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Network analysis for the study of technological collaboration in spaces for innovation. Science and technology parks and their relationship with the university

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Abstract

Universities have become a strategic element in the innovation process. Knowledge-based innovation makes them key players for the economic and social development of their environment. This article discusses how the University of Lleida interacts in the Agri-food Science and Technology Park of Lleida. It establishes whether a behavioural pattern exists in the cooperation between the companies and institutions of the park and emphasizes the role of the university as an intermediary between scientific knowledge and the market.

Keywords: Collaboration networks, Science and technology parks, University, Network analysis

Introduction

With the paradigm shift experienced by universities, the need has been acknowledged for them not only to form and create knowledge but also to stimulate development in their environment. Through knowledge transfer and innovation universities put their knowledge at the service of society and contribute to promoting the socio-economic progress of their surrounding area. To do so, strategic alliances with the business fabric and local institutions are paramount. Science and technology parks (STP) promote innovation and foster the competitiveness of the enterprises and institutions they host, and become a key player in the generation of scientific and technological knowledge and in technology transfer between universities, research centres and companies.

The aim of this study is to perform a social network analysis (SNA) to analyse the co-operation in research and development that takes place between the companies and institutions of the Agri-food Science and Technology Park of Lleida (PCiTAL) to find out if there is a positive relationship between cooperation, research and location; if there is a behavioural model concerning this cooperation; the intensity of the different partnerships; and what factors determine this behaviour. This study pays special attention to the role of the University of Lleida (UdL) as an intermediary between scientific knowledge and the market.

The article is divided into five sections. The introduction is followed by a presentation of the theoretical framework of the university-enterprise relationship and the contribution of science and technology parks as agents of the innovation system. Subsequently we introduce the methodology and data used to perform the study. The fourth section offers the results, and the paper ends with the conclusions.

The relationship between university and enterprise

An initial approach to the role of the university in the innovation process is the so-called linear model of innovation,[1] where the starting point is basic research that leads to applied research and subsequent technological development ending with innovations introduced to the market. There is no feedback in this model and knowledge comes from the scientific community. After World War II, the model was criticized by several authors (Arrow, 1962; Khun, 1962; Polanyi, 1958). The loss of competitiveness of US industry in the 1970s led to questions about the effectiveness of the funding of R&D in universities, since no direct relationship between R&D and corporate financial results was observed.

In the 1980s, the development of ICT enabled a paradigm shift. The closeness of Silicon Valley to Stanford University and the proximity of Massachusetts Institute of Technology to State Highway 128 helped them become hotbeds of innovation and entrepreneurship that resulted in positive impacts on the economic development of the surrounding areas. In this context, actions are proposed aimed at strengthening the relationship between university and enterprise. There is evidence that basic research is not enough to promote innovation. Innovation becomes the element that provides a competitive advantage to companies and scientific and technological research become the basis for wealth creation and economic development.

These issues led to new approaches to and perceptions of the role of the university in the innovation process, leading it to take a more active role in the dissemination of knowledge, to be more closely linked to its socio-economic environment and, as a key feature of knowledge, to adopt its applicability.

The university, in addition to its role in teaching and research, is attributed with the economic and social development of its environment based on knowledge. This implies a new vision of innovation, which is represented on the basis of dynamic and interactive models. The point that these models share is that innovation is not dependent on the isolated activity of the agents but on the dynamics of knowledge exchange generated between them. One of the most widespread approaches to the relations between the agents involved the innovation process is the triple helix (TH) (Etzkowitz & Leydesdorff, 1995). This is based on the idea that innovation arises from interactions between three key players; university, enterprise and administration. The general context of THs is evolutionary economics and institutional approaches in economic theory, supplemented by a sociological perspective on innovation processes (Cortes, 2006).

