Activities beyond the Traditional Separation between Manufacturing and Services: Identification of Patterns of Innovation

Estructuras formadas por actividades innovadoras que superan la tradicional separación entre manufacturas y servicios: identificación de patrones de innovación

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Abstract

This paper focuses on complementarities between innovative activities carried out by firms in the manufacturing and service sectors. A new methodology based on conditional probability is applied in order to determine similarities in the process of innovation in either sector. The empirical analysis uses data from the Community Innovation Survey 4 (CIS-4) of various European countries. As a contribution to innovation theory, the empirical analysis reveals structures of innovative activities that are common to sectors in taxonomies of Pavitt (1984) and Soete and Miozo (1989). Moreover, empirical evidence provides new patterns of innovation beyond the traditional separation of the manufacturing and service sectors.

Keywords: Innovative Activities Structure; Innovation Pattern; Integrative Approach.

Resumen

Este trabajo se centra en buscar complementariedades entre las actividades innovadoras que realizan las empresas de manufacturas y servicios con el objeto de encontrar similitudes entre los procesos de innovación de ambos sectores. Para ello se utiliza una metodología basada en el cálculo de probabilidades condicionales y se emplean datos del "Community Innovation Survey 4" (CIS-4) para varios países europeos. El análisis, que toma coma referencia las taxonomías de Pavitt (1984) Soete and Miozo (1989), lleva a identificar varias estructuras de actividades innovadoras que son comunes a ambos sectores. También se identifican patrones de innovación basados en esas estructuras que no responden a la tradicional separación entre manufacturas y servicios.

JEL Classification: L60, L80, O31.

1. Introduction

Research on innovation has traditionally been far more attracted to the study of manufacturing than of services. In addition, within the manufacturing sector, more attention has been paid to the analysis of high-tech manufacturing (HT) than low- and medium-tech (LMT) industries. This vision of innovation, which focuses on R&D and technological aspects, underlines the idea that external and non-endogenous technology is the main driving force of service innovation and LMT industries. Firms within the service and LMT industries buy goods outside the sector, especially in the form of computers and other equipment (Howells, 2010, p. 69). Hirsch-Kreinsen *et al.*, (2006) list several factors that explain the slant towards HT manufacturing, such as the consideration of services as a minor sector, the relevance of the linear model of innovation over long periods, and the availability of innovation statistics. These may have led to a misunderstanding of innovation.

The idea still remains to some extent that services constitute a passive sector and adopt technological innovation produced in the manufacturing sector, which has a more rational R&D-based innovation development and can be more efficient and economically beneficial (Sundbo, 2010; Toivonen, 2010, p. 223-224). As a consequence, numerous studies are based on classifications of manufacturing and service sectors that introduce an obsolete view of services as a backward, passive and minor sector of innovation. Although it is currently acknowledged that innovation in manufacturing is, to some extent, different from that in services, the idea that the service sector is less innovative than the manufacturing sector is increasingly being rejected. In many services, the level of high-tech capital intensity is greater than in a large part of manufacturing industries. On the other hand, manufacturing industries are increasingly facing market conditions where the launching of radical new goods is no longer the only means of achieving competitive advantage; firms have introduced production methods of a more flexible nature in accordance with the less physical character of their products and attempt to standardize many services where possible. Demand for products that combine both goods and services is growing in the market. As a result, goods and services are increasingly bundled together; there are now many intangible service products which have physical manifestations and require operations similar to those in manufacturing firms, and the process of innovation have become more integrated (Sundbo, 2010; Gallouj and Djellal 2010).

This change in the economy towards high convergence and the inter-relation between the production and consumption of goods and services, has led to a blurring of boundaries between these two sectors. Therefore, the concept of convergence between goods and services is becoming increasingly relevant for the study of innovation, not only in services but also in manufacturing, agriculture, and other parts of the primary sector (Sundbo, 2010). Consequently, research has striven to extend the analysis of innovation beyond the traditional separation between manufacturing and services. In recent years, numerous studies have sought similarities between the innovation process in manufacturing and services (Bowen *et al.*, 2002; Reed *et. al.*, 2009; Meyer and Detorre, 2001), and have frequently tackled the difficulties in measuring and conceptualizing both properly (Forsman, 2011). Numerous studies underline that different innovation modes (products, process, and non-technological innovation) co-exist in both manufacturing and service industries (Hollestein, 2003; OECD, 2008; Tether and Tajar, 2008). Other studies have found that economic performances usually improve when associated to a more complex or systematic type of strategy, in which different kinds of innovative activities (technological and non-technological) are involved (Brynjolfsson and Hitt, 2000; Bresnahan *et al.* 2002; Gera and Gu, 2004). On the other hand certain researchers have underline that a whole process of innovation, which involves both manufacturing and services, has not yet been described at a detailed level (Toivonen, 2010, p. 223). Frequently, studies "are still more or less based on a traditional industrial paradigm" (Toivonen, 2010, p. 223) and numerous authors point out that is necessary to advance the development of an integrated theory which involves both services and manufacturing in order to understand and adequately measure the true dimension of innovation in modern economies (Howells, 2010, p. 72; Gallouj and Djellal, 2010; Castellaci, 2008). In this paper, we advance towards this goal using a new methodology based on the search for complementarities between various innovative activities.