In many universities a third revolution takes place: the entrepreneurial university, characterized by major collaboration with its socio-economic environment (Etzkowitz & Leydesdroff, 2000). The cooperative centre of gravity is in the academic sphere, but participation and support by the enterprise through demand are essential. It provides innovative responses to new social demands, assumes the creation of companies or start-ups, and researchers become entrepreneurs of their own technologies, entrepreneurial scientists.

To the extent that universities are seen as promoting socio-economic development, the TH model provides interesting applications, particularly in remote regions with little technological dynamism and a productive system based on traditional SMEs, with little investment in R&D and a weak system of institutional support (González de la Fe, 2009; Torres, Enciso, Farré, & Sala, 2010). The TH model indicates that in these regions, based on the spiralling interaction between the three helices, the role of universities is critical for knowledge-based development (Miralles-Guasch, 2010). The administration must also participate actively through legislation and tax incentives to encourage cooperation. STPs are one of the interfaces that arise to stimulate a meeting point between universities, enterprise and administrations.

STPs create the ideal conditions to generate synergies between companies and institutions and between these and the region in which they are located, contributing to the creation of wealth. They are a meeting point for all of the agents involved in the innovation system, for the scientific community and for the innovating community.

There is a line of research that establishes a positive relationship between the variables of cooperation, innovation and location in an STP. It is believed that organizations located in the STP that interact with each other will be more innovative than those that do not (Montoro, Mora, & Ortiz, 2012). Several studies emphasize the relationship between location in an STP and innovation (Felsenstein, 1994; Lee & Yang, 2000; Squicciarini, 2009) and between innovation and cooperation (Laursen & Salter, 2006; Navarro, 2002; Santamaria, Nieto, & Barge-Gil, 2010). The theory of open innovation shows that companies do not innovate alone but cooperate with each other creating networks. Undoubtedly, STPs are a type of enterprise network where proximity between companies and institutions enhances cooperative relations.

Collaborative networks: methodology and data

Social network analysis was used as the methodology for the empirical analysis of the local collaboration networks of the PCiTAL. This methodology involves a series of principles that distinguish it from other approaches. One of its principles is that patterns of behaviour depend on the whole network and not dyads, since the relationships between each pair of companies will be conditioned by the relationships that each of them has with third-party companies; therefore, the interdependence of the agents and their actions is presupposed. Some of the pioneering studies on the use of this methodology for the study of networks are those by Tichy and Fombrun (1979) and Fombrun (1982). The analysis of collaborative networks for the exchange of knowledge between companies has been an area of interest to both academics and enterprise (Giuliani, 2007; Morrison & Rabellotti, 2009; Uzzi, 1997). In Spain, González (2007) and Martín-Ríos (2013) have applied it to networks in science parks.

This paper examines two of the most interesting issues in the study of networks: on the one hand, the reticular structure of the network, which are the nodes that occupy central positions, the strength of the links, and the form the network adopts and, on the other, various structural indicators of network analysis are calculated (Table 1) to ascertain the role that each node plays in the lattice of relationships.

The study data were obtained by means of a survey that was conducted by e-mail to the people responsible for research and development at the companies located in the PCiTAL; follow-up interviews were conducted by telephone at a later date. The questionnaire gathered information on the characteristics of the company and respondents

Table 1 Network indicators

Indicator	Description	Formula
Degree of centrality	Number of links incident upon a node	$C_d(G) = \frac{\sum_{i=1}^{N} Cd(v^*) - Cd(vi)}{H}$ *CD (g): degree centrality* *v^*: node with the highest centrality degree* *Vi:node i*
Index of centralization	The degree to which a network is organized around a point.	$C_d = \frac{\sum_{i=1}^{N} (C\max - Ci)}{\max\left[\sum_{i=1}^{N} (C\max - Ci)\right]}$ *C_{max}:centrality focal node* *Ci = centrality rest of nodes*
Degree of intermediation	Possibility of a node to mediate between pairs of nodes	$C_b = \frac{2\sum_{i=1}^{g} [Cb(n^*) - Cb(n_i)]}{[(g-1)^2(g-2))]}$ *Cb(n*):highest intermediation between agents* *g: number of nodes*
Degree of closeness	Average distance of each agent in respect of other agents.	$C_c = \sum_{x \in V-C} df(x, C)$ *X:node x*
Density	Existing links in relation to possible links.	$D = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} Xij}{n(n-1)}$ *Xij: adjacency matrix* *N: number of nodes*

Source: Borgatti *et al.* (2002)

were presented with a list of companies in the park and asked to identify with which ones they had had various kinds of relationships during the past 3 years. They were also asked about their cooperation with UdL.

The PCiTAL enterprise network is made up of 57 companies. The response rate obtained was 75.5 %. In our case, the nodes of the network are the companies and links for analysis are collaboration only among them in terms of cooperation, business relations and the exchange of confidential information.

The data network was processed using the UCINET 6 programme (Borgatti, Everett, & Freeman, 2002) in order to analyse the structure of inter-organizational relations. Graphs were produced using the Netdraw utility (Borgatti, 2007). In the graphs, the sector variable indicates that the company belongs to the following sectors: (A) agrifood, (B) biotechnology, (C) communication, audiovisual and marketing, (M) environment, (O), others (Q) chemical, (S) consultancy, advanced services and engineering, (T) information and communication technologies and (Z) automation. The attributes of the companies in the park included in the study are set out in Table 2.

The innovative capacity of firms variable takes three levels: “does not innovate” if the company has not carried out any kind of innovation in the past 3 years, “innovate1” if the company has carried out incremental innovation, that is, modifications or improvements to a product or service, and “innovate2” if the company has carried out radical innovation, i.e., has developed a new process or product. Another attribute contained in the graph is the location of the company, if it is in the business incubator or is on a plot. Finally, the age of the company was measured by the number of years it has been established in the park.[2]

Table 2 Attributes of companies and institutions

	Variables	Number	Percent
Sector	Agri-food	6	13.9
	Biotechnology	4	9.3
	Communication, audiovisual and marketing	5	11.6
	Environment	2	4.6
	Others	7	16.2
	Chemical	3	6.9
	Consultancy, advanced services and engineering	3	6.9
	ICT	10	23.2
	Automation	3	6.9
Attributes	Do not innovate	7	16.2
	Incremental innovation	18	41.9
	Radical innovation	18	41.9
	Company in incubator	12	27.9
	Company on plot	31	72.1
	Employees (<10)	35	81.4
	Employees (10-50)	3	7
	Employees (>50)	5	11.6
	Age (<2 years)	13	30.2
	Age (2-5 years)	19	44.2
	Age (>5 years)	19	25.6
Relational variables	Cooperation in R&D	23	53.4
	Cooperation in production	24	55.8
	Commercial cooperation	35	81.3
	Financial cooperation	8	18.6
	Exchange of confidential information	28	65.1
	Business relations	30	69.7
	Trust	23	53.4
	Business similarity	20	46.5

Source: compiled by authors

Studies that have focused on the analysis of inter-organizational relations show the factors that have an impact are both the attributes of firms and relational-type variables. Hence, we analysed different types of relational variables: the cooperation network, the business relations network, and the exchange of confidential information network (Table 2). The first variable is the sum of another four; cooperation in R&D, production, business, and finance. The relational variables take the value 1 if there is a relationship and 0 if there is not.

Commercial cooperation, interaction based on the flow of shared confidential information on the design of products, innovation processes, know-how or technological opportunities, and customer-supplier business relations are the most prevalent in the park. Regarding the type of innovation, there are seven companies that have not carried out any innovation, 42 % innovate incrementally, and the same percentage has launched a new product or process in the last 3 years. Most of the companies are located in their own building (72 %) compared to 27 % that are housed in the incubator. The average age is 3.5 years, bearing in mind that 30.2 % are very young companies that have spent less than

2 years in the park. The companies are small: 81.4 % have less than 10 employees and only five have over 50.