The objective of this paper is two-fold: 1) the determination of structures formed by a set of complementary innovative activities that are similar between firms in different sectors in order to identify any possible similarities in the process of innovation beyond the traditional separation between innovation in industry and that in services; 2) the creation of new patterns of innovation associated to those structures that are formed by complementary innovative activities, that is, by using an integrative approach. The analyses employ a new methodology, based on the conditional probability that enables the determination of structures formed by complementary innovative activities in the firms that constitute those sectors covered by Pavitt's (1984) and Soete and Miozo's (1989) taxonomies. These contributions have inspired a number of empirical studies that focus on different characteristics of firms in the manufacturing and service sectors (Evangelista and Mastrostefano, 2006;Malerba and Orseningo, 1995;Malerba and Montobbio, 2003). By contrast, this article focuses on the similarity between the sectors rather than the differences. The paper makes a double contribution. First, new structures formed by complementary innovative activities that are common to firms in manufacturing and service sectors are presented. Second, an integrative view is shown of the sectorial pattern of innovation covered by the taxonomies of Pavitt *et al.* (1984) and Soete and Miozo(1989).

Three parts, in addition to this introduction, constitute this article. In the following section, a theoretical framework is developed. In the third section, the empirical analysis searches for structures formed by complementary innovative activities that are similar between firms in manufacturing and service sectors. These structures are applied for the determination of new patterns of innovation based on an integrative approach. In order to perform this analysis, data from the Community Innovation Survey 4 (CIS-4) is used. Finally, in the fourth section, conclusions, limitations and implications of the research are presented.

2. Theoretical Framework

As we pointed out previously, the traditional view of innovation, which focuses on R&D and technological aspects, has become obsolete. Nowadays, service firms are frequently considered to be as innovative as, or even more innovative than, firms in the manufacturing industry. Likewise, low- and medium-tech (LMT) industries have been recognized for their crucial role in the process of innovation, not only as receptors of innovations, but also as producers of improvements in goods and processes (Santamaría, *et al.* 2009). One characteristic of innovation in those sectors is the major role played by non-technological types of knowledge assets, competences and strategies. Nevertheless, certain taxonomies of those sectorial patterns of innovation that are inspired in the traditional view have been widely applied by numerous scholars. It is implicitly assumed that those patterns are homogeneous, and focus especially on technological innovations (Hollenstein, 2003).

In 1984, Pavitt presented his well-known taxonomy. This has inspired a great amount of research in the field of innovation. The taxonomy by Pavitt *et al.* (1984) distinguishes between: 1) Supplier-dominated sectors, which make only a minor contribution to their own technology processes and products. In these firms, most innovations come from their suppliers of equipment and materials. 2) Scale-intensive sectors, whose process technology is mainly developed in their production engineering departments. Not only do these innovative firms produce a relatively high proportion of their own technology processes, but they also provide a relatively high level of vertical technological diversification into equipment. In addition, they produce goods aimed at large markets with a certain degree of standardization and make a relatively major contribution to innovations produced in their principal sector of activity. 3) Specialized-supplier firms that supply equipment and instrumentation for process innovations. These firms have a complementary relationship with customers and diversify relatively little technologically, either vertically or otherwise. 4) Science-based sectors, which produce a high proportion of product innovations used in both their own and other sectors. Most of their technological diversification is concentric/conglomerate rather than vertical.

The service sector has frequently been considered as a "supplier-dominated industry", although Pavitt *et al.* (1989) subsequently added another category named "information-intensive". This category has its main source of information in the advanced processing of data and covers activities related to computer systems, development software. Pavitt *et al* (1989) consider that financial services and retailing are in that category.

The taxonomy by Pavitt *et al.* (1984) inspired Soete and Miozo(1989) who proposed a sectorial pattern of innovation in services. They consider a category called "network-based industries", which covers two groups as "scale-intensive industries based on physical networks" (e.g. Transport and Wholesale) and "industries relying on information networks" (e.g. insurance, finance, and communications). According to Soete and Miozzo, a single sector could be in various categories at the same time. Furthermore, a characteristic of this typology, as in Pavitt's typology, is that diversity in relation to the innovation activities of firms is emphasized (Tether *et al.,* 2001).

The typologies by Pavitt *et al.,* (1984) and by Soete and Miozzo (1989) offer remarkable contributions towards the theory of innovation. Martin Meyer *et al.* (2004) analyze Pavitt's contributions to innovation studies in literature by using bibliometric data. They count all publications by those authors, both indexed and not indexed, in The *Social Sciences Citation Index (SSCI)* of Thomson-ISI, and show that the most cited article is "Sectoral Patterns of Technical Change" (Pavitt *et al.*, 1984) published in *Research Policy*. Apart from references in *Research Policy*, this article remains the most frequently cited in various journals indexed in SSCI, since it presents interdisciplinary work (Meyer *et al.,* 2004). Although Pavitt *et al.,* (1984) grouped data at industry level, this taxonomy has often been applied at firm and even at product level. Moreover, it has been extended to innovation in the service sector (Archibugui, 2001).

On the other hand, some authors have criticised Pavitt's taxonomy. Castellaci (2008) points out that it is probably useful for describing the growth of advanced economies in the Fordist age, but fails to present a correct description of current economies, within which the traditional view of services as a backward, passive, and minor innovative sector has become obsolete. Pavitt's taxonomy considers innovation in manufacturing to be different and superior to innovation in services. In contrast, this view is rejected by the integrative approach, which is has become more widely accepted over recent years. The integrative approach tends to minimize the differences between the industry and service sectors (and firms) in the assets of fundamental knowledge and in the types of innovation activities these sectors carry out (Evangelista and Vezzany, 2010).

Several factors explain the growing importance that the integrative approach has attained in recent decades with respect to the traditional view.

One factor is the continuous increase in the number of intangible service products that have physical manifestations and require operations similar to products in manufacturing firms. Moreover, manufacturing firms has to face more and more markets in which not only does competitive advantage depend on radically new goods, but it also depends on services. Nowadays the process of goods production cannot be separated from the process of service production (Sundbo, 2008) and the intense process of outsourcing over recent decades is leading to an increasing interdependence and intensive knowledge exchange between the manufacturing and service sectors (Castellaci, 2008).

Another factor which affects the current growth in the importance of the integrative approach is related to the attempt to wield more control over the innovation process by company managers, as they strive to systematize, steer and rationalize this process (Sundbo, 2010). In general, firms have made their methods of production more flexible and have frequently standardized many services. A third factor is a change in the notion of services as a supplier-dominated sector in a world in which the idea of innovation co-production in the supplier-client relationship has grown (Howells, 2010).Therefore the difference between services and manufacturing has become blurred and as a consequence the two fields are becoming fully integrated (Archibugi, 2001).

All these changes have led many researchers to broaden the traditional view on innovation via the integration and articulation of a variety of technological aspects in manufacturing and service industries. Furthermore, certain authors have demanded a more suitable description of the innovation process, of the flows and transactions associated with technology, and of a clarification of organizational and marketing innovation in order to develop a wider and more integrated holistic theory of innovation (Howells, 2010). As Dosi (1988, p. 222) pointed out, the integrative approach needs a broad concept of innovation that involves not only technological activities but also non-technological innovative activities common to both manufacturing and services, such as imitation, development, organization, marketing and experimentation (Dosi, 1988a, p. 222). In this sense, Gallouj and Djellal(2010) call for the development of an integrated analysis on innovation, in order to build general theoretical models independent from the sectorial context.

Research has principally focused on technological activities and has paid little attention to non-technological activities (Hollenstein, 2003; Laestadius *et al.*, 2005). Nevertheless, numerous studies have found that some non-technological activities are, to a large extent, common to manufacturing and services, and play a crucial role in innovation in both sectors. These activities include: training, acquisition of intensive technology via purchasing of machinery and equipment, marketing activities, and organization activities (Hollestein, 2003; Warner, 1996; Freel, 2005; Laestadius*et al* 2005, Santamaría *et al*, 2009). Nevertheless, no in-depth analysis has yet been performed on the extent to which these innovative activities are complementary to each other and/or to other technological activities. The literature mainly focuses on complementarities among a few innovative activities, such as acquisition of certain types of technologies, changes in organization, and the use of highly skilled workers and training (Bresnahan *et al.* 2002; Bartel *et al.*, 2007; Berman *et al.*, 1994), whereby the objective of the analyses is to ascertain the effect of those complementarities on innovation (Bresnahan *et al.* 2002) or productivity in firms (Boothby *et al.*, 2010). However, no studies analyze the complementarities between a wide-ranging list of innovative activities in manufacturing and services, that is, by using an integrative approach. This paper try to contribute to reduce that knowledge gap assuming the hypothesis that innovative activities in manufacturing and services sectors are complementary and create similar structures in both sectors.

3. Empirical analysis

The objective of the empirical analysis is two-fold:

1. Determination of whether there are structures formed by a set of complementary innovative activities that are similar between firms in different sectors in order to identify any possible similarities in the process of innovation beyond the traditional separation between innovation in industry and that in services.
2. The creation of out new patterns of innovation associated to those structures that are formed by complementary innovative activities, that is, by using an integrative approach.

3.1. Research Data

In order to perform this analysis, data from the Community Innovation Survey 4 (CIS-4) is used. Data made available by CIS enables a broad concept of innovation to cover the complex nature of innovative activities. The CIS has been designed to grasp the systemic nature of innovation and of the role played by external actors and sources of knowledge. The data offers a comprehensive set of indicators which provide information obtained by means of a survey of companies which, apart from other aspects, focuses on numerous company activities related to innovation, such as investment in machinery and equipment, acquisition of disembodied technology, training, R&D activities, processes and organization of innovation, and marketing. In addition, CIS provides data on cooperation, sources of knowledge, performances, and other company activities which contribute towards the understanding of their innovation strategies. The survey is carried out every four years. The Community Innovation Survey 4 (CIS-4) also introduces new items with respect to previous inquiries in order to measure non-technological innovation. The firms surveyed are asked about: a) innovations in goods and services; b) process innovation; c) innovation activity and expenditure; d) uncompleted and/or abandoned activities; e) public funding of innovation; f) sources of information for innovation; g) innovation cooperation; h) effects of innovation; i) hampered innovation activity; j) factors hampering innovation; k) intellectual property rights; l) organizational and marketing information; and m) effects of organizational innovation.