Results

Upon an initial analysis of the network of relationships, we considered interrelationships as the sum of cooperation in R&D, production, business and finance among the companies housed in the park and the university.

Figure 1 shows that the cooperation network is well established. The number of companies that are not involved in any kind of cooperation with the rest is very low, only five do not participate in the network. Most of them have been in the park for 1 or 2 years and belong to less prominent sectors within the park. It is observed that there are various focal enterprises and that the number of cooperation ties is high. The thickness of the lines shows the strength of the relationship between the nodes. It highlights the position of UdL, with strong ties to several companies; it has a significant degree of centrality, which allows it to exert some influence on the network (Table 3) and, in turn, it has the highest degree of intermediation, which ranks it as one of the bridging agents. It also highlights the central role of company S1 with numerous cooperation links. The index of centralization (18.77 %) is not very high, indicating an absence of clearly central companies.

Strong cooperation links do not occur only among the more central nodes. There are also some less central companies in the network that enjoy different types of collaboration between them. We can say that the cooperation ties are in response, on the one hand, to factors such as being central nodes, and on the other, because they are companies of the same sector located on their own plot.

The companies housed in the incubator are located on the periphery of the network, except for two companies in the technology sector that occupy a central position (T2, T3). They cooperate with various companies in the park, although their collaboration is not very intense.

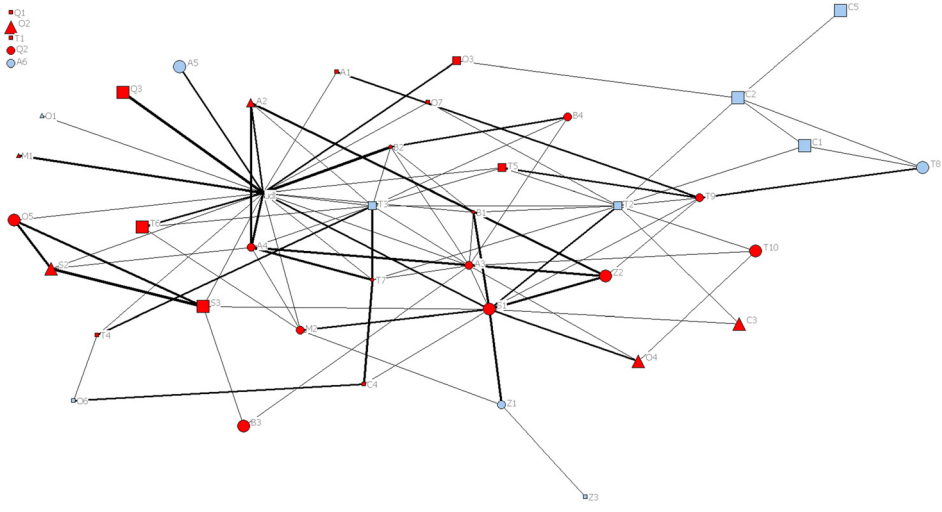

Fig. 1 Cooperation network. (Δ) Do not innovate, (□) Incremental innovation, (O) Radical innovation, (blue) In incubator, (red) On plot

There is a sub-network consisting of a set of ICT companies that have relations between them (T2, T3, T5, T7, T9). There is also a triad formed by companies working in the field of technological innovation in the construction sector (S2, S3, O5), with very intense cooperation between them.

By sectors, it should be noted that the communication, audio-visual and marketing and chemical sector participates little in the network. However, companies in the agri-food sector, barring two of them that perform radical innovation, occupy peripheral positions in the network. Nevertheless, all of them collaborate with UdL, some very intensely.

The other network analysed is business relations (Fig. 2). There are eight companies that have not had any business relationship with another company in the park. They are mainly young companies that have spent less than 2 years there. This network consists of two components, a primary sub-network and a binodal relationship. It has a mesh structure, there are two focal nodes, the University of Lleida and a company in the ICT sector (T9).

The centrality of the university is highly significant allowing it to have some influence on the network. The next two nodes according to the index of degree are company T9, recently housed in the park, although it has a great deal of experience in the ICT sector, along with the Consortium for Economic Development of the City of Lleida, which promotes economic development and entrepreneurship. Within this central part of the network, we detect a quasi-cycle formed by companies from different sectors, each located on a plot and having spent several years in the park (T6, S2, O5, S3, T9, M2). Also, as a link between the two central nodes (UdL and T9), we find a group of nodes in the ICT, communication, audio-visual and marketing sector, and the Consortium for Economic Development of the City of Lleida (T5, T8, O4, C1). In addition, there is a company of the communication, audio-visual and marketing sector (S1) that has a large number of connections. It is a company that, as we have seen, has numerous and intense cooperative relationships.

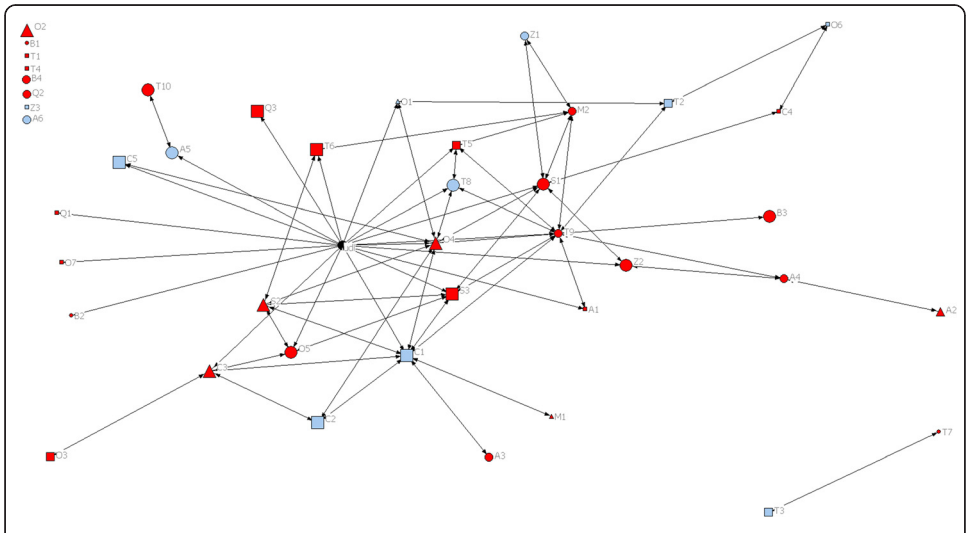

Fig. 2 Network of business relationships (Δ) Do not innovate, (□) Incremental innovation, (O) Radical innovation, (blue) In incubator, (red) On plot

There is also a binodal relationship between companies in the same sector (T3, T7) and a group of loosely connected companies is also observed, located on the periphery of the network, for most of which the connection node is the university. At the bottom of the network, we observe a triad of companies of the same sector that have business relationships between them.

As in the cooperation network, most incubator companies are located on the periphery. In the business relations network, there are more linear relationships and more isolated nodes and, hence, it is more scattered and weaker than the cooperation network.

There is no direct relationship between cooperation and business relations. The companies with the most business relationships are not the ones that have the most cooperation ties. However, the University is the entity that has both the most cooperation ties and the most business relations.

The last exchange network analysed is that of the flow of confidential information, in this case (Fig. 3) highlighting that there are 14 companies that are not connected. The network is more dispersed and less cohesive than the previous ones, and companies establish fewer, more sporadic and horizontal exchanges. This network consists of two components, a primary sub-network and a binodal relationship. The latter is formed by three companies working in the field of technological innovation in the construction sector and, as we have seen, they cooperate intensely among them (S2, S3, O5). In the primary sub-network there is a triad of companies, two of which belong to the communication, audio-visual and marketing sector and one to the ICT sector, which acts as the link-up to the primary sub-network. This triad is also repeated in the cooperation network. There is, therefore, a relationship between the exchange of confidential information and cooperation between companies, even if such partnerships do not lead to a business relationship.