The research presented in this article is carried out with the data from only 8 of the 29 countries covered by CIS-4 for the period from 2002 to 2004: Germany, Italy, Spain, Norway, Belgium, Greece, Czech Republic and Portugal. The sample data is representative of manufacturing and services across these 8 countries in accordance with the methodology used in the CIS-4. This methodology covers 15 manufacturing-grouped sectors and 14 service-grouped sectors with three separate classes for the size of the firm: 20–49; 50–249; and 250 or more employees. The data corresponds to a two-digit NACE classification. The availability of CIS-4 data at this level of aggregation was granted by the European Commission.

For this analysis, only those firms which carried out at least one innovative activity over the period of time that the survey covers have been selected. The non-innovative companies hold no interest for this research. A detailed description of the variables used in the empirical analysis is presented in Table 1.

Table 1. Variables in the analysis.

Innovative activities in analysis of complementarity		Range
RdIn	Engagement in intramural R&D	0 or 1
RdEx	Engagement in extramural R&D	0 or 1
RMAc	Engagement in acquisition of machinery	0 or 1
ROEk	Engagement in other external knowledge	0 or 1
RTr	Engagement in training	0 or 1
RMAr	Engagement in market introduction of innovation	0 or 1
Org.	Changes in organization	0 or 1
Variables in the analysis of pattern of innovation (logistic regression)		
STri	Dependent variable: four regressions (Table 12)	0 or 1
InPdgd	New or significantly improved goods introduced onto the market	0 or 1
InPdsv	A new or significantly improved service introduced onto the market	0 or 1
Inpspd	A new or significantly improved method of production introduced onto the market	0 or 1
Inpslg	A new or significantly improved logistic, delivery or System introduced onto the market	0 or 1
Inpssu	New or significantly improved supporting activities introduced onto the market	0 or 1
Orgsys	Improved knowledge management system introduced	0 or 1
Orgstr	Change to work organization introduced	0 or 1

Mktdes	significant design/packaging changes introduced	0 or 1
Mktmet	significantly changed sales/distribution methods introduced	0 or 1
SEntg	Sources from within the enterprise or enterprise group	0 to 3
SSup	Sources from Suppliers of equipment, materials, etc.	0 to 3
SCli	Sources from Clients or customers	0 to 3
SCom	Sources from Competitors and other enterprises in the same industry	0 to 3
Sins	Sources from consultants, commercial labs or private R&D institutes	0 to 3
Suni	Sources from Universities or other institutions of higher education	0 to 3
SGmt	Sources from Government or public research institutes	0 to 3
Scon	Sources from professional conferences, trade fairs, meetings	0 to 3
Sjou	Sources from Scientific journals, trade/scientific publications	0 to 3
Spro	Sources from Professional and industry associations	0 to 3

Source: Community Innovation Survey 4.

3.2 METHOD

Firstly, in order to identify which pairs of complementary activities (technological and non-technological) are common in manufacturing and service sectors, and to ascertain how the structure formed by those activities changes when change the sectors that constitute Pavitt's (1984) and Soete and Miozo's taxonomies (1989), the following conditional probability is calculated:

$$P_{AB} = \Pr\{A \text{ and } B / A \text{ or } B\} = A \cap B / A \cup B$$
$$P_{AB} = P_{BA}$$

This is the conditional probability that a company carries out innovative activities A and B, given that it executes A or B (or both). This probability is applied in order to measure the degree of complementarity for the innovative activities analyzed. We consider that when the conditional probability is above 50%, it indicates that the two innovative activities employed to calculate the likelihood are clearly complementary. In this case, if a company carries out one or the other activity, it is more likely than not that it will carry out both activities. On the other hand, when the conditional probability is below 50%, the degree of complementarity decreases or disappears.

Once several innovative-activity structures are identified, a possible pattern of innovation is sought by means of analyzing both major sources of information for innovation and the kind of innovation influencing those previously identified structures. In this part of the analysis, the logistic regression model is applied. The estimated logistic model presented below turns out to be useful in the search of patterns of innovation since when the effect of the explanatory variables (innovative activity) on the dependent variable is statistically significant, the model shows the increase in the likelihood that a source or kind of innovation is associated to a specific innovation structure with respect to the likelihood of that source or kind of innovation is associated to other different innovation structure. Therefore the logistic regression model is useful to predict the probability of a specific structure being present in a firm on the basis of the presence of certain types of innovation and the level of use of certain sources of information for innovation.

The logistic regression model estimates the covariate effects on the likelihood that a structure be present in a firm:

$$STR_i = \exp (\sum \mu_j Inn_{ij} + \sum \beta_k Sourc_{ik})$$

where STR_i is a dummy variable that takes the value of 1 if firm i contains a certain kind of innovative structure, and 0 otherwise (the model is applied to four dependent variables: see Table 12). Inn_{ij} is also a dummy variable that takes value 1 if firm i performs the type of innovation j (the model covers nine types of innovation: see Table 1). Finally, $Sourc_{ik}$ is another dummy variable that takes value 1 if firm i uses the source of information for innovation k (the model covers ten different sources of information: see Table 1).

3.3 Results

Table 2 presents the distribution of the innovative activities of firms in every sector covered by Pavitt's (1984) and Soete and Miozo's (1989) taxonomies. This table shows a first similarity between innovation in manufacturing and services. For example, acquisition of machinery and equipment (RMac) are very frequent innovative activities in both sectors. Differences also exist. Changes in organization (Org) is more frequent in services than in manufacturing, and engagement in intramural R&D is clearly more frequent in manufacturing than in services except in those activities based on scientific services. Nevertheless, in order to ascertain the similarities between innovation in manufacturing and services, the analysis of complementarity between the innovative activities involved in innovation of firms is fundamental. We measure this complementarity by means of applying the concept of conditional probability.

TABLE 2: DISTRIBUTION OF INNOVATIVE ACTIVITIES BY SECTORS (%).

	Supplier-dominat. manufac.	Intensive-scale manufac.	Specialised-supplier manufac.	Science-based manufac.	Supplier-dominat. services	Scale-intensive-physical-net. services	Information-network services	Science-based services
RRdIn	17%	18%	20%	20%	9%	11%	12%	22%
RRdEx	8%	11%	11%	11%	7%	7%	9%	8%
RMac	22%	18%	17%	18%	21%	19%	19%	16%
ROek	6%	7%	7%	7%	6%	8%	6%	7%
RTr	15%	15%	15%	15%	17%	18%	16%	17%
RMar	11%	13%	12%	13%	9%	13%	10%	12%
Org	20%	18%	17%	16%	31%	23%	28%	18%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Source: Calculation performed by the author using data from CIS-4.

Tables 3-6 present the conditional probabilities calculated for the manufacturing sectors covered by Pavitt's (1984) taxonomy. It can be seen in Table 3, which shows the conditional probabilities in Supplier-dominated manufacturing sectors, that there is a group of innovative activities which are complementary to each other, such as RMac-RTr-Org. RdIn is not complementary to any innovative activity, although it presents more than 40% probability in certain cells. In contrast, Table 4 shows that RdIn is complementary to every innovative activity except ROeck in Scale-intensive manufacturing sectors. Furthermore, the group formed by RMac-RTr-Org presents higher probabilities than in the previous table. Therefore, a structure formed by complementary innovative activities such as RdIn-RMac-Rtr-RMar-Org is clearly visible in Scale-intensive manufacturing sectors. Each of these activities are complementary to at least two other activities. This structure is more complex and larger than that in the Supplier-dominated manufacturing sectors. Rdex is also complementary to RdIn but not to any another activity. Moreover, in Specialized-supplier manufacturing sectors (Table 5), the complexity and extension of the structure formed by complementary innovative activities is higher than that in previous sectors. Not only is RDex complementary to RDIn, but it is also complementary to other activities, and together they all form a compact structure due to their high level of mutual complementarity.

Finally, Table 6 presents the conditional probabilities in Science-based manufacturing sectors and shows a structure formed by complementary activities very similar to that visible in Scale-intensive manufacturing sectors (Table 4), although here the conditional probabilities are higher than in the other sector.

Table 3. Complementary innovative activities in Supplier-dominated manufacturing sectors.

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	44.5	48.5	26.7	47.6	43.5	45.0
RRdEx		100	28.5	26.1	29.8	27.8	28.41
RMAc			100	23.7	54.7	38.5	51.8
ROEk				100	25.5	24.4	20.8
RTr					100	43.7	50.1
RMAr						100	36.0
Org							100

Table 4. Complementary innovative activities In Scale-intensive manufacturing sectors.

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	51.5	56.2	30.0	56.3	53.8	57.2
RRdEx		100	38.5	34.5	42.2	40.2	42.8
RMAc			100	30.6	58.3	49.8	55.7
ROEk				100	33.8	34.8	30.3
RTr					100	53.3	55.5
RMAr						100	48.1
Org							100

Table 5. Complementary innovative activities in Specialized-supplier manufacturing sectors .

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	60.1	65.6	31.3	63.7	57.1	60.6
RRdEx		100	49.5	38.6	49.6	46.4	49.1
RMAc			100	35.3	65.1	53.7	61.6
ROEk				100	36.8	34.3	34.0
RTr					100	58.6	60.9
RMAr						100	53.3
Org							100

Table 6. Complementary innovative activities Science-based manufacturing sectors.

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	49.6	65.2	30	58.5	58.6	55.0
RRdEx		100	39.8	34.5	40.4	42.8	40.9
RMAc			100	32.1	65.2	52.3	57.0
ROEk				100	33.7	33.0	33.0
RTr					100	54.0	55.7
RMAr						100	47.5
Org							100

Source: Calculation performed by the author using data from CIS-4.