Again, it is the companies located in the incubator that are relegated to the background, occupying the positions furthest from the network. The university, together with company S1 have implemented the most exchanges of information and, in turn, have a high degree of intermediation. They are the ones most able to mediate between pairs of nodes, and so

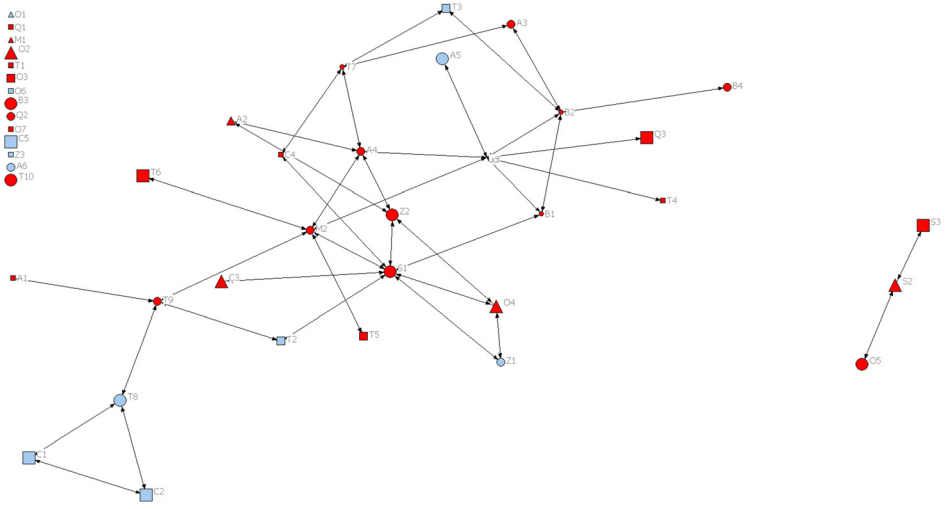

Fig. 3 Network for the exchange of confidential information (Δ) Do not innovate, (□) Incremental innovation, (O) Radical innovation, (blue) In incubator, (red) On plot

they enjoy certain power to act as a bridge between two companies. They are also the companies with the highest degree of closeness, which indicates that they are better able to exchange information with the rest. The companies found in the centre of the network and that have a higher degree of centrality, closeness and mediation are those engaged in radical innovation and that have spent longer in the park. Therefore, the exchange of confidential information is not carried out so much between companies in the same sector but rather because of the kind of innovation they perform.

Table 3 shows the structural indicators of centrality, intermediation and density of the three networks analysed and the value the university scores for each one.

If we analyse the density of the three networks, we note that the cooperation network is relatively dense (0.143) and yet the business relations, especially the exchange of confidential information networks, have a low density. Network density measures the proportion of existing relationships over the total possible relationships; in this regard, in the PCiTAL greater cooperation links are produced between enterprises than business relations or exchanges of information.

The degree of centrality is the number of agents to which a node is directly attached. In all networks, UdL is the agent with the highest degree of centrality, as it is the node with the greatest connectivity with the other agents. The index of centralization is greater in the network of business relations, indicating that they are more centralized around a node, in this case the university, as it is highly connected in this network. The index is lower in the other two networks.

The cooperation network has the highest index of intermediation, and so there are more companies that act as bridging agents that connect to disconnected nodes through cooperation in production, R&D, business or finance than through the exchange of business relations or information. UdL is one of the most important bridging agents in all networks.

The degree of closeness, despite being low in all networks, indicates that UdL is an agent with a significant capacity to relate commercially, cooperate or exchange information with the rest.

The companies keep business relationships and cooperate with each other; however, they exchange little confidential information and, in the latter network, the percentage of isolated nodes exceeds 30 %. The structural indicators show that companies are more connected to each other in the search for cooperation than in the establishment of business relations or information exchange.

Table 3 Main indicators

	Cooperation network		Network of business relationships		Information network	
	Average value	UdL	Average value	UdL	Average value	UdL
Degree of centrality	3.59	21.51	6.87	44.19	4.22	18.6
Degree of intermediation	2.58	35.33	2.04	31.36	1.73	15.12
Degree of closeness	13.88	15.46	7.936	8.793	2.38	5.382
Index of centralization	18.77 %		39.09 %		15.06 %	
Isolated nodes	11.36 %		18.18 %		31.81 %	
Density	0.143		0.069		0.042	

Source: compiled by authors

Conclusions

The first goal was to analyse the network of collaborations between companies and institutions of the PCiTAL to ascertain whether there is a behavioural pattern in these collaborations. The results are similar to other studies such as those by González (2007) and Martín-Ríos (2013). The novel aspect of this analysis is that it is applied in a peripheral region with little technological dynamism, where local proximity and the existence of spaces for innovation contribute to cooperation and economic development. We conclude that the park enhances knowledge flow and technology transfer. Proximity among firms fosters collaboration between them, both in the cooperation and in the business relations networks. The number of isolated companies is very low.

The cooperation network is well established. Cooperation takes place between companies in the same sector that are housed on their own plot and among those in the incubator. The ones that cooperate most intensely are those that perform radical innovation, regardless of their age. A positive relationship is detected between cooperation, innovation and location. The centralization index is not very high, indicating that it is not structured around a central node. There are several nodes, including UdL, that act as bridging agents. The companies that collaborate most with each other also exchange confidential information. There seems not to be a link between cooperation relationships and business relations. The companies with the most business links are not the ones that cooperate most with each other. The network of business relations is scattered and weak. However, it presents a high centralization index, which highlights the central role of the university in the structure of this network.

The second goal was to establish the role of UdL within the relational network of the PCiTAL. The results, in line with other studies (González de la Fe, 2009; Molina Morales & Masverdú, 2008), suggest a positive effect of universities as agents of intermediation between scientific knowledge and the market. In all networks analysed, UdL has numerous relationships with the other companies, although they do not involve the creation of companies, start-ups or the joint exploitation of patents, which are the aspects that are most characteristic of an entrepreneurial university. It boosts technological innovation in companies in its environment; in all networks, it acts as one of the bridging nodes and it has a significant degree of centrality. It can be concluded that UdL promotes and acts as a catalyst for relationships between the enterprises of the park.

A clear behavioural pattern that explains the relationship between companies of the PCiTAL was not detected, although there are some patterns of centrality that bring UdL and the longest-standing companies in the park performing radical innovation together in the centre of the network. The network structure is basically mesh-like, with few binodal relations and with the majority of companies participating in these networks. We again highlight the importance of physical proximity for establishing relationships that require the trust of the agents.

Finally, this study does have some limitations, such as the environment analysed, just one park, its youth, and the sample size. To complement the analysis, it would be interesting to conduct an in-depth survey to extend the characteristics of the companies and their relations with the others and reach less generalized conclusions to enable a better explanation of the existence of partnerships. Establishing the relationship between the lack of cooperation and business characteristics would help to better understand the positive cooperation-innovation spiral. As future lines of research, we propose looking in greater

depth at the analysis of the companies that do not cooperate, analysing the relationship between cooperation, innovation and business results, and broadening the scope of study to other parks.

Endnotes

[1]From the thesis by Merton (1942) and Bush (1945) on US science policy.

[2]The analysis of the sociograms obtained with the Netdraw application led us to dismiss the number of employees, since it did not determine greater or lesser cooperation.

Competing interests
The authors declare that they have no competing interests.

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