On the other hand, Tables 7-10 present the conditional probabilities calculated for service sectors that cover Soete and Miozo's (1989) taxonomy. Tables 7 and 8 show probabilities in Supplier-dominated service sectors and Scale-intensive Physical Network sectors, respectively. They are reasonably similar to each other. In both tables, RdIn is not complementary to any innovative activity and the group formed by Rmac-Rtr-Org presents a high complementarity, similar to that in Supplier-dominated manufacturing sectors. It can be seen that both Tables 7 and 8 are also similar, to a certain extent, to Table 3 (Supplier-dominated manufacturing sectors) as regards the complementarity between innovative activities. Nevertheless, several differences with respect to that sector are visible. Supplier-dominated manufacturing sectors present conditional probabilities corresponding to RdIn higher than those in service sectors, and in contrast the group formed by RMac-RTr-Org presents a higher level of complementarity in Supplier-dominated service sectors and in Scale-intensive physical network sectors than in Table 3. Therefore, the structure formed by complementary innovative activities, such as RMac-RTr-Org, in those Service sectors is stronger than that in Supplier-dominated manufacturing sectors.

Tables 9 and 10, which show the complementarities for innovative activities in Information-network service sectors and Science-based service sectors respectively, show the highest conditional probabilities in Services, similar to the equivalent sectors in manufacturing. Furthermore, these two sectors present a notable difference with respect the remaining sectors. Information-network service sectors provide no activity complementary to RRdIn but present a set of complementary innovative activities which is larger than those noted in Tables 7 and 8. In Information-network service sectors, the structure formed by complementary innovative activities such as RMac-RTr-Org is enlarged with RMar. Moreover, Science-based service sectors present an even larger structure since RDIn is complementary to RTr and Org.

As a summary, the analysis above demonstrates the following:

1. Although sectors present differences in the technological trajectories as regards the innovative activities developed by firms, notable similarities have been observed with respect to the way the businesses combine those activities.
2. *Engagement in acquisition of machinery* (RMac), *engagement in training* (RTr) and *changes in organization* (Org) are complementary to each other in every sector analyzed, that is, those innovative activities form a structure which is common to all the sectors covered by the taxonomies of Pavitt *et al.* (1984) and of Soete and Miozo (1989). We call this structure the basic structure of innovative activities.

Table 7. Complementary innovative activities in Supplier dominated service sectors.

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	43.3	27.9	21.0	32.7	35.7	35.5
RRdEx		100	28.9	19.5	27.8	36.3	27.2
RMAc			100	24.4	60.4	35.8	62.7
ROEk				100	23.8	22.0	21.4
RTr					100	39.5	59.4
RMAr						100	39.8
Org							100

Table 8. Complementary innovative activities Scale-intensive physical networks sectors (scala-intensive).

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	42.6	38.5	24.6	38.2	32.7	43.1
RRdEx		100	27.3	25.4	31.2	29.3	31.2
RMAc			100	26.7	60.7	35.5	58.8
ROEk				100	31.0	24.1	26.5
RTr					100	42.8	63.4
RMAr						100	39.4
Org							100

Table 9. Complementary innovative activities in information-network service sectors (specialized suppliers).

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	45.26	40.2	31.5	45.0	41.9	41.3
RRdEx		100	26.3	28.5	27.8	28.4	28.0
RMAc			100	34.3	70.9	51.6	69.0
ROEk				100	31.3	31.7	34.8
RTr					100	59.5	69.1
RMAr						100	53.6
Org							100

Table 10. Complementary innovative activities Science-based service sectors.

	RRdIn	RRdEx	RMAc	ROEk	RTr	RMAr	Org
RRdIn	100	43.6	45.0	27.3	65.1	47.0	56.6
RRdEx		100	31.8	28.2	27.8	29.5	29.8
RMAc			100	36.8	68.7	49.0	51.3
ROEk				100	34.8	37.0	29.1
RTr					100	55.8	55.4
RMAr						100	45.0
Org							100

Source: Calculation performed by the author using data from CIS-4.

3. The basic structure of innovative activities seems to become more complete and reinforced (a higher conditional probability) with the increase in the technological complexity of sectors. The most completed structure is in Specialized-supplier manufacturing sectors. Table 11 shows how the structure formed by complementary innovative activities changes throughout the sectors. Only those activities that are complementary to at least two other activities have been taken into account for the construction of the structure in order to ensure that it is well formed. The letters in bold indicate that the structure is stronger in that sector with respect others that present a similar structure, that is, the conditional probabilities are higher.
4. In addition to the basic structure, three further structures are identified: intermediate structure without R&D, intermediate structure with R&D, and complete structure. In Supplier-dominated manufacturing sectors, Supplier-dominated service sectors and Scale-intensive physical network sectors, only the basic structure of innovative activities appears and it presents a higher complementarity in service sectors. Information-network service sectors contain the intermediate structure without R&D, and the two Science-based sectors contain the intermediate structure with R&D. Finally, the complete structure is only contained in Specialized-suppliers manufacturing sectors (Table 11)

TABLE 11: STRUCTURES FORMED BY COMPLEMENTARY INNOVATIVE ACTIVITIES IN SECTORS.

Sectors	Complementary activities	Kind of structure
Supplier Dominated manufacturing sectors	RMac-RTr-Org	Basic structure
Supplier Dominated service sectors	*RMac-RTr-Org*	Basic structure
Scale-intensive physical networks sectors	*RMac-RTr-Org*	Basic structure
Information network service sectors	RMac-RTr-RMar-Org	Intermediate structure without R&D
intensive Scala manufacturing sectors	RdIn-RMac-Rtr-RMar-Org	Intermediate structure with R&D
Science Based service sectors	RdIn-RMac-Rtr-RMar-Org	Intermediate structure with R&D
Science Based manufacturing sectors	*RdIn-RMac-Rtr-RMar-Org*	Intermediate structure with R&D
Specialized suppliers manufacturing sectors	*RdIn-RDex-RMac-Rtr-RMar-Org*	Complete structure

Source: own elaboration.

Therefore, as a result, this first part of the empirical analysis shows that the taxonomies by Pavitt *et al.* (1984) and by Soete and Miozo (1989) can be integrated into a single taxonomy which is based on the structures formed by complementary innovative activities in firms. That taxonomy goes beyond the traditional separation between manufacturing and services since those structures do not depend on those sectors. A second part of this research is formed by the search for a possible pattern of innovation associated to those structures by means of analyzing both major sources of information for innovation and the type of innovation influencing those structures. A logistic regression model is used. In this model the variable dependent is a dichotomy variable. Here, the value 1 is taken when a firm presents certain structures presented in the previous step, and value 0 is taken otherwise. The variables independent in our case are nominative or ordinal (Table 1). The coefficient (exp(b)) shows the percentage of change in the ratio of probabilities [Pr(variable dependent) = 1/Pr(variable dependent) = 0)].

Table 12: Logistic Regression.

	Dependent Variable			
Variables in the equation	Basic Structure	Intermediate Structure without R&D	Intermediate Structure with R&D	Complete structure
InPdgd(1)	1,050	1,596***	1,614***	1,404**
InPdsv(1)	1,198**	1,068	,954	,846*
Inpspd(1)	,919	,394***	,437***	,428***
Inpslg(1)	1,040	1,070	1,093	1,193*
Inpssu(1)	1,008	,564***	,528***	,490***
Orgsys(1)	1,650***	2,237***	1,931***	1,565***
Orgstr(1)	1,578***	2,449***	2,235***	1,942***
Mktdes(1)	,994	1,727***	1,516***	1,507***
Mktmet(1)	1,054	1,594***	1,589***	1,336**
SEntg	,898***	,643***	,658***	,616***
SSup	1,042	1,701***	1,669***	1,647***
SCli	1,925*	1,919**	1,959*	1,904**
SCom	1,032	,938	,932	,949
Sins	,979	1,003	,984	1,058
Suni	1,069	1,246***	1,309***	1,465***
SGmt	1,005	1,090	1,124**	1,171**
Scon	1,029	1,002	,948	,934
Sjou	1,053	1,020	1,035	,943
Spro	,938***	,906**	,840**	,840**
X^2 Omnibus test	400,844***	1873,798***	2159,491***	3123,732***
-2 log of verisimilitude	6414.179	4670,0897	4385,205	3420,964
% Cases Correctly predicted	61,0	75,2	78,7	87,4
Number of observations	4916 (7396)	4721(7396)	4721(7396)	4721(7396)

*P<0.10
**P< 0.05
***p < 0.0001

Table 12 shows the results of four logistic regressions executed, one for every type of structure of innovative activities presented in Table 11. Here, it can be seen that there are remarkable differences between the result of the regression referring to the basic structure and those referring to the rest of the structures determined. The former predicts the probability of the basic structure, and only the basic structure, being present in a firm on the basis of the presence of certain types of innovation and the level of use of certain sources of information for innovation. The model is significant (X^2 = 400,844***). The basic structure, and only the basis structure, is more likely to be present in a firm when this innovates in services and organization. Other types of innovation are not statistically significant in this model. The probability that a firm has only the basic structure increases when clients are used as a source of information for innovation, and decreases when both the level of use of sources from within the enterprise or enterprise group and from Professional and industry associations increase. Other information sources are not statistically significant in this regression.

The other three regressions are also statistically significant. They show more complexity in the trajectory of innovation of firms than that referring to the basic structure, although a few differences between them do exist. In general, there are more independent variables (types of innovation and sources of information for innovation) which are statistically significant in these three regressions than in the first regression. In these three regressions, the ratio of probability (dependent variable) increases when a firm carries out innovation in products, in organization, or in marketing, while in the basic structure only innovation in services and organization are statistically significant. Another difference with respect to the basic structure is that the ratio of probability increases when the level of use of the two following sources of information for innovation increases: suppliers of equipment, materials, etc. and universities or other institutions of higher education. In addition, when the dependent variable is the intermediate structure with R&D or the complete structure, then the source from Government or public research institutes also shows a positive and statistical significance. Finally, the effects of independent variables on the dependent variable are, in general, higher in these three models.

4. Discussion and conclusions

In this paper, we have determined new characteristics of the patterns of innovation covered by the taxonomies of Pavitt *et al.* (1984) and Soete and Miozo (1989). The analysis goes beyond the traditional separation between innovation in manufacturing and services since it determines structures of innovative activities which are common to both sectors. A new methodology is applied which consists of calculating the conditional probability in order to ascertain the level of complementarity between innovative activities in firms. The analysis based on conditional probabilities determines four structures formed by technological and non-technological innovative activities of firms in those sectors covered by the taxonomies of Pavitt *et al.* (1984) and Soete and Miozo (1989). These structures are the following:

1) *The Basic Structure* which is formed by innovative activities such as *engagement in training, engagement in acquisition of machinery and equipment, and changes in organization*. This structure has been found in one manufacturing and two service sectors; the Supplier-dominated manufacturing sector, Supplier-dominated service sector, and Scale-intensive Physical Network sector. The structure becomes stronger (conditional probabilities are far above 50%) when moving from one sector to another in the order listed above.
2) *The Intermediate structure without R&D,* which is formed by the three innovative activities noted in the Basic Structure, plus *engagement in market introduction of innovation*. This structure has only been found in Information-network service sectors.
3) *The Intermediate structure with R&D,* which is similar to the previous structure plus Engagement in intramural R&D. This structure has been found in two manufacturing sectors and one service sector; the Scale-intensive manufacturing sector, Science-based service sector, and in the Science-based manufacturing sector where the structure is the strongest (conditional probabilities are far above 50%).
4) *The Complete structure,* which is similar to the previous structure plus *engagement in extramural R&D*, and shows a high level of complementarity between the innovative activities. This structure has been encountered only in the Specialized-supplier manufacturing sector.

This result is consistent with other studies which show that technological and non-technological innovations rather than substitutes are complements, and that various innovation modes co-exist which combine product, process and non-technological innovations in both manufacturing and services (Hollestein, 2003, Tether and Tajar, 2008). A major contribution of this paper is the demonstration that innovative firms present a certain kind of structure formed of complementary innovative activities (technological and non-technological) which do not depend on the global sector (manufacturing or services).

Furthermore, the empirical analysis shows that some non-technological innovative activities, such as training, changes in organization, and acquisition of machinery and equipment, play a crucial role in business innovation. Some of these activities have traditionally been considered as typical of technologically backward sectors. In contrast, our analysis shows that not only do these activities form a basic structure of innovation which is present in all innovative firms, but they are also the most frequent in every sector, especially the two latter activities (acquisition of machinery and equipment, and changes in organization). This is in line with the results by other studies which have found that human resources, machinery and equipment, and organization, among other activities, not only play a crucial role in the service innovation process but are also significant in manufacturing (Hollenstein, 2003; Warner, 1996; Freel, 2005; Laestadius et al 2005; Santamaría *et al.*, 2009). An explanation to those complementarities is that frequently when a firm buys a new machinery and equipment also needs carry out training activities for the personnel since the workers has to learn about using the new technology. Frequently a new machinery or equipment also causes changes in organization in order to fit the characteristics of the new technology. As a consequence, innovation is a function in which technological and non-technological activities complement each other. It is highly complicated to understand innovation without taking into account those complementarities, among which there are activities that have traditionally been disregarded in the analysis of innovation.

Moreover, the empirical analysis leads to two patterns of innovation associated to the aforementioned structures of innovative activities. One is associated to the basic structure, which is contained in Supplier-dominated manufacturing sectors, Supplier-dominated service sectors and Scale-intensive physical network sectors. Firms following this pattern of innovation tend to carry out innovation in services and in changes in organization, and make use of clients as a source of information for innovation. The other pattern presents more complexity. It is associated to the remaining structures formed of innovative activities and is common to firms that tend to innovate in products, organization and marketing. In addition, these firms tend to make use of clients, suppliers, government and universities as sources of information. The analysis therefore describes two principal patterns of innovation. One is associated to those firms that present the basic structure and only that structure, and the other is associated to those firms that present a more complex structure of innovative activities. This result suggests that the structure formed by innovative activities can be an additional element in order to characterize patterns of innovation by using an integrative approach, that is, beyond the traditional separation between manufacturing and services.

Therefore, this empirical analysis provides support for the integrative approach of innovation by presenting a methodology that allows a step to be taken towards a more integrated view of innovation. Hence, this paper contributes towards the provision of a response to the frequent demand by scholars for an integrated description of innovation (Castellaci, 2008, Gallouj and Weinstein, 1997, p. 538).

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Finally, a limitation of this study is that the empirical analysis is influenced by the characteristics of the CIS and the concepts which inspire the indicators of innovation, innovative activities and sources of information for innovation that the CIS adopted. This limits the scope of the analysis and determines its depth as it introduces a bias toward the CIS concepts. For example, with available data is not possible to observe at which extent the nature and characteristics of a specific innovative activity in the manufacturing sector (e.g RMAC) is the same as in service sector. Future research could extend the analysis on those issues in order to achieve a more accurate knowledge of the similarities between the structures of innovative activities that are common to both sectors. This will help to find out a better explanation to the complementarities determined in this analysis. Future research also might use data different from that the CIS provides in order to improve the characterization of the innovation patterns that this analysis has determined and the understanding of the role played by the sources of innovation and types of innovation in each of them. This could help to improve the understanding of the process of innovation in the firms.

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